SELECTED CHARACTERISTICS OF RIB STEAKS FROM CARCASSES OF VARYING DEGREES OF MATURITY AND MARBLING

by

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INTRODUCTION

Maturity and marbling of beef carcasses generally are regarded as important factors influencing the relative acceptability of the cooked meat. Those factors are given major emphasis in both the United States Department of Agriculture (U.S.D.A.) and the Packers' grades for beef (McBee and Wiles, 1967). However, the results of research on the role of fat in determining the palatability characteristics of meat are conflicting (Blumer, 1963). Some investigators showed that the quantity and distribution of fat greatly influence the tenderness and juiciness characteristics of meat, whereas others found little relationship between fat content and the palatability characteristics of meat (Gilpin et al., 1965).

In 1965 the U.S.D.A. standards for grading beef placed less emphasis than previously on maturity and marbling in the Prime, Choice, Good and Standard grades (U.S.D.A., 1965). Most of the studies found in the literature based maturity on the chronological age of the animal. Information is needed on the effect of maturity and marbling when maturity is based on the physiological age of the animal, i.e. the size, shape, and ossification of the bones and cartilages and the color and texture of the lean as specified in the U.S.D.A. standards (U.S.D.A., 1965).

This study, which is part of a larger investigation at Kansas State University, measured the effect of three levels of maturity and two levels of marbling in beef ribs on cooking time and losses of 2-in. steaks from the 7th and 8th thoracic

vertebrae. Color, pH, and selected objective measurements of juiciness and tenderness were measured on the longissimus dorsi (LD) muscle of those steaks.

REVIEW OF LITERATURE

Effect of Maturity on Selected Characteristics of Beef

Maturity of the beef carcass generally is recognized as an important factor influencing palatability of the meat. Goll et al. (1965) pointed out that wide extremes in maturity of the carcass influence the eating quality of beef a great deal more than wide extremes in marbling. Federal grade standards compensate for the adverse effect of maturity on palatability by requiring a higher degree of marbling with advancing maturity for a given grade (Romans et al., 1965). Dunsing (1959) noted that consumer household panels consistently favored steaks from young carcasses. Ritchey and Hostetler (1964), however, stated that in animals ranging in age from 33 to 62 weeks, only isolated data pointed toward any influence of age on palatability, and those cases were attributable to variation among animals. The influence of maturity on selected measurements reported for beef is reviewed.

Tenderness. There seems to be a consensus that tenderness is the characteristic of beef most eagerly sought by consumers. Much experimentation has been carried on to determine what makes one cut tender and another within the same carcass less tender. Breed, age, sex, grade, and muscle fiber diameter have been

explored as possible factors affecting tenderness. Immediately upon slaughter both muscle structure and composition undergo changes that affect tenderness. Quantity and distribution of fat and connective tissue in muscle have been associated with tenderness. The way the carcass is handled, such as boning, freezing, and conditions and time of aging; and the method, time, and temperature of cooking also affect tenderness of beef (Harrison et al., 1959).

Many workers agree that tenderness decreases with age of the animal (Hiner and Hankins, 1950; Tuma et al., 1962; Webb et al., 1964; and Walter et al., 1965). Tuma et al. (1962), however, pointed out that both Warner-Bratzler shear values and taste panel evaluations revealed a greater decrease in tenderness between 18- and 42-month-old animals than between 42- and 90-month-old animals. They suggested that animal age may be more critical with regard to tenderness at a point between 18 and 42 months than between 42 and 90 months of age. According to Dunsing (1959) and Simone et al. (1959) the critical age for tenderness may fall in the range of 18 to 20 months. Henrickson and Moore (1965) reported that Warner-Bratzler shear values indicated that carcasses from 6-, 42-, or 90-month-old animals were less tender than carcasses from 18-month-old animals.

Tuma et al. (1963) stated that panel tenderness and shear force values rated 6-month-old calves less tender at 2 days postmortem than 18-month-old animals; however, upon aging 14 days, 6-month-old calves were more tender. Thus, it appeared that aging

does not occur at the same rate in muscle from animals of all ages.

Ho and Ritchey (1967) measured tenderness by panel scores in three carcass groups — veal, baby beef, and mature beef. Age of the animal had no definite effect on the panel scores for tenderness when steaks were cooked to an internal temperature of 61°C, but at an end point of 80°C softness scores decreased as age increased, indicating drier and harder meat. A few workers reported no significant relationship between tenderness and maturity level (Nelson et al., 1930; Ritchey and Hostetler, 1964; and Romans et al., 1965).

Juiciness, moisture, and water holding capacity. An important property of muscle used for meat is its ability to retain moisture during cooking. Heating muscle affects the relative proportion of protein, water, and fat, and changes the hydration of muscle proteins, which affects the quality of cooked meat (Rogers et al., 1967). Moisture in the cooked meat can be measured subjectively by a taste panel (juiciness) or it may be measured by physical methods. Some of the physical methods for measuring moisture reported in the literature are: total moisture, press fluid yields, cooking losses, and water holding capacity (WHC). In this review the term water holding capacity is used as defined by Hamm (1960), "the ability of meat to hold fast to its own or added water during application of any force (pressing, heating, grinding, etc.)."

Most studies found in the literature agree that when

marbling is held constant, maturity level does not have a significant effect on juiciness when evaluated by a taste panel (Nelson et al., 1930; Tuma et al., 1962; Ritchey and Hostetler, 1965; Romans et al., 1965; Goll et al., 1965; and Field et al., 1966).

Tuma et al. (1963) reported that muscle from 6-month-old calves contained 72.63% moisture as compared to 68.92% for 90-month-old animals. Little difference in moisture was noted between the 18- and 42-month-old animals. Goll et al. (1963) also reported that muscle from young animals possessed more moisture than muscle from older animals. Jacobson and Fenton (1956) noted that as the age of the animal increased there was a consistent and highly significant decrease in juiciness of three beef muscles: longissimus dorsi, psoas major, and semimembranosus. They suggested that this may be related to the decrease in moisture with age. Ho and Ritchey (1967) reported that internal cooking temperature influenced the effect of maturity on juiciness. Juiciness decreased as animal age increased from three months to two years when LD muscle was cooked to an internal temperature of 80°C, but juiciness was not affected when that muscle was cooked to 61°C.

Color-difference and pH. Color may be expressed as hue, chroma, and value. Hue is associated with the sensation of redness, yellowness, blueness, or other colors. Chroma refers to the strength of hue or freedom from whiteness, whereas value indicates the brightness aspect (Brice, 1954).

Most workers agree that the three dimensions of color indicate that advancing maturity of beef animals is accompanied by a darker color of the muscle. Jacobson and Fenton (1956) noted a significant increase in redness of the semimembranosus muscle, both before and after cooking that was attributed to increasing age. Romans et al. (1965) measured 3 components of color (Munsell hue, value, and chroma) for muscle from beef animals at 4 levels of maturity with a Photovolt Reflection Meter. Of the three Munsell color components only value was affected significantly by maturity, the differences being significant only between the youngest and other levels. Value tended to decrease with increasing maturity.

The few studies found in the literature that investigated the relationship of animal age to pH seem contradictory. Ely (1965) found that pH decreased with advancing animal age from 16 to 25 months. Lockett et al. (1962) and Tuma et al. (1963) reported that pH was not related significantly to maturity. Tuma et al. (1963) reported that aging 2 to 14 days influenced the effect of maturity on pH. They noted that all four age groups studied did not show the same trend. An increase in pH was evident from 6 to 42 to 90 months of age, but not for the 18-month-old animals that were in the first group. Walter et al. (1965), however, found that pH increased with advancing maturity, from 15 months to 10 years.

Effect of Marbling on Selected Characteristics of Beef

Marbling, the visible fat dispersed within the lean portion of the muscle, has been given major emphasis in both the U.S.D.A. and Packers' grades for beef in the projection of raw beef characteristics to eating satisfaction in the cooked meat (Blumer, 1963). In general, fatter beef is graded higher than the less fat. However, in recent years doubts have been raised concerning the popularly accepted belief that more fat, and particularly more marbling, is associated with definite superiority in beef tenderness (Wellington and Stouffer, 1959).

Research has indicated that the uniformity of distribution of intramuscular lipid varies significantly among anatomical locations within one carcass. Cook et al. (1964) found highly significant differences in marbling among marbling classifications and among anatomical positions within the LD muscle. The extremities of the muscle contained a significantly higher level of intramuscular lipid than the medial section. The most uniform pattern of marbling distribution in the LD was observed at the 10-13th thoracic region, and uniformity of marbling tended to decrease toward the muscle extremities. Those observations, they pointed out, may reflect differences in cellular metabolism among different anatomical positions within a muscle.

Gilpin et al. (1965) also observed variation of marbling within a muscle; which, they believed, indicates that marbling may be inadequate as an index of carcass quality. The influence of marbling on selected measurements in beef is reviewed.

Tenderness. The role of intramuscular fat in tenderness seems to be controversial. Romans et al. (1965) found no significant relationship between shear force values and two marbling levels, moderate and slight. This lack of significant differences in shear force between marbling levels agrees with data published by Wellington and Stouffer (1959), Walter et al. (1965) and Goll et al. (1965).

Tuma et al. (1962) reported that the association between marbling and tenderness varied with animal age. "Slightly abundant" marbling, as compared to a "slight amount" of marbling, did not enhance the tenderness of steaks from 18-month-old animals. Greater tenderness in steaks from 42- and 90-month-old animals, however, was associated with the "slightly abundant" marbling level. Field et al. (1966), on the other hand, noted that when age was held constant, beef with high marbling scores generally was tender.

McBee and Wiles (1967) reported that tenderness increased with additional degrees of marbling in a direct, linear relationship, which agrees with the work of Cover et al. (1956) and Doty and Pierce (1961). Cover et al. (1958) made detailed studies with 203 beef carcasses of known history. About 11% of the variation in tenderness was accounted for by marbling when measured as percentage of ether extract. Blumer (1963) reviewed the literature on the relationship of marbling to the palatability of beef and concluded that a range of values of 0.01 to 36% of the variance in tenderness could be attributed to marbling. Prorated

according to number of samples in all the studies reported, this value would be about 5%.

Wang et al. (1954) noted that the manner in which fat was distributed throughout the muscle affected tenderness appreciably. In a histological study the distribution of fat in muscle was measured according to the amount of surface contact between fat cells and muscle protein, and referred to as "linear" fat. Consistently the tenderness score of a cooked sample correlated well with the "linear" fat content of raw muscle. That is, the higher the linear fat content, the more tender the cooked meat. They conceived that the beneficial effect of marbling may be explained on this basis.

Juiciness, moisture, and water holding capacity. Juiciness in cooked meat has two organoleptic components. The first is the impression of wetness during the first few chews and is produced by the rapid release of meat fluid. The second is one of sustained juiciness largely attributable to the stimulatory effect of fat on salivation (Weir, 1960).

A number of workers observed that juiciness increased linearly with additional degrees of marbling (Wellington and Stouffer, 1959; Doty and Pierce, 1961; Romans et al., 1965; Walter et al., 1965; and McBee and Wiles, 1967). The percentage of moisture decreased and percentage of ether extract increased with additional increments of marbling. Blumer reviewed the relationship of marbling to the palatability of beef, and concluded that approximately 16% of the variance in juiciness may

be attributable to fat.

Gilpin et al. (1965) reported that the relationship of marbling within a muscle to panel assessment of juiciness generally was inconsistent, and correlation coefficients were low. It appeared to Goll et al. (1965) and Tuma et al. (1962) that taste panel juiciness scores were not affected significantly by marbling.

Color-difference and pH. Meat pigment is composed largely of the chromoproteins, myoglobin and hemoglobin (Romans et al., 1965). Romans et al. (1965) reported that the pigment content of beef muscle did not differ significantly between moderate and slight marbling levels. Analysis of variance, however, indicated that marbling had a significant effect on Munsell hue. Hue means were 6.1 $\pm$ 0.4 R (red) for the moderate level and 5.0 $\pm$ 0.4 R for the slight level of marbling. The authors stated that the effect of increased marbling would push the hue reading higher, and thus closer to the yellow-red notation. Tuma et al. (1962), however, found that marbling did not influence significantly any of the three dimensions of color.

Few data were found relative to the effect of marbling on pH. Tuma et al. (1962) noted a significant ($P < 0.05$) increase in pH upon aging 14 days when the data from all carcasses (two levels of marbling) were pooled. He reported pH values of 5.19 and 5.48 for "slightly marbled" muscle at 2 and 14 days post-mortem, respectively; and found values for muscle with "slightly abundant marbling" of 5.45 and 5.45 at 2 and 14 days post-mortem.

EXPERIMENTAL METHOD

Meat Used

Rib steaks (120, 2-in. thick) at the 7th (leftside) and 8th (rightside) thoracic vertebrae were removed from 60 carcasses, which were selected to represent three levels of maturity (youthful, intermediate, and approaching maturity) and two levels of marbling (small and moderate) at each level of maturity. All carcasses were selected from two packing houses in Kansas City, Missouri, by two research assistants in the Department of Animal Husbandry at Kansas State University. The rib sections were brought to the Meat Processing Laboratory at Kansas State University. The steaks were cut from the ribs, wrapped in laminated freezer paper, and frozen at -20°C. They were held at that temperature for 9 to 12 months.

Preparation for Cooking, Cooking, and Sampling

Prior to each cooking period 4 steaks were defrosted 4 hr at room temperature (approximately 78°F) and 20 hr in a refrigerator (40°F), unwrapped and weighed. Each steak was placed on a wire rack 5 in. high, and a thermometer was inserted with the bulb in the center of the LD muscle (Fig. 1). The steaks were cooked in a rotary hearth gas oven at 400°F to an internal temperature of 70°C (Fig. 2). Percentage total, volatile, and dripping cooking losses were calculated. Total cooking time in min and the cooking time in min/lb were determined. The design for

Fig. 1. Rib steak shown on a 5 in. high wire rack with a thermometer inserted in the center of the LD muscle ready to be placed in the oven.

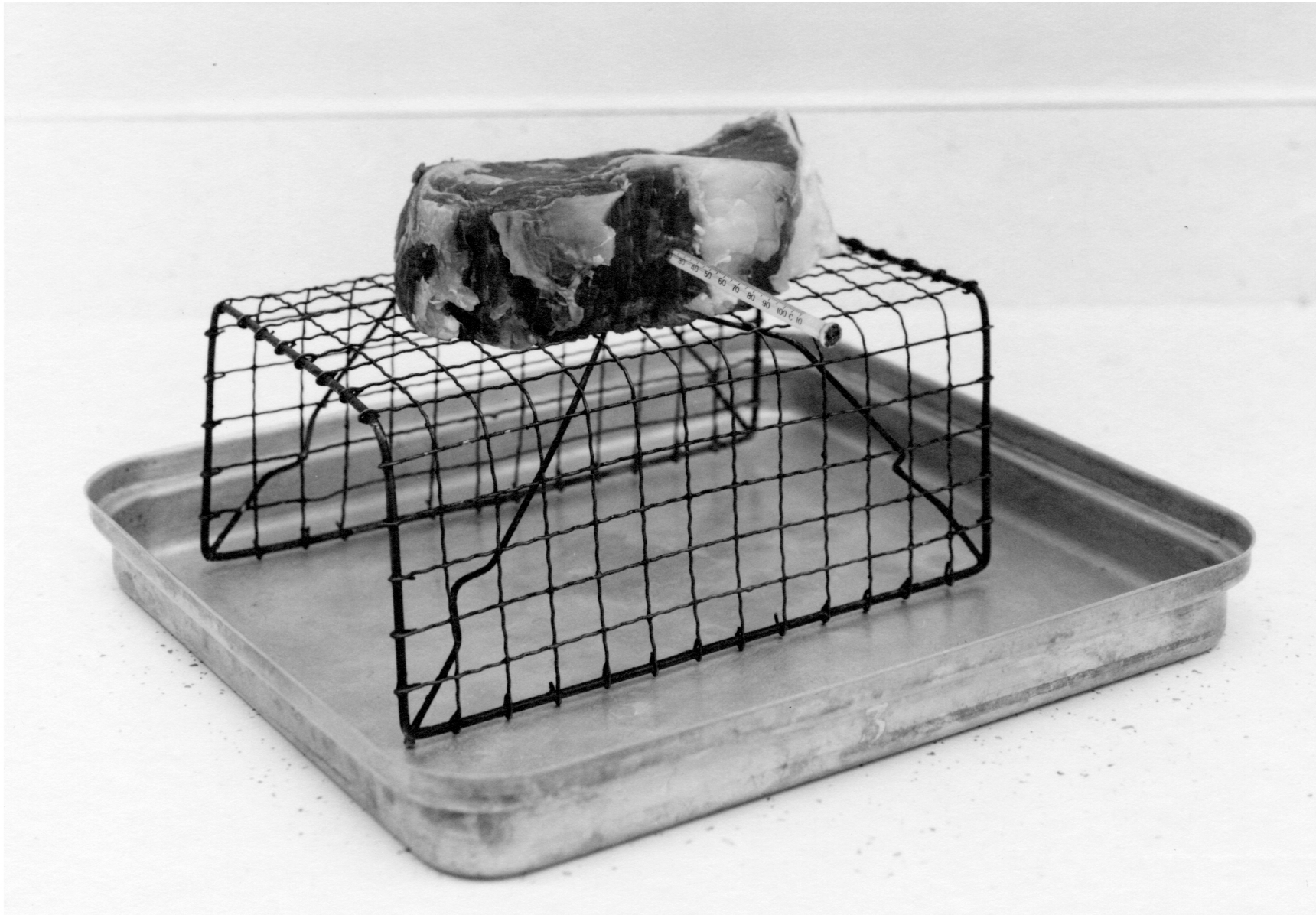
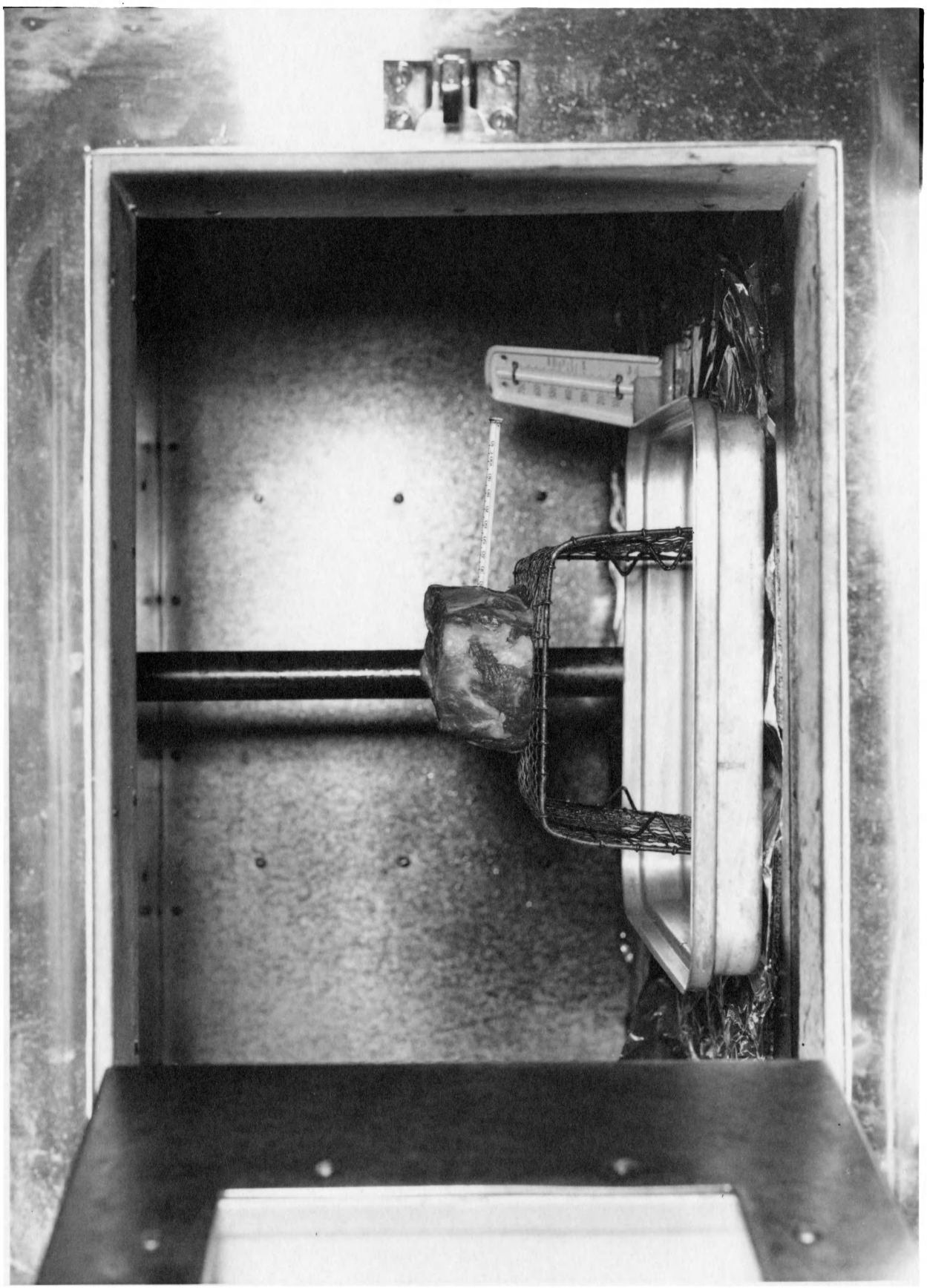


Fig. 2. Rib steak with inserted thermometer on wire rack in rotary hearth gas oven.



cooking consisted of 30 periods with 4 steaks cooked at each period (Table 1), randomized by left (7th thoracic vertebrae) and right (8th thoracic vertebrae) side of the carcass. After cooking all exterior fat, connective tissue, and browned surface were removed from the steak. Sampling of the LD muscle is illustrated in Fig. 3.

Evaluation of the LD Muscle

Warner-Bratzler shear values. Warner-Bratzler shear values (25-lb dynamometer, Fig. 4) were measured on 3 cores ($\frac{1}{2}$-in. diameter) from the lateral position and 3 from the medial position in each steak (Fig. 3). Two shears were made on each core.

pH. Five g of cooked, ground meat were blended with 50 ml distilled water for 2 min in a Waring blendor. The homogenate was poured into a beaker, and pH determined using the standard scale on a Beckman pH meter (Model 76). Two measurements were made with the instrument standardized against a commercially prepared buffer, pH 6.86. The homogenate was stirred 30 sec with a magnetic stirrer, and the pH reading taken. The beaker was turned 180°, the homogenate stirred an additional 15 sec, and the second pH reading taken.

Total moisture. The percentage moisture in the cooked LD was determined with the C. W. Brabender semi-automatic moisture tester. Duplicate 10-g samples of ground meat were weighed in calibrated dishes and subjected to a temperature of 121°C for 60 min (Fig. 5).

Table 1. Random distribution[a] among cooking periods of 120 rib steaks from 60 carcasses.

Cooking period		Cooking period		Cooking period	
1	YM2L - YM2R YM9L - YM9R	11	IS5L - IS5R YS7L - YS7R	21	YM8L - YM8R IS10L - IS10R
2	MS9L - MS9R IM9L - IM9R	12	MS5L - MS5R YS3L - YS3R	22	IS9L - IS9R YM7L - YM7R
3	MS2L - MS2R YM1L - YM1R	13	IS2L - IS2R YS2L - YS2R	23	MM1L - MM1R MS4L - MS4R
4	YS8L - YS8R MS6L - MS6R	14	YM4L - YM4R IM10L - IM10R	24	MM7L - MM7R IM6L - IM6R
5	MS8L - MS8R YM5L - YM5R	15	IM3L - IM3R IM5L - IM5R	25	IM7L - IM7R MS3L - MS3R
6	MM2L - MM2R IM2L - IM2R	16	YS4L - YS4R MM3L - MM3R	26	MM8L - MM8R MM5L - MM5R
7	IM8L - IM8R MM6L - MM6R	17	YS10L - YS10R YS1L - YS1R	27	YM6L - YM6R IM4L - IM4R
8	MM10L - MM10R IS7L - IS7R	18	YS6L - YS6R YM10L - YM10R	28	MS7L - MS7R IM1L - IM1R
9	IS1L - IS1R IS4L - IS4R	19	YS5L - YS5R IS8L - IS8R	29	YS9L - YS9R MM9L - MM9R
10	IS6L - IS6R MM4L - MM4R	20	YM3L - YM3R IS3L - IS3R	30	MS10L - MS10R MS1L - MS1R

[a]Randomized by left and right sides of carcasses.
L - left (7th thoracic vertebrae)
R - right (8th thoracic vertebrae)

Level of Maturity
Y - youthful
I - intermediate
M - approaching maturity

Level of Marbling
S - small
M - moderate

1-10 - carcass no. within each level of maturity and marbling

Fig. 3. Plan for sampling steaks.

Longissimus dorsi muscle (LD)

A - Lateral cores ($\frac{1}{2}$-in.) for shear value and water holding capacity (center portion of one or two cores selected at random).

B - Medial cores ($\frac{1}{2}$-in.) for shear value and water holding capacity (center portion of one or two cores selected at random).

C - Ground meat for pH, total moisture, and color difference measurements.

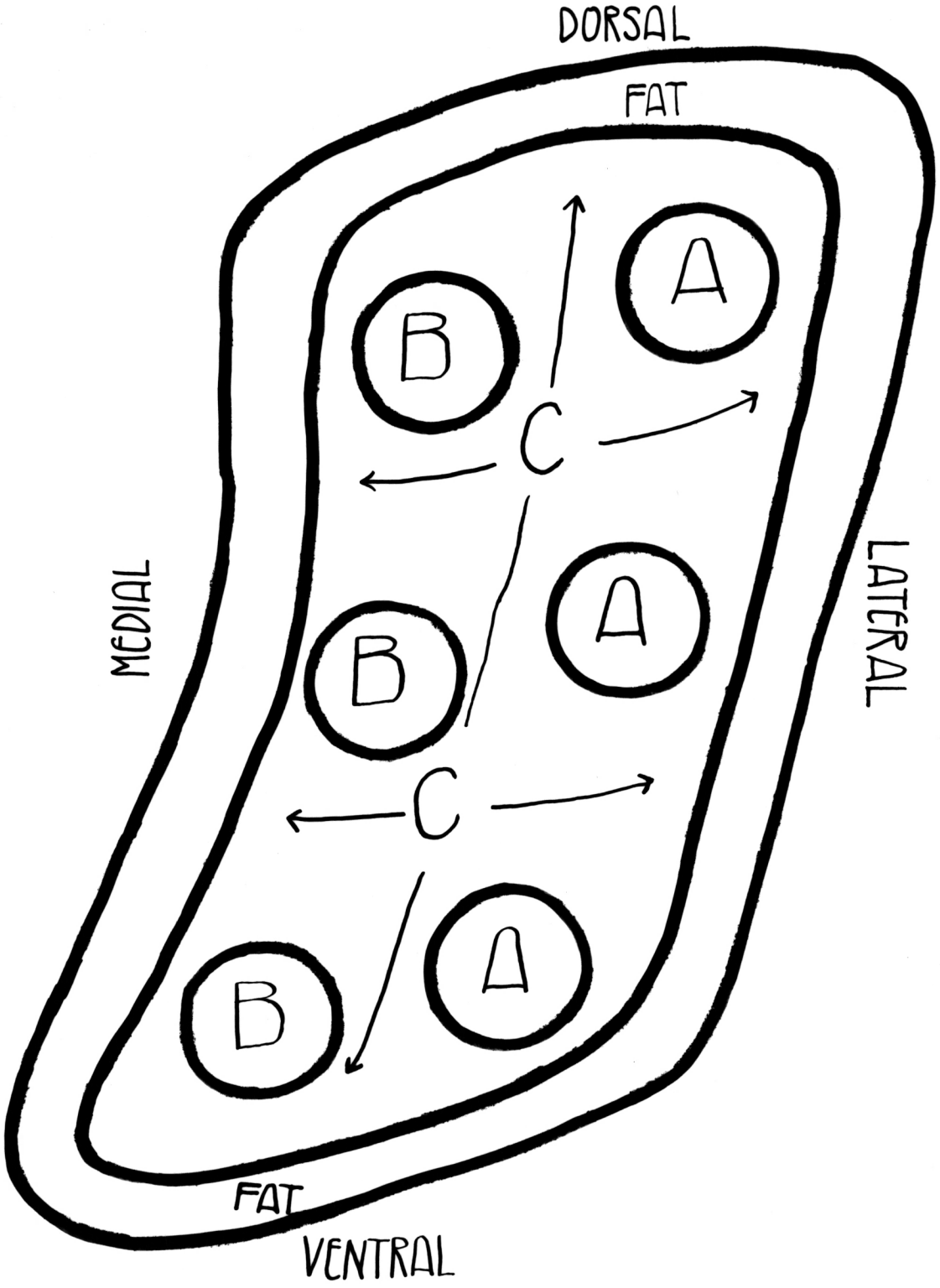
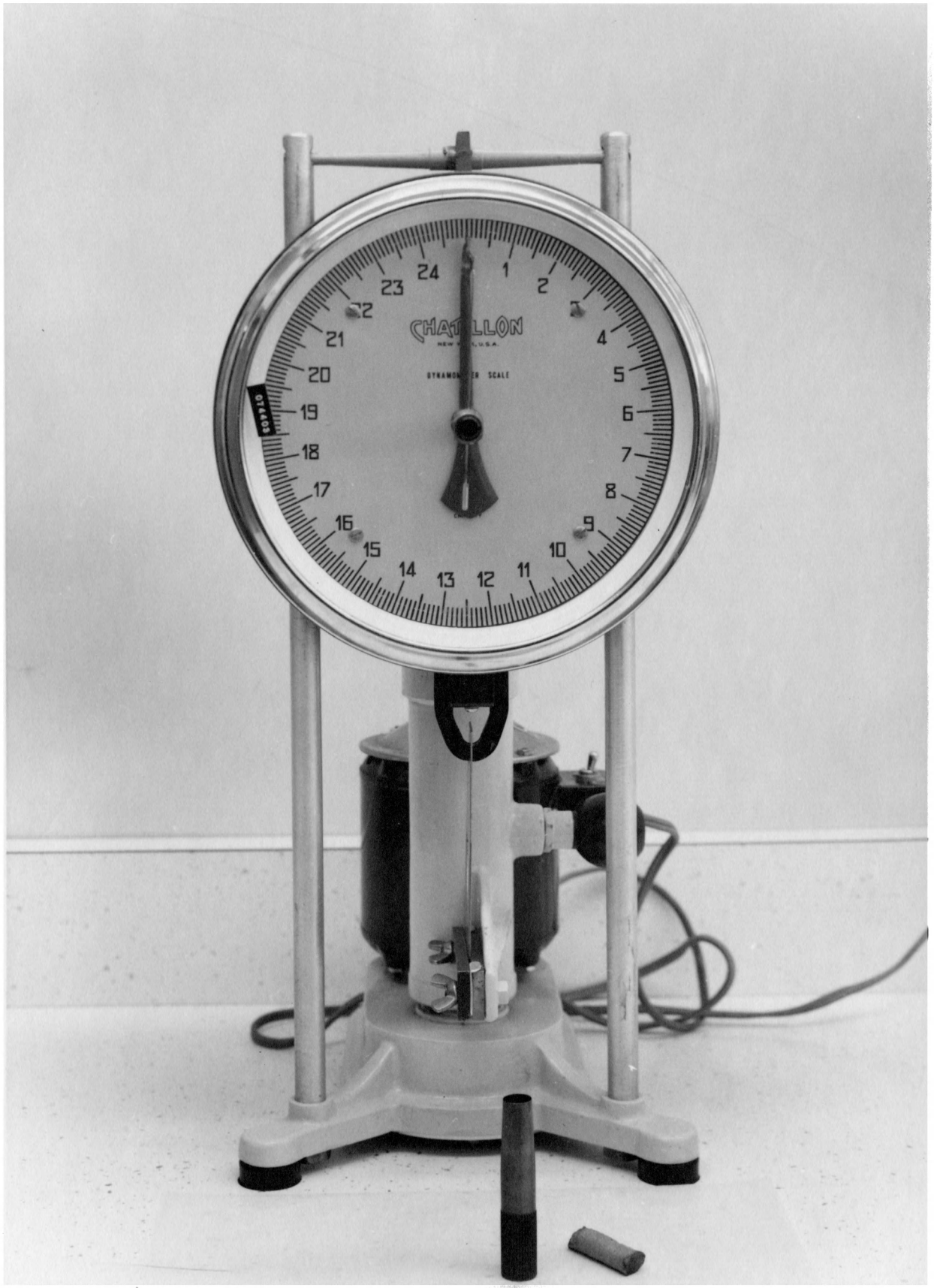

DORSAL
FAT
A
B
C
A
B
C
A
B
MEDIAL
LATERAL
FAT
VENTRAL

Fig. 4. Warner-Bratzler shearing apparatus (25-lb dynamometer) for the determination of tenderness with core of muscle and metal cylinder ($\frac{1}{2}$-in. diameter) for removing the core of muscle.


24
1
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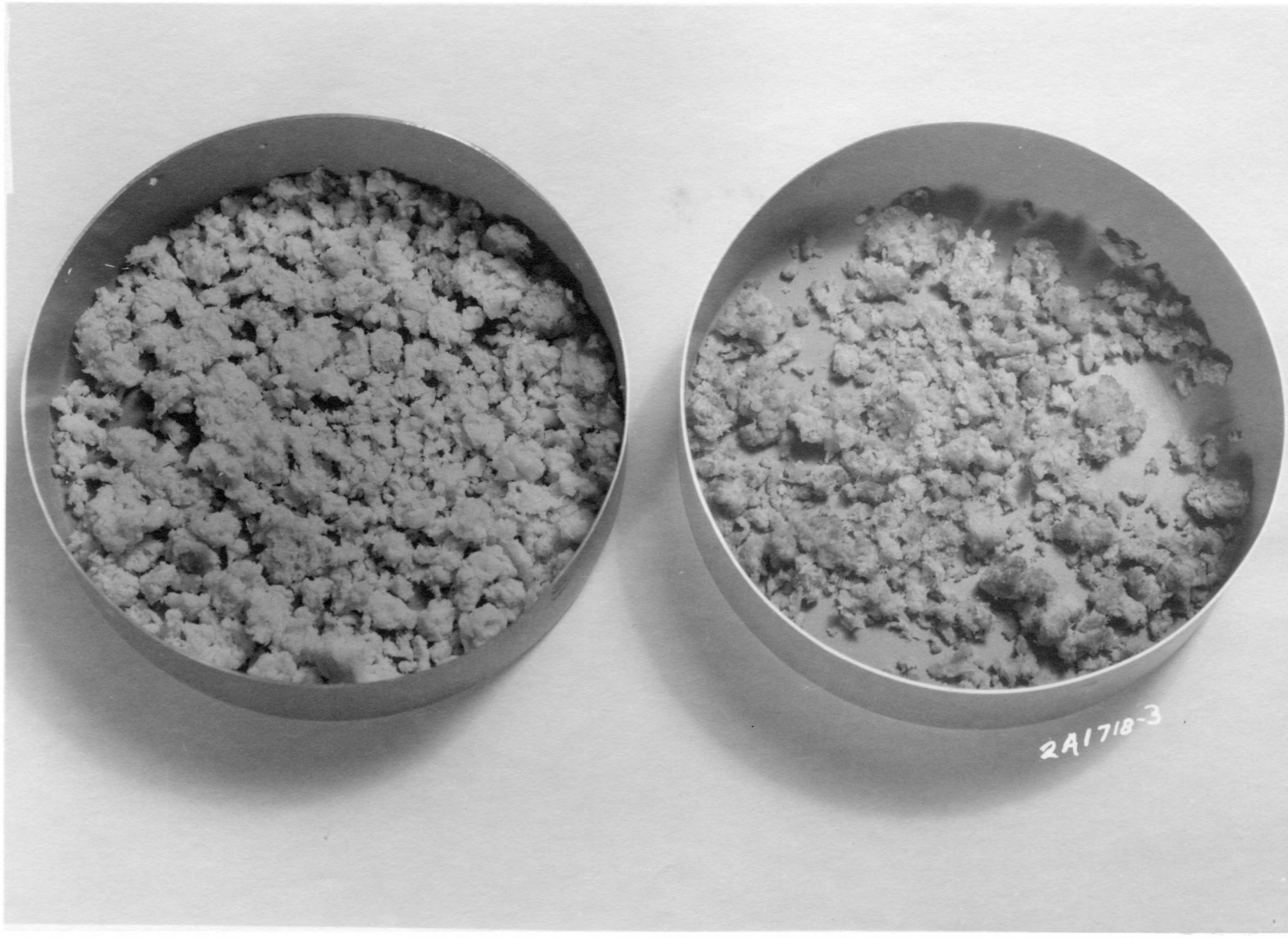
12
11

Fig. 5. Samples (10 g) of ground meat in calibrated dishes used for total moisture determination in a C. W. Brabender semi-automatic moisture tester.
Left - Before drying.
Right - After drying at 121°C for 60 min.


2A1718-3

Water holding capacity. WHC of the cooked steaks was determined as reported by Miller and Harrison (1965). Three values for WHC of each steak were obtained from samples taken at random from medial and lateral $\frac{1}{2}$-in. cores (Fig. 3, 6 and 7).

Color differences. Ground meat (25 g) was packed into a Gardner glass cell for measurement of Rd (reflectance), a+ (redness), and b+ (yellowness) values on the Gardner Color Difference Meter (Fig. 8). Duplicate readings were taken for each color-difference factor. After the first reading, the cell was rotated at 90° for the second reading. The instrument was standardized using a satin finish ceramic tile with calculated values of:

Rd	a+	b+
15.53	9.33	13.10

Statistical Analysis

Data were analyzed by analysis of variance as for a completely randomized design to study differences attributable to maturity and marbling levels and differences between the left and right sides of the carcass. When F-values were significant, least significant differences at the 5% level of probability were calculated. Also, orthogonal comparisons were used to determine differences between specific levels of maturity. Correlation coefficients were calculated to study relationships between selected chemical and physical characteristics of the LD muscle.

The analysis to study differences attributable to maturity and marbling (data for left and right sides of the carcass

Fig. 6. Carver Laboratory Press with stacked Plexiglas plates and filter paper for the pressing of 0.3 g muscle samples to measure water holding capacity.

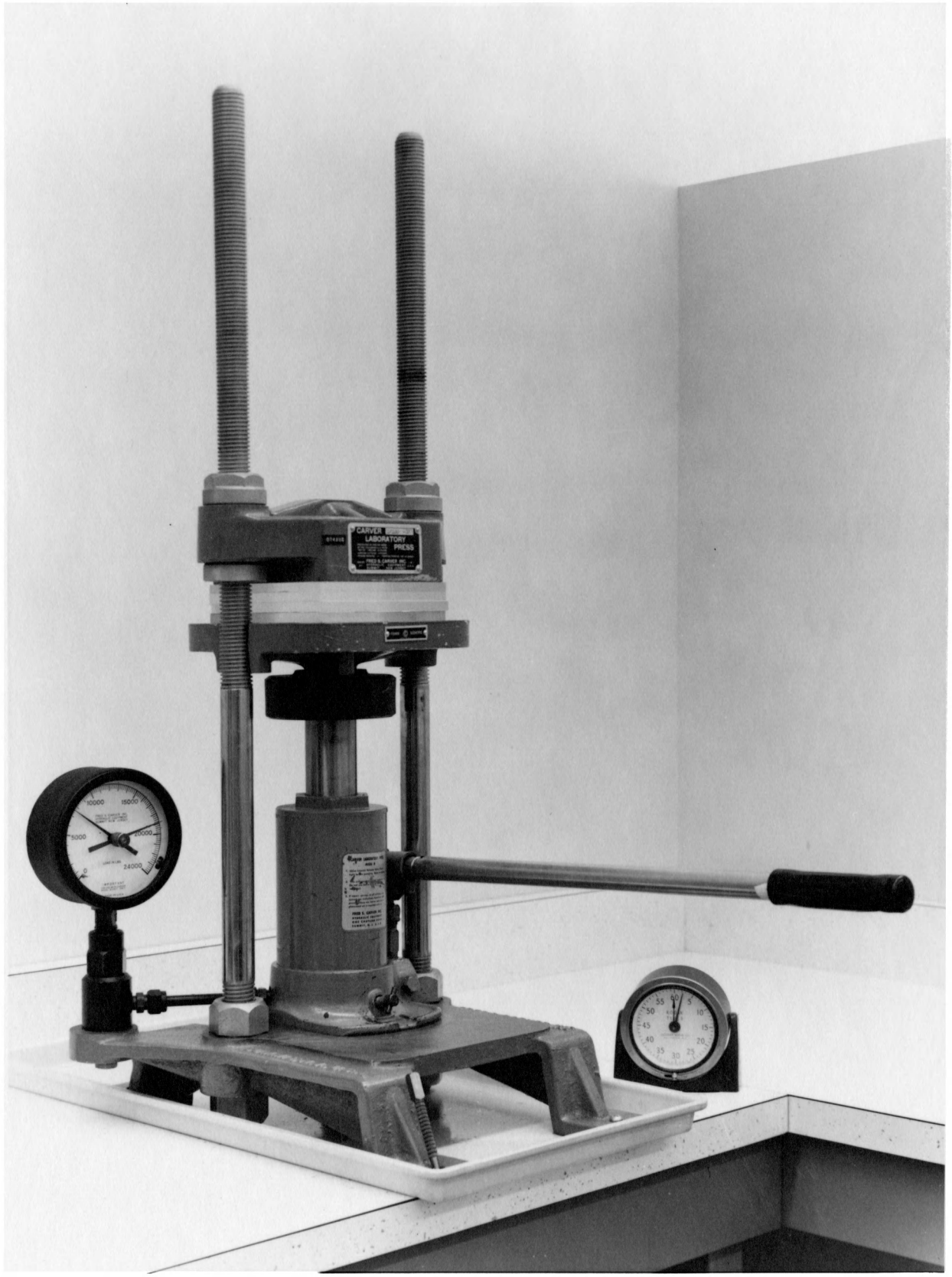

CARVER
LABORATORY
PRESS

Fig. 7. Mimeoscope for tracing markings on filter paper made by pressed muscle used to measure water holding capacity. The circumference of a sample of pressed muscle (inner circle) and its expressible liquid (outer circle) are shown on the filterpaper (6" x 6" square).

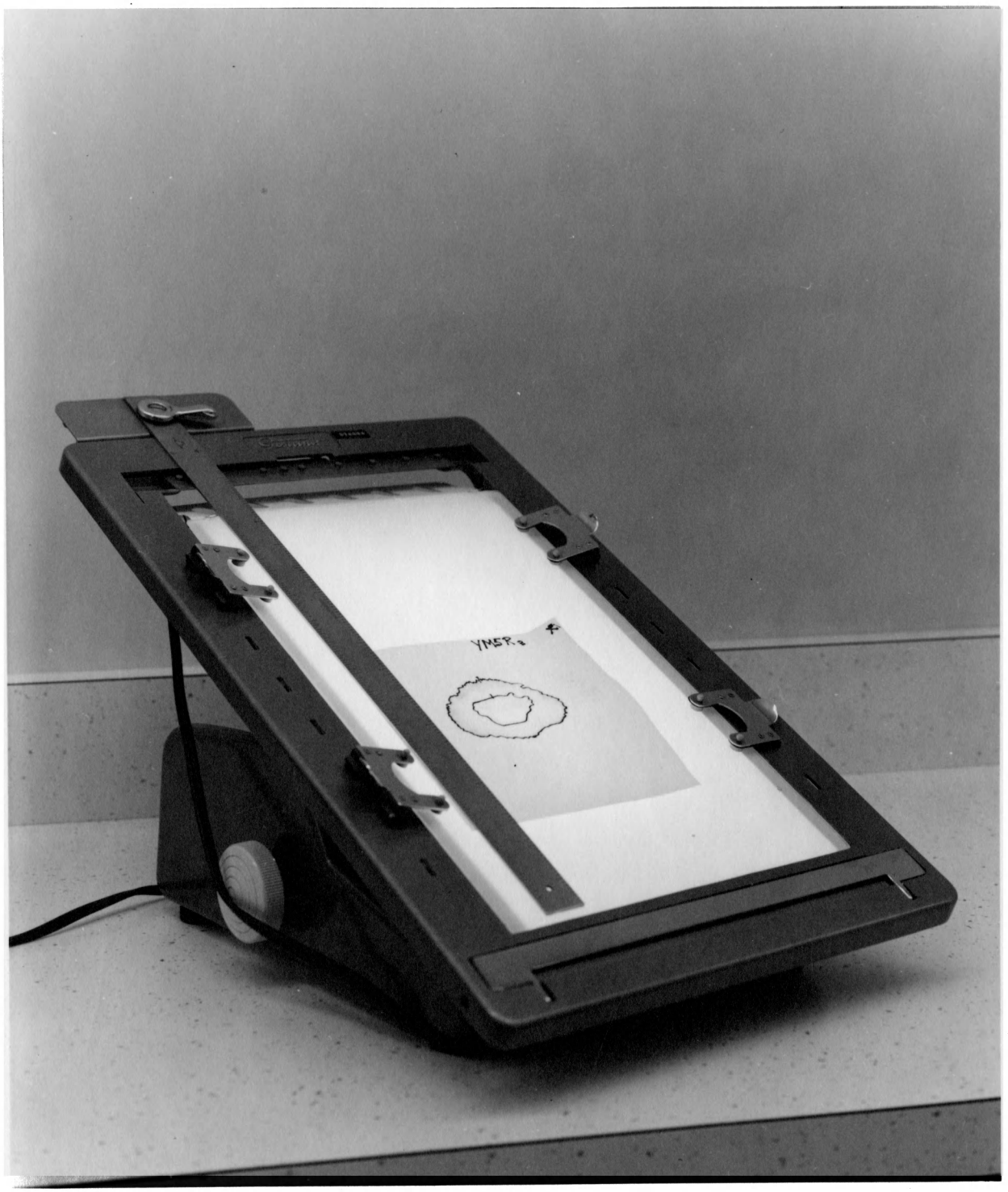

YNSP.

Fig. 8. Gardner Color-Difference Meter, a standard tile (at left on top of the instrument) and samples of ground beef in glass cells (at the center and right on top of the instrument at the left).


Rd
a
b
GARDNER AUTOMATIC COLOR DIFFERENCE METER
MODEL AC-2A SERIES 200
MADE BY
GARDNER LABORATORY, INC
BETHESDA 14, MD
U. S. PATENT
NO. 2,574,264
SERIAL NO. 279

pooled) was:

Source of Variation	D/F
Treatments	5
Error	114
Total	119

The analysis to study differences between the left and right sides of the carcass was:

Source of Variation	D/F
Treatments	5
Error	54
Total	59

RESULTS AND DISCUSSION

In the experimental design steaks were randomized among 30 cooking periods by left and right sides of the carcasses. There were no significant differences attributable to side of the carcass. Thus data for left and right sides of the carcass were pooled and analyzed as for a completely randomized design.

Effect of Maturity and Marbling on Objective Measurements

Cooking time. Cooking time, both total in minutes and minutes per pound, was not affected significantly by level of maturity and marbling (Table 2). Total cooking time was significantly ($P < 0.01$) related (Table 3) to the initial weight of

Table 2. Means and standard deviation[a], F-values, and LSD[b] attributable to maturity and marbling[c].

Measurement	Maturity and marbling levels						F-value	LSD[b]
	Youthful		Intermediate		Approaching maturity			
	Small	Moderate	Small	Moderate	Small	Moderate		
Initial weight, g	538.7 (100.4)	512.6 (52.0)	573.4 (111.9)	548.1 (106.3)	586.4 (67.9)	584.7 (95.5)	2.04 ns	
Cooking time, total min	51.7 (9.1)	51.4 (5.9)	51.0 (7.0)	54.2 (8.2)	56.1 (8.6)	55.4 (8.2)	1.60 ns	
min/lb	44.5 (4.9)	45.6 (4.4)	41.5 (5.9)	46.1 (8.0)	42.5 (6.0)	43.5 (5.5)	1.83 ns	
Cooking losses, total, %	23.4 (2.0)	24.5 (3.4)	23.1 (2.0)	23.6 (2.5)	23.5 (2.8)	24.3 (2.7)	0.95 ns	
volatile, %	18.1 (1.9)	17.4 (2.2)	18.2 (1.8)	17.5 (2.4)	18.1 (2.0)	17.3 (2.1)	0.70 ns	
dripping, %	5.2 (1.4)	6.9 (1.7)	4.6 (1.2)	5.8 (1.8)	5.1 (1.6)	6.8 (1.9)	7.04 ***	1.00
Shear value, lb/½-in. core medial	7.9 (1.4)	6.9 (1.0)	7.9 (1.6)	6.9 (1.6)	7.3 (0.9)	7.3 (1.5)	2.29 ns	
lateral	7.7 (1.8)	7.0 (1.0)	7.7 (1.5)	7.1 (1.4)	7.3 (0.9)	7.0 (1.4)	1.17 ns	
Total moisture, %	62.6 (1.7)	61.1 (2.1)	62.5 (2.0)	60.0 (2.1)	62.6 (2.0)	59.6 (2.1)	9.45 ***	1.25

Table 2. (concluded)

Measurement	Maturity and marbling levels						F-value	LSD[b]
	Youthful		Intermediate		Approaching maturity			
	Small	Moderate	Small	Moderate	Small	Moderate		
WHC[d]	0.62 (0.07)	0.60 (0.07)	0.55 (0.09)	0.60 (0.07)	0.61 (0.07)	0.59 (0.06)	2.13 ns	
pH	5.83 (0.09)	5.77 (0.16)	5.79 (0.11)	5.84 (0.08)	5.80 (0.17)	5.82 (0.08)	1.04 ns	
Color-difference,								
Rd (reflectance)	20.9 (1.6)	20.5 (1.9)	20.0 (2.0)	19.6 (1.7)	19.8 (1.2)	19.8 (1.3)	1.84 ns	
a+ (redness)	11.1 (1.7)	10.0 (2.6)	10.4 (1.8)	9.8 (1.7)	11.4 (2.3)	10.5 (2.3)	1.80 ns	
b+ (yellowness)	11.0 (0.5)	11.0 (0.7)	11.1 (0.7)	10.7 (0.7)	11.1 (0.4)	11.0 (0.5)	1.36 ns	

[a]Values in parenthesis are standard deviations.
[b]LSD = least significant difference at the 5% level.
[c]Data are pooled for left and right sides of the carcass.
[d]WHC = water holding capacity (1.0-expressible liquid index).
ns, not significant.
**, significant at the 1% level.
***, significant at the 0.1% level.

Table 3. Correlation coefficients for selected paired variates on the basis of maturity and marbling level.

Paired variates	r					
	Maturity and marbling levels					
	Youthful		Intermediate		Approaching maturity	
	Small	Moderate	Small	Moderate	Small	Moderate
Initial weight vs.						
cooking time, total, min	0.82**	0.65**	0.74**	0.64**	0.70**	0.82**
cooking time, min/lb	-0.39	-0.23	-0.66	-0.73**	-0.05	-0.58**
cooking losses, total, %	0.62**	0.30	0.24	0.12	0.28	0.17
Cooking time, total, min, vs.						
cooking losses, total, %	0.82**	0.62**	0.45*	0.65**	0.52*	0.53*
WHC	0.09	-0.12	0.09	-0.01	-0.09	0.16
total moisture	-0.39	-0.01	0.17	-0.02	-0.40	-0.22
pH vs.						
WHC	0.45*	0.11	-0.29	0.25	0.14	-0.08
shear value						
medial	0.38	0.14	0.14	0.29	-0.12	0.17
lateral	0.13	-0.13	0.01	0.38	-0.06	0.55*
color difference						
Rd	0.25	0.03	-0.06	0.44*	0.35	0.24
a+	-0.46*	0.06	-0.06	-0.31	-0.04	-0.10
b+	0.05	-0.13	0.20	0.15	0.02	0.18

Table 3. (concluded)

Paired variates	r					
	Maturity and marbling levels					
	Youthful		Intermediate		Approaching maturity	
	Small	Moderate	Small	Moderate	Small	Moderate
WHC vs.						
total moisture	0.36	-0.40	0.38	0.43	0.16	-0.01
total cooking losses	0.20	0.05	-0.16	0.24	-0.21	-0.03

*, significant at the 5% level (0.444).
**, significant at the 1% level (0.562).
WHC - water holding capacity (1.0 - expressible liquid index).

the rib steaks, which ranged from 1.1 to 1.3 pounds (Table 6, Appendix). Length of total cooking time was not related to WHC or total moisture (Table 3).

Cooking losses. Total and volatile cooking losses were not affected significantly by maturity and marbling level. However, percentage dripping losses were affected ($P < 0.001$) by maturity and marbling levels. At each level of maturity dripping losses were greater ($P < 0.05$) at the higher of the two levels of marbling. When marbling level was held constant, significant ($P < 0.05$) differences between maturity levels occurred only between the youthful and intermediate and between intermediate and approaching maturity levels with moderate marbling (Table 2).

Gilpin et al. (1965) reported that the relationship between cooking losses and marbling of the carcass was inconsistent. In their work the only significant relationship ($r = 0.41$) between cooking losses and marbling of beef was attributable to the percentage dripping loss from the eye of the round. In the study reported here, correlation coefficients were not calculated for marbling vs. cooking losses.

Warner-Bratzler shear values. The Warner-Bratzler shearing apparatus was used to measure tenderness. The shearing apparatus measures the number of pounds required to cut across a core of muscle of a given diameter. The core is cut so shearing is done at a right angle to the grain of the muscle.

Mean shear force values for $\frac{1}{2}$-in. cores from both the lateral and medial positions in the LD were not affected by level

of maturity and marbling. At any one level of maturity and marbling the difference in mean shear force between medial and lateral positions was never greater than 0.3 lb. When all levels of maturity and marbling were considered, the greatest difference was 0.9 lb (Table 2). Other workers (Wellington and Stouffer, 1959; Walter et al., 1965; and Goll et al., 1965) also found that shear force of LD was not affected by marbling. Field et al. (1960) reported that when marbling was held constant, maturity, determined by chronological age, had no effect on shear force values.

Total moisture. Percentage total moisture was measured by the C. W. Brabender semi-automatic moisture tester. F-values revealed that total moisture was affected significantly ($P < 0.001$) by level of maturity and marbling. Total moisture decreased ($P < 0.05$) with an increase in the marbling level. In moderately marbled muscle total moisture tended to decrease with increasing level of maturity with the difference between youthful and approaching maturity levels being significant ($P < 0.05$). Total moisture in muscle with a small amount of marbling tended to be consistent for all three maturity levels (Table 2).

When data for total moisture were compared with ether extract values for LD from the same carcasses (Tuma, 1968), the percentage of moisture decreased and percentage of ether extract increased with additional marbling.

Water holding capacity. The ratio of the area of the pressed meat sample to the area of the expressed liquid formed

on filter paper on which the sample was pressed was designated as expressible-liquid index by Miller and Harrison (1965). They obtained values for WHC by substracting the expressible-liquid index from 1.0, which arbitrarily was chosen as the maximum expressible-liquid index. In this study, data for WHC were obtained in the same manner. 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.

Mean values for WHC were not affected by level of maturity and marbling (Table 2). Correlation coefficients for WHC and total moisture and between WHC and total cooking losses were low and nonsignificant (Table 3).

Color-difference. Rd, measured by the Gardener Color Difference meter, is the reflectance value of the sample, which is the amount of light reflected as opposed to the amount of light transmitted or diffused. A completely absorbing sample (dark or opaque rather than light or clear) would have and Rd value of zero, whereas a perfectly diffusing white would have an Rd of 100.

Reflectance was not significantly different for steaks varying in degree of maturity and marbling. However, a trend toward slightly decreased reflectance with increasing maturity, indicating darker meat, was noted (Table 2). This is in agreement with Romans et al. (1965), who found that Munsell value (lightness) decreased with maturity.

Gardener Color Difference meter values of a denote redness or greenness, a+ being red, whereas a- is green. Only a+ values were obtained for the LD muscle evaluated in this study. A value of zero for either a or b components indicates some shade of gray.

Redness was not affected significantly by level of maturity and marbling. However, a trend toward slightly decreasing a+ values with increasing marbling level was observed (Table 2). This is in agreement with Romans et al. (1965) who reported that the pigment content of beef muscle did not differ significantly between moderate and slight marbling levels. However, analysis of variance of their data indicated that marbling had a significant effect on Munsell hue. Hue means were 6.1 ± 0.4 R (red) for the moderate level and 5.0 ± 0.4 R for the slight level of marbling. The authors stated that the effect of increased marbling would push the hue reading higher, and thus closer to the yellow-red notation.

Gardener values for b+ measure yellowness of a sample, whereas b- denotes blueness. Values of b+ were not significantly affected by level of maturity and marbling (Table 2).

The nonsignificant difference in color between the two marbling levels studied is in agreement with the work of Tuma et al. (1962), who found that marbling did not significantly influence any of the three dimensions of color (hue, chroma, and value).

pH. Maturity and marbling did not have a significant

effect on the pH of the muscle studied (Table 2). Most of the correlation coefficients for pH and WHC, pH and shear value, or pH and color difference were low and nonsignificant (Table 3). Miller and Harrison (1965) reported a moderate, but significant ($r = -0.45^{**}$) correlation coefficient for pH vs. WHC with 46 DF. Pengilly and Harrison (1966) reported moderate ($r = -0.45$) and low (0.21 and -0.20) correlation coefficients for pH vs. WHC with 10 DF when pork loin was cooked to 65, 75, and 85°C, respectively.

The low or nonsignificant correlation between pH and WHC may be attributed to the pH of the cooked LD, which ranged from 5.74 to 5.86 (Table 9, Appendix), and which is close to the isoelectric point of muscle proteins (pH 5.0). Hamm (1960) stated that the pH at which the WHC was at a minimum corresponded approximately to the isoelectric point of actomyosin. The addition of acid or base caused a swelling of the muscle because a repulsion between protein groups with the same charge took place. This repulsion enlarged the space between the peptide chains and more water could penetrate.

SUMMARY

Rib steaks (120, 2-in. thick) from the 7th (leftside) and 8th (rightside) thoracic vertebrae, representing three maturity levels (youthful, intermediate and approaching maturity) and two marbling levels (small and moderate), were used to investigate the effect of maturity (physiological age) and marbling on

selected characteristics of beef.

Cooking time and total and volatile cooking losses were not affected significantly by level of maturity and marbling. However, percentage dripping losses were affected ($P < 0.05$) by marbling levels, with losses higher for a moderate than for a small amount of marbling. Warner-Bratzler shear values, WHC, pH and color were not affected significantly by maturity and marbling level. Total moisture was affected significantly ($P < 0.001$) by level of maturity and marbling. Mean values for total moisture were less ($P < 0.05$) for the moderate than for the small level of marbling. In moderately marbled muscle total moisture tended to decrease with increasing maturity, and the difference between youthful and approaching maturity levels was significant ($P < 0.05$).

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APPENDIX

Table 4. Mean differences between left and right sides of the carcass, standard deviations[a], and F-values for objective measurements.

Measurement	Maturity and marbling levels						F-value
	Youthful		Intermediate		Approaching maturity		
	Small	Moderate	Small	Moderate	Small	Moderate	
Initial weight, g	56.0 (128.6)	-14.5 (44.3)	8.8 (114.9)	75.8 (138.9)	6.9 (91.5)	41.2 (97.9)	1.02 ns
Cooking time, total min	7.5 (11.1)	1.6 (3.3)	4.3 (8.1)	5.3 (11.1)	5.4 (8.6)	3.6 (9.0)	0.49 ns
min/lb	2.2 (5.7)	2.8 (5.3)	2.9 (6.1)	-3.8 (10.6)	4.2 (5.1)	-0.5 (6.7)	1.86 ns
Cooking losses, total, %	0.91 (2.99)	0.14 (2.68)	0.19 (3.54)	0.16 (3.16)	1.31 (3.20)	-0.29 (4.74)	0.29 ns
volatile, %	1.7 (2.0)	0.8 (2.0)	1.2 (2.8)	0.4 (3.0)	1.9 (2.3)	1.6 (2.4)	0.55 ns
dripping, %	-0.95 (1.5)	-0.86 (1.1)	-0.82 (1.4)	-0.15 (2.7)	-0.80 (1.7)	-2.11 (2.4)	1.13 ns
Shear value, lb/½-in. core medial	0.66 (1.9)	0.36 (1.6)	0.90 (1.7)	1.05 (1.8)	-0.22 (1.0)	0.82 (2.2)	0.73 ns
lateral	0.29 (1.6)	0.26 (1.2)	0.73 (1.4)	0.59 (1.9)	0.22 (1.1)	1.03 (1.5)	0.49 ns
Total moisture, %	-0.86 (2.3)	-0.84 (2.8)	-1.3 (2.1)	-0.34 (2.6)	-1.5 (3.1)	-0.64 (2.7)	0.27 ns

Table 4. (concluded)

Measurement	Maturity and marbling levels						F-value
	Youthful		Intermediate		Approaching maturity		
	Small	Moderate	Small	Moderate	Small	Moderate	
WHC[b]	-0.08 (0.06)	-0.01 (0.06)	-0.04 (0.11)	-0.04 (0.04)	-0.05 (0.08)	-0.03 (0.07)	0.89 ns
pH	-0.01 (0.10)	0.05 (0.09)	0.03 (0.06)	0.04 (0.06)	0.06 (0.08)	0.07 (0.07)	1.42 ns
Color-difference							
Rd (reflectance)	0.26 (1.2)	0.38 (1.6)	0.10 (1.2)	-0.90 (1.7)	0.06 (0.7)	-0.20 (1.0)	1.28 ns
a+	0.17 (2.6)	0.68 (3.2)	0.45 (2.3)	0.44 (2.4)	-0.10 (2.5)	0.59 (2.8)	0.12 ns
b+	0.13 (0.22)	-0.00 (0.30)	0.11 (0.28)	-0.14 (0.24)	0.01 (0.26)	-0.04 (0.31)	1.36 ns

[a]Values in parenthesis are standard deviations.

[b]WHC = water holding capacity (1.0-expressible liquid index)

ns, not significant.

Table 5. Initial weight and cooking time of rib steaks

Factor	Youthful				Intermediate				Approaching Maturity			
	Small		Moderate		Small		Moderate		Small		Moderate	
	L	R	L	R	L	R	L	R	L	R	L	R
Initial weight, gms												
	795	547	544	494	569	366	711	314	639	592	700	721
	554	559	472	455	529	655	680	512	663	607	712	686
	549	562	507	555	743	639	487	318	683	504	603	630
	696	429	437	454	606	611	592	527	532	575	662	549
	521	459	543	499	513	497	691	697	560	585	697	462
	410	537	434	465	762	684	585	519	716	616	580	458
	465	462	466	540	686	651	557	576	603	589	637	616
	612	688	596	583	571	521	542	591	509	619	430	507
	543	468	551	579	391	470	466	531	577	616	485	552
	522	396	503	574	408	596	549	517	416	526	547	460
Av.	567	511	505	520	578	569	586	510	590	583	605	564
Cooking time total, min												
	66	51	58	58	57	32	77	46	78	60	62	73
	58	49	46	45	48	49	54	59	71	59	67	60
	49	45	58	56	60	57	45	43	60	48	47	60
	72	43	45	37	53	54	62	48	47	52	58	45
	62	48	49	50	44	40	61	56	50	53	63	51
	47	49	47	49	59	58	59	52	65	54	53	46
	41	43	49	48	56	47	58	58	62	56	65	60
	55	65	57	50	56	50	48	47	45	51	49	48
	59	45	57	58	46	47	53	62	63	52	51	46
	45	41	56	55	52	54	52	45	47	49	57	47
Av.	55	48	52	51	53	49	57	52	59	53	57	54

Table 5. (concluded)

Factor	Youthful				Intermediate				Approaching Maturity			
	Small		Moderate		Small		Moderate		Small		Moderate	
	L	R	L	R	L	R	L	R	L	R	L	R
Cooking time min/lb	36.7	42.5	48.7	53.2	47.5	40.0	48.1	65.7	55.7	46.2	34.8	38.1
	48.3	40.8	44.2	45.0	40.0	35.0	36.0	53.6	48.6	44.0	41.9	40.0
	40.8	37.5	52.7	46.7	37.5	40.7	40.9	61.4	40.0	43.6	36.2	42.9
	48.0	47.7	45.0	37.0	40.8	41.5	47.7	40.0	31.4	32.6	41.4	37.5
	56.4	48.0	41.2	45.5	40.0	36.4	40.7	37.3	41.7	40.8	42.0	51.0
	52.2	40.8	47.0	49.0	34.7	38.7	45.4	47.3	40.6	38.6	40.8	46.0
	41.0	43.0	49.0	40.0	37.0	34.0	48.3	44.6	47.7	43.1	46.4	52.9
	42.3	42.7	43.8	38.5	43.1	45.4	40.0	36.2	40.2	37.5	54.4	43.6
	49.2	45.0	47.5	44.6	51.1	47.0	51.9	53.4	48.4	37.1	46.4	38.3
	40.9	45.6	50.9	42.3	57.8	41.5	43.3	40.9	52.2	40.8	48.0	47.0
Av.	45.6	43.4	47.0	44.2	42.9	40.0	44.2	48.0	44.7	40.4	43.2	43.7

L - left sides of the carcass.
R - right sides of the carcass.

Table 6. Percentage total, volatile and dripping losses during broiling.

Factor	Maturity and marbling level											
	Youthful				Intermediate				Approaching Maturity			
	Small		Moderate		Small		Moderate		Small		Moderate	
	L	R	L	R	L	R	L	R	L	R	L	R
Cooking losses, total	26.8	24.8	23.5	24.5	24.6	20.0	30.4	25.5	27.9	23.1	23.3	26.7
	22.1	23.7	25.4	27.4	20.6	26.0	22.4	26.8	23.1	21.4	27.7	25.2
	21.5	22.7	26.7	26.4	21.8	23.4	20.7	23.9	22.6	20.9	18.0	29.8
	27.7	21.8	22.8	17.4	20.1	23.1	22.7	20.4	18.0	21.7	25.3	20.2
	26.0	21.9	22.4	25.5	22.6	21.6	23.3	25.2	26.2	28.4	22.6	24.2
	23.7	22.0	21.7	23.2	24.2	25.5	22.6	21.3	25.4	20.6	24.1	24.4
	21.0	23.2	23.9	20.6	22.4	22.4	24.2	21.8	26.4	23.4	24.8	23.7
	21.9	24.9	23.2	21.0	27.2	20.7	24.2	22.3	20.6	23.7	23.7	23.3
	26.2	22.7	30.8	32.4	24.7	22.4	24.0	27.6	27.5	23.5	24.7	20.9
	21.3	21.4	25.8	26.4	23.5	24.7	22.5	20.6	23.8	21.7	27.4	26.1
Av.	23.8	22.9	24.6	24.5	23.2	23.0	23.7	23.5	24.2	22.8	24.2	24.4
Volatile	20.5	18.8	17.4	16.6	19.5	14.2	22.1	21.0	22.4	17.1	19.3	19.1
	18.0	18.2	17.8	19.1	16.8	18.8	15.7	23.1	19.3	17.4	21.2	17.6
	16.9	14.4	19.9	20.5	18.2	18.8	16.4	16.0	18.7	14.5	14.6	18.2
	22.8	17.5	17.2	12.8	15.7	15.3	19.4	15.7	15.8	17.2	17.0	13.1
	21.1	18.1	15.8	16.6	18.7	17.1	17.1	16.9	20.5	19.7	16.6	16.7
	18.3	16.4	15.7	16.3	19.2	19.4	16.6	14.8	19.0	16.1	19.5	18.8
	17.8	16.7	17.4	14.6	19.1	18.1	18.0	17.4	21.1	18.5	19.3	15.9
	15.4	17.6	17.3	14.9	22.1	16.5	17.2	15.9	15.7	17.6	17.0	14.4
	19.7	16.9	20.3	21.8	18.4	15.5	18.5	18.5	19.9	16.6	17.7	14.1
	18.8	17.7	19.1	16.9	19.9	19.1	16.6	13.9	18.0	16.7	19.0	17.2
Av.	18.9	17.2	17.8	17.0	18.8	17.6	17.8	17.3	19.0	17.1	18.1	16.5

Table 6. (concluded)

Factor	Maturity and marbling level											
	Youthful				Intermediate				Approaching Maturity			
	Small		Moderate		Small		Moderate		Small		Moderate	
	L	R	L	R	L	R	L	R	L	R	L	R
Dripping	6.3	6.0	6.3	7.9	5.0	3.6	8.3	4.5	5.2	5.4	3.9	7.4
	3.8	5.5	7.6	8.1	3.6	7.2	6.3	3.5	3.3	3.6	6.0	7.4
	4.2	7.8	5.1	6.1	3.4	4.5	4.1	7.9	3.7	6.2	3.3	11.4
	4.7	5.4	5.5	4.4	4.3	4.6	3.0	4.4	1.1	4.3	8.2	7.3
	4.6	3.7	6.4	8.8	3.7	4.4	5.9	8.2	5.5	8.7	5.7	7.6
	5.1	5.4	5.8	6.9	4.9	6.0	6.2	6.4	6.4	5.0	4.1	5.8
	3.2	6.5	5.4	5.9	3.2	3.7	5.9	2.4	5.3	4.6	5.3	7.6
	6.5	7.1	5.7	6.0	4.4	3.8	6.3	5.9	4.1	5.7	6.5	8.7
	6.1	5.6	10.3	10.2	6.1	6.8	6.0	9.0	7.1	6.7	6.8	6.9
	2.5	3.5	6.8	9.2	3.7	5.9	5.3	6.6	5.3	4.8	7.9	8.7
Av.	4.7	5.7	6.5	7.4	4.2	5.0	5.7	5.9	4.7	5.5	5.8	7.9

L - left sides of the carcass.
R - right sides of the carcass.

Table 7. Shear values based on medial and lateral position.

	Maturity and marbling level																			
	Youthful								Intermediate								Approaching maturity							
	Small				Moderate				Small				Moderate				Small				Moderate			
	L		R		L		R		L		R		L		R		L		R		L		R	
Factor	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l	m	l
Shear value, lb/½-in. core	9.4	10.4	9.6	8.7	7.8	6.6	6.4	5.7	9.1	8.5	5.2	5.3	11.6	11.5	6.7	6.9	9.2	8.0	7.4	7.8	7.8	6.8	6.8	6.0
	10.2	11.1	7.4	9.3	6.5	6.3	6.4	6.2	5.9	6.6	7.2	6.4	7.6	7.5	7.1	8.8	7.4	7.6	8.1	7.7	8.6	7.9	6.5	7.1
	6.6	6.0	5.9	5.5	7.7	8.2	6.6	7.4	7.9	6.6	6.4	5.4	7.6	7.7	6.3	5.7	6.4	6.9	5.9	6.7	5.9	4.9	7.3	6.4
	9.9	10.1	8.2	7.7	7.0	6.4	9.4	9.0	8.7	8.2	8.6	8.6	8.7	7.0	6.8	7.2	6.5	7.1	8.6	6.9	7.2	7.1	5.1	4.7
	7.5	7.0	7.2	7.0	5.7	6.7	8.1	7.4	8.5	8.9	5.6	6.1	4.8	5.6	5.3	6.2	7.3	5.8	7.7	7.1	7.3	8.0	9.4	6.5
	6.2	5.9	7.9	6.1	7.0	7.0	5.5	5.9	6.0	5.7	7.2	6.9	8.7	8.5	6.1	6.6	6.8	6.8	6.3	6.0	7.2	8.0	5.8	5.2
	7.1	7.4	9.4	10.6	6.8	7.1	5.8	6.7	8.4	7.4	7.5	7.8	7.1	7.0	7.2	7.6	7.8	7.9	8.6	8.3	11.9	10.2	7.5	8.2
	7.9	7.4	6.5	8.0	8.1	7.9	5.9	6.1	9.0	9.6	8.8	8.5	7.3	6.4	6.4	7.8	6.9	7.0	7.8	8.1	6.0	6.2	6.7	7.0
	10.6	7.1	6.8	7.1	7.8	8.9	7.0	8.1	8.7	8.5	8.6	8.4	5.0	6.1	4.9	5.7	6.2	7.6	6.5	6.0	9.1	9.3	6.2	6.8
	7.3	6.0	7.2	5.5	6.6	5.7	6.3	5.7	11.7	10.3	9.8	9.6	6.0	6.8	7.1	5.7	7.6	9.7	7.4	7.6	6.5	6.8	8.0	7.0
Av.	8.3	7.8	7.6	7.6	7.1	7.1	6.7	6.8	8.4	8.0	7.5	7.3	7.4	7.4	6.4	6.8	7.2	7.4	7.4	7.2	7.8	7.5	6.9	6.5

L - left sides of the carcass.
R - right sides of the carcass.
m - medial position of the LD muscle.
l - lateral position of the LD muscle.

Table 8. pH, total moisture, and WHC.

Factor	Maturity and marbling level											
	Youthful				Intermediate				Approaching Maturity			
	Small		Moderate		Small		Moderate		Small		Moderate	
	L	R	L	R	L	R	L	R	L	R	L	R
pH	5.83	5.84	5.90	5.88	6.00	5.89	5.95	5.84	5.77	5.70	5.87	5.74
	5.78	5.79	5.97	5.82	5.72	5.70	5.91	5.90	6.00	6.09	5.80	5.82
	5.68	5.80	5.82	5.65	5.82	5.77	5.86	5.81	5.78	5.78	5.78	5.83
	5.99	5.89	5.89	5.82	5.87	5.91	5.82	5.80	5.88	5.88	5.73	5.71
	5.77	5.70	5.33	5.39	5.66	5.72	5.86	5.81	5.94	5.76	5.80	5.69
	5.93	5.85	5.88	5.76	5.88	5.80	5.92	5.90	6.01	5.87	5.96	5.81
	5.65	5.86	5.74	5.68	5.77	5.80	5.81	5.73	5.84	5.82	6.03	5.87
	5.80	5.84	5.87	5.78	5.65	5.54	5.98	5.82	5.45	5.36	5.87	5.82
	5.95	5.88	5.73	5.78	5.82	5.80	5.82	5.83	5.79	5.70	5.78	5.76
	5.82	5.87	5.77	5.84	5.90	5.86	5.73	5.64	5.88	5.82	5.90	5.81
Av.	5.82	5.83	5.79	5.74	5.81	5.78	5.86	5.81	5.83	5.78	5.85	5.79
Total moisture, %	62.4	62.0	55.8	63.0	61.4	61.6	59.4	55.8	61.0	63.7	62.9	56.5
	61.9	61.2	60.4	60.6	60.1	61.1	62.0	59.0	60.1	64.5	58.0	57.1
	60.2	62.9	60.4	60.5	65.0	65.6	59.7	59.4	61.6	64.9	56.2	60.2
	62.4	65.7	59.0	59.2	59.9	63.3	63.2	64.3	65.7	63.6	57.4	59.5
	60.2	61.8	62.3	63.5	61.4	64.2	59.5	59.6	60.0	63.4	59.8	60.8
	61.3	64.6	60.2	61.2	64.0	61.0	56.8	59.3	63.0	63.2	57.6	59.0
	61.6	62.8	65.0	60.6	64.4	65.5	59.0	61.4	64.5	60.5	59.8	61.9
	64.2	59.8	63.7	64.3	59.2	63.6	60.4	59.2	63.6	62.0	59.7	61.3
	63.8	64.6	60.2	60.7	59.8	62.6	60.5	61.1	58.5	63.0	61.9	63.7
	64.0	65.2	59.4	61.2	63.4	63.1	58.2	63.0	60.8	65.2	59.8	59.2
Av.	62.2	63.1	60.6	61.5	61.9	63.2	59.9	60.2	61.9	63.4	59.3	60.0

L - left sides of the carcass.
R - right sides of the carcass.

Table 9. Gardner color-difference measurements of ground meat.

Factor		Maturity and marbling level											
		Youthful				Intermediate				Approaching Maturity			
		Small		Moderate		Small		Moderate		Small		Moderate	
		L	R	L	R	L	R	L	R	L	R	L	R
Color,													
Rd		20.59	21.91	24.68	24.51	21.10	20.73	17.54	21.62	18.94	19.85	18.76	20.50
		19.89	20.88	20.68	22.06	20.42	20.00	21.04	21.28	19.22	19.08	21.01	18.78
		19.22	19.51	19.83	21.51	17.94	18.87	17.81	20.39	18.98	17.90	19.51	20.19
		19.00	19.10	20.98	17.09	16.20	17.71	17.74	18.98	19.80	19.90	18.09	18.78
		22.47	20.94	21.46	20.83	23.60	22.72	19.06	20.85	21.10	21.08	19.99	20.96
		25.09	22.73	20.01	19.66	22.48	23.19	16.77	18.29	21.35	21.24	21.46	21.74
		19.99	19.31	18.68	19.83	20.02	20.92	21.40	20.27	20.95	21.24	19.71	19.17
		20.83	19.89	21.20	19.47	18.88	17.92	18.95	18.86	18.49	18.34	20.53	20.91
		22.22	22.99	20.39	20.19	20.40	17.92	18.47	18.80	21.14	19.81	17.34	17.27
		20.92	20.36	18.56	17.50	19.07	19.04	22.82	21.26	18.12	19.08	20.25	20.39
	Av.	21.02	20.76	20.65	20.27	20.01	19.90	19.16	20.06	19.81	19.75	19.67	19.87
a+		9.60	10.62	8.45	8.27	8.42	9.72	7.56	8.05	9.63	11.94	10.50	8.10
		12.46	12.28	9.53	7.89	11.17	7.67	10.26	7.96	9.15	12.16	8.46	8.28
		13.22	13.14	9.50	7.62	13.41	11.80	12.06	7.07	15.24	14.70	15.48	8.72
		8.10	12.74	10.64	18.24	12.98	9.42	9.53	12.18	15.04	12.50	9.02	11.36
		9.14	11.07	11.61	8.59	9.51	10.20	10.18	8.77	10.62	8.20	11.50	9.98
		8.87	10.20	13.09	9.59	10.61	8.34	10.47	11.27	9.48	11.57	11.31	10.56
		12.25	9.73	12.73	9.49	9.24	9.91	10.74	10.06	11.77	12.11	9.92	10.58
		14.66	9.90	11.81	11.23	8.94	11.89	10.95	9.83	14.00	9.77	11.23	12.68
		12.20	10.84	7.76	7.12	12.06	14.22	8.30	7.42	7.59	8.76	12.37	15.30
		11.49	9.80	8.48	8.75	10.20	8.91	9.79	12.83	11.04	12.88	8.08	6.38
	Av.	11.20	11.03	10.36	9.68	10.65	10.21	9.98	9.54	11.36	11.46	10.79	10.19

Table 9. (concluded)

Factor	Maturity and marbling level											
	Youthful				Intermediate				Approaching Maturity			
	Small		Moderate		Small		Moderate		Small		Moderate	
	L	R	L	R	L	R	L	R	L	R	L	R
Color, b+	11.08	11.25	11.67	12.03	11.68	11.53	10.38	18.85	11.07	11.27	10.65	10.64
	10.52	10.52	11.51	11.93	10.24	9.74	11.87	12.06	11.40	11.71	11.65	11.31
	10.20	10.28	11.14	11.16	11.18	11.07	9.91	9.91	11.17	10.96	11.26	10.79
	10.68	10.73	10.29	10.55	10.98	11.08	10.61	10.88	10.85	10.61	10.84	11.04
	11.27	10.87	11.62	11.66	12.11	12.31	9.84	9.93	10.06	10.32	10.49	10.63
	11.15	10.94	10.72	10.31	12.10	11.68	10.08	10.29	11.56	11.75	11.98	12.20
	11.96	11.66	10.01	9.93	11.64	12.05	11.20	10.90	11.48	11.16	10.79	10.78
	11.91	11.44	10.88	10.39	10.71	10.43	11.55	11.49	11.50	11.12	10.47	10.63
	11.61	11.34	11.53	11.58	10.78	10.57	11.11	11.10	11.49	11.53	10.54	11.17
	10.70	10.73	10.70	10.56	10.49	10.32	9.94	10.43	10.94	10.99	11.48	11.40
Av.	11.11	10.98	11.01	11.01	11.19	11.08	10.65	10.78	11.15	11.14	11.02	11.06

L - left sides of the carcass.
R - right sides of the carcass.

SELECTED CHARACTERISTICS OF RIB STEAKS FROM CARCASSES OF VARYING DEGREES OF MATURITY AND MARBLING

by

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U.S.D.A. graders place great emphasis on maturity and marbling of beef carcasses. However, the results of research on the role of those two factors in determining the characteristics of meat are conflicting. Moreover, most of the studies found in the literature based maturity on the chronological age of the animal. Therefore, it seemed appropriate to study the effect of the physiological age of the animal and marbling on selected characteristics of beef.

Rib steaks (120, 2-in. thick) from the 7th (leftside) and 8th (rightside) thoracic vertebrae representing three maturity levels (youthful, intermediate, and approaching maturity) and two marbling levels (small and moderate) were used to investigate the effect of maturity (physiological age) and marbling on selected characteristics of beef rib steaks.

Measurements on cooked LD included: Warner-Bratzler shear values, Gardener color-difference values (Rd, a+, b+), percentage total moisture, pH, and water holding capacity. Cooking time and losses of the steaks were noted. Data for each factor were analyzed by analysis of variance, and when F values were significant, least significant differences ($P < 0.05$) were calculated.

Cooking time and total and volatile cooking losses were not affected significantly by level of maturity and marbling. However, percentage dripping losses were affected ($P < 0.05$) by marbling levels with losses higher for a moderate than for a small amount of marbling. Warner-Bratzler shear values, WHC,

pH and color were not affected significantly by maturity and marbling level. Total moisture was affected significantly ($P < 0.001$) by level of maturity and marbling. Mean values for total moisture were less ($P < 0.05$) for the moderate than for the small level of marbling. In moderately marbled muscle total moisture tended to decrease with increasing maturity, and the difference between youthful and approaching maturity levels was significant ($P < 0.05$).