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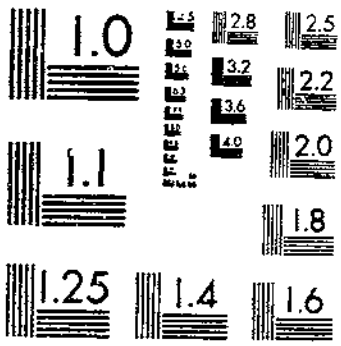

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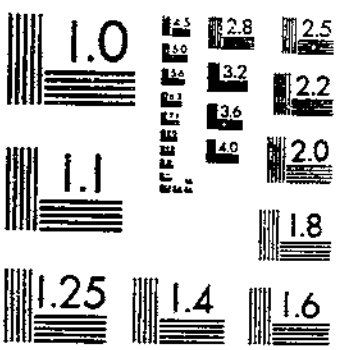

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NATIONAL BUREAU OF STANDARDS-1963-A

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SHRINKAGE AND COOKING TIME OF RIB ROASTS OF BEEF OF DIFFERENT GRADES AS INFLUENCED BY STYLE OF CUTTING AND METHOD OF ROASTING[1]

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INTRODUCTION

When meat is cooked enough to be palatable, there is bound to be some shrinkage. How to keep the shrinkage moderate and yet cook the meat to the stage desired in a reasonable time, are questions on which attention is centering. Hence, for a standard cut such as rib roast of beef, it is of practical as well as scientific interest to know the relation of shrinkage and cooking time to the grade, the degree of fatness, the style of the cut, whether standing or rolled—all factors in the selection of the meat in the market. It is equally important

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[2] Prepared in consultation with other members of the U. S. Department of Agriculture publications committee of the cooperative meat investigations, O. G. Hankins (chairman), Paul E. Howe, and W. H. Black of the Bureau of Animal Industry, and L. B. Burk and W. O. Fraser of the Bureau of Agricultural Economics. Acknowledgment is made to Elizabeth A. Engstrom and Meda K. Gates for laboratory and statistical assistance and to Lillian M. Grigg and Esther M. Lyerly for statistical assistance.

from the standpoint of preparation to know how shrinkage and cooking time are affected by oven temperature and the stage to which the meat is cooked. With sufficient data assembled, it would be possible to estimate how much shrinkage may reasonably be expected and how much time to allow when roasting a certain cut and quality of meat, for instance beef ribs of Good grade, under specified conditions of cooking.

An extensive literature has grown out of meat-cookery investigations conducted at the University of Illinois 40 years ago and recently revived, with broader scope, in a number of State agricultural experiment stations and colleges and in the United States Department of Agriculture.

The main findings with regard to the shrinkage of beef are in general accord. The more fat a cut contains, the more fat and the less water it loses during cooking; also for beef roasted to the rare or the medium stage, the higher the oven temperature the greater is the loss of weight. Searing a roast does not reduce the shrinkage as it was once believed to do. But there is comparatively little published information that links either a specified degree of fatness or the carcass grade to the expected shrinkage of beef ribs when cooked by various methods. Also, comparatively few figures have been reported on the shrinkage of well-done beef or on the influence of the style of cutting a rib roast on the cooking losses.

Investigators agree that the style of cutting influences the number of minutes per pound required to roast beef ribs, but there are not many figures available on rolled roasts. When data on cooking time have been reported in relation to oven temperature, or the stage to which meat was cooked, or to the style of cutting, in comparatively few cases has the meat been described as to its degree of fatness or its carcass grade.

Accordingly this bulletin presents data on eight different methods of roasting 595 rib cuts of beef, some standing and some rolled, and ranging in grade from U. S. Choice down to U. S. Plain (formerly Common). The different methods of roasting include searing methods and the constant-temperature methods.

REVIEW OF LITERATURE

SHRINKAGE

The literature of the past 45 years on meat shrinkage, or loss of weight during cooking, deals with the causes and the mechanism of shrinkage, with constituents lost by the meat, and with factors that influence the character and the extent of shrinkage.

In a series of experiments to determine changes taking place in meat during cooking, Nothwang (*27*)[3] heated meat in boiling water and in steam for varying lengths of time and found that the longer the heating period the more weight the meat lost. Ferrati (*11*) heated small pieces of meat in hermetically sealed tubes immersed in water at different temperatures for 1 hour and found that the higher the temperature the more weight the meat lost.

Histological investigations were conducted by Meigs (*23*, *24*) to determine why animal tissues lose weight on heating. Comparing coagulative changes, changes in length, and changes in weight when

[3] Italic numbers in parentheses refer to Literature Cited, p. 34.

smooth and striated muscles of the frog were heated to between 40° and 50° C., Meigs found that in both kinds of muscle the proteins were coagulated, that in both there were changes in length, with striated muscle becoming shorter and smooth muscle longer, but that neither showed any marked tendency to change in weight. However, when heated above 50° both smooth and striated muscle shortened and both lost water and consequently weight. Meigs concluded that loss of weight was not a result of the coagulation of proteins but of the passage of fluid out of the tissue interstices when tissues saturated with fluid were heated above 50°. He stated that if such tissues were held at higher temperature than 50° the loss of weight may be very much more marked.

More recently McCance and Shipp (*22*), in a study of the mechanism of cooking losses of flesh foods (beef and fish), reported that lean meat changes very little in volume below 60° to 63° C. They use the term "shrink" for the reduction in volume that takes place when meat tissues contract on heating and force out juice. These investigators state that if meat could be made palatable below 60° the loss of weight associated with cooking would be negligible.

According to McCance and Shipp, the loss of weight of meat during roasting in dry air, that is, in an uncovered pan in a ventilated oven, is made up mainly of fat, which melts out and drains into the dripping pan, and of water, evaporated from the juice which is expressed through "shrink." On reaching the surface of a piece of meat exposed to dry air, the juice loses at least seven-eighths of its water content by evaporation, and the remaining fraction of the water drips into the pan, carrying with it salts and nitrogenous constituents. The loss of salts and nitrogen is a small proportion of the loss of weight. In their findings regarding the constituents lost by meat during roasting in dry air, McCance and Shipp confirmed the earlier work of Grindley and Mojonnier (*14*). Further evidence that the loss of weight of roasted meat consists mainly of fat and water appears in data reported by Thille, Williamson, and Morgan (*30*) for beef ribs roasted at 210° C. oven temperature.

As a result of the intensive investigations on the chemistry of meat cookery conducted at the University of Illinois by Bevier, Grindley, Sprague, and their associates, three factors were shown to influence the character and extent of the cooking losses, namely, the composition of the meat, the cooking temperature, and the degree of cooking. Grindley, McCormack, and Porter (*13*) in 1901 stated that the fattest pieces of meat lost the most fat and the least water when pan-broiled, boiled, or stewed. No experiments were reported on roasted meats. However, all investigators (*1, 4, 5, 17, 18, 26, 30*) who have made note of the fat content of beef ribs before cooking have shown that the better the cut the greater was the fat or the drippings loss, and the smaller the water or the volatile loss during roasting.

Shrinkage of meat was related directly to oven temperature by Bevier and Sprague (*3*) who found that total cooking losses of seared one-rib beef roasts varied from 5.9 percent at 83° C. oven temperature for the finish to 20.6 percent at 260°. More recently, Cline and her associates (*8*) roasted three-rib cuts to the rare stage as determined by a meat thermometer and reported that the loss of weight ranged from

6.79 percent for cuts cooked at 110° constant oven temperature to 30.44 percent for those cooked at 260°. For pairs of three-rib roasts cooked to the rare stage, in a comparison of 125° with 173° oven temperature for the finish after 20 to 30 minutes searing, Alexander (*1*) found that the loss of weight averaged 11.5 and 17.4 percent, respectively. Three-rib cuts were roasted medium and well done by Latzke (*20*) who reported for seared roasts that the loss of weight ranged from 13.5 percent at 110° oven temperature for the finish to 22.5 percent at 175°. Cover (*9*) reported for paired three-rib roasts cooked medium rare that the loss of weight averaged 7.1 percent when the oven temperature was 125° and 20.2 when 225° was used. Comparing these two oven temperatures for cooking three-rib roasts to the well-done stage, Cover reported cooking losses of 23.0 and 37.5 percent, respectively.

Searing a roast at the outset does not reduce the amount it shrinks, according to Stanley and Cline (*29*). They reported that rib cuts of beef seared at 260° C. for 20 minutes and finished at 125° lost 11.23 percent of their weight; whereas rib cuts cooked at a constant oven temperature of 125° lost only 8.12 percent. They also found that rib cuts seared at 288° for 20 minutes and finished at 149° lost 17.36 percent, and rib cuts cooked at 150° constant oven temperature lost 11.31.

The stage to which meat is cooked has been shown to have a marked influence on the shrinkage. Bevier and Sprague (*3*) cooked paired left and right one-rib roasts of beef at the same oven temperature but for different lengths of time. The more thoroughly the roasts were cooked the more they shrank. In 1904 Grindley and Mojonnier (*14*) published experiments on the roasting of one-rib roasts of beef to rare, medium, and well-done stages as determined by their appearance when carved. The cooking losses increased in proportion to the degree of cooking. Latzke (*20*) used 125° C. oven temperature for the finish after searing three-rib cuts and cooked them to different stages as determined by meat thermometers in the center of the roasts. She reported for rare roasts (described as very fat but no analyses given) evaporation losses 8.08 percent, drippings losses 8.75; for medium roasts, evaporation losses 11.92 percent, drippings losses 6.14; for well-done roasts, evaporation losses 14.93 percent, drippings losses 7.37. Cover's data cited above also showed that well-done roasts shrank much more than medium-rare roasts.

The style of cutting beef ribs influences the amount they shrink, according to Child and Esteros (*7*), who found that paired standing and rolled two-rib roasts cooked at 149° C. oven temperature to 58° internal temperature lost, respectively, 11.51 and 14.29 percent of their weight.

COOKING TIME

The time required to roast beef ribs, expressed as the number of minutes per pound, has been shown to be influenced by the oven temperature used, by the degree to which the meat is cooked, by the fat content of the roast, its weight, and the style of cutting.

Preliminary to their study of factors that influence cooking time, Sprague and Grindley (*28*) worked out a convenient method of determining when beef was rare, medium, or well done. They inserted short chemical thermometers into beef rib roasts in such a way that

the bulb was as nearly as possible in the center of the large muscle, then cooked the meat to different temperatures, when they cut the roasts open and observed the degree of cooking. According to Sprague and Grindley (*28, pp. 14–15*), "if the inner temperature of a roast is between 55° C. and 65° C. the meat will be rare; if it is between 65° C. and 70° C., it will be medium rare; and if between 70° and 80° C., it will be well done." Subsequent investigators (*1, 2, 4, 5, 8, 9, 16, 19, 20, 25, 29*) have been in general agreement that these meat temperatures define rare, medium, and well-done beef.

Showing that oven temperature and stage of cooking influenced the time required, Sprague and Grindley reported for two-rib rolled roasts, finished at 195° C. oven temperature after being seared 15 minutes at 250°, 20.1 minutes per pound at the rare stage, 26.5, medium, and 34.4, well done. When finished at 100° oven temperature, however, two-rib rolled roasts required 38.5 minutes per pound to be rare, 42.8, medium, and 79.8, well done. Latzke (*19, 20*) reported for three-rib standing cuts of beef finished at 125° oven temperature after being seared, 14.19 minutes per pound for rare, 16.44 for medium, and 22.91 for well-done roasts. For medium-done roasts finished at different oven temperatures after searing Latzke found cooking time to range from 20.75 minutes per pound in an oven at 110° to 12.83 at 175°. Stanley and Cline (*29*) published cooking time for 13 methods of roasting prime ribs of beef to the rare stage, showing that the number of minutes per pound varied from 28.80 in an oven at 110° to 10.65 at 250°. Cover (*9*) reported that paired three-rib roasts required 22.7 and 11.6 minutes per pound, respectively, when cooked medium rare at 125° and at 225° oven temperature. When cuts were cooked until well done in a comparison of these oven temperatures, she found the respective times required by paired three-rib roasts to be 42.2 and 19.0 minutes per pound.

The fat content of beef ribs was related to cooking time by Thille, Williamson, and Morgan (*30*), who roasted three-rib standing cuts at 210° C. oven temperature to 65° at the center. For roasts described as having "little or no surface fat" and weighing 2,790 g, 23.4 minutes per pound was required, and for roasts with "thick layer of surface fat" and weighing 3,666 g, 19.3. These investigators concluded that exterior fat speeds up the rate of heat penetration but interior fat may retard it. Nelson, Lowe, and Helser (*26*) reported that three-rib standing roasts containing 9.40 percent visible fat and weighing 1,173 g required 24.6 minutes per pound, whereas those containing 34.56 percent visible fat and weighing 5,302 g cooked in 18.3 minutes per pound, when all were seared for 20 minutes at oven temperatures varying from 230° to 275°, finished at 125°, and cooked rare (57°). These investigators stated that weight rather than degree of fatness was believed to be responsible for the difference in cooking time of the two groups of roasts.

The weight of a roast influences the number of minutes per pound required to cook it, according to Sprague and Grindley, who reported that for two-rib rolled roasts of the same character cooked by the same method, one weighing 4 pounds 7 ounces required 27 minutes per pound and another weighing 7 pounds 14 ounces required only 22.9 minutes per pound. These investigators concluded that, other things being equal, the heavier the roast the less will be the time per pound required to cook it.

The style of cutting beef rib roasts has been shown to influence the number of minutes per pound required for cooking. Sprague and Grindley compared the cooking time of single short-rib standing roasts with that of two-rib rolled roasts, using the same oven temperature, 195° C., for the finish after searing. At the rare stage the standing roasts required 16.3 minutes per pound and the rolled roasts 20.1. Cooked until medium, the difference was greater, with 19.2 minutes per pound required by the standing roasts and 27.9 by the rolled roasts. Alexander (*2*) compared the cooking time of two-rib standing with that of two-rib rolled roasts, using 300° F. (149° C.) for the finish after searing. The standing roasts reached the rare stage in 16 minutes per pound, the medium in 23, and the well done in 33, in striking contrast to the rolled roasts, which required, respectively, 27, 37, and 51 minutes to the pound. Child and Esteros (*7*) reported that two-rib standing and two-rib rolled roasts cooked to the rare stage at 149° C. oven temperature required, respectively, 23.00 and 35.48 minutes per pound.

EXPERIMENTAL PROCEDURE

DESCRIPTION OF BEEF SAMPLES

The majority of the beef samples for which cooking data are reported were from animals in meat-production experiments. To provide additional data on style of cutting and method of cooking, cuts were purchased in Washington, D. C., markets.

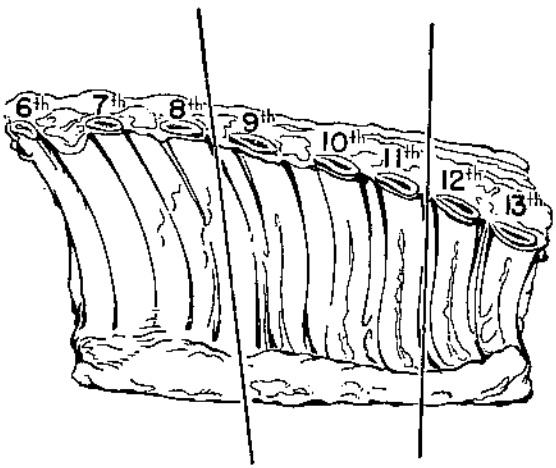

FIGURE 1.—Eight-rib wholesale cut of beef (New York style) divided into two three-rib and one two-rib retail roasts.

The 340 experimental animals were used in projects at Federal agricultural experiment stations or in cooperative projects at the State agricultural experiment stations of Arkansas, Colorado, Louisiana, Michigan, Mississippi, Missouri, Nebraska, North Carolina, Ohio, South Carolina, Virginia, West Virginia, Wisconsin, Wyoming, or at the privately owned King Ranch, Kingsville, Tex.

After the experimental animals were slaughtered the carcasses were graded by representatives of the Bureaus of Animal Industry and Agricultural Economics and of State agricultural experiment stations, in accordance with the standards established by the Bureau of Agricultural Economics (*10*). In a total of 340 beef carcasses there were 55 of Choice, 129 of Good, 125 of Medium, and 31 of Plain (formerly Common) grade.

The cutting methods for experimental animals were in all but three cases similar to the Chicago style and are described in the outline for the cooperative meat investigations.[4] The ribs were numbered 1 to 13, No. 1 being the rib next to the neck. The cut used as standard for palatability tests included the 9th, 10th, and 11th ribs from the left side of the carcass. The location of this roast in a wholesale rib cut (New York style) is shown in figure 1. Three of the experimental animals were represented by the 12th and 13th ribs. One animal of incomplete history from a Federal station was represented by the pair of 6th to 13th ribs, inclusive.

The meat purchased in Washington markets came from 77 carcasses. Of the 77, 8 were graded as Choice, 26 as Good, 18 as Medium, and 18 as Plain by representatives of the Bureaus of Agricultural Economics and Animal Industry, and 7 were not graded.

Portions purchased were the 6th to 13th ribs inclusive, the 6th, 7th, and 8th ribs, the 9th, 10th, and 11th ribs, and the 12th and 13th ribs, but the number and location of the roasts varied with different carcasses.

Rib cuts were cooked either as standing roasts or they were boned and rolled before cooking. All the 337 left 9th, 10th, and 11th rib cuts from experimental animals were cooked as standing roasts. Of the remaining cuts from experimental animals and the cuts purchased on the market, 227 were cooked as standing roasts and 31 as rolled roasts.

ROASTING METHODS

The eight methods of roasting beef used in the experiments differed from each other in oven temperature. Four methods of roasting employed a very hot oven for a short time at the start to sear the meat, and an oven temperature to finish ranging from slow to very hot. For the other four methods, constant oven temperatures, ranging from slow to very hot, were used.

Differences in the stage of doneness to which the meat was cooked are indicated by the following temperatures, determined with a thermometer in the center of the thickest portion: A range of temperatures around 60° C. at which beef is considered rare; 70°, at which beef has lost some of its rosy pinkness and is medium done; 75°, at which there is usually only a suggestion of pink juice and beef is called medium to well done; 80°, the well-done stage, at which beef usually becomes gray brown and is probably more done than most people prefer.

For all experiments the ovens were gas heated, indirect in action, ventilated, uninsulated, and equipped with glass doors and temperature regulators. Portable thermometers in the same relative position in the several ovens registered the oven temperatures, which were read through glass doors. Two units of four ovens each were used.

Roasts were prepared for the oven without salt, pepper, or flour. Each rib roast was weighed and then placed fat side up in a weighed open roasting pan. For the standing roasts the ribs acted as a natural rack to keep the meat out of the drippings in the bottom of the pan. Rolled roasts were supported on wire racks. Placed with the fat covering uppermost, the roasts were self-basting. A roast-meat

[4] UNITED STATES BUREAU OF ANIMAL INDUSTRY. A STUDY OF THE FACTORS WHICH INFLUENCE THE QUALITY AND PALATABILITY OF MEAT. 76 pp., illus. 1927. [Mimeographed.]

thermometer was inserted into the center of the eye muscle and kept there throughout the cooking period to show when the desired stage of doneness was reached. The meat was cooked uncovered and without water added to the pan.

QUICK SEAR AND SLOW FINISH

Roasts were seared for 20 minutes at an average oven temperature of 265° C. after which the cooking was continued in another oven held at 125° until the meat thermometer registered 58°, when they were removed from the oven and weighed. They were then allowed to stand at room temperature until the internal temperature had reached 62°, and again weighed.

For a number of years this method of cooking was the standard laboratory method adopted for rib roast of beef in connection with the cooperative meat investigations.[5] The greater number of the samples reported in this bulletin were cooked by this method for palatability tests as part of experiments involving production phases.

QUICK SEAR AND MODERATE FINISH

Roasts were seared as in the above method but the finishing oven temperature was 150° C., and the meat was cooked to 60°, 70°, 75°, and 80° internal temperature, respectively.

Or, roasts were seared as described above but finished at 175° C. to an internal temperature of 52° to 54° and allowed to stand outside the oven until the temperature at the center rose to 62°.

QUICK SEAR AND RAPID FINISH

Roasts were seared as in the above methods but finished at 225° C. to an internal temperature of 50°, and allowed to stand outside the oven until the temperature at the center rose to 62°.

CONSTANT LOW TEMPERATURE

Roasts were cooked at 125° C. oven temperature the entire time. For rare roasts the meat was either cooked to an internal temperature of 58° and allowed to stand outside the oven until the temperature at the center rose to 62°, or it was left in the oven until the meat thermometer registered 60°. Meat was cooked also to 70°, 75°, and 80° internal temperature, respectively.

CONSTANT MODERATE TEMPERATURE

Roasts were cooked at 150° C. oven temperature the entire time to an internal temperature of 56°, and allowed to stand outside the oven until the temperature at the center reached 62°. This constant very moderate temperature method supersedes the standard laboratory method (quick sear and slow finish) formerly adopted for palatability tests in connection with the cooperative meat investigations.

Or, roasts were cooked at 175° C. oven temperature the entire time. For rare roasts the meat was cooked either to an internal temperature of 52°, 54°, or 58° and allowed to stand outside the oven

[5] UNITED STATES BUREAUS OF HOME ECONOMICS and ANIMAL INDUSTRY. METHODS OF COOKING MEAT FOR PALATABILITY. 36 pp., illus. Revised, 1933. [Mimeographed.]

until the temperature at the center reached 62°, or it was left in the oven until the meat thermometer registered 60°. Meat was cooked also to 70°, 75°, and 80° internal temperature, respectively.

CONSTANT HIGH TEMPERATURE

Roasts were cooked at 235° C. the entire time to an internal temperature of 62°.

DETERMINATION OF SHRINKAGE

In these investigations shrinkage is defined as loss of weight during cooking. The shrinkage of each roast was determined as total loss of weight, and also as two fractions of the total, namely, pan-drippings loss and loss due to evaporation of water (*14*). Drippings loss is the weight of the mixture of fat and juice that cooks out of meat and collects in the roasting pan or on a tray after removal from the oven. Loss of weight due to the evaporation of water is the difference between total loss of weight and the weight of the drippings. Unless otherwise indicated, the shrinkage of each roast was calculated as percentage of the weight of the raw cut, ready for the oven, trimmed, and including bone.

On the basis of principles established through chemical analysis (*14*, *22*), it is possible to discuss the evaporation and drippings fractions of the loss of weight as approximations to losses, respectively, of water and of fat from meat during roasting. It appears that the evaporation fraction of the loss of weight is less than the true water loss but is a fairly good estimate of it. Pan drippings usually are mainly melted fat, especially when beef is cooked to the rare stage in a slow oven. The composition of the pan drippings undoubtedly varies considerably, hence this fraction of the loss of weight has no definition in terms of exact amounts of fat, water, salts, and nitrogenous constituents.

DETERMINATION OF COOKING TIME

The total time of cooking recorded in minutes includes the searing period but terminates on removal of the roast from the oven. The number of minutes per pound was calculated by dividing the total time by the weight in pounds of the uncooked roast, ready for the oven, unless otherwise indicated.

PLAN OF EXPERIMENTS

Preliminary to the studies on the influence of style of cutting and of cooking temperature on shrinkage and time, five series of experiments were carried out. In the first series wholesale cuts consisting of eight ribs, the 6th to 13th ribs inclusive, were divided into three roasts containing, respectively, the 6th, 7th, and 8th ribs, the 9th, 10th, and 11th ribs, and the 12th and 13th ribs, as shown in figure 1. Adjacent roasts were cooked by the same method in order to compare their shrinkage and cooking time.

Since the 9th, 10th, and 11th rib roast is the sample used for palatability tests on experimental beef animals in the cooperative meat investigations,[6] the second series of preliminary tests was made on

[6] See footnotes 4 and 5, pp. 7 and 8.

paired 9th, 10th, and 11th rib cuts from the same carcass. These were cooked in the same way for the purpose of obtaining shrinkage and cooking time data to be used as checks for experiments in which the style of cutting or the temperature of cooking was to be a variable factor.

In the third series, 9th, 10th, and 11th rib roasts of the same temperature at the start of cooking but of different weights were cooked by the same method to show how weight would influence the rate of cooking.

In the fourth series, 9th, 10th, and 11th rib roasts which fell within a narrow range of weight but differed in temperature when placed in the oven were cooked by the same method to show the relation of initial meat temperature to the time required for cooking.

In the fifth series of preliminary tests the object was to show how the length of the rib bones of standing roasts may affect shrinkage and cooking time. Paired 12th and 13th rib roasts were selected. The bones were not disturbed on the left roasts but were sawed off short from the rights. All were cooked by the same method.

For the experiments set up to show how shrinkage and cooking time are influenced by the style of cutting a rib roast, paired standing roasts from the same carcass were selected, one was left as a standing roast and the other was boned and rolled, and both were cooked by the same method.

Relations between oven temperature and shrinkage and cooking time were studied by using different oven temperatures on paired left and right roasts cut in the same way and cooked to the same meat temperature at the center. To relate the degree of doneness of a piece of beef to its shrinkage and cooking time, roasts were cooked rare, removed from the oven and weighed, put back into the oven until medium, weighed again, and then returned to the oven to cook until well done for the final weighing.

How the grade of beef determined shrinkage and cooking time was indicated by comparing the shrinkage and cooking time of the same rib portion cooked by the same method when this cut came from different grades.

PRELIMINARY TESTS

SHRINKAGE AND COOKING TIME OF DIFFERENT PORTIONS OF AN EIGHT-RIB CUT OF BEEF

Thirteen eight-rib cuts of beef, containing the 6th to 13th ribs, inclusive, were purchased in Washington markets. Included in the 13 cuts were 4 pairs, 1 pair each from Choice, Good, Medium, and Plain carcasses. There were four single cuts, taken, respectively, from three Good carcasses and one Plain carcass. The remaining single cut was not graded.

The eight-rib cuts were each divided into three parts, as shown in figure 1, for experiments on the shrinkage and cooking time of the different portions. The left-hand adjacent 6th, 7th, and 8th rib, 9th, 10th, and 11th rib, and 12th and 13th rib standing roasts from the four pairs of graded eight-rib cuts were cooked rare by the quick-sear-and-slow-finish method. The corresponding right roasts were cooked rare by the lower constant-moderate temperature of 150° C. The sets of adjacent roasts from the four single graded eight-rib cuts were cooked rare by the higher constant-moderate temperature of 175°. The adjacent roasts from the ungraded eight-rib cut were cooked rare by the constant-high temperature of 235°. The data are shown in table 1.

TABLE 1.—*Shrinkage and cooking time of 3- and 2-rib standing roasts from the same 8-rib cut of beef (6th to 13th ribs, inclusive)*

Roasting method, oven and meat temperatures (° C.)	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
				Evaporation	Drippings	Total	
		Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare)	4, left, 6th, 7th, and 8th ribs	4,222	5.3	9.7	2.6	12.3	22.7
	4, left, 9th, 10th, and 11th ribs	3,605	6.8	7.8	3.6	11.4	20.6
	4, left, 12th and 13th ribs	2,021	9.3	7.2	4.8	12.0	21.9
Constant moderate temperature (150°): Meat, 56° to 62° (rare)	4, right, 6th, 7th, and 8th ribs	4,590	4.9	10.6	2.7	13.3	19.0
	4, right, 9th, 10th, and 11th ribs	3,518	8.5	9.0	4.1	13.1	18.2
	4, right, 12th and 13th ribs	1,973	9.9	6.2	3.8	10.0	22.4
Constant moderate temperature (175°): Meat, 54° to 62° (rare)	2, left / 2, right } 6th, 7th, and 8th ribs	4,642	4.8	15.5	3.2	18.7	19.9
	2, left / 2, right } 9th, 10th, and 11th ribs	4,006	5.3	11.1	4.1	15.2	17.6
	2, left / 2, right } 12th and 13th ribs	2,288	7.3	10.4	5.0	16.0	20.7
Constant high temperature (235°): Meat, 62° (rare)	1, left, 6th, 7th, and 8th ribs	5,584	4.0	18.5	8.6	27.1	13.6
	1, left, 9th, 10th, and 11th ribs	4,801	5.0	17.6	14.7	32.3	14.7
	1, left, 12th and 13th ribs	3,274	12.0	10.8	15.0	25.8	13.4

SHRINKAGE AND COOKING TIME OF PAIRED ROASTS COOKED BY THE SAME METHOD

The paired 9th, 10th, and 11th rib roasts from 20 beef carcasses were purchased in Washington markets.

Ten pairs of standing roasts were cooked by the quick-sear-and-slow-finish method, and 10 pairs by a constant-moderate temperature. Data on shrinkage and cooking time for the corresponding left and right roasts of the two series are given in tables 2 and 3.

TABLE 2.—*Shrinkage and cooking time of 10 pairs of 3-rib standing roasts of beef (9th, 10th, 11th ribs), cooked by the same quick-sear-and-slow-finish method*

[Oven: 265° C. for 20 minutes, 125° for finishing. Meat: 58° to 62° (rare)]

Grade of beef	Weight of uncooked roast		Temperature of uncooked roast		Shrinkage during roasting						Cooking time per pound	
					Evaporation		Drippings		Total			
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
	Grams	*Grams*	*° C.*	*° C.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Minutes*
Good	4,323	4,445	7.0	7.0	8.8	8.9	5.1	5.2	13.9	14.1	21.1	21.8
	4,270	4,163	8.0	6.0	7.5	7.9	3.5	3.6	11.0	11.5	18.8	20.5
	4,154	4,089	4.0	4.0	7.3	6.7	4.8	4.8	12.1	11.5	20.2	20.6
	4,840	4,807	11.0	9.5	6.8	7.3	3.9	4.6	10.7	11.9	20.3	20.5
Mean	4,398	4,371	7.5	6.6	7.6	7.7	4.3	4.6	11.9	12.3	20.1	20.9
Plain	2,273	2,661	14.0	14.0	7.9	8.3	.8	.6	8.7	8.9	19.0	17.9
	3,048	2,987	4.0	6.0	7.6	7.4	3.1	2.8	10.7	10.2	21.0	21.1
	2,295	2,444	15.0	13.5	8.5	8.8	4.3	3.6	12.8	12.4	18.8	18.4
	3,134	3,255	4.0	6.0	8.7	7.8	2.3	1.4	11.0	9.2	21.7	23.4
Mean	2,687	2,837	9.3	9.9	8.2	8.1	2.6	2.1	10.8	10.2	20.1	20.2
No data	4,226	3,728	12.5	14.0	9.1	9.4	5.8	5.6	14.9	15.0	17.9	19.6
	3,749	3,574	13.5	11.5	8.3	7.3	5.1	4.0	13.4	11.3	19.2	20.2
Mean	3,988	3,651	13.0	12.8	8.7	8.4	5.5	4.8	14.2	13.2	18.6	19.9
Mean of 10	3,632	3,613	9.3	9.2	8.1	8.0	3.9	3.6	12.0	11.6	19.8	20.4

TABLE 3.—*Shrinkage and cooking time of 10 pairs of 3-rib standing roasts of beef (9th, 10th, 11th ribs), cooked by the same constant-moderate-temperature method*

[Oven: 175° C. Meat: 54° to 62° (rare)]

Grade of beef	Weight of uncooked roast		Temperature of uncooked roast		Shrinkage during roasting						Cooking time per pound	
					Evaporation		Drippings		Total			
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
	Grams	*Grams*	*° C.*	*° C.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Minutes*	*Minutes*
Good	3,843	3,838	0.0	6.0	12.2	12.2	4.8	5.5	17.0	17.7	18.5	19.1
	4,092	4,015	2.0	3.0	11.1	11.7	3.1	3.3	14.2	15.0	17.2	17.5
	4,627	4,881	8.0	6.0	10.7	9.7	4.2	3.9	14.9	13.6	15.7	16.1
	3,892	3,900	8.0	7.0	12.2	12.5	4.3	4.6	16.5	17.1	14.5	15.5
	3,990	4,005	5.0	5.0	9.9	8.9	4.8	4.1	14.7	13.0	16.0	16.5
Mean	4,089	4,128	5.8	5.4	11.2	11.0	4.2	4.3	15.4	15.3	16.4	16.9
Plain	3,304	3,408	4.0	5.0	8.6	10.5	2.0	3.6	11.2	14.1	18.3	18.2
	4,090	3,768	4.0	3.0	14.0	12.0	3.1	3.3	17.1	15.3	16.1	16.6
	3,832	3,615	6.0	6.0	13.2	11.9	3.6	3.5	16.8	15.4	15.3	16.6
	3,430	3,550	8.0	10.0	12.8	12.0	3.1	3.3	15.9	15.3	14.3	15.9
	3,403	3,318	2.5	3.0	10.7	11.0	5.3	5.7	16.0	16.7	17.7	16.9
Mean	3,594	3,545	4.9	5.4	11.9	11.5	3.5	3.9	15.4	15.4	16.3	16.8
Mean of 10	3,841	3,836	5.4	5.4	11.5	11.2	3.9	4.1	15.4	15.3	16.4	16.9

COOKING TIME AS INFLUENCED BY WEIGHT OF RAW CUT

Thirty-two standing roasts (9th, 10th, and 11th ribs) of the same initial temperature (8° C.) but of different weights were chosen from meat-production experiments. They were cooked by the quick-sear-and-slow-finish method. The data appear in table 4.

TABLE 4.—*Relation between the weight of 3-rib standing roasts of beef (9th, 10th, 11th ribs) and the time required for cooking by the quick-sear-and-slow-finish method*

[Oven: 235° C. for 20 minutes, 125° for finishing. Meat: 58° to 62° (rare)]

Roasts [1] (number)	Range in weight of uncooked roast	Cooking time per pound		Roasts [1] (number)	Range in weight of uncooked roast	Cooking time per pound	
		Average	Range			Average	Range
	Grams	*Minutes*	*Minutes*		*Grams*	*Minutes*	*Minutes*
2	1,250–1,749	22.6	21.3–23.9	8	3,750–4,249	20.1	17.6–21.8
1	1,750–2,249	24.7		4	4,250–4,749	21.3	20.6–22.7
3	2,250–2,749	21.3	19.3–23.5	3	4,750–5,249	19.0	18.5–19.5
1	2,750–3,249	23.3		1	5,250–5,749	19.1	
7	3,250–3,749	20.5	16.9–22.8	2	5,750–6,249	17.5	16.6–18.4

[1] All roasts were the same temperature (8° C.) at the center when put into the oven.

COOKING TIME AS INFLUENCED BY TEMPERATURE OF CUT WHEN PUT INTO OVEN

Seventy-six standing roasts (9th, 10th, and 11th ribs) within the weight range 2,948 to 3,397 g, inclusive, were chosen from meat-production experiments. These roasts differed in temperature when placed in the oven. They were cooked to the same final temperature by the quick-sear-and-slow-finish method. The data relating initial meat temperature to time required for cooking are presented in table 5.

TABLE 5.—*Relation between the temperature of 3-rib standing roasts of beef (9th, 10th, 11th ribs) when put into the oven and time required for cooking by the quick-sear-and-slow-finish method*

[Oven: 265° C. for 20 minutes, 125° for finishing. Meat: 58° to 62° (rare)]

Roasts (number)	Range in temperature of uncooked roast	Average weight of uncooked roast	Cooking time			
			Total		Per pound	
			Average	Range	Average	Range
	°C.	*Grams*	*Minutes*	*Minutes*	*Minutes*	*Minutes*
6	5.0– 6.9	3,058	153	149–165	22.8	20.7–24.4
12	7.0– 8.9	3,233	154	137–166	21.6	18.7–24.3
21	9.0–10.9	3,160	145	114–167	20.8	17.1–23.0
20	11.0–12.9	3,217	139	129–158	19.6	18.5–21.6
9	13.0–14.9	3,150	129	113–144	18.7	16.4–20.0
6	15.0–16.9	3,042	130	126–136	19.4	18.8–20.6
2	17.0–18.9	3,126	123	123–123	17.9	17.1–18.6

SHRINKAGE AND COOKING TIME AS INFLUENCED BY LENGTH OF THE RIB BONES

Three pairs of 12th and 13th rib roasts were purchased in Washington markets. One pair was graded Choice and the other two pairs Medium.

To determine how the length of the rib bones influenced the shrinkage and cooking time, the left roasts were cooked as received from the market, but from the corresponding right roasts several inches of bone were sawed, making blocky short-rib cuts.

All roasts were cooked rare by a quick-sear-and-moderate-finish method and taken from the oven and weighed. The roasts were then

returned to the oven to cook to the medium-done stage, when they were again weighed. Again the roasts were put back into the oven and cooked well done, when the final weights were taken. For each stage of cooking the shrinkage and cooking time were calculated. Results are given in table 6.

TABLE 6.—*Shrinkage and cooking time of 3 pairs of 2-rib standing roasts of beef (12th and 13th ribs), as affected by the length of the rib bones*

Roasting method, oven and meat temperatures (° C.)	Number and description of roast	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time	
				Evaporation	Drippings	Total	Total	Per pound
Quick sear (265°) and moderate finish (150°):		*Grams*	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*	*Minutes*
Meat, 60° (rare)	{3, left, long bones	3,157	12.0	7.3	6.1	13.4	103	14.8
	{3, right, short bones	2,732	11.8	7.3	5.3	12.6	105	17.4
Meat, 70° (medium)	{3, left, long bones	3,157	12.0	10.0	7.9	17.9	139	20.2
	{3, right, short bones	2,732	11.8	9.6	6.4	16.0	143	23.7
Meat, 80° (well done)	{3, left, long bones	3,157	12.0	13.4	9.7	23.1	184	26.9
	{3, right, short bones	2,732	11.8	12.9	7.5	20.4	192	32.0

The five series of preliminary experiments showed, respectively, the following results. Three portions of the same eight-rib cut shrank somewhat differently and cooked at different rates. When the center portion, the 9th, 10th, and 11th rib cut, was paired with the same cut from the same carcass and cooked by the same method there was considerable variation in shrinkage and cooking time within pairs. For single 9th, 10th, and 11th rib cuts of the same temperature, the greater the weight, the faster was the rate of cooking. For groups of 9th, 10th, and 11th rib cuts averaging approximately the same in weight the lower the meat temperature, the slower was the rate of cooking. The length of the rib bones of 12th and 13th rib cuts affected the shrinkage and the number of minutes per pound required for cooking but not the total time. These results suggest that probably factors other than the particular one under investigation were operative. For example, weight, temperature, and proportion of bone were operating factors in every experiment.

According to table 1, the data on the shrinkage of adjacent roasts from the same wholesale rib of beef showed a progressive decrease in evaporation loss and with one exception an increase in drippings loss from the chuck end to the loin end of the cut. The total shrinkage of the 6th, 7th, and 8th rib roasts was greater than for the 12th and 13th rib roasts, but that of the 9th, 10th, and 11th rib roasts was not related consistently to the others for all cooking methods used.

The relative shrinkage during cooking of the three adjacent roasts is believed to be explained chiefly on the basis of composition. Data of nearest application are those of Hall and Emmett (*15*) who reported physical analyses of four adjacent retail rib cuts from the same wholesale cut, giving the percentage of lean and visible fat, respectively, as follows: For 6th rib, 61.43 and 23.72 percent; 7th and 8th ribs, 56.00 and 27.81 percent; 9th and 10th ribs, 54.26 and 31.41 percent; and 11th and 12th ribs, 49.44 and 37.44 percent. The progressive increase in drippings loss from the 6th, 7th, and 8th rib to the 12th and 13th rib portion parallels the progressive increase in fat content reported

by Hall and Emmett. This result would be expected, because the higher the fat content of beef roasts the greater is the drippings loss during cooking, according to data published by Alexander (*1*), by Black and his associates (*4, 5*), by Hankins (*17*), by Helser (*18*), by Nelson, Lowe, and Helser (*26*), and by Thille, Williamson, and Morgan (*30*). As regards evaporation loss, the inverse relation observed here between fat content and evaporation loss has been noted by all the above investigators.

The data on cooking time of the adjacent roasts were variable, but for those cooked by quick-sear-and-slow-finish and by constant-moderate-temperature methods the 9th, 10th, and 11th rib portion required the smallest number of minutes per pound. On the basis of their relative weights, the 6th, 7th, and 8th rib cuts would have been expected to require the smallest number of minutes per pound, and the 12th and 13th ribs the greatest, with the 9th, 10th, and 11th ribs intermediate. The meat temperature, however, was an interfering factor, as it was the smallest for the heaviest roasts and the largest for the lightest roasts. It is very difficult to keep roasts of different weights at the same temperature. Another interfering factor should be considered for the 6th, 7th, and 8th rib roasts. In this portion of the eight-rib cut there is a heavy covering of small muscles over the eye and this covering seems to slow down the rate of heat penetration into the eye where the meat thermometer is placed.

As given in table 1, the relative shrinkage and cooking time of adjacent 6th, 7th, and 8th and 9th, 10th, and 11th rib roasts cooked by the quick-sear-and-slow-finish method were in general accord with data on these two cuts published by Nelson, Lowe, and Helser (*26*), as follows: Volatile cooking losses, 10.7 and 8.9 percent; drippings losses, 7.2 and 8.6 percent; minutes per pound for cooking, 19.3 and 16.8.

In table 6, the data on shrinkage show that on the average the roasts with long bones lost relatively more of their raw weight than the short-rib roasts at every stage of cooking. The greater shrinkage of the roasts with long bones is believed to be accounted for by their greater surface of fat and lean, also possibly by their extra amount of connective tissue and bone. With regard to connective tissue and bone, it is interesting to note the observations of Grindley and Mojonnier (*14*) and also of McCance and Shipp (*22*) that little is known of the portion of the cooking losses contributed by those constituents.

The data on shrinkage show also more difference in the drippings losses than in the evaporation losses of the two series of roasts. This is reasonable because the rib ends of Choice- and Medium-grade roasts usually contain more fat than lean, and extra length of ribs would be expected to contribute more to drippings losses than to evaporation losses.

As regards the shrinkage and cooking time data for paired 9th, 10th, and 11th rib cuts, shown in tables 2 and 3, the discrepancies within pairs are believed to be partially explained by differences in weight and in temperature between corresponding left and right roasts. The results of cooking roasts having rib bones of different lengths seem particularly applicable to the data on paired roasts in tables 2 and 3, although cuts and cooking methods differed. It goes without saying that the composition of a rib roast as regards lean, fat, and

bone is governed to a considerable extent by the way the ribs are cut out of the carcass and trimmed. So unless a pair of roasts were turned out exactly alike, which is practically impossible to do, they would not be the same in composition, and could not be expected to shrink identically or require precisely the same number of minutes per pound when cooked by the same method.

The only published data on pairs of beef roasts cooked by the same method, so far as the writers know, are those of Sprague and Grindley (*28*) who reported the cooking time of seven pairs of two-rib rolled roasts. All the roasts were seared at the start for 15 minutes at 250° C. and then finished at 195° oven temperature. Two pairs of roasts were taken from the oven when the meat temperature was 43°, three pairs at 55°, and the other two were allowed to remain in the oven until they reached 70°. The differences in the time of cooking per pound of the paired roasts ranged from 0.4 to 3.6 minutes. Sprague and Grindley were of the opinion that slight differences in the position of the thermometers in the paired roasts were responsible for the differences in cooking time. No doubt this was a factor in the tests reported here.

These results from preliminary experiments suggest that an efficient way to compare different methods of cooking is to use paired left and right cuts from the same carcass, trimmed to match as nearly as possible and kept at the same temperature. These results also indicate that when comparing different cooking methods it is well to repeat tests as many times as possible, to use different grades and cuts of meat, and to guard against attributing too much significance to small differences between averages. Consistent variation through a series of pairs is what counts when deciding whether one method of cooking affects meat differently from another.

SHRINKAGE AND COOKING TIME AS INFLUENCED BY STYLE OF CUTTING BEEF RIBS

STANDING AND ROLLED THREE-RIB ROASTS

Ten pairs of 6th, 7th, and 8th rib cuts of beef were purchased in Washington markets. Six pairs were Good grade and four pairs Plain grade beef.

The right roasts were weighed as standing roasts, then boned and rolled. Right rolled roasts and left standing roasts were cooked by the same method and shrinkage and cooking time determined. In addition, the shrinkage and the cooking time of the rolled roasts were calculated, respectively, as percent and as minutes per pound of the weight before boning and rolling.

Five pairs of left, standing and right, rolled roasts were cooked by a quick-sear-and-moderate-temperature method to 60°, to 70°, and to 75° C. meat temperature. Three of the five pairs of roasts were cooked to 80° but, of the other two pairs, only the standing roast of Good grade and the rolled roast of Plain grade reached this stage. The data on pairs which reached the same stage are presented in table 7.

Five pairs of left, standing and right, rolled roasts were cooked by a constant-moderate-temperature method. The data are given in table 8.

TABLE 7.—*Shrinkage and cooking time of paired 3-rib roasts of beef (6th, 7th, 8th ribs), standing and rolled, cooked by a quick-sear-and-moderate-finish method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time	
					Evaporation	Drippings	Total	Total	Per pound
Quick sear (265°) and moderate finish (150°):			*Grams*	° *C.*	*Percent*	*Percent*	*Percent*	*Minutes*	*Minutes*
Meat, 60° (rare)	Good	3, left, standing	4,826	4.2	12.0	4.2	16.2	208	19.4
		3, right, rolled	3,573	5.0	15.0	3.3	18.3	240	30.7
		3, right, standing	[1] 4,858		[2] 11.0	[2] 2.5	[2] 13.5		[2] 22.5
	Plain	2, left, standing	4,052	3.5	10.7	2.2	12.9	179	20.0
		2, right, rolled	2,850	4.3	14.8	2.6	17.4	198	31.6
		2, right, standing	[1] 3,802		[2] 11.0	[2] 2.0	[2] 13.0		[2] 23.7
Meat, 70° (medium)	Good	3, left, standing	4,826	4.2	16.6	4.8	21.4	266	25.0
		3, right, rolled	3,573	5.0	20.5	4.7	25.2	316	40.4
		3, right, standing	[1] 4,858		[2] 15.1	[2] 3.5	[2] 18.6		[2] 29.6
	Plain	2, left, standing	4,052	3.5	16.0	3.4	19.4	248	27.9
		2, right, rolled	2,850	4.3	20.4	3.6	24.0	261	41.4
		2, right, standing	[1] 3,802		[2] 15.3	[2] 2.7	[2] 18.0		[2] 31.0
Meat, 75° (medium well done)	Good	3, left, standing	4,826	4.2	20.4	5.3	25.7	321	30.2
		3, right, rolled	3,573	5.0	24.2	5.6	29.8	377	48.2
		3, right, standing	[1] 4,858		[2] 17.8	[2] 4.1	[2] 21.9		[2] 35.4
	Plain	2, left, standing	4,052	3.5	20.3	3.8	24.1	311	35.1
		2, right, rolled	2,850	4.3	24.5	4.3	28.8	313	49.7
		2, right, standing	[1] 3,802		[2] 18.4	[2] 3.2	[2] 21.6		[2] 37.2
Meat, 80° (well done)	Good	2, left, standing	4,715	3.5	24.3	5.6	29.9	382	36.7
		2, right, rolled	3,493	3.5	27.1	5.8	32.9	415	54.5
		2, right, standing	[1] 4,653		[2] 20.3	[2] 4.4	[2] 24.7		[2] 40.7
	Plain	1, left, standing	4,292	1.0	20.2	5.3	25.5	325	34.4
		1, right, rolled	2,660	2.5	23.3	5.8	29.1	309	52.7
		1, right, standing	[1] 3,545		[2] 17.5	[2] 4.3	[2] 21.8		[2] 39.5

[1] Weight of right roasts, trimmed and including bone, before being made into rolls.
[2] Shrinkage and cooking time of rolled roasts when calculated on the basis of their weights as standing roasts.

TABLE 8.—*Shrinkage and cooking time of 5 pairs of 3-rib roasts of beef (6th, 7th, 8th ribs), standing and rolled, cooked by a constant-moderate-temperature method*

Roasting method, oven and meat temperatures (°C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time	
					Evaporation	Drippings	Total	Total	Per pound
Constant moderate temperature (175°):			*Grams*	° *C.*	*Percent*	*Percent*	*Percent*	*Minutes*	*Minutes*
Meat, 60° (rare)	Good	3, left, standing	5,200	4.7	14.0	4.2	18.2	216	18.9
		3, right, rolled	3,760	4.2	17.0	4.3	21.3	224	27.1
		3, right, standing	[1] 5,027		[2] 12.7	[2] 3.2	[2] 15.9		[2] 20.3
	Plain	2, left, standing	4,259	4.5	16.6	2.6	19.2	168	20.3
		2, right, rolled	2,923	5.0	17.9	1.9	19.8	200	31.3
		2, right, standing	[1] 3,956		[2] 13.2	[2] 1.4	[2] 14.6		[2] 23.2
Meat, 70° (medium)	Good	3, left, standing	5,200	4.7	18.5	5.0	23.5	268	23.5
		3, right, rolled	3,760	4.2	21.5	5.2	26.7	271	32.7
		3, right, standing	[1] 5,027		[2] 16.2	[2] 3.9	[2] 20.1		[2] 24.6
	Plain	2, left, standing	4,259	4.5	20.5	3.1	23.6	230	24.6
		2, right, rolled	2,923	5.0	23.7	2.9	26.6	264	39.8
		2, right, standing	[1] 3,956		[2] 17.6	[2] 2.1	[2] 19.7		[2] 29.5
Meat, 75° (medium well done)	Good	3, left, standing	5,200	4.7	21.7	5.3	27.0	306	26.9
		3, right, rolled	3,760	4.2	24.3	5.9	30.2	304	36.7
		3, right, standing	[1] 5,027		[2] 18.2	[2] 4.4	[2] 22.6		[2] 27.5
	Plain	2, left, standing	4,259	4.5	24.2	3.4	27.6	270	29.0
		2, right, rolled	2,923	5.0	28.1	3.2	31.3	295	46.2
		2, right, standing	[1] 3,956		[2] 20.7	[2] 2.4	[2] 23.1		[2] 34.3
Meat, 80° (well done)	Good	3, left, standing	5,200	4.7	24.6	5.9	30.5	345	30.4
		3, right, rolled	3,760	4.2	27.1	6.6	33.7	339	41.0
		3, right, standing	[1] 5,027		[2] 20.4	[2] 4.9	[2] 25.3		[2] 30.7
	Plain	2, left, standing	4,259	4.5	27.5	3.6	31.1	309	33.3
		2, right, rolled	2,923	5.0	31.2	3.6	34.8	332	52.1
		2, right, standing	[1] 3,956		[2] 23.0	[2] 2.6	[2] 25.6		[2] 38.7

See footnotes to table 7.

STANDING AND ROLLED TWO-RIB ROASTS

Four pairs of 12th and 13th rib cuts of beef of Good grade were purchased in Washington markets.

As in the tests made on the paired 6th, 7th, and 8th rib cuts, the right 12th and 13th rib roasts were boned and rolled, and cooked by the same method as used on the left, standing roasts. Two pairs of left, standing and right, rolled roasts were cooked by a quick-sear-and-moderate-temperature and the other two pairs by a constant-moderate-temperature method. Data are given in table 9.

TABLE 9.—*Shrinkage and cooking time of paired 2-rib roasts of beef (12th, 13th ribs) of Good grade, standing and rolled, cooked by quick-sear-and-moderate-finish and by constant-moderate-temperature methods*

Roasting method, oven and meat temperatures (°C.)	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time	
				Evaporation	Drippings	Total	Total	Per pound
		Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*	*Minutes*
Quick sear (265°) and moderate finish (150°):								
Meat, 60° (rare)	2, left, standing	2,840	6.0	8.6	6.4	15.0	114	18.1
	2, right, rolled	2,214	7.0	11.6	7.1	18.7	144	29.6
	2, right, standing	[1] 3,045		[2] 8.5	[2] 5.2	[2] 13.7		[2] 21.5
Meat, 70° (medium)	2, left, standing	2,840	6.0	10.6	7.4	18.0	141	22.5
	2, right, rolled	2,214	7.0	14.3	8.6	22.9	174	35.6
	2, right, standing	[1] 3,045		[2] 10.5	[2] 6.3	[2] 16.8		[2] 25.9
Meat, 80° (well done)	2, left, standing	2,840	6.0	14.5	8.8	23.3	184	29.4
	2, right, rolled	2,214	7.0	19.3	11.0	30.3	223	45.7
	2, right, standing	[1] 3,045		[2] 14.1	[2] 8.0	[2] 22.1		[2] 33.4
Constant moderate temperature (175°):								
Meat, 60° (rare)	2, left, standing	2,570	6.5	11.0	5.5	16.5	108	19.1
	2, right, rolled	1,931	7.5	14.3	6.1	20.4	135	31.8
	2, right, standing	[1] 2,572		[2] 10.7	[2] 4.6	[2] 15.3		[2] 23.8
Meat, 70° (medium)	2, left, standing	2,570	6.5	13.7	6.1	19.8	120	22.0
	2, right, rolled	1,931	7.5	17.7	7.4	25.1	155	36.4
	2, right, standing	[1] 2,572		[2] 13.3	[2] 5.5	[2] 18.8		[2] 27.3
Meat, 80° (well done)	2, left, standing	2,570	6.5	18.6	7.3	25.9	164	28.9
	2, right, rolled	1,931	7.5	22.9	9.1	32.0	190	44.7
	2, right, standing	[1] 2,572		[2] 17.2	[2] 6.8	[2] 24.0		[2] 33.5

See footnotes to table 7.

As a whole, the results of these experiments on paired standing and rolled roasts were in general agreement in showing that the shrinkage and cooking time of standing roasts were relatively less than those of rolled roasts. The small differences in average initial temperature of the paired roasts probably did not exert an important influence on the cooking time.

The figures on relative shrinkage of standing and rolled two-rib roasts, each calculated as percentages of their weight when ready for the oven, are in general agreement with results published by Child and Esteros (*7*). Cooking-time relations between standing and rolled roasts confirm the findings of Sprague and Grindley (*28*), of Alexander (*2*), and of Child and Esteros (*7*). Sprague and Grindley were of the opinion that the faster cooking of standing roasts was explained by the greater surface exposed in proportion to cubic contents as compared with rolled roasts.

As shown in tables 7, 8, and 9, the total shrinkage of the rolled roasts, expressed as percentage of their weight before being boned, was, with one exception, consistently less than that of standing roasts

cooked as such. This result would seem to indicate that boning and rolling a rib roast reduced its cooking shrinkage, whereas just the opposite might be expected from the fact that rolled roasts had to remain in the oven so much longer than standing roasts in order to cook to any given stage of doneness at the center. That the cooked meat of rolled roasts contains less juice than that of standing roasts was reported by Child and Esteros (*7*). Their findings would of course indicate that the edible portion of rolled roasts actually shrinks more than that of standing roasts. Therefore, in looking for the source of the relatively greater shrinkage of the cuts cooked as standing roasts in the tests reported here, it is suggested that bone and connective tissue may have been important factors. Possibly the bone and connective tissue contributed so large a proportion of the shrinkage of the cuts cooked as standing roasts as to more than offset a probably greater shrinkage of the edible portion of the cuts cooked as rolled roasts.

SHRINKAGE AND COOKING TIME AS INFLUENCED BY METHOD OF ROASTING

COMPARISON OF METHODS WHICH INCLUDE SEARING

Thirty-six pairs of 9th, 10th, and 11th rib roasts representing Choice, Good, Medium, and Plain grades were purchased in Washington markets. All were cooked as standing roasts.

TABLE 10.—*Shrinkage and cooking time of paired 3-rib standing cuts of beef (9th, 10th, 11th ribs), roasted to the rare stage; quick-sear-and-slow-finish method compared with quick-sear-and-moderate-finish and with quick-sear-and-rapid-finish methods*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare).	Choice	4, left	4,835	3.1	7.2	4.1	11.3	21.6
	Good	9, left	4,121	4.3	8.2	5.2	13.4	21.8
	Medium	8, left	3,860	5.3	8.9	3.6	12.5	21.2
	Plain	4, left	3,197	4.8	10.0	3.0	13.0	21.4
	All	25, left	4,004	4.7	8.6	4.2	12.8	21.5
Quick sear (265°) and moderate finish (175°): Meat, 52° to 62° (rare).	Choice	4, right	4,934	3.5	11.1	7.9	19.0	15.8
	Good	9, right	4,159	5.2	11.2	7.8	19.0	15.4
	Medium	8, right	4,101	5.6	12.0	5.8	18.4	14.8
	Plain	4, right	3,142	5.3	13.7	5.0	18.7	15.6
	All	25, right	4,102	5.9	12.0	6.7	18.7	15.3
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare).	Good	2, left 2, right	4,050	7.8	7.1	4.7	11.8	20.9
	Medium	4, left	3,997	9.3	7.6	4.5	12.1	20.7
	Plain	1, left 2, right	3,009	8.3	9.4	2.6	12.0	20.7
	All	7, left 4, right	3,911	8.5	7.9	4.0	11.9	20.8
Quick sear (265°) and rapid finish (225°): Meat, 59° to 62° (rare).	Good	2, right 2, left	3,938	9.2	13.7	10.9	24.6	12.7
	Medium	4, right	3,606	10.6	13.9	9.6	23.5	12.8
	Plain	1, right 2, left	3,576	8.2	17.0	4.9	21.9	12.1
	All	7, right 4, left	3,719	9.4	14.7	8.8	23.5	12.6

Twenty-five pairs were used in a comparison of the quick-sear-and-slow-finish method with a quick-sear-and-moderate-finish method. The remaining 11 pairs were used to compare the quick-sear-and-slow-finish method with the quick-sear-and-rapid-finish method. The results of the tests are presented in table 10.

COMPARISON OF CONSTANT-TEMPERATURE METHODS

The pair of 6th to 13th ribs, inclusive, from an experimental animal of unrecorded grade were boned and rolled and used for a comparison of the constant-low temperature with a constant-moderate temperature method.

TABLE 11.—*Shrinkage and cooking time of a pair of 8-rib rolled roasts of beef (6th to 13th ribs, inclusive); constant-low-temperature compared with constant-moderate-temperature method*

Oven temperature (° C.)	Number and description of roasts	Weight of uncooked roast	Location of meat thermometer [1]	Meat temperature [1]		Shrinkage during roasting			Cooking time per pound
				Uncooked	Cooked	Evaporation	Drippings	Total	
		Grams		*° C.*	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Constant low (125°)	1, left	4,415	Chuck	4	60	7.7	1.6	9.3	25.4
			Middle	4	64				
			Loin	5	76				
Constant moderate (175°)	1, right	4,402	Chuck	6	60	11.3	5.1	16.4	17.8
			Middle	6	66				
			Loin	6	82				
Constant low (125°)	1, left	4,415	Chuck	4	70	13.4	3.6	17.0	34.1
			Middle	4	74				
			Loin	5	84				
Constant moderate (175°)	1, right	4,402	Chuck	6	70	15.6	6.4	22.0	22.0
			Middle	6	74				
			Loin	6	88				
Constant low (125°)	1, left	4,415	Chuck	4	75	16.9	5.6	22.5	41.0
			Middle	4	79				
			Loin	5	87				
Constant moderate (175°)	1, right	4,402	Chuck	6	75	18.2	7.6	25.8	24.8
			Middle	6	80				
			Loin	6	92				
Constant low (125°)	1, left	4,415	Chuck	4	80	20.1	6.9	27.0	47.7
			Middle	4	84				
			Loin	5	92				
Constant moderate (175°)	1, right	4,402	Chuck	6	80	20.2	8.1	28.3	27.2
			Middle	6	83				
			Loin	6	94				

[1] 3 meat thermometers were placed in each roast, 1 in the chuck end, 1 in the middle, and 1 in the loin end. Each of the roasts was weighed at 4 successive stages, when the chuck end reached 60°, 70°, 75°, and 80° C., respectively.

Three meat thermometers were placed in each rolled roast—one in the center of the thickest portion, or chuck end, one in the center of the thinnest portion, or loin end, and one in the center halfway between the two ends. Each roast was cooked according to the thermometer in the chuck end and was taken from the oven and weighed when the temperature of this portion reached 60°, 70°, 75°, and 80° C., respectively. The corresponding temperatures in the middle and in the loin end were recorded. The data are shown in table 11.

COMPARISON OF SEARING AND CONSTANT-TEMPERATURE METHODS

All the cuts used in comparing searing and constant-temperature methods of roasting were purchased in Washington markets.

For a comparison of the quick-sear-and-slow-finish with a constant-low-temperature method 10 pairs of three-rib cuts (9th, 10th, and 11th

ribs) were selected. The grades represented were Choice, Good, Medium, and Plain. The cuts were all cooked as standing roasts. The data are given in table 12.

The quick-sear-and-slow-finish method was also compared with two constant-moderate-temperature methods employing, respectively, 150° and 175° C. For the former comparison four pairs each of 6th, 7th, and 8th, 9th, 10th, and 11th, and 12th and 13th rib roasts were cooked (p. 11). The data are presented in table 1. The latter comparison was made on seven pairs each of three-rib (6th, 7th, 8th ribs) and two-rib cuts (12th and 13th ribs), taken from seven carcasses. Four represented Choice, Good, and Medium grades and three were of unrecorded grade. All cuts were cooked as standing roasts. The data for the 6th, 7th, and 8th rib roasts are given in table 13, and those for the 12th and 13th rib roasts in table 14.

TABLE 12.—*Shrinkage and cooking time of 10 pairs of 3-rib standing cuts of beef (9th, 10th, 11th ribs), roasted to the rare stage; quick-sear-and-slow-finish compared with constant-low-temperature method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare).	Choice	2, left	5,197	6.0	8.1	8.4	16.5	17.9
	Good	3, left	4,390	5.4	9.1	8.0	17.1	20.0
	Medium	3, left	4,199	6.7	9.1	4.2	13.3	20.4
	Plain	2, left	3,692	11.0	8.8	3.0	11.8	18.1
	All	10, left	4,355	7.3	8.8	5.9	14.7	19.3
Constant low temperature (125°): Meat, 58° to 62° (rare).	Choice	2, right	5,192	4.0	7.2	5.5	12.7	21.0
	Good	3, right	4,509	6.2	7.3	4.2	11.5	23.0
	Medium	3, right	3,940	9.0	7.2	2.4	9.6	22.4
	Plain	2, right	3,962	6.0	7.2	1.8	9.0	22.6
	All	10, right	4,363	6.6	7.2	3.4	10.6	22.3

TABLE 13.—*Shrinkage and cooking time of 7 pairs of 3-rib standing cuts of beef (6th, 7th, 8th ribs), roasted to the rare stage; the quick-sear-and-slow-finish compared with a constant-moderate-temperature method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare).	Choice	1, right	6,030	2.0	1	4.8	14.8	19.3
	Good	1, left 1, right	4,562	4.3	9.3	4.8	14.1	19.8
	Medium	1, right	4,473	4.0	9.4	3.9	13.3	21.4
	No data	3, left	5,050	4.7	9.6	4.9	14.5	19.6
	All	4, left 3, right	5,354	4.1	9.5	4.7	14.2	19.9
Constant moderate temperature (175°): Meat, 52° to 62° (rare).	Choice	1, left	6,510	2.0	16.5	7.4	23.9	16.4
	Good	1, right 1, left	4,437	6.0	13.1	6.2	19.3	14.9
	Medium	1, left	5,120	8.0	17.0	4.8	22.4	15.6
	No data	3, right	5,906	6.0	13.8	7.2	21.0	14.3
	All	4, right 3, left	5,500	5.3	14.5	6.6	21.1	15.0

TABLE 14.—*Shrinkage and cooking time of 7 pairs of 2-rib standing cuts of beef (12th, 13th ribs), roasted to the rare stage; the quick-sear-and-slow-finish compared with a constant-moderate-temperature method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare).	Choice	1, left	2,382	11.0	6.0	6.4	12.4	19.6
	Good	2, left	3,011	10.5	6.8	8.2	15.0	21.5
	Medium	1, left	2,656	8.0	5.9	7.2	13.1	19.3
	No data	3, left	3,827	5.7	7.2	7.2	14.4	21.6
	All	7, left	3,220	8.1	6.7	7.4	14.1	21.0
Constant moderate temperature (175°): Meat, 54° to 62° (rare).	Choice	1, right	2,649	7.0	6.1	5.0	11.1	17.8
	Good	2, right	2,659	10.0	6.8	7.2	14.0	17.2
	Medium	1, right	2,394	10.0	7.1	6.9	14.0	18.4
	No data	3, right	3,308	7.7	8.7	7.7	16.4	17.1
	All	7, right	2,808	8.6	7.6	7.1	14.7	17.4

TABLE 15.—*Shrinkage and cooking time of paired 3-rib standing cuts of beef (6th, 7th, 8th ribs), roasted to rare, medium, medium-well-done, and well-done stages; a quick-sear-and-moderate-finish compared with a constant-moderate-temperature method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and moderate finish (150°): Meat, 60° (rare)	Good	2, left	4,515	4.0	12.1	3.5	15.6	21.4
	Plain	3, left	3,926	3.5	12.3	2.6	14.9	20.0
	All	5, left	4,161	3.7	12.2	3.0	15.2	20.6
Constant moderate temperature (175°): Meat, 60° (rare)	Good	2, right	4,237	5.0	14.3	4.0	18.3	20.8
	Plain	3, right	3,878	4.3	14.5	2.3	16.8	19.9
	All	5, right	4,021	4.6	14.4	2.9	17.3	20.2
Quick sear (265°) and moderate finish (150°): Meat, 70° (medium)	Good	2, left	4,515	4.0	16.7	4.6	21.3	28.2
	Plain	3, left	3,926	3.5	16.8	3.7	20.5	26.6
	All	5, left	4,161	3.7	16.8	4.0	20.8	27.2
Constant moderate temperature (175°): Meat, 70° (medium)	Good	2, right	4,237	5.0	18.4	4.7	23.1	25.6
	Plain	3, right	3,878	4.3	19.1	2.9	22.0	24.9
	All	5, right	4,021	4.6	18.8	3.6	22.4	25.2
Quick sear (265°) and moderate finish (150°): Meat, 75° (medium well done).	Plain	3, left	3,926	3.5	20.4	4.2	24.6	32.2
Constant moderate temperature (175°): Meat, 75° (medium well done).	Plain	3, right	3,878	4.3	22.6	3.3	25.9	29.3
Quick sear (265°) and moderate finish (150°): Meat, 80° (well done).	Plain	3, left	3,926	3.5	24.1	4.5	28.6	38.8
Constant moderate temperature (175°): Meat, 80° (well done).	Plain	3, right	3,878	4.3	25.8	3.7	29.5	34.0

A quick-sear-and-moderate-finish was compared with a constant-moderate-temperature method, using five pairs of three-rib cuts (6th, 7th, and 8th ribs) and 11 pairs of two-rib cuts (12th and 13th ribs). Good and Plain (formerly Common) grades of beef were represented.

The three-rib cuts were cooked as standing roasts. Within pairs, the Good grade roasts were not carried to comparable stages of doneness beyond 70° C. The data for the tests are presented in table 15.

Of the two-rib cuts five pairs were cooked as standing roasts and six pairs as rolled roasts. The data for the standing roasts are presented in table 16 and for the rolled roasts in table 17.

TABLE 16.—*Shrinkage and cooking time of 5 pairs of 2-rib standing cuts of beef (12th, 13th ribs), roasted to rare, medium, and well-done stages; a quick-sear-and-moderate-finish compared with a constant-moderate-temperature method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Per cent*	*Per cent*	*Per cent*	*Minutes*
Quick sear (265°) and moderate finish (150°): Meat, 60° (rare)	Good	2, left	2,395	8.0	8.5	6.3	14.8	22.4
	Plain	3, left	1,672	6.0	8.0	3.9	11.9	23.6
	All	5, left	1,961	6.8	8.2	4.8	13.0	23.1
Constant moderate temperature (175°): Meat, 60° (rare)	Good	2, right	2,499	9.0	10.0	7.8	17.8	21.5
	Plain	3, right	1,794	6.7	8.2	3.9	12.1	22.8
	All	5, right	2,076	7.6	8.9	5.4	14.3	22.3
Quick sear (265°) and moderate finish (150°): Meat, 70° (medium)	Good	2, left	2,395	8.0	10.7	7.4	18.1	28.8
	Plain	3, left	1,672	6.0	10.3	4.6	14.9	30.8
	All	5, left	1,961	6.8	10.5	5.7	16.2	30.0
Constant moderate temperature (175°): Meat, 70° (medium)	Good	2, right	2,499	9.0	12.7	8.9	21.6	25.8
	Plain	3, right	1,794	6.7	10.8	4.8	15.6	28.3
	All	5, right	2,076	7.6	11.5	6.4	17.9	27.3
Quick sear (265°) and moderate finish (150°): Meat, 80° (well done)	Good	2, left	2,395	8.0	15.2	9.4	24.6	40.1
	Plain	3, left	1,672	6.0	14.5	5.8	20.3	42.9
	All	5, left	1,961	6.8	14.7	7.2	21.9	41.8
Constant moderate temperature (175°): Meat, 80° (well done)	Good	2, right	2,499	9.0	16.9	10.4	27.3	32.5
	Plain	3, right	1,794	6.7	14.1	5.5	19.6	34.8
	All	5, right	2,076	7.6	15.2	7.5	22.7	33.9

MEAT-TEMPERATURE COMPARISONS

To show how the stage to which beef is cooked influences the shrinkage and cooking time, cuts were cooked rare, medium, medium to well done, and/or well done, as determined by a meat thermometer in the center of the thickest part of a roast. Data obtained for the same roasts at these different stages are presented in tables 6, 7, 8, 9, 11, 15, 16, and 17.

TABLE 17.—*Shrinkage and cooking time of 6 pairs of 2-rib rolled cuts of beef (12th, 13th ribs), roasted to rare, medium, and well-done stages; a quick-sear-and-moderate-finish compared with a constant-moderate-temperature method*

Roasting method, oven and meat temperatures (° C.)	Grade of beef	Number and description of roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
			Grams	*° C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and moderate finish (150°): Meat, 60° (rare)	Good	2, left	2,038	6.0	9.6	5.2	14.8	31.3
	Plain	4, left	1,555	6.0	11.1	3.9	15.0	32.9
	All	6, left	1,716	6.0	10.6	4.3	14.9	32.4
Constant moderate temperature (175°): Meat, 60° (rare)	Good	2, right	2,102	7.0	9.7	4.7	14.4	30.8
	Plain	4, right	1,674	6.0	11.1	3.5	14.6	33.8
	All	6, right	1,817	6.3	10.7	3.9	14.6	32.8
Quick sear (265°) and moderate finish (150°): Meat, 70° (medium)	Good	2, left	2,038	6.0	12.8	6.9	19.7	39.4
	Plain	4, left	1,555	6.0	15.0	5.2	20.2	43.0
	All	6, left	1,716	6.0	14.2	5.8	20.0	41.8
Constant moderate temperature (175°): Meat, 70° (medium)	Good	2, right	2,102	7.0	13.1	6.5	19.6	37.9
	Plain	4, right	1,674	6.0	15.0	4.8	19.8	39.8
	All	6, right	1,817	6.3	14.3	5.4	19.7	39.2
Quick sear (205°) and moderate finish (150°): Meat, 80° (well done)	Good	2, left	2,038	6.0	18.6	9.7	28.3	53.5
	Plain	4, left	1,555	6.0	21.5	7.1	28.6	61.4
	All	6, left	1,716	6.0	20.5	8.0	28.5	58.8
Constant moderate temperature (175°): Meat, 80° (well done)	Good	2, right	2,102	7.0	18.8	9.1	27.9	47.7
	Plain	4, right	1,674	6.0	21.4	6.3	27.7	50.6
	All	6, right	1,817	6.3	20.5	7.2	27.7	49.6

DISCUSSION OF RESULTS

According to the data in table 10, the lower the oven temperature used for the finish after searing the smaller was the shrinkage and the longer the time required in cooking 9th, 10th, and 11th rib standing roasts to the rare stage. Results are in general accord with the findings of other investigators (*1*, *3*, *8*, *20*, *29*).

The shrinkage data in table 11 show that, when eight-rib rolled roasts were rare in the chuck end, the one cooked by the constant-low-temperature method shrank much less than its twin cooked by the constant-moderate temperature. However, as the roasts were cooked more thoroughly the differences in shrinkage became less until they were comparatively small by the time both had reached 80° C. in the chuck end. The rate of heat penetration as indicated by the cooking time was always slower when the oven temperature was 125° than when it was 175°, with the spread in time increasing as the meat temperature increased. Results with respect to the shrinkage and cooking time of these roasts at the rare stage are in general accord with the findings of Cline and others (*8*) and of Stanley and Cline (*29*) for standing roasts.

The data reported in table 12 show that 9th, 10th, and 11th rib standing roasts cooked by the quick-sear-and-slow-finish method shrank more and required less time than when a constant-low-temperature method was employed. Since the two cooking methods differed only in the initial quick sear, this experiment revealed the

effect of searing on the shrinkage and the cooking time of rare beef roasts. Results showed that searing not only did not reduce shrinkage as it was formerly believed to do but actually increased it significantly. There was proportionately greater increase in drippings than in evaporation loss, so the extra loss associated with searing was mainly fat. Searing reduced the cooking time. These findings as to the effect of searing on shrinkage and cooking time are in general accord with those published by Stanley and Cline (*29*).

Experiments comparing the quick-sear-and-slow-finish method with two constant-moderate-temperature methods revealed that three-rib and two-rib standing roasts behaved somewhat differently. Data in table 1 showed that the three-rib roasts cooked by the first method shrank less and cooked more slowly than when a constant temperature of 150° C. was used, but that the two-rib roasts shrank more and required a little less time. According to the results reported in table 13, the three-rib roasts cooked by the quick-sear-and-slow-finish method shrank less and cooked more slowly than those cooked at a constant temperature of 175°. In contrast, the findings with respect to shrinkage of the two-rib roasts cooked by these two methods, as shown in table 14, were variable and on the average there was little difference associated with the method of cooking. More time was required to cook two-rib roasts by the quick-sear-and-slow-finish method.

Also in the experiments which compared a quick-sear-and-moderate-finish with a constant-moderate-temperature method, the three-rib and two-rib roasts behaved somewhat differently as shown in tables 15, 16, and 17. According to the data in table 15 the three-rib Good-grade standing roasts shrank somewhat less when seared. Also the figures for the three-rib Plain-grade standing roasts cooked by the searing method were smaller as to evaporation and total losses, but larger as to drippings losses. The rate of cooking was slower by the former method than by the latter.

The results for two-rib standing roasts in table 16 showed that those of Good grade cooked by the quick-sear-and-moderate-finish method shrank less than when a constant-moderate oven temperature was used. For the Plain-grade roasts there was little difference in shrinkage between these methods at any stage of doneness of the meat. The rate of cooking was slower when the searing method was used. Data in table 17 for the rolled two-rib roasts show that evaporation loss was practically the same when the different methods were used, but that both drippings and total loss were slightly greater for cuts that were seared. With the exception of the Plain-grade roasts at the rare stage, in table 17 the rate of cooking was slower when the searing method was used.

Taken as a whole, the results presented in tables 15, 16, and 17 suggest that the shrinkage differences associated with the particular oven temperatures (that is, up to 175° C. as the highest constant temperature) are relatively unimportant. Judging by the cooking time data in these tables it appears that a quick sear followed by a moderate temperature of 150° usually functioned the same as a lower average oven temperature than 175° for the entire time.

The data shown in tables 6, 7, 8, 9, 11, 15, 16, and 17 revealed consistently that for any piece of meat the more thoroughly it was cooked the greater was the shrinkage and the cooking time, regardless of

the grade of beef, the rib portion, the style of cutting, or the oven temperature used. Results concerning the effect of the stage of doneness on shrinkage and cooking time are in general accord with the published work of other investigators (*1, 2, 8, 9, 11, 14, 20, 21, 22, 23, 24, 27, 28*).

When all the experiments on cooking methods are taken into consideration it can be said that, in general, smaller shrinkage was associated with lower oven temperature, when beef was cooked rare or medium, independently of whether searing methods or constant-temperature methods of roasting were employed. At the well-done stage, however, shrinkage was less definitely related to oven temperature.

In order to explain why roasts cooked to approximately the same rare or medium stage at the center shrank differently, depending on the oven temperature used, it is necessary to examine the uniformity of the cooking from center to surface, and thus to get a rough idea of the relative proportions of rare, medium, and well-done meat. It is a common observation on cutting into a piece of meat cooked at low oven temperature that, when the center is rare, the rest of the roast is rare and juicy almost to the very edge. On the other hand if a high oven temperature is used, the outer portions of a roast are well done, often overdone and dried out, by the time the center reaches the rare stage, and of course the proportion of rare meat is small. Fortunately, the uniformity of cooking in terms of meat temperature has been studied by several investigators who placed thermometers in different portions of the same roast to determine meat temperature gradients in relation to various oven temperatures.

The first work of this kind, so far as the writers know, was reported by Sprague and Grindley (*28*), who seared four two-rib rolled roasts of beef at 250° C. for 15 minutes, then finished two at 100° and the other two at 175° oven temperature. When the roasts finished at 100° reached the rare stage at the center there was a difference of only 5° in meat temperature between the center and a point about a quarter of an inch under the surface, but a corresponding difference of 13° for those finished at 175°. That is, there was probably a larger proportion of rare meat in the roasts finished at 100°. Shrinkage was not reported.

According to data published by Latzke (*20*) for a three-rib roast of beef seared at 250° C. for 20 minutes and finished at 125° oven temperature, when the meat temperature at the center was 61°, it was 75° near the surface, and the intermediate temperature was 65°. Latzke also published data on the distribution of meat temperature in a three-rib roast seared as above and finished at 175° oven temperature, showing that when the center temperature was 56°, it was 98° near the surface, and the intermediate temperature was 66°. These meat temperatures suggest that there was probably a smaller proportion of well-done meat in the roast finished at 125° than in the one finished at 175°. For several cuts cooked by the former method Latzke reported average shrinkage of 18.09 percent and for several cooked by the latter method, 22.49 percent.

Thille, Williamson, and Morgan (*30*) roasted three-rib cuts of beef at 210° C. oven temperature, placing several meat thermometers in each roast. When the meat temperature at the center was 65°, it was 102° just under the fat on the surface, and about 90° one-half inch from the edge. The average shrinkage of roasts cooked at 210°

oven temperature to 65° at the center was 30.8 percent, according to data published by these investigators.

Taken as a whole, the data published by Sprague and Grindley, by Latzke, and by Thille, Williamson, and Morgan indicate that the lower the oven temperature the greater is the uniformity of cooking in a roast that is rare or medium at the center. The fact that the proportions of rare, medium, and well-done meat in a roast vary considerably with the oven temperature used is significant in relation to shrinkage.

According to Ferrati (*11*), McCance and Shipp (*22*), and Meigs (*23, 24*) the temperature to which muscle is heated determines how much weight it will lose. The higher the temperature of meat the more juice is squeezed out by the heat-shortening of the tissues and consequently the greater is the loss of weight. Also, of course, fat is rendered out in proportion to the time (*30*) and the temperature of heating, adding further to the loss of weight. When the shrinkage data reported by Latzke and by Thille and her associates are compared with the meat temperatures reported by them, it is evident that the amounts the roasts shrank were closely associated with the proportions of rare, medium, and well-done meat. The more nearly rare a roast was throughout, the smaller was the shrinkage and the more nearly well done, the greater the shrinkage.

It is possible to make general application of the data cited from Sprague and Grindley, Latzke, and Thille and her associates to the results obtained in the experiments here reported. By analogy, it would be expected that the roasts cooked rare at the center contained the largest proportion of rare meat when the constant low oven temperature of 125° C. was used and the smallest at the constant high oven temperature of 235°. Comparing the shrinkage data in tables 12 and 1 for 9th, 10th, and 11th rib standing roasts cooked by these two methods, there would seem to be no doubt that the temperatures to which the meat was heated in the roast as a whole were mainly responsible for the amount of shrinkage. The other methods used, whether searing or constant-temperature methods, functioned as average oven temperatures higher than 125° and probably lower than 235°. Therefore, it is reasonable to find a progressive rise in the shrinkage of roasts cooked rare at the center as the average oven temperature stepped up above 125°. Of course it is reasonable also to find that the more thoroughly roasts were cooked at the center, using the same oven temperature, the greater was the amoun. they shrank.

For roasts cooked well done at the center there are no published data showing meat-temperature gradients from center to surface in relation to oven temperature, so far as the writers know. According to data reported for eight-rib rolled roasts in table 11 different parts came closer together in temperature the longer the roasts were in the oven. These were end-to-end temperatures in a long roll but it is possible that oven temperature may make less difference on the uniformity of cooking from center to surface of roasts carried to the well-done stage than only to the rare stage. This idea is borne out by the shrinkage data in tables 11, 15, and 16, which show in general that as roasts were cooked more thoroughly at the center the less difference the oven temperature made on shrinkage. That the time required in cooking was also a factor related to shrinkage

was apparent in these tests. When one oven temperature was lower than another the spread in cooking time widened as the meat was cooked more thoroughly. An excessively long time was required to cook meat well done when the oven temperature was 125° C., and it is significant that the shrinkage was almost as great as when 175° was used for shorter time. It appears to be impossible to cook meat thoroughly done without having it shrink on the average not less than 20 to 25 percent of its raw weight.

SHRINKAGE AND COOKING TIME OF BEEF RIBS ACCORDING TO GRADE

Of special interest to meat producers and to those consumers who are looking for pointers on selection is the shrinkage and cooking time of rib roasts of beef of different grades. This section brings together for the different grades represented here the data on the same rib portion cooked by the same method.

For a comparison of the shrinkage and cooking time of 9th, 10th, and 11th rib standing roasts according to grade, 337 were chosen from meat-production experiments and cooked by the quick-sear-and-slow-finish method. This sample includes the cuts reported in tables 4 and 5. The data for 337 roasts are presented in table 18.

TABLE 18.—*Shrinkage and cooking time of 3-rib standing roasts of beef (9th, 10th, 11th ribs), by grade, cooked by the same quick-sear-and-slow-finish method*

[Oven: 265° C. for 20 minutes, 125° for finishing. Meat: 58° to 62° (rare)]

Grade of beef	Roasts	Weight of uncooked roast		Temperature of uncooked roast		Shrinkage during roasting				Cooking time per pound	
						Evaporation		Drippings			
		Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
	Number	*Grams*	*Grams*	*°C.*	*°C.*	*Percent*	*Percent*	*Percent*	*Percent*	*Minutes*	*Minutes*
Choice	55	4,022	941	9.1	2.8	7.0	0.90	5.3	1.2	20.5	1.3
Good	126	3,506	789	10.5	3.4	7.3	1.2	4.6	1.2	20.1	1.9
Medium	125	3,299	936	10.5	2.9	8.4	1.3	3.4	1.6	20.2	1.9
Plain	31	2,348	668	12.0	3.0	8.9	1.4	2.0	.88	20.7	1.9

Grade comparisons can be made of 9th, 10th, and 11th rib standing roasts cooked by this same quick-sear-and-slow-finish method in tables 2, 10, and 12. Tables 3, 10, and 12 also contain data by grades for this cut cooked by other methods.

The data according to grade for 6th, 7th, and 8th rib standing roasts were combined from tables 1, 7, 8, 13, and 15, and are presented in table 19, together with several of the cuts which did not appear in paired comparisons at 75° and/or 80° C. The grade comparisons of 6th, 7th, and 8th rib rolled roasts are found in tables 7 and 8.

The data according to grade for 12th and 13th rib rolled roasts combined from tables 9 and 17 are presented in table 20, together with those for three cuts from experimental animals cooked by the quick-sear-and-slow-finish method, which do not appear elsewhere in this bulletin.

The data according to grade for 12th and 13th rib standing roasts were combined from tables 1, 6, 9, 14, and 16 and are given in table 21.

TABLE 19.—*Shrinkage and cooking time of 8-rib standing roasts of beef (6th, 7th, 8th ribs), by grade*

Roasting method, oven and meat temperatures (°C.)	Grade of beef	Roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
		Number	*Grams*	*°C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 58° to 62° (rare)	Choice	2	5,129	3.0	8.9	4.3	13.2	21.0
	Good	3	4,534	3.5	9.1	4.3	13.4	21.0
	Medium	2	4,231	4.0	9.6	2.8	12.4	22.6
	Plain	1	4,193	11.0	12.6	1.5	14.1	21.0
Quick sear (265°) and moderate finish (150°): Meat, 60° (rare)	Good	5	4,701	4.1	12.1	3.9	16.0	20.2
	Plain	5	3,976	3.5	11.7	2.5	14.2	20.0
Meat, 70° (medium)	Good	5	4,701	4.1	16.6	4.7	21.3	26.3
	Plain	5	3,976	3.5	16.5	3.5	20.0	27.1
Meat, 75° (medium well done).	Good	5	4,701	4.1	20.2	5.3	25.5	31.5
	Plain	5	3,976	3.5	20.3	4.1	24.4	33.3
Meat, 80° (well done)	Good	3	4,826	3.8	23.8	5.9	29.7	35.8
	Plain	4	4,018	2.9	23.1	4.7	27.8	37.7
Constant moderate temperature (150°): Meat, 58° to 62° (rare)	Choice	1	4,919	1.5	10.3	4.4	14.7	19.8
	Good	1	4,660	2.0	10.3	3.1	13.4	19.6
	Medium	1	4,993	5.0	9.7	1.7	11.4	19.0
	Plain	1	4,746	11.0	12.0	1.6	13.6	17.5
Constant moderate temperature (175°): Meat, 52° to 62° (rare)	Choice	1	6,510	2.0	16.5	7.4	23.9	16.4
	Good	7	4,707	5.1	13.8	4.7	18.5	18.3
	Medium	1	5,129	8.0	17.6	4.8	22.4	15.6
	Plain	5	4,030	4.4	15.3	2.4	17.7	20.0
Meat, 70° (medium)	Good	5	4,815	4.8	18.4	4.9	23.3	24.3
	Plain	5	4,030	4.4	19.6	3.0	22.6	24.8
Meat, 75° (medium well done).	Good	4	5,031	4.5	21.0	5.6	27.5	28.1
	Plain	5	4,030	4.4	23.3	3.3	26.6	29.2
Meat, 80° (well done)	Good	5	4,815	4.8	24.3	6.0	30.3	31.3
	Plain	5	4,030	4.4	26.5	3.6	30.1	33.7

TABLE 20.—*Shrinkage and cooking time of 2-rib rolled roasts of beef (12th, 13th ribs), by grade*

Roasting method, oven and meat temperatures (°C.)	Grade of beef	Roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
		Number	*Grams*	*°C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°): Meat, 60° to 62° (rare)	Good	3	1,191	10.7	9.1	6.3	15.4	45.2
Quick sear (265°) and moderate finish (150°): Meat, 60° (rare)	Good	4	2,126	6.5	10.6	6.1	16.7	30.4
	Plain	4	1,555	6.0	11.1	3.9	15.0	32.9
Meat, 70° (medium)	Good	4	2,126	6.5	13.5	7.8	21.3	37.5
	Plain	4	1,555	6.0	15.0	5.2	20.2	43.0
Meat, 80° (well done)	Good	4	2,126	6.5	18.9	10.3	29.2	49.6
	Plain	4	1,555	6.0	21.5	7.1	28.6	61.4
Constant moderate temperature (175°): Meat, 60° (rare)	Good	4	2,016	7.3	12.0	5.4	17.4	31.3
	Plain	4	1,674	6.0	11.1	3.5	14.6	33.8
Meat, 70° (medium)	Good	4	2,016	7.3	15.4	7.0	22.4	37.1
	Plain	4	1,674	6.0	15.0	4.8	19.8	39.8
Meat, 80° (well done)	Good	4	2,016	7.3	20.8	9.1	29.9	45.2
	Plain	4	1,674	6.0	21.4	6.3	27.7	50.6

TABLE 21.—*Shrinkage and cooking time of 2-rib standing roasts of beef (12th, 13th ribs), by grade*

Roasting method, oven and meat temperatures (°C.)	Grade of beef	Roasts	Weight of uncooked roast	Temperature of uncooked roast	Shrinkage during roasting			Cooking time per pound
					Evaporation	Drippings	Total	
		Number	*Grams*	*°C.*	*Percent*	*Percent*	*Percent*	*Minutes*
Quick sear (265°) and slow finish (125°):								
Meat, 58° to 62° (rare)	Choice	2	2,460	8.5	5.4	5.9	11.3	20.3
	Good	3	2,735	9.7	6.8	7.6	14.4	21.8
	Medium	2	2,183	8.5	6.6	5.4	12.0	20.4
	Plain	1	1,655	14.0	10.1	4.0	14.1	22.5
Quick sear (265°) and moderate finish (150°):								
Meat, 60° (rare)	Choice	2	3,705	9.5	7.2	7.9	15.1	16.4
	Good	4	2,618	7.0	8.6	6.4	15.0	20.2
	Medium	4	2,565	13.1	7.4	4.6	12.0	16.0
	Plain	3	1,672	6.0	8.0	3.9	11.9	23.6
Meat, 70° (medium)	Choice	2	3,705	9.5	9.4	10.0	19.4	21.5
	Good	4	2,618	7.0	10.8	7.4	18.0	25.6
	Medium	4	2,565	13.1	10.0	5.8	15.8	22.2
	Plain	3	1,672	6.0	10.3	4.6	14.9	30.8
Meat, 80° (well done)	Choice	2	3,705	9.5	12.0	12.1	24.1	27.6
	Good	4	2,618	7.0	14.8	9.1	23.9	34.7
	Medium	4	2,565	13.1	13.7	6.9	20.6	30.4
	Plain	3	1,672	6.0	14.5	5.8	20.3	42.9
Constant moderate temperature (150°):								
Meat, 58° to 62° (rare)	Choice	1	2,470	6.0	4.7	4.8	9.5	20.6
	Good	1	2,005	10.0	5.4	4.2	9.6	21.3
	Medium	1	1,782	10.5	6.8	2.5	9.3	24.2
	Plain	1	1,033	13.0	7.9	3.7	11.6	23.3
Constant moderate temperature (175°):								
Meat, 58° to 62° (rare)	Choice	1	2,649	7.0	6.1	5.0	11.1	17.8
	Good	6	2,576	8.1	9.3	6.8	16.1	19.2
	Medium	1	2,394	10.0	7.1	6.9	14.0	18.4
	Plain	3	1,794	6.7	8.2	3.9	12.1	22.8
Meat, 70° (medium)	Good	4	2,534	7.3	13.2	7.5	20.7	24.2
	Plain	3	1,794	6.7	10.8	4.8	15.6	28.3
Meat, 80° (well done)	Good	4	2,534	7.3	17.7	8.9	26.6	30.7
	Plain	3	1,794	6.7	14.1	5.5	19.6	34.8

With comparatively few exceptions, there was the same general trend in the relation of grade to shrinkage independent of the method of cooking. The higher the grade of beef the greater was the drippings loss, except in isolated instances where there were very few samples to represent the grades compared. In table 18, where there are many samples in each grade, the differences between the average evaporation losses were tested by the method of Fisher (*12*) and it was found that Good grade lost significantly less than Medium-grade roasts. As between Choice and Good, and between Medium and Plain, however, differences would not be statistically significant, but in this series they indicated that as grade declined evaporation loss increased. In the smaller groups there were several reversals, as might be expected.

The results obtained are believed to be explained chiefly by the average fat content of beef of different grades. Data on the fat content of 234 9th, 10th, and 11th rib cuts which were analyzed by the Bureau of Animal Industry have been published (*1*). As would be expected from the fact that fat is one of the chief factors in determining grade, the higher the grade the greater on the average is the fat content of the 9th, 10th, and 11th rib cut. In Chatfield's (*6*) classification of beef sides by fatness, thin beef is claimed to correspond to Plain grade, medium to Medium grade, fat to Good, and very fat to Choice and Prime, and the fat content of the entire side of beef is closely related to the fat content of the wholesale rib cut. Therefore,

although no similar data were available on the 6th, 7th, and 8th rib and 12th and 13th rib cuts, it would be expected that their fat content would be related to grade in the same general way as that of the analyzed 9th, 10th, and 11th rib cuts.

The published analyses of 9th, 10th, and 11th rib cuts showed that there was considerable variation in fat content within grades. It is therefore not surprising to find in the shrinkage data in table 18 that standard deviations were high in large groups representing the same grade, and that when small groups were compared the data on shrinkage were not generally in close accord.

The number of minutes per pound required in cooking was not significantly related to carcass grade, although slight trends were observed. For example, in table 18, where there were large numbers of 9th, 10th, and 11th rib standing roasts in each grade, the time data suggested a tendency for Good- and Medium-grade rib roasts to cook relatively more rapidly than either Choice or Plain. When the averages for Good and Plain roasts, which differed most in the series, were tested by Fisher's (*12*) method, $t=1.63$ and $p=0.1$, indicating that the difference was not great enough to be really significant. A similar result was obtained by testing the difference between the averages for Good- and Choice-grade roasts. In the small groups of 9th, 10th, and 11th rib standing roasts cooked by various methods there appeared to be no relationship between grade and cooking time. Good-grade beef tended to cook at a more rapid rate per pound than Plain, as shown for 6th, 7th, and 8th rib and 12th and 13th rib standing roasts. There was a consistent difference between rolled roasts of Good- and Plain-grade beef, with Good beef cooking the more rapidly in minutes per pound and the spread increasing beyond the rare stage. The number of 6th, 7th, and 8th rib and 12th and 13th rib roasts in any grade, however, was very small.

In trying to explain the slight trends observed between the number of minutes per pound and carcass grade, the respective influence of weight and temperature must be taken into account. On the basis of weight it would be expected that, on the average, the higher the grade the smaller should be the number of minutes per pound required in cooking. The initial temperature of the roasts was a complicating factor, operating in many cases to make the heaviest roasts, which were often the coldest, require more time than would have been needed had they been less cold at the start.

Furthermore, two attributes of grade that must have influenced the rate of cooking are fat content and conformation, or thickness of fleshing (*10*). Thille and her associates (*30*) reported that fat roasts required fewer minutes per pound than lean roasts. According to Lowe (*21*), the thicker a rib roast is in proportion to its width the slower is the rate of cooking. Also, the higher the grade the smaller is the proportion of bone (*6*). On the basis of fat content, the higher the grade of beef the fewer minutes per pound required in cooking. On the basis of conformation and bone content, however, the higher the grade the more minutes per pound required.

It is not possible to state quantitatively the extent of the influence of these separate factors, but apparently the net effect was such as to indicate that grade did not exert an important influence on the rate of cooking. It is suggested that conformation, bone content, and temperature together may have slightly more than offset weight

and fatness in the Choice grade. In contrast, it is possible that weight and leanness in combination counteracted the effect of conformation, bone content, and temperature where Plain was compared with Good grade.

The only portion of the data on shrinkage and cooking time according to grade that can be compared with results reported by Cover (*9*) concerns three-rib standing roasts (9th, 10th, and 11th ribs) cooked at constant-low oven temperature, in table 12. For six Good, eight Medium, and eight Plain roasts, Cover's findings are, respectively, as follows: For raw weight in grams; for volatile cooking loss and for total cooking loss, each expressed as percent of the raw weight; and for the number of minutes per pound required to cook the meat medium rare, 3,866, 5.0, 6.9, 20.8; 3,165, 5.6, 7.0, 24.4; 3,283, 5.5, 7.3, 22.4.

SUMMARY AND CONCLUSIONS

In a series of experiments on 595 rib roasts, which represented U. S. Choice, Good, Medium, and Plain (formerly Common) grade beef, studies were made on the influence of the style of cutting and of the temperature of cooking on the shrinkage (loss of weight) and cooking time. Standing roasts were compared with rolled roasts. The 8 methods of roasting employed oven temperatures ranging from 125° to 265° C. Constant temperature roasting methods were compared with those including an initial sear at high temperature. Beef was cooked to four stages of doneness as determined by a roast-meat thermometer: Rare, about 60°; medium, 70°; medium-well-done, 75°; well done, 80°.

Preliminary experiments were conducted on three-rib and two-rib roasts from the same eight-rib cut, on paired roasts cooked by the same method, on roasts that differed in weight, on roasts that differed in temperature when placed in the oven, and on roasts with long and short rib bones. According to the results, adjacent portions of the eight-rib cut differed in shrinkage and rate of cooking. Paired cuts also differed more or less in shrinkage and rate of cooking. Heavy roasts cooked more rapidly in relation to weight than did light ones. As would be expected the colder a roast was at the start the longer time it required. Roasts with long rib bones shrank slightly more than those with the bones sawed off short and cooked in practically the same total time but in fewer minutes per pound. The results of these preliminary experiments were applicable in a general way to the interpretation of data obtained in experiments on the style of cutting and the temperature of cooking, also in grade comparisons.

When roasts were classified according to grade, the data on shrinkage showed that, on the average, the higher the grade the smaller was the evaporation loss and the larger the drippings loss, independent of the style of cutting or of the method of cooking. This result is consistent with the relative average fatness of the different grades of beef. Fat content is one of the most important factors in determining grade; on the average the higher the fat content the higher the grade.

Within grades shrinkage varied considerably, even when the location of the cut was the same and the same cooking method was used. Hence, grade differences with respect to shrinkage were consistent only where there was a large number of the same cuts in each grade and the same cooking method was used throughout. This

condition was fulfilled within reason for the 9th, 10th, and 11th rib standing roasts of beef cooked to the rare stage by a quick-sear-and-slow-finish method. The average shrinkage by grade for these roasts was, respectively, for evaporation and drippings fractions, as follows: U. S. Choice, 7.0, 5.3; U. S. Good, 7.3, 4.6; U. S. Medium, 8.4, 3.4; U. S. Plain, 8.9, 2.0. With cooking time expressed as minutes per pound, grade did not seem to exert an important effect on the rate of cooking. There was, however, a slight trend toward faster cooking in relation to the weight of U. S. Good beef as compared with the same rib cut of U. S. Plain beef.

Standing and rolled three-rib and two-rib cuts were cooked to the rare, medium, medium-well-done, and/or well-done stages, using a quick-sear-and-moderate-finish method, and also a constant-moderate oven temperature method. Comparison of shrinkage and cooking time of standing and rolled roasts, on the basis of their respective weights when ready for the oven, showed that standing roasts shrank less and cooked more rapidly than rolled roasts. For example, a group of standing roasts when rare lost, on the average, 16.2 percent and required 19.4 minutes per pound, whereas the corresponding rolled roasts cooked by the same method lost 18.3 percent and required 30.7 minutes per pound. On the other hand, when the shrinkage of the rolled roasts was expressed as percentage of their weight before being boned, it was 13.5 percent, that is, somewhat less than that of the standing roasts.

These results seem to indicate that boning and rolling a rib roast reduce shrinkage. However, the standing roasts were exposed to the oven heat for less total time and therefore it might be expected that they would lose relatively less than the rolled roasts. Also, other investigators have reported that standing roasts are juicier than rolled roasts, indicating smaller loss from the edible portion when the bones were left in. Hence it is believed that the greater relative shrinkage of the standing roasts came from bone and connective tissue rather than from the edible portion.

Of the factors studied, cooking temperature had the greatest influence on shrinkage and cooking time. In general, when roasts were cooked rare or medium, as determined by a thermometer in the center of the thickest portion, the lower the oven temperature the smaller the shrinkage and the slower the rate of cooking. For instance, an eight-rib rolled roast (6th to 13th ribs, inclusive) that was cooked rare at 125° C. oven temperature shrank 9.3 percent and required 25.4 minutes per pound; whereas the corresponding cut in an oven at 175° shrank 16.4 percent and required 17.8 minutes per pound. At the well-done stage, however, shrinkage was less definitely related to oven temperature, as shown by 27.0 percent shrinkage for the roast in the 125° oven and 28.3 percent for that in the 175° oven. The time required was, respectively, 47.7 and 27.2 minutes per pound. These figures serve also to emphasize that the more thoroughly beef is cooked the more it shrinks. Even with very slow cooking at low oven temperatures it was not possible to cook meat well done and keep shrinkage low.

Comparisons of constant-temperature roasting with methods that included an initial sear, using paired cuts, confirmed the findings of other investigators that searing in itself does not reduce shrinkage as it was formerly thought to do. But whether searing methods or con-

stant-temperature methods were associated with greater shrinkage of roasts was dependent not on searing alone but on average oven temperature and on the cut used. For example, a combination of a quick sear (265° C. for 20 minutes) with a reduced temperature of 125° for the finish obviously functioned as a higher average oven temperature than did 125° the entire time. The result was that a group of seared three-rib standing roasts (9th, 10th, and 11th ribs) cooked rare shrank more than unseared corresponding roasts as shown by the figures, respectively, 14.7 and 10.6 percent. On the other hand, this same quick-sear-and-slow-finish method functioned as a lower average oven temperature than a constant temperature of 175°, as indicated by the comparative time required in cooking to the rare stage three-rib standing roasts (6th, 7th, and 8th ribs) and likewise two-rib standing roasts (12th and 13th ribs). Seared roasts, in this comparison of roasting methods, shrank less than unseared ones as shown by the figures for three-rib roasts, respectively, 14.2 and 21.1 percent, and for two-rib roasts, respectively, 14.1 and 14.7 percent. Furthermore, these and other similar results suggested that the shrinkage of two-rib roasts was less consistently governed by oven temperature than that of three-rib roasts.

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