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To the Graduate Council:

I am submitting herewith a thesis written by Barbara Hammer Bayne entitled "Response of Small and Large Rib and Round Beef Roasts of Two Degrees of Finish to Two Rates of Heat Application." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science.

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RESPONSE OF SMALL AND LARGE RIB AND ROUND BEEF ROASTS OF TWO DEGREES OF FINISH TO TWO RATES OF HEAT APPLICATION

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Barbara Hammer Bayne

August 1968

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B. H. B.

ABSTRACT

Eighty roasts consisting of paired small and large, bone-in rib and boneless top-round cuts from five low-finish and five high-finish Hereford steers were studied. One cut from each pair was roasted at 200°F and the other at 300°F to end points of 152° and 158°F respectively, according to a balanced-lattice design. Tenderness, juiciness, and flavor were evaluated by a trained taste panel. An objective measurement of tenderness was obtained with the Warner-Bratzler Shear. Cooking loss and cooking time were determined also.

Cuts roasted at 200°F had lower total cooking losses, longer cooking times per pound, and were more tender than those roasted at 300°F. The 200°F heat treatment afforded relatively more increase in tenderness of round cuts than of rib cuts.

Rib roasts scored higher in tenderness, flavor, and juiciness and had lower total cooking losses and shorter cooking times per pound than round roasts. Cooking times per pound were longer and total cooking losses higher for small than large roasts. Small rounds scored and sheared more tender than large rounds but tenderness of rib cuts was not affected by size.

Only flavor scores were affected by degree of finish, being higher for high-finish than for low-finish cuts.

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CHAPTER I

INTRODUCTION

Tenderness is thought by many to be the prime indicator of meat quality. Among the many ante-mortem and post-mortem factors influencing beef tenderness are: breed, age, and class of the animal; feeding regime; aging treatment; and cooking method. Although the inherent tenderness of beef as it reaches the consumer is dependent upon all of these factors, ultimate eating quality may be either enhanced or degraded by the cooking method chosen.

Traditionally, oven roasting has been an approved cooking method for "tender" cuts such as rib whereas moist heat methods have been employed for cooking "less tender" cuts such as round. The currently recommended temperature for roasting beef is 300° to 325°F. In the past few years, however, several investigators have reported that roasting at low oven temperatures in the range of 150° to 250°F results in more tender meat than when higher temperatures are used. Many of these studies have involved only less tender cuts, particularly those from the round (Griswold, 1955a; Bramblett et al., 1959; Bramblett et al., 1964; Neilsen et al., 1965).

The comparative effects of roasting at low and conventional oven temperatures on tender as well as less tender beef cuts has had limited study. Cover (1937) found standing rib, chuck, and rump roasts to be more tender when roasted at 257° than at 437°F, the improvement being somewhat greater for chuck and rump than for rib cuts. A later study by Cover (1943) indicated that both rib and chuck roasts were more tender when roasted at an extremely low oven temperature of 176° than at 257°F. Heat penetration was much slower and the connective tissue appeared to be transformed into a moist, viscous mass in the roasts cooked at 176°F.

Few studies in the literature provide information regarding the response of different size roasts to reduced oven temperatures. When 10-lb top-round cuts of beef were roasted at oven temperatures from 200° to 375°F at 25° intervals, tenderness was not significantly affected as indicated by Warner-Bratzler shear values (Marshall et al., 1960; Hunt et al., 1963). Simmers (1965) reported that 2.5-lb top-round cuts roasted at 200°F were more tender but had higher cooking losses and were less juicy than roasts cooked at 300°F.

Marbling and finish have been thought to contribute to improved eating quality of beef as indicated by their importance in the USDA grading system. In recent years, however, neither carcass grade nor marbling have been reliably related to tenderness (Lowe et al., 1961; Goll et al., 1965; Walter et al., 1965; Suess et al., 1966) and further investigation seemed warranted.

The present study was designed to provide further evidence concerning the response of different cuts, different size roasts, and roasts differing in degree of finish to a reduced roasting temperature. Eight paired roasts consisting of small and large, bone-in rib and boneless top-round cuts were obtained from each of five low-finish and five high-finish Hereford steer carcasses. One roast from each pair was cooked at 200°F and the other at 300°F according to a balanced-lattice design encompassing five replications. Cut, size, and finish combinations were assigned to each oven temperature as designated by the experimental design. Tenderness, juiciness, and flavor were evaluated by a sensory panel. An objective measurement of tenderness was obtained with the Warner-Bratzler Shear. Cooking losses and cooking times were determined also. Data were subjected to analysis of variance according to the method of least squares.

CHAPTER II

REVIEW OF LITERATURE

Tenderness is perhaps the most important criterion of meat quality. As indicated in the Introduction, many factors influence meat tenderness. Some of the literature relating tenderness to different cuts, to effect of heating on muscle tissue components, to time-temperature effects on different cuts, and to fat content will be reviewed in this chapter.

I. VARIATION IN TENDERNESS AMONG DIFFERENT CUTS WITHIN THE BEEF CARCASS

Meat is composed primarily of two structural components, muscle fibers and connective tissue. Although it is recognized that both muscle fibers and connective tissue influence tenderness, connective tissue has been implicated as the principal cause of inherent toughness in meat.

The connective tissue content has been reported to vary considerably among muscles within the beef carcass. It is generally conceded that those muscles containing the least connective tissue are most tender and those containing the largest amount of connective tissue are least tender.

Ramsbottom *et al*. (1945) assessed the tenderness of 25 large muscles in the beef carcass as determined by shear values on raw and cooked meat, organoleptic ratings, and histological ratings based upon amounts of collagenous and elastic connective tissue present. Muscles varied in amounts of collagenous and elastic tissue as well as in amounts of fat and size of muscle bundles. Generally, muscles with less connective tissue had low shear readings whereas muscles with large amounts of connective tissue had higher shear readings. The longissimus dorsi muscle in the loin had less connective tissue, lower shear values, and a higher organoleptic rating than the semimembranosus muscle from the round.

Hiner et al. (1950) compared the relative tenderness of beef samples from nine different locations in the carcasses of animals of widely differing ages. Samples were heated in an electric oven at 392°F to an internal temperature of 140°F and tested for tenderness by a Warner-Bratzler Shear. On the basis of shear values, the cuts were grouped into four tenderness classifications from least to most tender as follows: neck and foreshank; round; chuck, rib, shortloin, and loin end, which among themselves did not always hold the same order; and the tenderloin. In older animals, muscles from the loin were significantly more tender than those from the round. Only small differences in tenderness were observed between cuts from veal calves.

The relation of the amount and character of connective tissue from beef of known history to tenderness of the heated meat was investigated by Hiner et al. (1955). Samples from 11 muscles representing various locations within the carcass were examined histologically for collagenous and elastic fiber distribution and content. Collagenous fibers were observed to comprise a larger portion of the connective tissue than elastic fibers in all muscles studied. Elastic fibers were more numerous and larger in muscles which were most used, such as in the neck and round, than in muscles of less extensive usage, such as psoas major in the loin. The more extensively used muscles also were characterized by larger amounts of collagenous fibers whereas muscles with less activity had smaller amounts.

Ritchey et al. (1963) evaluated the tenderness of muscles from the rib and round of beef by relating collagen content, as determined chemically, to sensory scores for the connective tissue component of tenderness. Steaks from the longissimus dorsi and biceps femoris muscles were broiled to internal temperatures of 142° and 176°F. Longissimus dorsi muscle contained considerably less collagen than biceps femoris whether raw or cooked. Tenderness scores were not clearly related to collagen content.

Skelton et al. (1963) compared the collagen nitrogen content of beef longissimus dorsi and semimembranosus cuts cooked in a 300°F oven to different internal temperatures. Collagen nitrogen determinations on raw and cooked samples indicated that the semimembranosus muscle contained a greater amount of collagen nitrogen than the longissimus dorsi muscle. When cooked, the semimembranosus muscle had higher shear values and lower tenderness scores than the longissimus dorsi muscle (Visser et al., 1960).

II. EFFECT OF HEATING ON TENDERNESS OF MUSCLE TISSUE COMPONENTS

Hamm (1966) stated that "the most drastic changes in meat during heating are those that involve the muscle proteins." Muscle fibers tend to become tougher and connective tissue more tender upon heating. Although both of these reactions are time-temperature dependent, the time factor is more important for collagen softening whereas temperature seems to be more important for fiber toughening (Weir, 1960).

Upon heating, muscle fibers become tougher due to a tightening and stiffening of myofibrillar protein structure. Hamm (1966) has outlined changes occurring during the heat denaturation process as follows: between 95° and 122°F myofibrillar protein molecules are unfolded; at 95°F coagulation begins caused by an aggregation of the unfolded molecules and accompanied by the formation of relatively unstable cross linkages; between 122° and 158°F the processes of unfolding as well as coagulation are continued resulting in a tight protein network linked by relatively stable bonds.

An early investigation of the effect of coagulation of muscle fiber proteins on different properties of beef muscles was conducted by Satorius et al. (1938). Among the factors studied were shear force and muscle-cell diameter of pairmates heated to an internal temperature of 136°F. Muscle fiber diameters decreased during coagulation. When semitendinosus muscle from the round was heated to internal temperatures of 136°, 153°, and 167°F, tenderness was increased and muscle fiber diameter was decreased up to 153°F. From 153° to 167°F, tenderness was decreased but the diameter of muscle fibers did not change. These results indicated that shrinkage of fibers resulting from coagulation of muscle plasma was complete at 153°F.

The histological characteristics of beef longissimus dorsi roasted to internal temperatures of 140°, 158°, and 170°F at 225° and 325°F were investigated by Bley (1968). Muscle fiber diameter decreased as end points increased from 140° to 158°F at both oven temperatures. With heating, fibrous collagenous connective tissue was changed to banded fibers that appeared opaque and swollen. Continued heating resulted in the formation of a gray granular network. As end point and oven temperatures increased there appeared to be greater degradation of collagen in that granulated connective tissue increased as banded decreased.

Physical changes in connective tissue induced by heating in water were studied by Winegarden _et al._ (1952) in an effort to relate such changes to the cooking of meat. Strips of connective tissue from the aponeurotic sheet, ligamentum nuchae, and deep flexor tendon were heated in a water bath at 9° intervals from 140° to 203°F for 1, 2, 4, 16, and 64 min at each temperature. Shear values indicated that there was little or no softening at 140°F even after 64 min of heating. At 149°F softening was slight for the shorter times but more pronounced after 16 and 64 min. There was extensive softening of all strips heated only 1 min at temperatures of 176°F and higher. Connective tissues containing more collagen softened to a greater degree than those containing more elastin.

When heated at higher temperatures for longer periods of time, strips composed primarily of collagenous tissues became sticky and translucent, shorter in length, and thicker. The authors concluded that connective tissues softened to a greater degree as time and temperature of heating were increased and as the collagen content of the tissues increased.

III. RELATION OF TIME AND TEMPERATURE OF HEATING TO TENDERNESS OF DIFFERENT BEEF CUTS

The effect of a particular cooking method on tenderness of beef is determined by the proportion of collagenous connective tissue to muscle fiber (Cover et al., 1960). Since muscle fibers tend to become tougher and collagenous connective tissue softer upon heating, cooking procedures involving long times and low temperatures would seem beneficial for improving tenderness, particularly of those cuts high in connective tissue.

The effect of heating at different temperatures for various lengths of time on tenderness of semimembranosus muscle was determined by Tuomy et al. (1963). Meat "logs" were cooked in stainless steel tubes in a water bath held at 140°, 160°, 180°, 190°, 200°, and 210°F from 1 to 7 hr. L.E.E. Kramer shear values and tenderness scores indicated that the initial effect of heat was a rapid toughening which was accentuated as the temperature was increased. At temperatures below 180°F, tenderness was dependent upon temperature with time having very little effect. When the meat was held at 180°F or above, tenderness was achieved at a rate and to a degree dependent upon both time and temperature.

Cover (1937) investigated the effect of roasting at a low oven temperature on the tenderness of different cuts of beef. Standing rib, chuck, and rump cuts were cooked at 257° and 437°F to an internal temperature of 176°F. Roasts cooked at 257°F were significantly more tender than pairmates cooked at 437°F. A higher percentage of tenderness judgments favored the lower temperature for chuck and rump than for rib cuts. A marked decrease in the rate of heat penetration, indicated by an abrupt flattening in heat penetration curves, was characteristic for cuts having the highest tenderness ratios. It was concluded that the increase in tenderness at the low oven temperature was more closely related to time required for cooking than to oven temperature alone.

In a later study (Cover, 1943), the effect of roasting at an extremely low oven temperature of 176°F on tenderness of standing-rib and arm-bone chuck roasts was compared with roasting at 257°F. Rate of heat penetration was markedly reduced at 176°F so that roasts were always scored as "tender" when 30 hr were required for the meat to lose its pink color. The connective tissue in well-done roasts cooked at 176°F was changed from a hard, tough state to a moist, viscous mass which offered no resistance to cutting or chewing. Cover proposed that the water of hydration was released slowly enough from the meat proteins so that it was used efficiently for converting collagen into gelatin.

Bramblett <u>et al.</u> (1959) cooked paired muscles from the round at 145°F for 30 hr and at 155°F for 18 hr. Both shear values and tenderness scores indicated that muscles cooked at 145°F were more tender than paired cuts cooked at 155°F. Tensile strength measurements on muscle fibers were lower for muscles cooked at 145° than at 155°F. The length of time the internal temperature of the meat was held in the range of 135° to 140°F seemed to be related to an increase in tenderness. In a follow-up study, muscles from U. S. Good and U. S. Standard grade beef round were cooked at oven temperatures of 155° and 200°F to an internal temperature of 149°F (Bramblett *et al.*, 1964). Tenderness scores, number of chews, Warner-Bratzler shear values, and L.E.E. Kramer shear press values indicated that meat cooked at 155°F was more tender than paired cuts cooked at 200°F.

Griswold (1955a) compared palatability scores and shear values of Commercial and Prime grade beef round cooked by 14 different methods. One phase of the study involved a comparison of a standard braising procedure with roasting at 250° and 300°F to an internal temperature of 185°F. Shear values indicated that roasts cooked at 250°F were significantly more tender than those cooked at 300°F. Scores for roasts cooked at 250° and 300°F generally were higher than those for braised roasts. The cuts roasted at 250°F were described as having an undesirable dark, hard surface with a dry, mealy interior which was so tender the meat was difficult to cut.

The effect of a reduced oven temperature on the tenderness of 4-lb beef rib roasts was studied by Fugate (1967). Roasts were cooked at 225°F and 325°F to end points of 140°, 158°, and 170°F. Shear values indicated that ribs cooked at 225°F to end points of 158° and 170°F were significantly more tender than those cooked by all other heat-treatment combinations.

Simmers (1965) compared tenderness of 2.5-lb top-round cuts cooked at 200° and 300°F to end points of 154° and 158°F respectively. The 200°F roasts were significantly more tender than those roasted at 300°F as determined by both shear values and sensory scores.

Although several investigators have reported that tenderness of beef is improved by roasting at low oven temperatures, results from other studies fail to corroborate such findings. Nielsen et al. (1965) roasted 4-lb blade and rump roasts at 225° and 325°F to an internal temperature of 160°F. Blade roasts were significantly more tender when cooked at 225° than at 325°F as determined by shearing tests. However, tenderness of rump roasts was not affected by oven temperature.

When Choice grade 10-lb top-round cuts of beef were roasted at oven temperatures ranging from 200° to 375°F at 25° intervals to end points of 140°, 158°, and 176°F, tenderness was not significantly affected as indicated by Warner-Bratzler shear values (Marshall et al., 1960; Hunt et al., 1963). Limited palatability evaluations by a taste panel reflected no consistent trends in palatability attributable to oven temperature.

Davenport (1968) roasted boneless sirloin butts weighing from 14 to 20 lb by forced convection at 200° and 300°F. Neither tenderness scores nor Warner-Bratzler shear values differed significantly for cuts roasted at the two oven temperatures.

IV. RELATION OF FAT CONTENT TO PALATABILITY OF BEEF

Marbling and finish have been assumed to play a major role in the enhancement of eating quality of beef by improving tenderness, juiciness, and flavor. That marbling and finish have been thought to be associated with improved palatability is evidenced by their importance in the USDA grading system. The influence of fat on juiciness has been attributed to its stimulatory effect on salivary flow resulting in a sustained juiciness sensation upon chewing meat (Weir, 1960). Fat has been thought to contribute to tenderness by distending cells and spreading apart strands of connective tissue between muscle fibers and between bundles thereby diluting connective tissue elements (Cover _et al.,_ 1960). In recent years, however, neither carcass grade nor marbling have been reliably related to tenderness of beef.

Cover _et al._ (1960) tested the tenderness of steer carcasses grading U. S. Choice, Good, Standard, and Utility. Steaks from the loin and bottom round were oven cooked at 350°F to 142° and 176°F. Ether extract was used as a chemical measure of marbling. Neither carcass grade nor marbling were consistently nor closely related to tenderness as determined by sensory scores or shear values. High carcass grades and presence of marbling did not insure a superior tenderness rating. Loin steaks cooked to the rare stage were tender regardless of carcass grade. However, well-done loin steaks from some Standard and Good grade carcasses had high shear values. Tenderness varied considerably among carcasses within a grade indicating that factors other than those which determine carcass grade are important for tenderness.

Walter et al. (1965) compared palatability characteristics of steaks from the longissimus dorsi muscle of carcasses representing six marbling groups. The degree of marbling ranged from moderately abundant to practically devoid. Shear values on the broiled steaks indicated that marbling did not significantly affect tenderness. When these steaks were evaluated by a sensory panel, Goll et al. (1965) reported that marbling had no effect on scores for tenderness, juiciness, or flavor. However, a finer texture and more even distribution of marbling was associated with increased tenderness.

Various carcass traits including carcass grade and marbling were studied by Suess et al. (1966) for their influence on palatability of beef longissimus dorsi and semimembranosus muscles. Regression analyses indicated that carcass grade and marbling had a negligible effect on tenderness of either muscle relative to other carcass and growth measurements. Carcass fat and marbling were among the factors contributing least to juiciness of both muscles.

A comprehensive study by Lowe et al. (1961) included an examination of the relationship of carcass grade to palatability of roasted and braised beef cuts. Choice and Commercial grade carcasses were used. Rib, loin, and tenderloin cuts were roasted whereas muscles from the round were braised to internal temperatures of 158° and 194°F. There was no consistent relationship of carcass grade with tenderness, juiciness, flavor, or aroma of the cuts evaluated.

CHAPTER III

PROCEDURE

I. SOURCE OF MEAT

Eighty roasts were obtained from ten Hereford steers five of which were low-finish and five high-finish animals produced on two energy level rations for 210 days by The University of Tennessee Animal Husbandry-Veterinary Science Department. The low-energy ration consisted of corn silage *ad lib* and 1.5 lb cottonseed meal per day. The high-energy ration consisted of corn *ad lib*, 10 lb corn silage, and 1.5 lb cottonseed meal. Low-finish carcasses had a mean fat thickness at the 12th rib of 4.0 mm and graded an average of U. S. Low Good. High-finish carcasses had a mean fat thickness at the 12th rib of 10.8 mm and graded an average of U. S. Low Choice.

Eight paired roasts consisting of small and large, bone-in rib and boneless top-round cuts were removed from each carcass. Small rib roasts contained the 11th and 12th ribs and averaged 2.1 ± 0.6 lb and 2.9 ± 0.5 lb for low-finish and high-finish respectively. Large rib roasts contained the 7-10th ribs and averaged 6.7 ± 1.3 lb for low-finish and 10.2 ± 1.2 lb for high-finish. Small top-round roasts were removed proximal to the ischium and low-finish and high-finish cuts averaged 1.8 ± 0.4 lb and 1.9 ± 0.3 lb respectively. Large top-round cuts were removed distal to the ischium and averaged 5.5±0.4 lb and 6.3±0.5 lb for low-finish and high-finish respectively. Rib cuts had a fat covering varying in thickness with degree of finish, whereas round cuts were stripped of external fat. Roasts were frozen at -20°F and stored at -5°F until the day prior to cooking. Freezer storage time ranged from three to nine months.

II. PLAN OF STUDY

One roast from each pair was cooked at 200°F and the other at 300°F according to a balanced-lattice design involving five replications (Table I). Roasts were cooked in lots of four, two at 200°F and two at 300°F, on each of 20 test days. Cut, size, and finish combinations were assigned to each oven temperature as designated by the experimental design.

III. COOKING PROCEDURE

On the day prior to cooking, roasts were thawed at room temperature to an internal temperature of 32°F in the approximate center of the test muscle and then refrigerated overnight. Throughout the study, meat temperatures and oven temperatures were measured by copper-constantan thermocouples and recorded by a multipoint temperature recorder.

On the day of cooking roasts were wiped free of any drip which may have accumulated and weighed to the nearest gram on a Torsion balance. Rib roasts were placed fat-side up in tared roasting pans with the rib

TABLE I

EXPERIMENTAL DESIGN

Replication Number	Test Number	Oven Temperature 200°F Low Finish[a]	High Finish[a]	300°F Low Finish[a]	High Finish[a]
I	1	A	D	D	A
	2	D	A	A	D
	3	B	C	C	B
	4	C	B	B	C
II	5	A D	-	-	C B
	6	-	A D	C B	-
	7	C B	-	-	A D
	8	-	C B	A D	-
III	9	A	C	B	D
	10	C	A	D	B
	11	B	D	A	C
	12	D	B	C	A
IV	13	A C	-	A C	-
	14	-	A C	-	A C
	15	B D	-	B D	-
	16	-	B D	-	B D
V	17	A B	A B	-	-
	18	C D	C D	-	-
	19	-	-	A B	A B
	20	-	-	C D	C D

[a]A - Small Rib
B - Large Rib
C - Small Round
D - Large Round

bones serving as racks. Top-round roasts were placed on racks in tared roasting pans. A thermocouple was inserted into the measured center of the longissimus dorsi muscle of rib cuts and the semimembranosus muscle of small top-round cuts. In view of the irregular shape of large top-round cuts, the thermocouple was located in the thickest portion of the semimembranosus muscle in these roasts.

Roasts were cooked in two household electric ranges in which the temperature fluctuation was ±25°F. Ranges were not preheated prior to beginning cooking. Cooking periods were begun so that all roasts would be ready for sensory evaluation at about the same time. The internal temperature of each roast and temperature in the center of each oven was recorded at 3-min intervals throughout the cooking period. Roasts were cooked to end points of 152° and 158°F at 200° and 300°F respectively. Preliminary investigation indicated that these oven-end point combinations produced meat which appeared medium-done. When the specified end point temperature was reached, roasts were removed from the oven and allowed to cool for 30 min or until undergoing maximum temperature rise, whichever was longer. Appropriate weights were then taken for the determination of evaporation and drip losses. The sum of evaporation and drip loss expressed as a percentage of the original weight of the roast was recorded as per cent total cooking loss.

IV. METHODS OF EVALUATION

After roasts were cooled and weights for calculation of cooking losses obtained, the longissimus dorsi muscle was stripped from the bone of rib cuts and the semimembranosus muscle separated from the adductor muscle of top-round cuts. After the outer slice of all roasts was discarded, three adjacent slices approximately 1/4 in thick were removed and each cut in half to provide six samples for sensory evaluation. Judges received one sample from small roasts and two samples from large roasts. Slices were taken from the 12th rib side of small rib cuts and from both the 7th and 10th rib sides of large rib cuts. Slices from round roasts were removed from the dorsal end of the semimembranosus muscle with samples from large roasts taken in the areas adjacent to and opposite from the adductor muscle.

A panel of six judges experienced in judging beef scored each roast for tenderness, flavor, and juiciness. Tenderness was evaluated on an 11-point scale and flavor and juiciness on a 9-point scale with highest scores representing maximum quality. A sample score sheet is included in the Appendix, p. 43. Each judge received samples from the same relative position in each roast throughout the study. Warm samples were coded alphabetically and presented on individual plates. The order of sample presentation was randomized in order to minimize the effect of positional bias on the part of the judges.

An objective index to tenderness was obtained by use of the Warner-Bratzler Shear. From two to four 1-in cores were removed from each roast parallel to muscle fibers in the region adjacent to that from which samples for sensory tests were taken. Cores were cooled to room temperature and sheared three times. An average shear value was then calculated for each roast.

Data were subjected to analysis of variance executed by an IBM computer according to the method of least squares. Correlation coefficients were obtained also.

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECT OF OVEN TEMPERATURE, CUT, AND SIZE ON COOKING TIME AND COOKING LOSS

Main treatment means for cooking time and cooking loss are presented in Table II. Data for low-finish and high-finish cuts have been averaged for all variables except flavor since the analyses of variance indicated that only flavor scores were affected by degree of finish. Mean squares from the variance analyses are shown in Table III.

Cooking time. Cooking times per pound were longer at 200° than at 300°F and for small than for large roasts at both oven temperatures (Table II; $P<.001$, Table III). Twenty-nine per cent of the variation in cooking time was attributable to temperature treatment, 23 per cent to size differences, and only 3 per cent to cut differences. Cooking time at 200°F was approximately twice the time at 300°F for all cuts except the small round which required almost four times longer to reach the end point at 200°F.

Least squares means for significant treatment interactions are presented in Table IV. Interactions of temperature with cut, temperature with size, and cut with size were operative for cooking time ($P<.001$). Least squares means indicated that at 200°F cooking times per pound were

TABLE II

COOKING TIME AND COOKING LOSS FOR BEEF RIB AND TOP ROUND ROASTED AT TWO OVEN TEMPERATURES

Cut, Size, and Temperature	Cooking Time (min/lb)	Total Cooking Loss (%)
Rib		
Small		
200°F	116	12.6
300°F	54	15.2
Large		
200°F	53	8.6
300°F	30	18.7
Round		
Small		
200°F	194	29.8
300°F	52	26.0
Large		
200°F	64	20.8
300°F	29	23.6

TABLE III

MEAN SQUARES FROM VARIANCE ANALYSES

Source of Variation	df	Cooking Time	Total Cooking Loss	Shear Value	Sensory Scores		
					Tenderness	Flavor	Juiciness
Temperature	1	67340.24***	100.20***	60.45***	19.03***	.002	.10
Cut	1	7182.56***	1968.25***	105.06***	20.59***	1.000***	13.05***
Size Cut	1	54931.62***	167.64***	26.01**	3.66**	.660**	.46
Finish	1	708.89	.25	3.33	.44	2.213***	.00
Temp. x Cut	1	7612.56***	167.70***	.28	1.66*	.391*	.17
Temp. x Size	1	19951.56***	169.94***	.07	.03	.026	1.26*
Cut x Size	1	4641.02***	52.44***	78.54***	3.85***	.006	.46
Residual	50	333.64	4.15	3.62	.30	.06	.21

*** Significant P<.001
** Significant P<.01
* Significant P<.05

TABLE IV

LEAST SQUARES MEANS FOR VARIABLES WITH SIGNIFICANT INTERACTIONS

Interaction	Cooking Time (min/lb)	Total Cooking Loss (%)	Shear Value (lb)	Sensory Score		
				Tenderness	Flavor	Juiciness
Temp. x Cut						
200°F						
Rib	85	11.0		8.7	7.9	
Round	128	25.3		7.9	7.8	
300°F	***	***	NS	*	*	NS
Rib	41	16.7		7.9	8.1	
Round	42	24.6		6.5	7.7	
Temp. x Size						
200°F						
Small	153	21.4				7.2
Large	59	14.9				7.6
300°F	***	***	NS	NS	NS	*
Small	53	20.6				7.4
Large	30	20.6				7.2
Cut x Size						
Rib						
Small	84	14.6	14.1	8.3		
Large	42	13.1	13.2	8.3		
Round	***	***	***	***	NS	NS
Small	122	27.4	14.4	7.6		
Large	47	22.4	17.9	6.7		

*** Significant P<.001

* Significant P<.05

shorter for ribs than for rounds but were not influenced by cut at 300°F. At 200°F, cooking times for small cuts were approximately two and a half times longer than for large cuts while at 300°F small cuts required only about twice as long as large cuts. Cooking times were twice as long for small as for large rib cuts whereas small rounds required about two and a half times longer than large rounds. These three interactions were undoubtedly influenced by the prolonged cooking time for small rounds at 200°F.

Long cooking times have been found to be associated with low oven temperatures and small cuts by other investigators. Simmers (1965) noted that 2.5-lb top-round roasts required about 3 hr per pound at 200°F and only 1 hr per pound at 300°F. Griswold (1955a) found that 1.5-lb round cuts cooked to the well-done stage required 2.5 hr per pound at 250°F compared with 1 hr per pound at 300°F. These cooking times are comparable to those for small rounds in the present study. Bramblett et al. (1964) reported that muscles from the round required from two to four times longer when cooked at 155° than at 200°F. Longer cooking times for small than for large cuts were observed by Marshall et al. (1959). They found that when 5, 10, and 15-lb top-round roasts were cooked at 300°F to an end point of 158°F, cooking times were 37, 25, and 21 min per pound respectively. As in the present study, Cover (1937) found that cooking times differed markedly with respect to cut at a low oven temperature. When cooked to the well-done stage at 257°F, standing rib and rump roasts required 42 and 58 min per pound respectively, but there was very little difference in cooking time for the two cuts at 437°F.

Cooking loss. Total cooking loss was affected by oven temperature, cut, and size ($P<.001$, Table III, p. 23). Cooking losses were lower at 200° than at 300°F for all cut-size combinations except small rounds (Table II, p. 22). Evaporation comprised the major portion of the total cooking loss at both oven temperatures: 83 per cent at 200°F and 72 per cent at 300°F. Rib roasts had lower cooking losses than round roasts at both oven temperatures. This cut difference accounted for 50 per cent of the variation in total cooking loss. However, a difference in response of the two cuts to the two heat treatments is not necessarily indicated, since rib cuts contained bone and had an external fat covering whereas round cuts were boneless and devoid of external fat.

A temperature by cut interaction indicated that cooking losses for rib roasts were lower at 200° than at 300°F but losses for round roasts were essentially unaffected by heat treatment (Table IV, p. 24). A temperature by size interaction indicated that losses were higher for small than for large roasts at 200°F but were not related to size at 300°F. A cut by size interaction indicated that losses were higher for small than large rounds, whereas size had a negligible effect on cooking losses of rib cuts. The large exposed surface area of the small rounds in relation to total mass probably contributed to the high cooking loss for this cut. Cooking loss for large ribs at 300°F undoubtedly was influenced by a rise in internal temperature upon removal from the oven.

The average temperature rise above the end point temperature of 158°F was 5°F for low-finish ribs and 9°F for high-finish ribs. The temperature rise in all other cuts did not exceed 2°F at either oven temperature.

The various temperature, cut, and size combinations reported for other studies involving low temperature roasting of beef make a valid comparison of cooking losses with those in the present study difficult. However, there does seem to be a trend toward higher cooking losses for boneless round cuts when cooked at low than at high oven temperatures whereas the reverse seems to be true for bone-in rib cuts. Simmers (1965) reported that losses for small top-round roasts cooked at 200° and 300°F were 35 per cent and 30 per cent respectively. Griswold (1955a) found that losses for round roasts from Prime grade carcasses were 37 per cent when cooked at 250°F and 28 per cent at 300°F. Bramblett _et al_. (1964) noted that losses for individual muscles from the round cooked at 155° and 200°F were 26 per cent and 19 per cent respectively. In contrast, rib roasts cooked at 225° and 325°F to an end point of 158°F had a cooking loss of 18 and 21 per cent respectively (Fugate, 1967). Cover (1937) found that cooking losses for well-done rib roasts were 23 per cent at 257° and 37 per cent at 437°F.

II. EFFECT OF OVEN TEMPERATURE, CUT, SIZE, AND DEGREE OF FINISH ON JUICINESS AND FLAVOR

Juiciness. Panel scores for juiciness are shown in Table V. Oven temperature had no significant effect on juiciness scores (Table

III, p. 23). There is not complete agreement among other studies regarding the effect of low oven temperatures on juiciness of beef. Neilsen et al. (1965), Fugate (1967), and Davenport (1968) reported that juiciness scores for roasts cooked at 200° to 225°F did not differ significantly from those at 300° to 325°F. In contrast, Griswold (1955a), Bramblett et al. (1964), and Simmers (1965) found that lower oven temperatures and longer cooking times yielded meat which was less juicy than meat cooked at higher oven temperatures.

TABLE V

JUICINESS SCORES FOR BEEF RIB AND TOP ROUND
ROASTED AT TWO OVEN TEMPERATURES

	Small Rib		Large Rib		Small Round		Large Round	
	200°F	300°F	200°F	300°F	200°F	300°F	200°F	300°F
Juiciness Score	7.8	8.0	8.0	7.6	6.6	6.8	7.2	6.9

Rib roasts were more juicy (P<.001, Table III) than round roasts at both oven temperatures. Differences attributable to cut accounted for 38 per cent of the variation in juiciness. A temperature by size interaction indicated that at 200°F small roasts were less juicy than large roasts but at 300°F small roasts were slightly more juicy than large roasts (Table IV, p. 24). Juiciness scores were very highly correlated with total cooking loss (r -.802, P<.001). The lower juiciness scores for round than rib cuts may be attributed to the greatly increased cooking times of rounds at 200°F, more importantly small rounds, resulting in higher cooking losses and a corresponding decrease in juiciness.

Degree of finish had no significant effect on juiciness scores (Table III, p. 23). This observation substantiates results from several recent studies in which neither carcass grade nor marbling were related to juiciness of beef (Lowe et al., 1961; Goll et al., 1965; Suess et al., 1966).

Flavor. Panel scores for flavor are presented in Table VI. Flavor scores differed with respect to finish ($P<.001$, Table III) being higher for high-finish than for low-finish cuts. Finish differences accounted for 23 per cent of the variation in flavor scores. Flavor was not significantly affected by oven temperature. A temperature by cut interaction indicated that flavor scores were higher for rib than round at 300°F but were unaffected by cut at 200°F (Table IV, p. 24). The temperature rise which occurred in large ribs at 300°F probably influenced the flavor scores for this cut. Fugate (1967) found that the flavor of beef with a greater degree of doneness was scored higher by the same panel which performed the sensory evaluations for the present study. Lowe et al. (1961) and Ramsbottom et al. (1948) have reported that the longissimus dorsi muscle has a higher fat content than the semimembranosus muscle in the same carcass. A higher fat content in the rib than round cuts may have been another factor which influenced flavor scores for this cut.

TABLE VI

FLAVOR SCORES FOR BEEF RIB AND TOP ROUND OF TWO DEGREES OF FINISH ROASTED AT TWO OVEN TEMPERATURES

Cut, Size, and Temperature	Low Finish	High Finish
Rib		
Small		
200°F	7.6	7.9
300°F	7.8	8.2
Large		
200°F	7.9	8.0
300°F	8.0	8.4
Round		
Small		
200°F	7.7	7.8
300°F	7.4	7.8
Large		
200°F	7.8	8.0
300°F	7.6	8.0

Although significant differences in flavor were obtained, the differences were not large enough to have practical importance since all roasts scored from "good" to "very good" on the scale used.

III. EFFECT OF OVEN TEMPERATURE, CUT, SIZE, AND DEGREE OF FINISH ON TENDERNESS

Main treatment means for shear values and tenderness scores are presented in Table VII. Both shear values and tenderness scores indicated that roasts subjected to the 200°F heat treatment were more tender than those roasted at 300°F ($P<.001$, Table III, p. 23). The correlation coefficient of panel scores with shear values was -.760 ($P<.001$). The variation attributable to temperature treatment was 10 per cent for shear values and 24 per cent for tenderness scores. Rib cuts were more tender than round cuts (Table VII) at each oven temperature according to both tenderness measurements ($P<.001$, Table III). Cut differences accounted for 17 per cent of the variation in shear values and 26 per cent in tenderness scores. Size accounted for about 4 per cent of the variation in both measures of tenderness.

As reported by other investigators (Lowe et al., 1961; Goll et al., 1965; Walter et al., 1965; Suess et al., 1966), neither tenderness scores nor shear values were significantly affected by finish (Table III).

A temperature by cut interaction was operant for tenderness scores but not for shear values (Table IV, p. 24). Tenderness scores indicated that roasting at 200°F had a greater tenderizing effect on round than

TABLE VII

SHEAR VALUES AND TENDERNESS SCORES FOR BEEF RIB AND TOP ROUND ROASTED AT TWO OVEN TEMPERATURES

Cut, Size, and Temperature	Shear Value (lb)	Tenderness Score
Rib		
Small		
200°F	12.9	8.6
300°F	14.8	8.0
Large		
200°F	12.2	8.6
300°F	14.2	8.1
Round		
Small		
200°F	13.2	8.4
300°F	16.1	6.8
Large		
200°F	17.3	7.2
300°F	18.8	6.3

rib cuts. Moreover, round cuts cooked at 200°F and rib cuts cooked at 300°F received comparable scores which were identified as "tender" on the scale used. The greatest contrast in tenderness scores was observed between rib cuts cooked at 200°F and round cuts cooked at 300°F which received scores of "very tender" and "slightly tender" respectively. A cut by size interaction for shear values and tenderness scores indicated that tenderness of rib cuts was not related to size whereas small rounds sheared 3.5 lb lower and scored 0.9 point higher than large rounds.

Other workers have reported that tenderness of beef cuts is increased by roasting at low oven temperatures in the range of 150° to 250°F (Cover, 1937; Cover, 1943; Griswold, 1955a; Bramblett et al., 1959; Bramblett et al., 1964).

The findings of the present study indicate that roasting at 200°F had a tenderizing effect on both rib and round cuts with the improvement in tenderness being more pronounced for rounds. Hamm (1966) stated that an increase in tenderness upon cooking of meat cannot be caused by changes in myofibrillar proteins since they are toughened by heat, but rather must be the result of a change in the collagen of connective tissue. Round cuts inherently have a higher collagen content than rib cuts from the same animal (Ritchey et al., 1963; Skelton et al., 1963; Herring et al., 1967). Collagen undergoes a series of changes believed to be initiated at about 140° to 147°F which include a progressive softening and ultimately transformation into gelatin thereby enhancing tenderness (Bendall, 1964; Lawrie, 1966). As shown in Figure 1, the

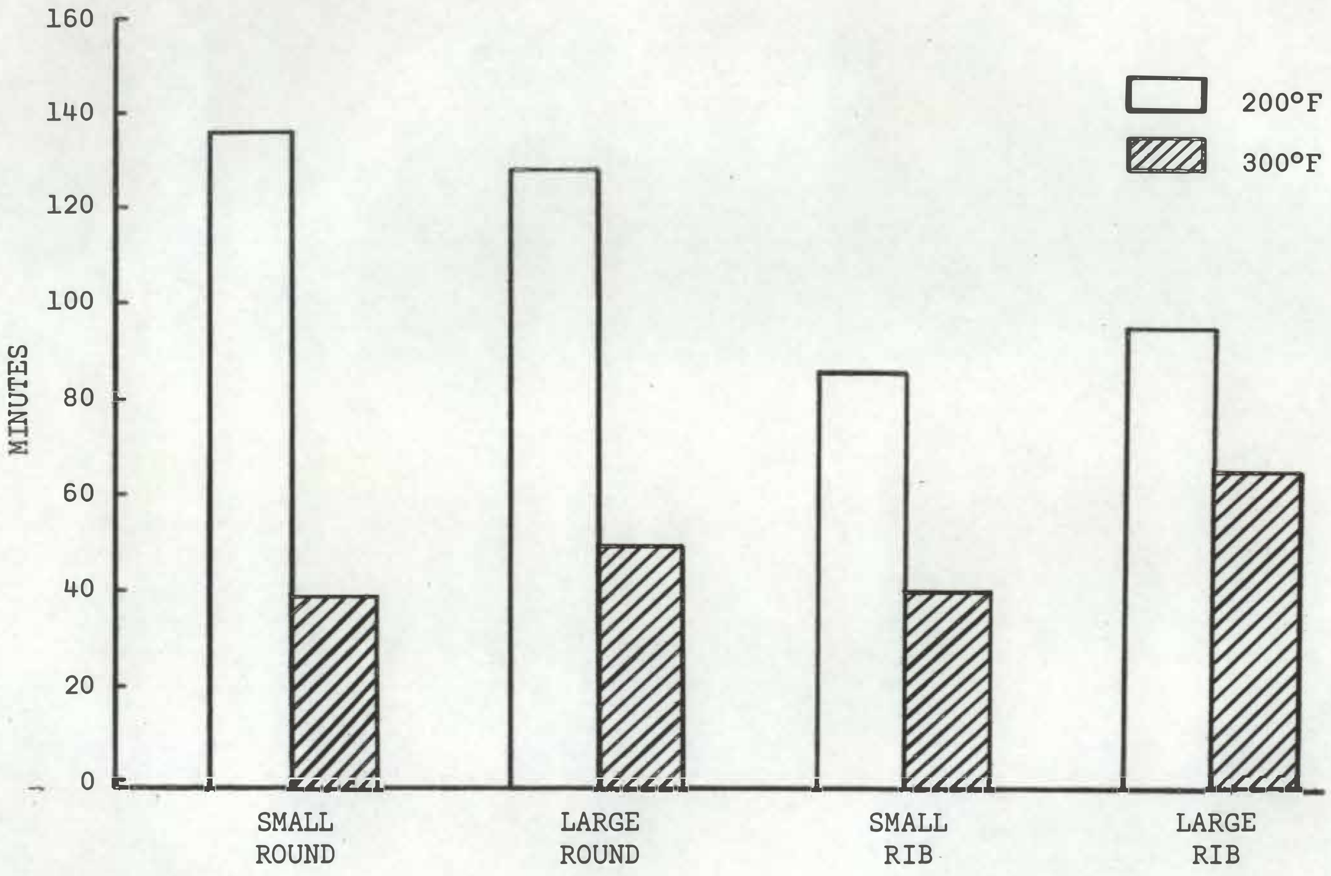

Figure 1. Average time the temperature in the center of the test muscle was above 140°F.

internal temperature in the center of the test muscle was maintained above 140°F for longer times in roasts cooked at 200° than at 300°F and for longer times in round than rib cuts at 200°F. The increased times at 200°F were: small rounds - 96 min; large rounds - 78 min; small ribs - 47 min; and large ribs - 30 min. There is limited information concerning the relative disappearance of collagen in beef cuts roasted at low and conventional oven temperatures. Griswold (1955b) reported that collagen losses were higher in beef top round roasted at 250° than at 300°F. A higher collagen content coupled with the longer time available for collagen degradation is a possible explanation for the greater relative increase in tenderness of round than of rib cuts roasted at 200°F. In view of the lower collagen content of rib than round cuts, it is interesting that tenderness of rib roasts was significantly improved by the 200°F heat treatment. Fugate (1967) also noted that rib roasts were significantly more tender when cooked to 158° or 170°F at 225° than at 325°F.

Although the length of time roasts were maintained in the temperature range conducive to collagen degradation was associated with an improvement in tenderness, chemical and/or histological evidence is needed before the tenderization of roasts cooked at the low oven temperature could be attributed to collagen degradation.

CHAPTER V

SUMMARY

I. SCOPE OF THE STUDY

The effects of two rates of heat application produced by roasting at 200° and 300°F on tenderness and other sensory properties, cooking losses, and cooking times of small and large, rib and top-round beef roasts of two degrees of finish were investigated. Eighty roasts consisting of paired small and large, bone-in rib and boneless top-round cuts from five low-finish and five high-finish Hereford steers produced on two energy level rations were studied. One cut from each pair was roasted at 200° and the other at 300°F to end points of 152° and 158°F respectively. Roasts were cooked in lots of four, two at 200° and two at 300°F on each of 20 test days according to a balanced-lattice design. Tenderness, juiciness, and flavor were evaluated by a panel of six judges. The Warner-Bratzler Shear provided an objective measure of tenderness. Cooking losses and cooking times were determined.

II. PRINCIPAL FINDINGS

Cuts roasted at 200°F had lower total cooking losses, longer cooking times per pound, and were more tender than those roasted at 300°F. Tenderness scores indicated that the 200°F heat treatment had a greater tenderizing effect on round than rib cuts. The length of time roasts were maintained above 140°F seemed to be related to an increase in tenderness. Oven temperature had no significant effect on juiciness or flavor scores.

Rib cuts scored higher in tenderness, flavor, and juiciness and had lower total cooking losses and shorter cooking times per pound than round roasts. Small cuts had longer cooking times per pound and higher total cooking losses than large cuts. Small rounds scored and sheared more tender than large rounds but tenderness of rib cuts was not related to size. At 200°F, small cuts were slightly less juicy than large cuts but at 300°F small cuts were slightly more juicy than large cuts. Flavor was the only variable affected by degree of finish, with scores being higher for high-finish than for low-finish cuts.

Results of the present study indicate that small and large rib and round cuts respond differently to the two oven temperatures employed. The desirability of roasting at 200°F in preference to the conventional temperature of 300°F would be dependent upon the specific cut and size of roast. The relative merits of the two cooking methods for different cuts and sizes should be evaluated further.

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APPENDIX

GRADING CHART FOR MEAT

Date___________________________ Name___________________________

Directions: Give full value for excellent quality.
Do not use fractional points.

Scale for scoring tenderness:

10 - Extremely Tender
9 - Very Tender
8 - Tender
7 - Moderately Tender
6 - Slightly Tender
5 - Slightly Tough
4 - Moderately Tough
3 - Tough
2 - Very Tough
1 - Extremely Tough
0 - Reject Sample

Scale for scoring flavor and juiciness:

9 - Excellent
8 - Very Good
7 - Good
6 - Fair plus
5 - Fair
4 - Fair minus
3 - Poor
2 - Very Poor
1 - Extremely Poor

Sample No.								
Flavor								
Juiciness								
Tenderness								

Comments:

VITA

The author was born on April 11, 1943, in Knoxville, Tennessee. From 1949 to 1957 she attended elementary and junior high school in Oak Ridge, Tennessee. In 1957 her family moved to Knox County where she attended Karns High School and was graduated in 1961. In the fall of 1961 she entered The University of Tennessee and was graduated with a B. S. degree in Home Economics in 1965. From 1965 to the present she has been engaged in graduate study as a research assistant in the Department of Food Science and Institution Management.

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