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# TEXAS AGRICULTURAL EXPERIMENT STATION

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BULLETIN NO. 542 JUNE, 1937

DIVISION OF RURAL HOME RESEARCH



# THE EFFECT OF TEMPERATURE AND TIME OF COOKING ON THE TENDERNESS OF ROASTS

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS
T. O. WALTON, President

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Well-done round-bone chuck and rump roasts were much more tender cooked at a low oven temperature of 125 degrees Centigrade (257 degrees Fahrenheit) than at a high oven temperature of 225 degrees Centigrade (437 degrees Fahrenheit); well-done standing rib and half-ham roasts were, also, more tender cooked at the low oven temperature; but there was little difference in the results of the two methods of cooking for the well-done leg of lamb roasts or for the medium-rare rib and chuck roasts. Oven temperature, therefore, seems to be an important factor in producing tenderness in some roasts but not in others. Any apparent relationship between tenderness and oven temperature observed in these tests seems to be much better explained on the basis of a difference in the time required for cooking—the well-done round-bone chuck roasts requiring about six hours longer cooking time at the low oven temperature than at the high oven temperature; the well-done rump roasts about five hours longer; the well-done rib and half-ham roasts about three and a quarter hours longer; and the well-done leg of lamb and the medium-rare rib and chuck roasts less than two hours longer.

The longer time of cooking at the low oven temperature actually required less gas for each of the cuts except the rump and round-bone chuck. Gas consumption was not obtained for the rump, but for the chuck the cost of the gas was not increased by as much as one cent per roast even though the difference in cooking time was about six hours.

Although a decided advantage in the tenderness of some of the paired cuts was obtained with the low oven temperature, in none of the cuts did the low oven temperature method produce roasts all of which were scored "very tender." More work needs to be done before recommendations can be made of processes of cooking which will uniformly produce tender roasts. Present knowledge would indicate, however, that a housewife will have a better chance of obtaining a tender roast if she cooks it at a low oven temperature than if she cooks it at a high oven temperature.

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# THE EFFECT OF TEMPERATURE AND TIME OF COOKING ON THE TENDERNESS OF ROASTS

**Sylvia Cover, Foods Specialist, Division of Rural Home Research**

Research in food preparation seeks to determine the cause of the changes which take place when food is prepared for the table. Such changes may be those which delight the eye or the palate as well as those which influence nutritive value. Among such changes, those influencing the palatability of meat have recently been studied systematically, so that now former explanations of these changes may be evaluated. As a result, some of the old explanations are being discarded entirely, such as the one which advocated the searing of meat on the theory that the crust formed by the searing held in the juices during subsequent cooking. Other statements or so-called "principles" may be found to be true in a much more restricted sense than was formerly supposed.

For many years the use of low temperatures in meat cookery has been defended by the statement that high temperatures toughen protein. This statement has been used arbitrarily in regard to cooking in water ("simmering" versus "boiling," where all of the temperatures are relatively low) as well as to cooking in an oven ("slow" oven versus "hot" oven, where all of the temperatures are relatively high). While high temperatures may toughen a thin layer of meat in contact with them, they may have no effect on meat in the center of a large roast where the temperature does not approach closely that of even a low temperature oven. With tenderness of meat one of the most important qualities of palatability and with oven temperature one of the physical factors over which the housewife has most adequate control, the effect of high and low oven temperatures on the tenderness of meat seemed a problem worthy of study.

This study is the first of a series to be conducted at this station, the ultimate aim of which is to find out what causes tenderness or toughness in meat so that procedures may be recommended which will uniformly produce tender roasts. The study is also a part of the national cooperative project "A study of the Factors which Influence the Quality and Palatability of Meat."

## CONTRIBUTIONS OF PREVIOUS INVESTIGATORS

Before 1925 extensive studies of the changes in meat during cooking were made in two laboratories, that of Lehmann at the Hygienic Institute in Wurzburg, Germany (1895-1907), and that of Grindley at the University of Illinois (1898-1907). Although Lehmann (17) and his students were especially interested in tenderness, their work was done with raw and boiled meat. No work with roasted meat or meat cooked at different temperatures was reported.

In Grindley's work with roasted meat, observations in regard to tenderness of the products were reported in only a few instances. A right 5th rib (13) taken from a four-year-old Aberdeen-Angus steer was seared at an oven temperature of 249°C (480°F) for 15 minutes and then cooked for 1 hour and 10 minutes at an oven temperature as near as possible to 193°C (380°F). The cooking time was 20.1 minutes per pound and the cooked meat was described as "somewhat tough and dry." In another experiment (13), "a rib" taken from a well fattened steer was seared for 15 minutes at an oven temperature of 240°C (464°F) and then cooked for 1 hour and 20 minutes at 193°C (380°F). The cooking time was 24 minutes per pound. "The cooked meat was medium done, juicy and tender." As an oven with a temperature of 193°C (380°F) may be regarded as a "hot" oven, the observation that some of the meat cooked at this temperature was tough and some of it tender is of interest even though meat thermometers were not used for determining doneness and the internal temperature of the roasts may have varied considerably.

Sprague and Grindley (20) reported one test made by cooking duplicate samples from the same animal, one in the gas range oven at 195°C (383°F) and the other in the Aladdin oven (practically no oven ventilation) at 100°C (212°F). "It was agreed that the latter gave the best results in regard to the flavor and juiciness of the meat but that there was little difference in the tenderness of the two roasts." While they gave no description of the cut used in this test, the tests described just previously in the bulletin were with two-rib rolled roasts. Meat thermometers were used in their other tests but the internal temperature of these roasts was not reported. We may safely assume, however, that it was the same or nearly so in both roasts.

In 1925 the National Livestock and Meat Board took steps to organize as a national cooperative project "A Study of the Factors which Influence the Quality and Palatability of Meat," with the United States Department of Agriculture and the State Agricultural Experiment Stations cooperating. While the production and the handling phases of the problem were emphasized, an important place in the project outline was given to the effect of methods of cooking on palatability. Two distinct aims have been clearly stated by the cooperators doing the meat cookery research under this comprehensive project:

1. The development of standard methods of cooking urgently needed by many cooperators for testing the effect on palatability of such differences as age, sex, breeding, ration, and management of the animals.
2. The development of the best methods of cooking the meat for serving, methods which are especially adapted for the use of the housewife or for large quantity cookery.

The distinction between these two lines of investigation is aptly expressed in the following quotation from Alexander (1) of the Bureau of Home Economics, who was especially interested in developing standard

methods of cooking. "What we are most concerned with . . . is cooking for the purpose of determining the quality of meat. Cooking in this case is not primarily to produce an attractive dish although that should be done if possible. Its function is to prepare the meat in a way which will enable those who test it to estimate the inherent characteristics of the meat under consideration, and furthermore, what is equally important, to prepare it under conditions which are applicable to the kind and cut of meat in question and under conditions which can be standardized." The first cooking procedure adopted as a standard method was essentially a low oven temperature method but required the use of two ovens and was not suitable for the housewife. The procedure was as follows: the roast was seared for 20 minutes in an oven heated to 275°C (527°F); the cooking was finished slowly in another oven regulated to 125°C 257°F) and held at that temperature until the desired temperature at the center of the roast was reached—57°C for beef (4), and later 75°C for lamb (5); after removal from the oven the roast was allowed to stand until the temperature of the center had reached its maximum.

A special grading chart for cooked meat was devised by the cooperators. In this grading chart the roasts are scored individually for each factor of palatability. Consideration is given to the intensity of seven factors—aroma, texture, flavor of fat, flavor of lean, tenderness, quality of juice, and quantity of juice—and to the desirability of three factors—aroma, flavor of fat, and flavor of lean. The adjectives are weighted from 1 to 7, 7 representing the adjective describing the most intense or the most desirable state of the factor under consideration. Each roast then receives a numerical measure or score for each factor—this score being the average of the opinions of several judges. As a result of systematic records of the various factors of palatability, many contributions to a better understanding of the entire problem of the relationship between methods of cooking and the palatability of meat have been made, but only the published contributions which deal with the effect of oven temperatures on tenderness will be considered here.

As early as 1929, Alexander (2) said, "Questions have recently arisen concerning the effects which may be produced on the palatability of roasted meats by the employment of different oven temperatures. It has been suggested by some of our investigators that the low oven temperature and consequent slow cooking of the standard method may produce effects akin to pot-roasting. This may so modify the toughness of meat, they hold, as to bring to one level of tenderness, when cooked, a series of pieces of meat which originally in the raw state exhibited a wide range of toughness or tenderness." Consequently she cooked 8 left and 8 right legs of lamb from different animals by the standard method and their pair mates by a method which differed from the standard in that the final cooking took place at 150°C (302°F) instead of at 125°C (257°F) as in the standard method. She reported that comparison of the scores for tenderness showed that 75% of the samples roasted by the standard method were judged to be more tender than their mates which were

cooked more quickly when the oven temperature was raised from 125°C to 150°C. The mean of the tenderness scores for the legs from 16 different animals was 4.25 for the standard method and 3.81 for the method using the higher oven temperature. But because the range of the scores was from 3.00 to 5.80 for the standard method and from 3.00 to 5.00 for the higher oven temperature method, she concluded that "while it is too soon to draw many conclusions, these results indicate that the standard method of roasting lamb does not destroy the individuality of samples cooked according to its directions." Later Alexander (3) said that when almost any reasonable oven temperature is used for roasting meat, "there seems to be no significant modification of the palatability of the meat that can be detected by the measures now employed."

Developing and testing methods of cooking suitable for the housewife was emphasized in the first meat cookery work at the University of Missouri. Cline, Cover, and Whipple (6, 11), using constant oven temperatures of 325°F (163°C), 375°F (191°C), and 425°F (218°C) with chuck I roasts cooked to an internal temperature of 57°C, found the respective mean scores for tenderness to be 5.81 (8 roasts), 5.46 (7 roasts), and 5.32 (7 roasts). The scores decreased very slightly with increasing oven temperature.

Cline, Trowbridge, Foster, and Fry (10) have reported that high oven temperatures decrease the tenderness of meat cooked to an internal temperature of 57°C (medium-rare). This conclusion was supported by data from two series of tests. In the first series, prime ribs of beef roasted at constant oven temperatures of 110°C (230°F), 163°C (325°F), 191°C (376°F), 218°C (424°F), and 260°C (500°F) were reported to have respective scores for tenderness as follows: 20.89, 19.56, 18.76, 17.65, and 16.87. The number of roasts by each method was not stated nor was any information given in regard to the score card used, yet it is obvious that the scores for tenderness decrease slightly with increasing temperature. In the second series, 6 pairs of cuts from each of 6 good grade heifers were cooked at constant oven temperatures of 125°C (257°F) and 165°C (329°F) to an internal temperature of 57°C. The mean scores* for tenderness for oven temperatures of 125°C and 165°C respectively were reported as prime rib 5.56, 5.29; chuck I 5.63, 5.75; chuck II 5.33, 4.92; rump 4.17, 3.98; sirloin tip 5.44, 5.21; and heel of round 4.55, 4.30. The difference between the mean scores for any one cut is slight and no statistical analysis was reported to show whether or not the difference was significant in any of the 6 cuts, yet the fact that higher mean scores for tenderness were obtained with the lower oven temperature in 5 out of the 6 cuts may be taken as an indication that a low oven temperature of 125°C produces a more tender medium-rare roast than does a higher oven temperature of 165°C. Furthermore, when the scores for tenderness alone were selected from the scores for

* The grading chart of the national cooperative meat investigations was used: 1=extremely tough, 2=very tough, 3=tough, 4=slightly tough, 5=moderately tender, 6=tender, 7=very tender.

**Table 1. Scores for tenderness of paired roasts rearranged from data by Cline and coworkers.**

| Animal number | Prime rib | | Chuck I | | Chuck II | | Rump | | Sirloin tip end | | Heel of round | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 125°C (257°F) | 165°C (329°F) | 125°C (257 F) | 165°C (329°F) | 125°C (257°F) | 165°C (329°F) | 125°C (257°F) | 165°C (329°F) | 125°C (257°F) | 165°C (329°F) | 125°C (257°F) | 165°C (329°F) |
| 8 | 5.80 | 5.40 | 5.75* | 6.75* | 5.00* | 5.75* | 4.33 | 4.00 | 5.00* | 5.83* | 4.80 | 4.20 |
| 11 | 4.60 | 4.00 | 5.50* | 5.75* | 6.00 | 4.25 | 3.33* | 4.00* | 4.16* | 5.16* | 4.80 | 4.20 |
| 17 | 5.60 | 5.00 | 5.50* | 6.00* | 5.25 | 4.50 | 3.66 | 3.66 | 5.66 | 4.66 | 4.40 | 4.40 |
| 8b | 6.00 | 5.83 | 6.00 | 5.25 | 5.50 | 5.00 | 4.70 | 4.20 | 6.20 | 5.40 | 4.50* | 4.75* |
| 17b | 5.50* | 5.83* | 6.00 | 5.50 | 5.60 | 5.00 | 4.80 | 3.80 | 5.80 | 5.00 | 4.00* | 4.25* |
| 72 | 5.80 | 5.66 | 5.00* | 5.25* | 4.60* | 5.00* | 4.20 | 4.20 | 5.80 | 5.20 | 4.87 | 4.00 |
| Mean..... | 5.55 | 5.29 | 5.63* | 5.75* | 5.33 | 4.92 | 4.17 | 3.98 | 5.44 | 5.21 | 4.56 | 4.30 |

*In favor of high oven temperature.

all of the factors of palatability for each cut from each animal and when these were arranged together in Table 1, a comparison of the roast scores showed that 24 out of a total of 36 or 67% of the roasts cooked at 125°C were more tender than their mates which were cooked more quickly at 165°C.

Cline, Loughead, and Schwartz (8) used prime rib, chuck I, chuck II, rump, sirloin tip, and heel of round roasts from 6 animals including a medium and a high-medium grade steer, a low-good and a good grade heifer, and a low-good and a good grade cow. These roasts were cooked at constant low oven temperatures of 257°F (125°C) and 311°F (155°C). As this was merely an annual report, no palatability data were given and no direct reference was made to a comparison of the two methods for tenderness, but they said, "There was no decided advantage of one method of roasting over the other, as far as palatability was concerned."

Cline and Foster (7) used beef roasts of known history cooked by three methods: constant oven temperatures of 100°C (212°F) and 225°C (437°F), and the standard method: sear at 260°C (500°F) and finish at 125°C (257°F). No data on tenderness were given nor was any information given concerning the number or kind of cuts used. In this annual report they said, "There was a very slight difference in tenderness in favor of the roast cooked at low oven temperatures."

At the Kansas Station (14, 15) less tender cuts free from bone were used. One of each pair was cooked in a steam jacketed kettle and the other in a covered cast aluminum roaster. The cuts included 10 pairs of clod (U. S. Medium), 10 pairs of rump (U. S. Good), and 20 pairs of bottom round (U. S. Good). The approximate weight of each cut was 10 pounds for the rump and 15 pounds for each of the other two. Samples were tested for palatability and shear but no data for palatability or shear were given in the brief progress reports. It was reported, however, that the air temperature of the cooker had a greater effect than the method of cooking. An air temperature of 160°F (71°C) inside either utensil gave a more tender product than did a temperature of from 200°F (93°C) to 210°F (99°C) when the meat was cooked to an internal temperature of 160°F (71°C).

The data of the various workers seems to indicate a relationship between oven temperature and tenderness but the workers do not agree on the interpretation which should be placed on the data.

## EXPERIMENTAL PROCEDURE FOR WELL-DONE ROASTS

Limiting the problem to only one of the factors (oven temperature) which may have an influence on the best method of cooking for the highest degree of palatability and to only one of the factors of palatability (tenderness) provides an excellent opportunity for studying intensively the relationship between these two factors.

The methods used were, in general, those recommended by the cooking committee of the national cooperative project. Several changes were made to simplify the problem still further. The standard removal temperature for beef roasts is 57°C (135°F) and is the one generally used in work previously reported. The beef roasts used in the present experiment were left in the oven until an internal temperature of 80°C or 176°F (well-done) was reached. Well-done roasts were used for two reasons: first, many families prefer well-done roasts and the proof of a definite effect of high and low oven temperatures on the tenderness of well-done meat is of practical importance; and, second, if oven temperature does have an influence on tenderness the longer the roast remains exposed to the oven temperature the more pronounced the effect should be.

Only two oven temperatures were used, 125°C (257°F) and 225°C (437°F) (as low as convenient without special adjustment of the gas and as high as possible without producing a burned roast). These oven temperatures were held constant throughout the cooking period. Either temperature would be easy to use in a home kitchen.

As the differences in tenderness previously reported were small, it seemed particularly important in setting up this experiment to provide the conditions necessary for the application of statistical analysis to the data which would be obtained. With only the two extremes of oven temperature, the effect on tenderness could be compared directly by the use of paired roasts from the right and left sides of the same animal. The pairing of the samples was carried still further by testing tenderness by the "paired-eating method"—a new method (devised in this laboratory) in which comparative judgments are obtained from paired bites from paired slices from paired roasts. These precautions in pairing the samples and in the method of testing give an important advantage when the data are subjected to statistical analysis (18, 22). The details of this method are given in a previous report (12). Only those judgments were used which were made after the judge had had some experience with this method. This limited the number of official judges to 12 persons, 3 of whom were regular in attendance during the entire 3 year period, but 4 to 6 were usually available for judging on any one day.

In order to have a record of how tender or how tough the meat actually was—something to which the paired-eating method gives no clue — a 5-point grading chart (12) was devised similar to the 7-point grading chart of the national cooperative project. The adjectives (very tender, tender, neutral, tough, and very tough) were weighted from 1 to 5, 5 representing "very tender."

The cuts of meat used were (a) a rib roast of beef including the 9th, 10th, and 11th ribs cut with the knife crowding the rear edge of the 8th and 11th ribs; (b) a round-bone chuck roast of beef which included the first three inches and was cut parallel to the lower edge of the square cut chuck; (c) a rump roast of beef which included the first three inches and was cut parallel to the surface adjacent to the round; (d) a half-ham

roast of pork cut just behind and parallel to the exposed projection of the aitch bone; and (e) a leg of lamb roast cut back of the flare of the ilium where the bone is round or slightly wedge-shaped.

The beef was obtained from the Department of Animal Husbandry and from two packing houses in Fort Worth. The carcass grades included U. S. Prime, U. S. Choice, U. S. Good, U. S. Medium, and U. S. Common. The pork was obtained from the Department of Animal Husbandry and was in most cases from animals fed by the Department of Animal Husbandry of the College or by the Division of Swine Husbandry in the Experiment Station. The lamb was obtained from the Department of Animal Husbandry and from one packing house in Fort Worth. With meat obtained from so many sources, storage temperatures, time of cutting retail cut, and ripening periods could not be kept constant for all cuts. They were identical, however, for any pair of cuts. This was the important consideration when tenderness was tested by the paired eating method.

The muscles tested were the longissimus dorsi in the rib, the triceps brachaii in the round-bone chuck, the biceps femoris in the rump, and the semimembranosus and the biceps femoris in the half-ham and the leg of lamb roasts.

## RESULTS FROM WELL-DONE ROASTS

### Tenderness

Data from tests for tenderness of individual pairs of roasts are found in the supplementary tables (Tables A, B, and C). The summary of these data given in Table 2 shows that:

1. The majority of the paired judgments for the rib, chuck, rump, and half-ham roasts is in favor of the constant low oven temperature method—125°C (257°F). (See column headed "Tenderness ratio". The numbers in this column may be changed into percentages by multiplying by 100.)
2. These majorities are not due to chance, since the deviations are more than 3 times their standard deviations. (See column headed $\frac{d}{\sigma}$.)
3. The majority is larger in the case of the round-bone chuck (96%) and the rump (93%) roasts than in the case of the standing rib (69%) and the half-ham (75%) roasts.
4. The difference in tenderness between the two methods of cooking is more "decided" in the case of the round-bone chuck roasts than of the standing rib roasts or of the half-ham roasts of pork. (See columns headed "slight" and "decided" under 125°C.)
5. The difference in tenderness between the two methods of cooking becomes more "decided" as the grade of the carcass decreases and becomes particularly important for the chuck roasts from the lowest grade carcasses.
6. The leg of lamb roasts are conspicuous in that the very slight majority (51%) of the paired judgments in favor of the low oven

temperature method is not significant, as the deviation is only 0.2 times its standard deviation.

7. The roasts cooked at the low oven temperatures were only rarely given the highest possible score—5—for tenderness and those cooked at the high oven temperature only rarely given the lowest score—1. (See columns headed "weighted adjectives".)

### Time and Gas

In addition to the results for tenderness, comparisons of the time and gas required for cooking the roasts well-done at the two oven temperatures are worthy of practical consideration. These comparisons for the individual roasts cooked after individual gas meters were installed are given in the supplementary tables (Table D). The summary given in Table 3 shows that:

1. The low oven temperature method required a longer total time as well as a longer time per pound than did the high oven temperature method. This is in agreement with the findings of other workers (6, 7, 9, 10, 16, and 20).
2. With the rib, half-ham, and leg of lamb roasts, less gas was required for the low oven temperature method even though the cooking period was longer. As a result, the cost of cooking for the low oven temperature method was lower than for the high oven temperature method; this was, respectively, for the rib \$0.019, \$0.024; for the half-ham \$0.021, \$0.027; for the leg of lamb \$0.01, \$0.013. This agrees with the results reported by other workers (9).
3. With the well-done chuck roasts the time of cooking at the low oven temperature was so exaggerated in length (average about 8¼ hours) that the gas consumption was greater than when the high oven temperature was used. This increased the average cost of cooking at the low oven temperature to \$0.027, while the average cost of cooking at the high oven temperature was only \$0.018.

### Possible Connection Between Slower Cooking and Tenderness-Response

As it was shown in a previous publication (12) from this station that the tenderness-ratio of the round-bone chuck roasts is significantly greater than that of the rib roasts (chuck 0.9628 — rib 0.6908 = 0.2720 $\pm$ 0.0325), it became of interest to determine any possible causes of this difference.

Factors causing an increase in tenderness are known to include an increase in the length of the ripening period and are thought to include an increase in the amount of marbling and a decrease in the amount of connective tissue present. In these experiments there is a difference in

**Table 2. Summary of tests for**

| U. S. carcass grade | Number of pairs | Ripening period in days | Number of | | | |
|---|---|---|---|---|---|---|
| | | | 125°C | | | |
| | | | More tender | Difference | | No difference |
| | | | | Slight | Decided | |
| **Beef—9th, 10th, and 11th ribs** | | | | | | |
| Prime | 1 | 10.0 | 2 | 2 | 0 | 3 |
| Choice | 11 | 10.4 | 80 | —† | — | 11 |
| Good | 2 | 10.0 | 12 | 10 | 1 | 3 |
| Medium | 5 | 10.6 | 27 | 19 | 8 | 5 |
| Common | 7 | 10.4 | 47 | 27 | 20 | 4 |
| Total | 26 | 10.4‡ | 168 | 58 | 29 | 26 |
| **Beef—Round-bone chuck** | | | | | | |
| Prime | 1 | 10.0 | 8 | 4 | 4 | 0 |
| Choice | 4 | 8.2 | 36 | —† | — | 0 |
| Good | 2 | 9.0 | 16 | 12 | 4 | 0 |
| Medium | 4 | 9.5 | 33 | 16 | 17 | 3 |
| Common | 6 | 9.0 | 48 | 12 | 34 | 0 |
| Total | 17 | 9.0‡ | 141 | 44 | 59 | 3 |
| **Beef—rump** | | | | | | |
| Choice | 9 | 9.8 | 75 | —† | — | 4 |
| **Pork—half-ham** | | | | | | |
| | 16 | 6.9 | 104 | 67 | 36 | 25 |
| **Lamb—leg** | | | | | | |
| Choice | 2 | 7.0 | 4 | 3 | 1 | 4 |
| Good | 6 | 7.0 | 32 | 23 | 9 | 12 |
| Medium | 6 | 6.3 | 21 | 11 | 10 | 12 |
| Total | 14 | 6.7‡ | 57 | 37 | 20 | 28 |

†Judgments of U. S. Choice carcasses were obtained before records were kept of how decided were the differences in tenderness.
‡Mean of all roasts.

the ripening periods of the rib and chuck roasts but this difference (an average of less than two days as shown in Table 3) appears to be too small to account for the rather wide difference in tenderness-response.

The rib cuts are supposed to show more marbling than do the round-bone chuck cuts, and the higher grade carcasses to show more than the lower grade carcasses, but the effect of high and low oven temperatures

**tenderness of well-done roasts.**

| Tenderness judgments by the paired-eating method | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 225°C | | | Total N | For statistical treatment | | | | | | Weighted adjectives average per roast | |
| More tender | Difference | | | More tender* | | Tenderness ratio $n_s/N$ | Deviation $d = n_s - \frac{N}{2}$ | Standard deviation $\sigma = \sqrt{Npq}$ | $\frac{d}{\sigma}$ | 125°C | 225°C |
| | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | | | | | |
| **Beef—9th, 10th and 11th ribs** | | | | | | | | | | | |
| 3 | 3 | 0 | 8 | 3.5 | 4.5 | | | | | 3.8 | 3.9 |
| 31 | — | — | 122 | 85.5 | 36.5 | | | | | 3.4 | 3.1 |
| 5 | 2 | 3 | 20 | 13.5 | 6.5 | | | | | 3.9 | 3.9 |
| 12 | 11 | 1 | 44 | 29.5 | 14.5 | | | | | 3.5 | 3.0 |
| 17 | 12 | 2 | 68 | 49.0 | 19.0 | | | | | 2.9 | 2.5 |
| 68 | 28 | 6 | 262 | 181.0 | 81.0 | 0.6908 | 50.0 | 8.09 | 6.2 | 3.3‡ | 3.0‡ |
| **Beef—round-bone chuck** | | | | | | | | | | | |
| 0 | 0 | 0 | 8 | 8.0 | 0.0 | | | | | 5.0 | 4.4 |
| 4 | — | — | 40 | 36.0 | 4.0 | | | | | 3.9 | 3.9 |
| 0 | 0 | 0 | 16 | 16.0 | 0.0 | | | | | 4.0 | 3.6 |
| 0 | 0 | 0 | 36 | 34.5 | 1.5 | | | | | 4.2 | 3.4 |
| 0 | 0 | 0 | 48 | 48.0 | 0.0 | | | | | 4.4 | 3.0 |
| 4 | 0 | 0 | 148 | 142.5 | 5.5 | 0.9628 | 68.5 | 6.08 | 11.3 | 4.2‡ | 3.5‡ |
| **Beef—rump** | | | | | | | | | | | |
| 4 | — | — | 83 | 77.0 | 6.0 | 0.9277 | 35.5 | 4.60 | 7.7 | 3.7 | 2.9 |
| **Pork—half-ham** | | | | | | | | | | | |
| 27 | 19 | 8 | 156 | 116.5 | 39.5 | 0.7468 | 38.5 | 6.25 | 6.2 | 3.6 | 3.1 |
| **Lamb—leg** | | | | | | | | | | | |
| 4 | 4 | 0 | 12 | 6.0 | 6.0 | | | | | 4.2 | 4.0 |
| 24 | 15 | 9 | 68 | 38.0 | 30.0 | | | | | 2.5 | 2.5 |
| 27 | 16 | 11 | 60 | 27.0 | 33.0 | | | | | 2.7 | 2.7 |
| 55 | 35 | 20 | 140 | 71.0 | 69.0 | 0.5071 | 1.0 | 5.9 | 0.2 | 2.8‡ | 2.8‡ |

*To include judgments checked "no difference," 0.5 is added to each of the two groups for each such judgment.
‡Mean of all roasts.

on tenderness is in the reverse order. It is doubtful whether marbling as such increases the effect of oven temperatures on tenderness.

The relative amounts of connective tissue contained in the small pieces of the two muscles tested is not known. The bites, however, were paired in such a way that visible heavy connective tissue was avoided wherever

**Table 3. Summary of time and gas required to cook roasts**

| U. S. carcass grade | Number of pairs | Ripening period in days | 125°C | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Weight of roast | | Internal temperature | | Time in oven minutes | |
| | | | Grams | Pounds | Initial °C | Removal °C | Total | Per Pound |
| **9th, 10th, and 11th ribs of beef** | | | | | | | | |
| Prime | 1 | 10.0 | 5335 | 11.8 | 6.0 | 80 | 435 | 36.9 |
| Choice | 11 | 10.4 | 3641 | 8.0 | 7.0 | 80 | 343 | 42.8 |
| Good | 2 | 10.0 | 4756 | 10.5 | 4.5 | 80 | 399 | 38.0 |
| Medium | 4 | 10.5 | 4156 | 9.2 | 4.3 | 80 | 370 | 41.4 |
| Common | 7 | 10.4 | 3544 | 7.8 | 3.4 | 80 | 337 | 43.6 |
| Mean of all roasts... | 25‡ | 10.4 | 3853 | 8.5 | 5.3 | 80 | 354 | 42.2 |
| **Round-bone chuck of beef** | | | | | | | | |
| Prime | 1 | 10.0 | 3977 | 8.8 | 8.0 | 80 | 455 | 51.7 |
| Choice | 4 | 8.3 | 2838 | 6.3 | 8.5 | 80 | 406 | 64.8 |
| Good | 2 | 9.0 | 3396 | 7.5 | 6.5 | 80 | 526 | 70.5 |
| Medium | 4 | 9.5 | 2962 | 6.5 | 6.8 | 80 | 534 | 82.5 |
| Common | 6 | 9.0 | 2871 | 6.3 | 5.3 | 80 | 531 | 83.9 |
| Mean of all roasts... | 17‡ | 9.0 | 3011 | 6.6 | 6.7 | 80 | 497 | 75.6 |
| **Rump of beef** | | | | | | | | |
| Choice | 9 | 9.8 | 3417 | 7.5 | 7.4 | 80 | 434 | 58.1 |
| **Half-ham of pork** | | | | | | | | |
| | 16 | 6.9 | 4676 | 10.3 | 5.5 | 84 | 392 | 38.4 |
| **Leg of lamb** | | | | | | | | |
| Choice | 2 | 7.0 | 2488 | 5.5 | 4.5 | 76 | 252 | 45.9 |
| Good | 6 | 7.0 | 1989 | 4.4 | 9.3 | 76 | 181 | 41.3 |
| Medium | 6 | 6.3 | 2002 | 4.4 | 10.7 | 76 | 192 | 44.0 |
| Mean of all roasts... | 14‡ | 6.7 | 2066 | 4.6 | 9.2 | 76 | 195 | 43.1 |

‡Total.

possible. It is worthy of note that this was at least as difficult in the longissimus dorsi of the rib as in the triceps brachii of the chuck.

Another factor which has been considered important in making meat tender is slowness of cooking, but this factor has been so closely connected with the temperature of cooking that no distinction between the two has been made in previous work. A marked difference in cooking time may be noted in Table 3 between the rib and chuck roasts when the same oven temperature (125°C) was used—the standing rib cooking to 80°C in an average of 42.2 minutes per pound while the round-bone chuck roasts required an average of 75.6 minutes per pound (Table 3). This

**well-done at constant oven temperatures of 125°C and 225°C.**

| | | 225°C | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Gas* | | Weight of roast | | Internal temperature | | Time in oven minutes | | Gas* | |
| Cubic feet | Cost cents | Grams | Pounds | Initial °C | Removal °C | Total | Per pound | Cubic feet | Cost cents |
| 9th, 10th, and 11th ribs of beef | | | | | | | | | |
| 33.5 | 2.3 | 5592 | 12.3 | 2.0 | 80 | 217 | 17.6 | 45.2 | 3.1 |
| —— | —— | 3668 | 8.1 | 7.8 | 80 | 158 | 19.5 | —— | —— |
| 31.1 | 2.1 | 4709 | 10.4 | 5.5 | 80 | 183 | 17.6 | 38.6 | 2.6 |
| 27.6 | 1.9 | 3987 | 8.8 | 3.8 | 80 | 162 | 18.8 | 32.0 | 2.2 |
| 26.3 | 1.8 | 3585 | 7.9 | 4.6 | 80 | 149 | 18.8 | 33.0 | 2.2 |
| 28.0 | 1.9 | 3856 | 8.5 | 5.8 | 80 | 160 | 19.0 | 34.7 | 2.4 |
| Round-bone chuck of beef | | | | | | | | | |
| 37.7 | 2.5 | 4548 | 10.0 | 8.0 | 80 | 120 | 12.0 | 27.8 | 1.9 |
| —— | —— | 3430 | 7.5 | 8.0 | 80 | 126 | 16.9 | —— | —— |
| 41.2 | 2.8 | 3422 | 7.6 | 8.0 | 80 | 124 | 16.5 | 27.1 | 1.9 |
| 38.4 | 2.6 | 2999 | 6.6 | 6.5 | 80 | 132 | 20.2 | 26.6 | 1.8 |
| 40.4 | 2.7 | 2882 | 6.4 | 6.0 | 80 | 125 | 19.8 | 26.4 | 1.8 |
| 39.7 | 2.7 | 3200 | 7.0 | 6.9 | 80 | 127 | 18.3 | 26.7 | 1.8 |
| Rump of beef | | | | | | | | | |
| —— | —— | 3692 | 8.1 | 7.9 | 80 | 125 | 15.4 | —— | —— |
| Half-ham of pork | | | | | | | | | |
| 30.8 | 2.1 | 4867 | 10.7 | 5.8 | 84 | 197 | 18.6 | 39.3 | 2.7 |
| Leg of lamb | | | | | | | | | |
| 19.3 | 1.3 | 2562 | 5.7 | 4.0 | 77 | 124 | 21.9 | 24.9 | 1.7 |
| 12.2 | 0.8 | 1993 | 4.4 | 9.7 | 76 | 83 | 18.9 | 17.1 | 1.2 |
| 13.6 | 0.9 | 2015 | 4.2 | 9.5 | 76 | 86 | 19.5 | 11.8 | 0.8 |
| 15.3 | 1.0 | 2084 | 4.5 | 8.8 | 76.1 | 90 | 19.6 | 19.1 | 1.3 |

*Preheating of ovens not included. In 30 tests the preheating of the ovens to 125°C averaged 5.4 cubic feet, costing $0.004. In 20 tests the preheating to 225°C averaged 11.8 cubic feet, costing $0.008. Cost of gas $0.675 per 1000 cubic feet.

was brought to the attention of the writer in an impressive manner, for it became necessary to start the working day several hours earlier in order to secure well-done chuck roasts in time for judging.

Time-temperature curves for the rib and chuck cuts were plotted and the interesting observation was made that the two curves for the low oven temperature method differed considerably in shape. The curves for the standing rib roasts showed a gradual decrease in slope as the cooking continued—this was also noted by Sprague and Grindley (20)—but the

curves for the round-bone chuck roasts were flattened rather abruptly at about 65°C. The flattening was so decided between 65°C and 75°C that usually at least half of the total time in the oven was required for raising the internal temperature from the medium-rare (63°C) to the well-done stage (80°C) of cooking. There was no marked difference in the shape of the curves for the rib and chuck roasts cooked at the high oven temper-

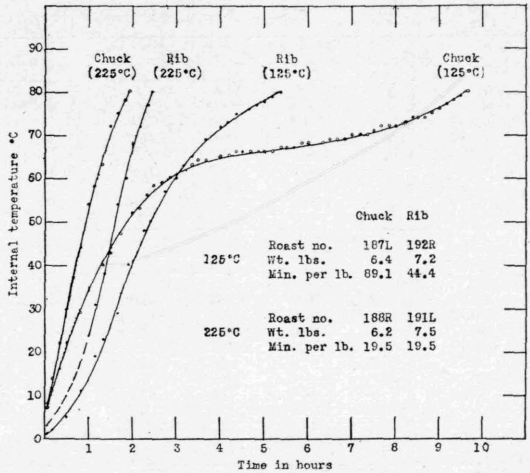


Figure 1. Time-temperature curves of round-bone chuck and standing rib roasts from the same carcass cooked at oven temperatures of 125°C and 225°C to an internal temperature of 80°C.

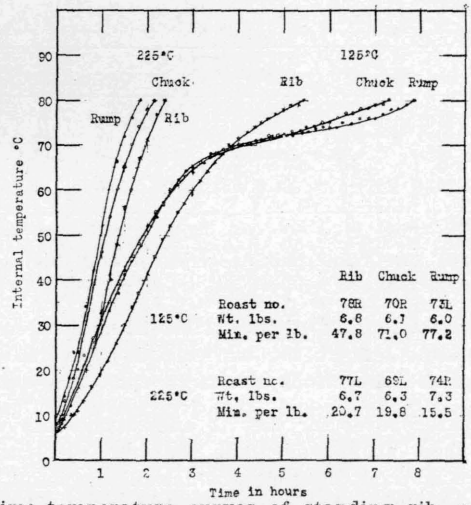


Figure 2. Time-temperature curves of standing rib, round-bone chuck, and rump roasts from the same carcass cooked at oven temperatures of 125°C and 225°C to an internal temperature of 80°C.

ature. One set of time-temperature curves for round-bone chuck roasts and standing rib roasts from the same carcass is given in Figure 1.

The time-temperature curves for the rump roasts cooked by the low oven temperature method, like those for the round-bone chuck roasts,

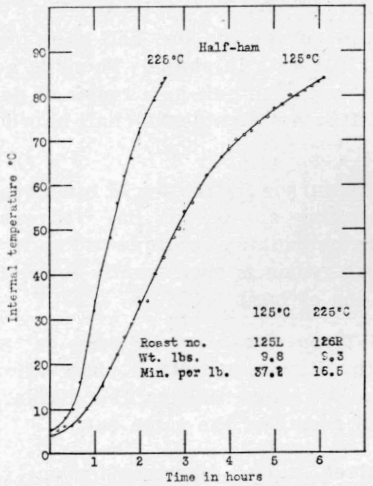


Figure 3. Time-temperature curves of half-ham roasts of pork from the same carcass cooked at oven temperatures of 125°C and 225°C to an internal temperature of 84°C.

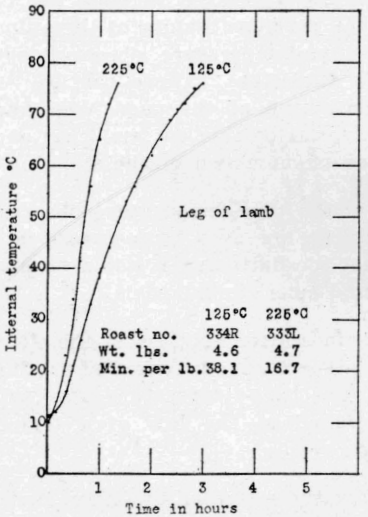


Figure 4. Time-temperature curves of leg of lamb roasts from the same carcass cooked at oven temperatures of 125°C and 225°C to an internal temperature of 76°C.

show a flattening between the rare and well-done stages of cooking. One set of curves for a rib, a chuck, and a rump roast from the same carcass is given in Figure 2. The tenderness ratio of the rump roasts is significantly greater than that of the rib roasts (rump 0.9277 — rib 0.6908 = 0.2369 $\pm$ 0.0403) but not significantly lower than that of the chuck roasts (chuck 0.9628 — rump 0.9277 = 0.0351 $\pm$ 0.0323).

The time-temperature curves for the half-ham roasts (Figure 3) resemble those for the rib roasts in shape. There is a slight difference in tenderness response between the half-ham roasts of pork and the standing rib roasts of beef, but it is not significant (half-ham 0.7468 — rib 0.6908 = 0.0560 $\pm$ 0.0451).

The time-temperature curves for the leg of lamb roasts are even steeper than are the corresponding curves for the rib roasts, showing only a slight decrease in slope as cooking continues (Figure 4). The tenderness ratio of the leg of lamb roasts is significantly lower than that of the rib roasts (rib 0.6908 — leg of lamb 0.5071 = 0.1837 $\pm$ 0.0429).

As the curves for different roasts of the same cut were never identical, scatter diagrams of the time-temperature observations have been given in Figure 5 to bring out more clearly the similarity or dissimilarity between the individual roasts of the same cut.

In Figure 5a are given scatter diagrams for one chuck roast and one rib roast taken from each of 16 different animals and cooked at the low oven temperature. As these data were selected so that a rib cut was always matched with a chuck cut from the same animal, there is no reason to suppose that the difference between the two cuts can be due to variation either in the previous history of the animal or in the storage of the carcass. The time-temperature observations for the 16 chuck roasts are remarkably consistent. There can be little doubt that the abrupt and decided flattening of the curve observed in Figure 1 is a cooking phenomenon typical of this cut and that such abrupt flattening is not a typical cooking phenomenon of the standing rib roasts.

A scatter diagram of the time-temperature observations for all of the rump roasts cooked at the low oven temperature is given in Figure 5b. It may be observed that the flattening is not always as prolonged as it is in the case of the round-bone chuck roasts.

In Figure 5c is given a scatter diagram of the time-temperature observations for all of the half-ham roasts cooked at the low oven temperature. A scatter diagram of the time-temperature observations for all of the leg of lamb roasts cooked at the low oven temperature is given in Figure 5d.

It may be noted from these scatter diagrams that a decrease in slope as the cooking continues appears to be rather closely related to an increase in the tenderness ratios of the cuts. Abrupt flattening of the time-

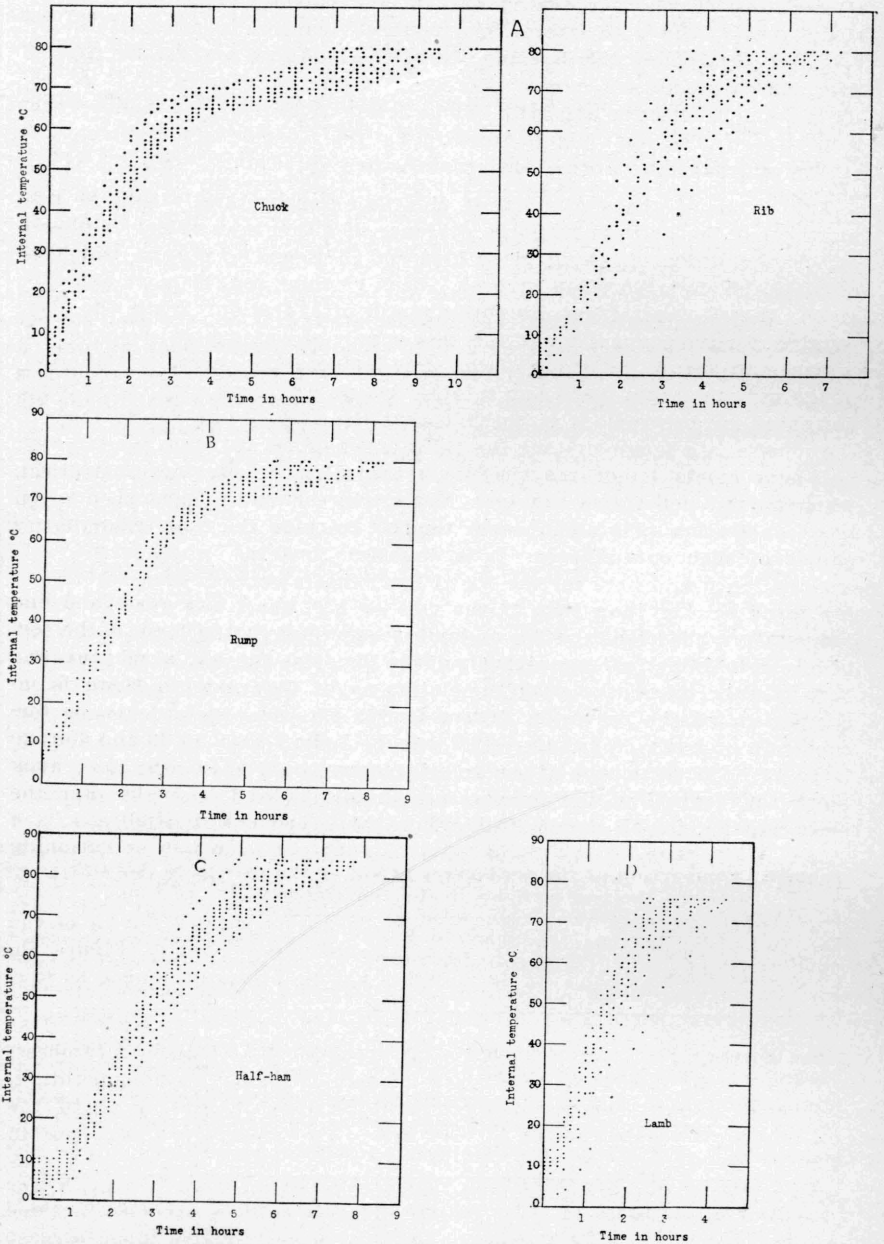


Figure 5. Scatter diagrams of time-temperature observations for well-done roasts cooked at an oven temperature of 125°C.

a. One chuck and one rib roast of beef from each of 16 different animals.
b. Nine rump roasts of beef.
c. Sixteen half-ham roasts of pork.
d. Fourteen leg of lamb roasts.

temperature curves is observed only in the round-bone chuck and the rump roasts, the cuts having the highest tenderness ratios (0.9628, 0.9277). A middle group is composed of the half-ham and the rib roasts, with time-temperature curves decreasing rather gradually in slope as the cooking continues and with tenderness ratios of 0.7468 and 0.6908 respectively. The leg of lamb roasts show the steepest time-temperature curves and have the lowest tenderness ratios (0.5071).

The cause of the flattening of the time-temperature curves is not known, but the flattening affords evidence of either a chemical or physical change which is taking place between 65°C and 75°C and which is accompanied by absorption of heat. Meat proteins coagulate at approximately these temperatures, liberating water of hydration. While the heat required for the evaporation of this new supply of water might be expected to cause an abrupt flattening of the time-temperature curves, coagulation of the proteins takes place also in other roasts where no such comparable flattening is observed. It is possible that the area of the cut surface of the muscle is a factor or that the thick layer of fat covering the rib and half-ham roasts either reduces the evaporation or provides fat which when melted penetrates the lean below, increasing the normal rate of heat penetration (21) and thereby tending to make the time-temperature curves of such cuts steeper. It is doubtful, however, whether the last explanation would hold for the leg of lamb roasts because their fat covering is no thicker than that of the ribs or half-hams and yet the time-temperature curves of the leg of lamb roasts showed the least flattening of any cut. Some indication that volatile losses at the low oven temperature may be associated with the flattening of the curve is given by a comparison of the curves in Figure 5 with the mean volatile losses for each cut: chuck 28.8, rump 21.6, rib 15.5, half-ham 15.2, and leg of lamb 11.1. These means of the volatile losses could have been used with more confidence had the temperature, humidity, and length of storage been constant for all roasts (Table E in the supplementary tables).

**Table 4. Comparison of the tenderness ratios of the cuts with the difference between the two methods in the time required for cooking.**

| Cut of meat | Tenderness ratio | | Difference in time of cooking | |
|---|---|---|---|---|
| | | | Total | Per pound |
| | | d/σ* | Minutes | Minutes |
| Round-bone chuck | 0.9628 | 11.3 | 370 | 57.3 |
| Rump | 0.9277 | 7.7 | 309 | 42.7 |
| Half-ham | 0.7468 | 6.2 | 195 | 19.8 |
| Rib | 0.6908 | 6.2 | 194 | 23.2 |
| Leg of lamb | 0.5071 | 0.2 | 105 | 23.5 |

*The deviation divided by its standard deviation. If this value is above 3, the results are significant.

From the shape of the cooking curves at the low oven temperature, it was expected that the difference in the time of cooking between the two

methods might follow the same grouping as do the tenderness ratios. Table 4 shows that this is true for the total time in the oven but is not true when the cooking time is expressed as minutes per pound.

The findings with the well-done roasts made the possibility of a connection between slower cooking and tenderness-response appear worthy of further investigation, and so a second series of experiments was undertaken in which rib and chuck roasts were cooked to an internal temperature of 63°C—medium-rare according to Tables 1 and 4 by Sprague and Grindley (20). This temperature is near the point at which the flattening of the time-temperature curves begins. If longer cooking between 65°C and 75°C was responsible for the difference in tenderness-response of the two cuts, when they were cooked well-done, only slight if any difference in tenderness-response would be expected if they were cooked medium-rare. The curves for the high and low oven temperature methods for each cut are also rather close at this point, and if a large difference in cooking time is responsible for high tenderness ratios, it seemed doubtful whether the tenderness ratios obtained from medium-rare roasts would be high enough to show a significant difference between the two methods of cooking.

## EXPERIMENTAL PROCEDURE FOR MEDIUM-RARE ROASTS

The procedures described for well-done roasts were followed for the medium-rare roasts except in regard to the internal temperature at which they were removed from the oven. Sprague and Grindley (20), and Latzke (16), as well as other workers, have found that roasts of beef, if removed from the oven before the well-done stage of cooking is reached, will continue to rise in temperature for some time and may reach a maximum internal temperature more than 10°C above that at which they were removed from the oven. This rise in temperature has been reported (20) to depend upon the temperature of the oven, the internal temperature of the roast when removed, and the size and shape of the roast. No data were available to show at what internal temperatures standing rib and round-bone chuck roasts should be removed from the oven to reach a maximum of 63°C (medium-rare) when constant oven temperatures of 125°C and 225°C were used. After several trials with the standing rib roasts, 55°C was found to be a satisfactory internal temperature for removal from the low temperature oven and 45°C from the high temperature oven. A maximum of 63°C could not be obtained in every instance, but those roasts reaching maximum internal temperatures of 60°C to 65°C were used for the palatability tests, as roasts within this range were considered medium-rare. Table F in the supplementary tables gives these data for the preliminary roasts as well as for those roasts used in tests for palatability.

Removal from the oven to permit a maximum internal temperature of approximately 63°C, while necessary to provide an equal degree of done-

ness in the paired rib roasts, is nevertheless open to the criticism that the roasts in each pair were exposed unequally to the heat influence of the oven as judged by the internal temperatures at the time of removal. No practical way of getting around this difficulty was found, as the cooking time of each roast could not be predicted with sufficient accuracy to permit cutting and judging immediately on removal at 63°C and before a rise in internal temperature occurred. This criticism, however, is apparently not so serious as might be supposed. In Figure 6 are given representative time-temperature curves for the medium-rare rib roasts.

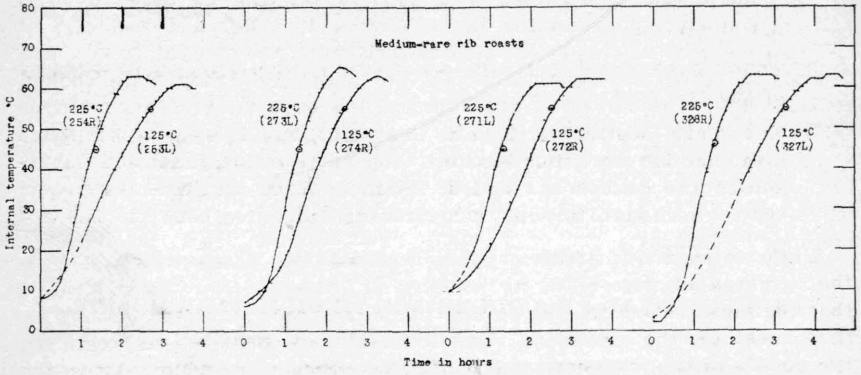


Figure 6. Time-temperature curves of medium-rare rib roasts cooked at constant oven temperatures of 125°C and 225°C. The circles denote removal from the oven.

It is obvious that no marked break in the slope of the curves occurs after removal from the oven until about the time the maximum internal temperature is reached. It may be observed also that the portion of the curve due to the rise in internal temperature after removal from the oven follows rather closely the shape of the curves at the same internal temperatures for the rib roasts in Figures 1 and 2 where the roasts were left in the oven during this part of the cooking. As the cooking at this stage seems to proceed similarly whether the roast is in or out of the oven, there is little necessity for the time-of-cooking factor, with which we are particularly concerned in this experiment, to be regarded as a source of error. Especially is this true in view of the fact that we are concerned only with the portion of the roast which closely surrounds the bulb of the thermometer.

The round-bone chuck roasts were not such a problem, for their internal temperatures only rarely reached a maximum above the removal temperature of 63°C (Table E in the supplementary tables).

The time-temperature relationships between the rib and chuck roasts cooked at the high and low oven temperatures may, therefore, be accepted as satisfying the conditions desired in this series of experiments.

## RESULTS FROM MEDIUM-RARE ROASTS

### Tenderness

Data from tests for tenderness of individual pairs of roasts are found in the supplementary tables (Table G). The summary of these data in Table 5 shows that:

1. While a slight majority of the paired judgments for the rib and chuck roasts cooked to the medium-rare stage of doneness is in favor of the constant low oven temperature method (125°C), it is not significant for either cut.
2. There is no significant difference between the tenderness-response of the two cuts.
3. The roasts cooked at the low oven temperature were only rarely given the highest possible score—5—for tenderness and only rarely were those cooked at the high oven temperature given the lowest score—1. (See columns headed "weighted adjectives".)

While no statistical treatment was used with the scores obtained from the weighted adjectives, it may be noted in Table 2 as well as in Table 6 that the mean scores for the round-bone chuck roasts are slightly higher than those for the rib roasts. The impression is quite general that the eye muscle of the rib easily ranks first in tenderness in roasts, but in the present work the triceps brachii of the round-bone chuck was found to be at least as tender. Cline, Trowbridge, Foster, and Fry (10) reported data in which the mean scores for the infraspinatus muscle from chuck I roasts were slightly higher than the mean scores for the eye muscle of rib roasts in 6 carcasses (Table 1). Perhaps the rib roasts have a reputation for preëminence in tenderness to which they are not entitled.

The idea that rib roasts may be less tender than some other roasts seemed so preposterous that tests were made to determine whether or not some parts of the eye muscle might be more tender than others. The eye muscle is divided into two parts in the region of the tenth rib by an indentation of connective tissue and fat (if the carcass grade is high enough). The part next to the spines is rather small in area compared with that farthest away from the spines. Since two strips from each slice were needed to furnish enough paired bites for the judges, both of them had been cut from that part farthest away from the spines so that they might be as close together as possible. The two slices from each roast, therefore, had furnished one sample each for each judge. A third sample was obtained by cutting only one strip from each of the two slices from that part nearest the spines. All of the samples were used for judgments by the paired-eating method but only the first two were used for the scores as given in Tables 2 and 5. Comparisons of the scores of the two parts of the eye muscle (Table 6) show that the part nearest the spines is somewhat more tender than the part farthest away and that it is also somewhat more uniformly tender—being scored below 3.5 (tender) only

**Table 5. Summary of tests for tenderness**

| U. S. carcass grade | Number of pairs | Ripening period in days | Number of | | | |
|---|---|---|---|---|---|---|
| | | | 125°C | | | |
| | | | More tender | Difference | | No difference |
| | | | | Slight | Decided | |
| 9th, 10th, and 11th ribs | | | | | | |
| Good | 6 | 8.3 | 35 | 25 | 10 | 9 |
| Medium | 8 | 7.9 | 34 | 18 | 16 | 16 |
| Common | 8 | 8.4 | 52 | 26 | 25 | 17 |
| Total | 22 | 8.2‡ | 121 | 69 | 51 | 42 |
| Round-bone chuck | | | | | | |
| Good | 7 | 8.0 | 25 | 21 | 3 | 17 |
| Medium | 6 | 6.7 | 17 | 10 | 7 | 11 |
| Common | 8 | 6.8 | 30 | 22 | 7 | 19 |
| Total | 21 | 7.1‡ | 72 | 53 | 17 | 47 |

‡Mean of all roasts.

three times at 225°C and none at 125°C, while the part farthest away from the spines was scored below 3.5 (tender) 9 times at 225°C and 5 times at 125°C.

**Table 6. Comparison of the scores of the two parts of the eye muscle of rib roasts (medium-rare).**

| U. S. carcass grade | 125°C | | | 225°C | | |
|---|---|---|---|---|---|---|
| | Roast number | Part farthest away from the spines | Part closest to the spines | Roast number | Part farthest away from the spines | Part closest to the spines |
| Choice | 343L | 3.8 | 4.0 | 344R | 4.0 | 3.6 |
| | 346R | 4.3 | 4.2 | 345L | 3.3 | 4.4 |
| | 379L | 4.4 | 4.4 | 380R | 5.0 | 4.6 |
| Medium | 246R | 2.1 | 3.6 | 245L | 2.5 | 3.2 |
| | 271L | 3.0 | 4.7 | 272R | 3.2 | 4.3 |
| | 274R | 3.5 | 4.3 | 273L | 1.8 | 2.7 |
| | 327L | 3.6 | 3.6 | 328R | 3.3 | 3.2 |
| | 330R | 4.0 | 4.8 | 329L | 3.6 | 4.4 |
| Common | 253L | 3.3 | 4.0 | 254R | 2.9 | 3.3 |
| | 256R | 3.1 | 4.3 | 255L | 1.6 | 2.3 |
| | 275L | 2.5 | 4.8 | 276R | 3.3 | 4.8 |
| | 278R | 5.0 | 5.0 | 277L | 4.6 | 5.0 |
| | 311L | 3.6 | 3.7 | 312R | 3.2 | 3.7 |
| | 314R | 4.2 | 4.8 | 313L | 4.1 | 4.2 |
| | Mean | 3.6 | 4.3 | | 3.3 | 3.8 |

**of medium-rare roasts of beef.**

Tenderness judgments by the paired-eating method

| 225°C | | | Total N | For statistical treatment | | | | | | Weighted adjectives average per roast | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| More tender | Difference | | | More tender* | | Tenderness ratio $n_s/N$ | Deviation $d = n_s - \frac{N}{2}$ | Standard deviation $\sigma = \sqrt{Npq}$ | $\frac{d}{\sigma}$ | 125°C | 225°C |
| | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | | | | | |
| 9th, 10th, and 11th ribs | | | | | | | | | | | |
| 31 | 20 | 11 | 75 | 39.5 | 35.5 | | | | | 4.3 | 4.2 |
| 38 | 22 | 16 | 88 | 42.0 | 46.0 | | | | | 3.0 | 3.1 |
| 31 | 20 | 11 | 100 | 60.5 | 39.5 | | | | | 3.7 | 3.3 |
| 100 | 62 | 38 | 263 | 142.0 | 121.0 | 0.5399 | 10.5 | 8.1 | 1.3 | 3.6‡ | 3.4‡ |
| Round-bone chuck | | | | | | | | | | | |
| 20 | 19 | 1 | 62 | 33.5 | 28.5 | | | | | 4.7 | 4.6 |
| 20 | 11 | 9 | 48 | 22.5 | 25.5 | | | | | 3.8 | 3.9 |
| 19 | 12 | 7 | 68 | 39.5 | 28.5 | | | | | 3.7 | 3.7 |
| 59 | 42 | 17 | 178 | 95.5 | 82.5 | 0.5365 | 6.5 | 6.7 | 1.0 | 4.1‡ | 4.1‡ |

*To include judgments checked "no difference," 0.5 is added to each of the two groups for each such judgment.
‡Mean of all roasts.

The more uniform tenderness of this small section may perhaps have led to the popular impression of the preëminence of the eye muscle of the rib in tenderness, but it is more likely due to lack of familiarity with other tender muscles in the animal. A complete and satisfactory classification of muscles on the basis of tenderness has not yet been made. In view of the startling indications obtained by Mitchell and Hamilton (19) that certain muscles from exercised cattle were more tender than corresponding muscles from non-exercised cattle, the old explanation that the toughness of tough muscles is due to their more frequent use seems to need investigation.

## Time and Gas

Comparisons of the time and gas required for cooking the individual medium-rare roasts at the two oven temperatures are given in the supplementary tables (Table F). The summary given in Table 7 shows that:

1. For the rib roasts the time in the oven (total time as well as time per pound) was longer for the low oven temperature method than for the high oven temperature method. This was due in part to slower cooking (Figure 6) and in part to the removal temperature of these roasts which was 10°C higher than it was for the roasts cooked at the high oven temperature.

**Table 7. Summary of removal temperatures, time, and gas required to obtain**

| Cut of meat | U. S. carcass grade | Number of pairs | Ripening period days | Weight of roast | |
|---|---|---|---|---|---|
| | | | | Grams | Pounds |
| | | 125°C | | | |
| 9th, 10th, and 11th ribs. | Good | 6 | 8.5 | 3866 | 8.5 |
| | Medium | 8 | 7.9 | 3165 | 7.0 |
| | Common | 8 | 8.4 | 3283 | 7.2 |
| | Mean of all roasts | 22‡ | 8.2 | 3399 | 7.5 |
| Round-bone chuck | Good | 7 | 8.0 | 3354 | 7.4 |
| | Medium | 6 | 6.7 | 2537 | 5.6 |
| | Common | 8 | 6.8 | 2638 | 5.8 |
| | Mean of all roasts | 21‡ | 7.1 | 2848 | 6.3 |
| | | 225°C | | | |
| 9th, 10th, and 11th ribs. | Good | 6 | 8.5 | 3929 | 8.7 |
| | Medium | 8 | 7.9 | 3042 | 6.7 |
| | Common | 8 | 8.4 | 3291 | 7.3 |
| | Mean of all roasts | 22‡ | 8.2 | 3375 | 7.4 |
| Round-bone chuck | Good | 7 | 8.0 | 3487 | 7.7 |
| | Medium | 6 | 6.7 | 2648 | 5.9 |
| | Common | 8 | 6.8 | 2681 | 5.9 |
| | Mean of all roasts | 21‡ | 7.1 | 2940 | 6.5 |

‡Total.

2. For the rib roasts the time required to reach maximum temperature was longer (total time as well as time per pound) for the high oven temperature method than for the low oven temperature method, but the rise in temperature averaged 18.3°C for the roasts cooked at 225°C and only 7.2°C for those cooked at 125°C.
3. The entire time required to produce medium-rare rib roasts was longer (total time as well as time per pound) for the low oven temperature method than for the high oven temperature method.
4. For the chuck roasts, the total time of cooking as well as the time per pound was longer for the low oven temperature method than for the high oven temperature method.
5. For both the rib and the chuck roasts less gas was required for the low oven temperature method than for the high oven temperature method and the cost of the gas was less also.

Representative time-temperature curves for the medium-rare rib roasts have been given in Figure 6. They show that both curves are rather steep. Separate curves for the medium-rare chuck roasts were not given because these roasts were removed from the oven at the medium-rare stage of cooking and their time-temperature curves up to this point

**medium-rare roasts of beef at constant oven temperatures of 125°C and 225°C.**

| Internal temperature | | | Time in minutes | | | | Gas* | |
|---|---|---|---|---|---|---|---|---|
| | | | In oven | | To reach maximum | | | |
| Initial °C | Removal °C | Maximum °C | Total | Per pound | Total | Per pound | Cubic feet | Cost cents |
| | | | | 125°C | | | | |
| 6.8 | 55.0 | 61.7 | 176 | 20.8 | 40 | 4.7 | 14.5 | 1.0 |
| 6.0 | 55.0 | 62.8 | 166 | 24.4 | 38 | 5.6 | 13.8 | 0.9 |
| 7.0 | 54.9 | 62.0 | 161 | 22.4 | 40 | 5.5 | 15.0 | 1.0 |
| 6.6 | 55.0 | 62.2 | 167 | 22.7 | 39 | 5.3 | 14.4 | 1.0 |
| 8.7 | 63.0 | 63.0 | 224 | 30.3 | 0 | —— | 16.5 | 1.1 |
| 8.8 | 63.0 | 63.0 | 173 | 31.4 | 0 | —— | 12.8 | 0.9 |
| 10.4 | 63.0 | 63.0 | 164 | 28.2 | 0 | —— | 13.1 | 0.9 |
| 9.4 | 63.0 | 63.0 | 186 | 29.8 | 0 | —— | 14.0 | 0.9 |
| | | | | 225°C | | | | |
| 6.7 | 44.8 | 62.7 | 92 | 10.6 | 51 | 5.8 | 20.5 | 1.4 |
| 5.9 | 45.1 | 63.6 | 80 | 12.4 | 47 | 7.3 | 17.6 | 1.2 |
| 7.4 | 45.1 | 63.5 | 84 | 11.7 | 45 | 6.3 | 17.0 | 1.2 |
| 6.6 | 45.0 | 63.3 | 85 | 11.6 | 47 | 6.5 | 17.9 | 1.2 |
| 8.0 | 62.6 | 63.0 | 100 | 13.1 | 4 | —— | 20.2 | 1.4 |
| 9.0 | 63.0 | 63.0 | 74 | 12.8 | 0 | —— | 14.7 | 1.0 |
| 9.4 | 63.3 | 63.5 | 78 | 13.2 | 3 | —— | 16.4 | 1.1 |
| 8.8 | 63.0 | 63.2 | 84 | 13.0 | 2 | —— | 17.0 | 1.1 |

*Preheating of ovens not included. In 30 tests, the preheating of the ovens to 125°C averaged 5.4 cubic feet, costing $0.004. In 20 tests, the preheating to 225°C averaged 11.8 cubic feet, costing $0.008. Cost of gas $0.675 per 1000 cubic feet.

(63°C) would be similar to those already given in Figures 1, 2, and 5 for the well-done chuck roasts.

The difference between the two methods in the entire time required to produce medium-rare roasts is relatively small (rib 74 minutes, chuck 100 minutes) and is associated with low tenderness ratios (rib 0.5399, chuck 0.5365). The medium-rare rib and chuck roasts, therefore, may be included in the group with the leg of lamb roasts in Table 4.

## DISCUSSION OF RESULTS

How tough or how tender the meat was before cooking is not known, but the fact that tender meat was not always obtained with the low oven temperature method nor was tough meat always obtained with the high oven temperature method agrees with the statement by Alexander (2) that the standard method of roasting lamb did not destroy the individuality of the samples. Alexander, using the 7-point grading chart, reported individual roast scores which ranged from 3.00 (tough) to 5.80 (tender) for the lower oven temperature method and from 3.00 (tough) to 5.00 (moderately tender) for the higher oven temperature method. In the work with lamb at this station the scores for the individual roasts ranged

from 2.0 (tough) to 4.5 (very tender) for the low oven temperature method and from 1.7 (tough) to 4.5 (very tender) for the high oven temperature method on the basis of a 5-point grading chart. While a direct comparison of the data from the two laboratories is not possible because different grading charts were used, it is probable that as much variation within one method has been found in this laboratory as in that of Alexander.

The evidence obtained from these experiments concerning the relationship between oven temperature and tenderness may be stated briefly as follows:

1. The use of high or low oven temperatures produced roasts which were scored uniformly neither "very tender" nor "very tough."
2. While oven temperatures of 125°C and 225°C produced a significant difference in the tenderness of well-done rib, rump, and round-bone chuck roasts of beef and half-ham roasts of pork, the same oven temperatures failed to produce significant differences in well-done leg of lamb roasts or medium-rare rib and round-bone chuck roasts of beef. These facts lead to the conclusion that oven temperature per se is only one (if one) of the factors influencing tenderness in roasts.
3. Nor can the cooking of meat in a low temperature oven be defended by the familiar statement that "high temperatures toughen protein". In paired well-done round-bone chuck roasts cooked at high and low oven temperatures, the tenderness-response was in favor of the low oven temperature method (96%). The paired samples from which these results were obtained were taken from the middle of the roasts near the bulb of the thermometer and the internal temperature in each roast of the pair was the same (80°C).

The inconsistencies observed in trying to connect oven temperature and tenderness are so great that some other explanation has been sought. The suggestion that the difference in tenderness produced in the meat cooked at high and low oven temperatures may have been due to the different lengths of cooking time required has received some support from this investigation. The tenderness-response was highest in those cuts in which the cooking to the well-done stage proceeded **slowly** at the low oven temperature, but those were the cuts (chuck and rump) which showed the most marked flattening of the time-temperature curves and which also showed the greatest difference between the two methods in the time required for cooking. The leg of lamb roasts in which the cooking to the well-done stage proceeded **relatively quickly** at the low oven temperature showed no significant difference in tenderness between the two methods of cooking. In addition, when rib and chuck cuts were cooked medium-rare, a stage of cooking preceding that at which the time-temperature curves for the well-done chuck roasts were markedly flattened and at which there is relatively only a small difference in cooking time, there was no significant difference in tenderness-response either when high and low oven temperature methods were compared or when rib and chuck cuts were compared. Thus the differences in tenderness,

which in these tests have appeared to be related to oven temperature, seem to be explained in a more satisfactory manner on the basis of the length of time required for cooking.

That the relationship between tenderness ratio and difference in total time of cooking may not be a basic relationship is indicated by its failure to hold for the individual roasts of any cut (Tables E and H of the supplementary tables). But how much these variations may have been influenced by the difference in the initial temperature of the roasts, it is impossible to say. There is not sufficient evidence to determine whether an explanation of the effect of high and low oven temperatures on tenderness may be found in the difference in the total cooking time between the two methods, irrespective of the internal temperatures at which the prolonged cooking takes place.

Is it possible that a suitable explanation of the effect of high and low oven temperatures on tenderness of well-done meat may be found in the length of cooking time available after an internal temperature of 65°C has been reached? If so, perhaps it may be possible to control the rise in internal temperature artificially so as to produce a high tenderness-response in all cuts.

Is it possible that the chemical or the physical changes which are responsible for causing the flattening of the time-temperature curves may also be concerned directly in tendering the meat? If this hypothesis is assumed to be correct, then what are the chemical or physical changes which take place? And can any means be devised to take full advantage of them in producing tender roasts?

The answers to these questions may have great practical value as well as add somewhat to our store of fundamental knowledge of what happens during the cooking process. Investigations along these lines are now in progress at this station.

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## SUMMARY

In this study, the problem has been limited to only one of the factors (oven temperature) which may have an influence on the problem of the best method of cooking for the highest degree of palatability and to only one of the factors of palatability (tenderness). The problem was limited in this way in order to permit intensive study of the relationship between oven temperature and tenderness.

In the first series, the cuts were cooked well-done. They included the 9th, 10th, and 11th ribs, the round-bone chuck, and the rump roasts of beef, the half-ham roasts of pork, and the leg of lamb roasts. In the second series, the cuts were cooked medium-rare. They included only the 9th, 10th, and 11th ribs and the round-bone chuck roasts of beef.

The roasts in the first series were cooked well-done at constant oven temperatures of 125°C and 225°C. Carefully paired samples from 164 roasts were tested for tenderness by a committee of judges who used the paired-eating method as well as a rating scale of adjectives.

The results from the paired-eating method show that the roasts fall into three groups: first, the roasts which showed the largest percentage of judgments in favor of the low oven temperature method, round-bone chuck 96% and rump 93%; second, the roasts which showed a majority, but a lower majority, of judgments in favor of the low oven temperature method, half-ham 75% and rib 69%; and third, the roasts which showed no significant majority in favor of the low oven temperature method, leg of lamb 51%.

It was observed that the corresponding time-temperature curves for each of these cuts fell into the same grouping as did their tenderness results, the decrease in slope as the cooking continued being accentuated in the chuck and rump roasts, being noticeable but not so pronounced in the half-ham and rib roasts, and being only slightly noticeable in the leg of lamb roasts.

The difference in total cooking time between the high and low oven temperature methods, also, fell into the three groups: chuck 370 minutes and rump 309 minutes; half-ham 195 minutes and rib 194 minutes; and leg of lamb 105 minutes.

These observations suggested that the results for tenderness were due to the longer time of cooking and not to oven temperature per se. Accordingly, a second series of experiments were started in which 22 rib and 21 chuck roasts were cooked at constant oven temperatures of 125°C and 225°C so as to provide an internal temperature of 63°C (medium-rare), a point on the time-temperature curve preceding the accentuated decrease in slope shown by the well-done chuck roasts and a point at which the difference in cooking time between the two cuts is relatively small. At this point, also, the curves for the two methods of cooking for each cut are fairly close. The results show that there was no significant

difference in tenderness either between the two cuts or between the two methods of cooking.

The evidence presented points to a relationship between tenderness and slow cooking. The differences in tenderness, which in these tests have appeared to be related to oven temperature, seem to be explained in a more satisfactory manner on the basis of the length of time required for cooking.

More work needs to be done before anyone is able to recommend processes of cooking which will uniformly produce tender roasts. Present knowledge would indicate, however, that a housewife will have a better chance of obtaining a tender roast if she cooks it at a low oven temperature than if she cooks it at a high oven temperature.

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# Supplementary Tables

**Table A. Data from tests for tenderness of individual pairs of roasts**

| Carcass | | Ripening period in days | Roast Number | | 125°C | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Difference | |
| U. S. Grade | Weight pounds | | 125°C | 225°C | More tender | Slight | Decided |
| 9th, 10th, and 11th ribs | | | | | | | |
| Prime | 600–700 | 10 | 233L | 234R | 2 | 2 | 0 |
| Choice | 500–600 | 11 | 38R | 37L | 15 | — | — |
| | | 11 | 59L | 60R | 6 | — | — |
| | | 10 | 67L | 68R | 5 | — | — |
| | | 10 | 72R | 71L | 9 | — | — |
| | | 10 | 99L | 100R | 0 | — | — |
| | | Total | | | 35 | — | — |
| | 400–500 | 10 | 29L | 30R | 4 | — | — |
| | | 11 | 39L | 40R | 14 | — | — |
| | | 10 | 58R | 57L | 4 | — | — |
| | | 11 | 65L | 66R | 0 | — | — |
| | | 10 | 78R | 77L | 12 | — | — |
| | | 10 | 98R | 97L | 11 | — | — |
| | | Total | | | 45 | — | — |
| Good | 500–600 | 10 | 184R | 183L | 3 | 3 | 0 |
| | | 10 | 185L | 186R | 9 | 7 | 1 |
| | | Total | | | 12 | 10 | 1 |
| Medium | 500–600 | 11 | 152R | 151L | 0 | 0 | 0 |
| | | 11 | 176R | 175L | 6 | 4 | 2 |
| | | 10 | 200R | 199L | 7 | 6 | 1 |
| | | 10 | 201L | 202R | 8 | 5 | 3 |
| | | Total | | | 21 | 15 | 6 |
| | 300–400 | 11 | 177L | 178R | 6 | 4 | 2 |
| Common | 500–600 | 10 | 192R | 191L | 8 | 5 | 3 |
| | | 10 | 193L | 194R | 6 | 2 | 4 |
| | | 11 | 212R | 211L | 8 | 3 | 5 |
| | | 11 | 213L | 214R | 6 | 6 | 0 |
| | | 10 | 220R | 219L | 12 | 4 | 8 |
| | | 10 | 221L | 222R | 3 | 3 | 0 |
| | | Total | | | 43 | 23 | 20 |
| | 400–500 | 11 | 153L | 154R | 4 | 4 | 0 |

**of beef cooked to an internal temperature of 80°C (well-done).**

| Tenderness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of judgments by paired eating method | | | | | | | | Weighted adjectives average per roast | |
| No difference | 225°C | | | Total N | For statistical treatment | | | | |
| | More tender | Difference | | | More tender | | Ratio $n_s/N$ | | |
| | | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | 125°C | 225°C |
| 9th, 10th, and 11th ribs | | | | | | | | | |
| 3 | 3 | 3 | 0 | 8 | 3.5* | 4.5* | 0.4375 | 3.8 | 3.9 |
| 0 | 0 | — | — | 15 | 15.0 | 0.0 | | 3.8 | 3.2 |
| 0 | 0 | — | — | 6 | 6.0 | 0.0 | | 2.7 | 2.0 |
| 2 | 2 | — | — | 9 | 6.0 | 3.0 | | 3.1 | 2.8 |
| 2 | 4 | — | — | 15 | 10.0 | 5.0 | | 2.6 | 2.8 |
| 2 | 10 | — | — | 12 | 1.0* | 11.0* | | 3.7 | 4.0 |
| 6 | 16 | — | — | 57 | 38.0 | 19.0 | 0.6667 | 3.2‡ | 3.0‡ |
| 1 | 7 | — | — | 12 | 4.5* | 7.5* | | 3.3 | 3.6 |
| 1 | 0 | — | — | 15 | 14.5 | 0.5 | | 4.0 | 3.7 |
| 1 | 1 | — | — | 6 | 4.5 | 1.5 | | 3.3 | 3.0 |
| 2 | 7 | — | — | 9 | 1.0* | 8.0* | | 2.7 | 3.0 |
| 0 | 0 | — | — | 12 | 12.0 | 0.0 | | 4.0 | 2.8 |
| 0 | 0 | — | — | 11 | 11.0 | 0.0 | | 4.0 | 3.7 |
| 5 | 15 | — | — | 65 | 47.5 | 17.5 | 0.7307 | 3.6‡ | 3.3‡ |
| 2 | 5 | 2 | 3 | 10 | 4.0* | 6.0* | | 3.2 | 3.6 |
| 1 | 0 | 0 | 0 | 10 | 9.5 | 0.5 | | 4.6 | 4.2 |
| 3 | 5 | 2 | 3 | 20 | 13.5 | 6.5 | 0.6750 | 3.9‡ | 3.9‡ |
| 0 | 8 | 7 | 1 | 8 | 0.0* | 8.0* | | 3.6 | 3.9 |
| 2 | 0 | 0 | 0 | 8 | 7.0 | 1.0 | | 4.3 | 3.5 |
| 3 | 0 | 0 | 0 | 10 | 8.5 | 1.5 | | 2.2 | 1.8 |
| 0 | 2 | 2 | 0 | 10 | 8.0 | 2.0 | | 3.3 | 2.3 |
| 5 | 10 | 9 | 1 | 36 | 23.5 | 12.5 | 0.6528 | 3.4‡ | 2.9‡ |
| 0 | 2 | 2 | 0 | 8 | 6.0 | 2.0 | 0.7500 | 3.9 | 3.3 |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | | 2.3 | 1.6 |
| 0 | 2 | 2 | 0 | 8 | 6.0 | 2.0 | | 3.5 | 2.8 |
| 1 | 1 | 1 | 0 | 10 | 8.5 | 1.5 | | 3.5 | 2.8 |
| 1 | 2 | 1 | 1 | 9 | 6.5 | 2.5 | | 3.4 | 3.3 |
| 0 | 3 | 1 | 0 | 15 | 12.0 | 3.0 | | 1.8 | 1.3 |
| 1 | 6 | 4 | 1 | 10 | 3.5* | 6.5* | | 1.5 | 1.4 |
| 3 | 14 | 9 | 2 | 60 | 44.5 | 15.5 | 0.7417 | 2.7‡ | 2.2‡ |
| 1 | 3 | 3 | 0 | 8 | 4.5 | 3.5 | 0.5625 | 4.4 | 4.6 |

*The majority of the paired judgments in this roast were in favor of high oven temperature. These roasts were apparently distributed in random manner in all of the groups of rib roasts.

‡Mean.

**Table A. Data from tests for tenderness of individual pairs of roasts of**

| Carcass | | Ripening period in days | Roast Number | | 125°C | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Difference | |
| U. S. Grade | Weight pounds | | 125°C | 225°C | More tender | Slight | Decided |
| **Chuck** | | | | | | | |
| Prime | 600–700 | 10 | 231L | 233R | 8 | 4 | 4 |
| Choice | 500–600 | 7 | 52R | 51L | 10 | — | — |
| | | 14 | 80R | 79L | 8 | — | — |
| | | 6 | 92R | 91L | 8 | — | — |
| | | Total | | | 26 | — | — |
| | 400–500 | 6 | 70R | 69L | 10 | — | — |
| Good | 500–600 | 9 | 180R | 179L | 8 | 6 | 2 |
| | | 9 | 181L | 182R | 8 | 6 | 2 |
| | | Total | | | 16 | 12 | 4 |
| Medium | 500–600 | 9 | 195L | 196R | 10 | 5 | 5 |
| | | 9 | 198R | 197L | 10 | 1 | 9 |
| | | Total | | | 20 | 6 | 14 |
| | 300–400 | 10 | 171L | 172R | 5 | 5 | 0 |
| | | 10 | 174R | 173L | 8 | 5 | 3 |
| | | Total | | | 13 | 10 | 3 |
| Common | 500–600 | 9 | 187L | 188R | 8 | 1 | 6 |
| | | 9 | 190R | 189L | 8 | 2 | 6 |
| | | 9 | 207L | 208R | 10 | 2 | 8 |
| | | 9 | 210R | 209L | 10 | 0 | 9 |
| | | 9 | 215L | 216R | 6 | 4 | 2 |
| | | 9 | 218R | 217L | 6 | 3 | 3 |
| | | Total | | | 48 | 12 | 34 |
| **Rump** | | | | | | | |
| Choice | 500–600 | 9 | 28R | 27L | 9 | — | — |
| | | 10 | 33L | 34R | 10 | — | — |
| | | 10 | 56R | 55L | 10 | — | — |
| | | 9 | 64R | 63L | 9 | — | — |
| | | 13 | 76R | 75L | 8 | — | — |
| | | 9 | 96R | 95L | 4 | — | — |
| | | Total | | | 50 | — | — |
| | 400–500 | 10 | 36R | 35L | 9 | — | — |
| | | 9 | 73L | 74R | 8 | — | — |
| | | 9 | 94R | 93L | 8 | — | — |
| | | Total | | | 25 | — | — |

**beef cooked to an internal temperature of 80°C (well-done)—Continued.**

| Tenderness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of judgments by paired eating method | | | | | | | | Weighted adjectives average per roast | |
| No difference | 225°C More tender | 225°C Difference Slight | 225°C Difference Decided | Total N | For statistical treatment More tender 125°C $n_s$ | For statistical treatment More tender 225°C $n_t$ | Ratio $n_s/N$ | 125°C | 225°C |
| **Chuck** | | | | | | | | | |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | 1.0000 | 5.0 | 4.4 |
| 0 | 4 | — | — | 14 | 10.0 | 4.0 | | 3.6 | 3.6 |
| 0 | 0 | — | — | 8 | 8.0 | 0.0 | | 4.0 | 3.8 |
| 0 | 0 | — | — | 8 | 8.0 | 0.0 | | 4.0 | 4.0 |
| 0 | 4 | — | — | 30 | 26.0 | 4.0 | 0.8667 | 3.9‡ | 3.8‡ |
| 0 | 0 | — | — | 10 | 10.0 | 0.0 | 1.0000 | 4.0 | 4.0 |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | | 3.8 | 3.4 |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | | 4.1 | 3.8 |
| 0 | 0 | 0 | 0 | 16 | 16.0 | 0.0 | 1.0000 | 4.0‡ | 3.6‡ |
| 0 | 0 | 0 | 0 | 10 | 10.0 | 0.0 | | 4.2 | 3.0 |
| 0 | 0 | 0 | 0 | 10 | 10.0 | 0.0 | | 4.0 | 2.8 |
| 0 | 0 | 0 | 0 | 20 | 20.0 | 0.0 | 1.0000 | 4.1‡ | 2.9‡ |
| 3 | 0 | 0 | 0 | 8 | 6.5 | 1.5 | | 4.1 | 4.1 |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | | 4.5 | 3.8 |
| 3 | 0 | 0 | 0 | 16 | 14.5 | 1.5 | 0.9063 | 4.3‡ | 4.0‡ |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | | 4.1 | 2.9 |
| 0 | 0 | 0 | 0 | 8 | 8.0 | 0.0 | | 4.1 | 2.9 |
| 0 | 0 | 0 | 0 | 10 | 10.0 | 0.0 | | 4.4 | 2.4 |
| 0 | 0 | 0 | 0 | 10 | 10.0 | 0.0 | | 4.9 | 3.4 |
| 0 | 0 | 0 | 0 | 6 | 6.0 | 0.0 | | 4.3 | 3.2 |
| 0 | 0 | 0 | 0 | 6 | 6.0 | 0.0 | | 4.5 | 3.2 |
| 0 | 0 | 0 | 0 | 48 | 48.0 | 0.0 | 1.0000 | 4.4‡ | 3.0‡ |
| **Rump** | | | | | | | | | |
| 0 | 0 | — | — | 9 | 9.0 | 0.0 | | 4.0 | 3.9 |
| 0 | 0 | — | — | 10 | 10.0 | 0.0 | | 3.5 | 2.6 |
| 2 | 0 | — | — | 12 | 11.0 | 1.0 | | 4.0 | 3.6 |
| 1 | 0 | — | — | 10 | 9.5 | 0.5 | | 4.0 | 3.4 |
| 0 | 0 | — | — | 8 | 8.0 | 0.0 | | 4.0 | 2.6 |
| 0 | 4 | — | — | 8 | 4.0 | 4.0 | | 3.0 | 2.6 |
| 3 | 4 | — | — | 57 | 51.5 | 5.5 | 0.9035 | 3.8‡ | 3.1‡ |
| 1 | 0 | — | — | 10 | 9.5 | 0.5 | | 3.6 | 2.9 |
| 0 | 0 | — | — | 8 | 8.0 | 0.0 | | 3.5 | 2.8 |
| 0 | 0 | — | — | 8 | 8.0 | 0.0 | | 3.4 | 2.1 |
| 1 | 0 | — | — | 26 | 25.5 | 0.5 | 0.9808 | 3.5‡ | 2.6‡ |

‡Mean.

**Table B. Data from tests for tenderness of individual pairs of half-ham**

| Ration | Chilled carcass weight in pounds | Ripening period in days | Roast numbers | | 125°C | | |
|---|---|---|---|---|---|---|---|
| | | | 125°C | 225°C | More tender | Difference | |
| | | | | | | Slight | Decided |
| Garbage | 156 | 7 | 121L | 122R | 5 | 5 | 0 |
| Woods raised, garbage | 125 | 7 | 124R | 123L | 2 | 2 | 0 |
| Garbage, grain last 2 months | 197 | 8 | 125L | 126R | 11 | 10 | 1 |
| Garbage | 196 | 8 | 128R | 127L | 7 | 5 | 2 |
| Tankage, kafir, and cottonseed meal** | 151† | 7 | 131L | 132R | 3 | 1 | 1 |
| | 150† | 7 | 133L | 134R | 3 | 3 | 0 |
| Ration unknown but identical*** | 202 | 7 | 156R | 155L | 7 | 3 | 4 |
| | 172 | 7 | 158R | 157L | 4 | 1 | 3 |
| Garbage | 185 | 7 | 303L | 304R | 7 | 5 | 2 |
| Garbage | 171 | 7 | 306R | 305L | 10 | 5 | 5 |
| Garbage | 186 | 6 | 319L | 320R | 7 | 6 | 1 |
| Garbage | 199 | 6 | 322R | 321L | 9 | 4 | 5 |
| Garbage | 171 | 7 | 335L | 336R | 10 | 8 | 2 |
| Garbage | 170 | 7 | 338R | 337L | 12 | 7 | 5 |
| Tankage, kafir, and corn | 159 | 6 | 351L | 352R | 0 | 0 | 0 |
| | 155 | 6 | 354R | 353L | 7 | 2 | 5 |
| Total | ..... | ..... | ..... | ..... | 104 | 67 | 36 |

**Litter mates.
***Litter mates.
†Warm weight of carcass.

**roasts of pork cooked to an internal temperature of 84°C (well-done).**

| Tenderness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of judgments by paired eating method | | | | | | | | Weighted adjectives average per roast | |
| No difference | 225°C | | | Total N | For statistical treatment | | | | |
| | More tender | Difference | | | More tender | | Ratio $n_s/N$ | | |
| | | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | 125°C | 225°C |
| 3 | 3 | 3 | 0 | 11 | 6.5 | 4.5 | | 3.0 | 3.0 |
| 1 | 9 | 8 | 1 | 12 | 2.5* | 9.5* | | 4.4 | 4.7 |
| 0 | 1 | 1 | 0 | 12 | 11.0 | 1.0 | | 3.7 | 3.2 |
| 0 | 1 | 1 | 0 | 8 | 7.0 | 1.0 | | 3.4 | 2.8 |
| 1 | 0 | 0 | 0 | 4 | 3.5 | 0.5 | | 3.8 | 3.3 |
| 1 | 0 | 0 | 0 | 4 | 3.5 | 0.5 | | 2.8 | 2.5 |
| 0 | 0 | 0 | 0 | 7 | 7.0 | 0.0 | | 3.4 | 2.8 |
| 2 | 2 | 0 | 2 | 8 | 5.0 | 3.0 | | 2.8 | 2.5 |
| 0 | 3 | 2 | 1 | 10 | 7.0 | 3.0 | | 4.1 | 3.8 |
| 0 | 0 | 0 | 0 | 10 | 10.0 | 0.0 | | 3.2 | 2.1 |
| 3 | 2 | 2 | 0 | 12 | 8.5 | 3.5 | | 4.0 | 3.7 |
| 3 | 0 | 0 | 0 | 12 | 10.5 | 1.5 | | 3.9 | 3.0 |
| 5 | 0 | 0 | 0 | 15 | 12.5 | 2.5 | | 4.1 | 3.5 |
| 2 | 0 | 0 | 0 | 14 | 13.0 | 1.0 | | 3.2 | 2.4 |
| 4 | 6 | 2 | 4 | 10 | 2.0* | 8.0* | | 4.0 | 4.5 |
| 0 | 0 | 0 | 0 | 7 | 7.0 | 0.0 | | 3.7 | 2.4 |
| 25 | 27 | 19 | 8 | 156 | 116.5 | 39.5 | 0.7468 | 3.6‡ | 3.1‡ |

*The majority of the paired judgments in these roasts were in favor of the high oven temperature.
‡Mean.

**Table C. Data from tests for tenderness of individual pairs of leg**

| Carcass | | Ripening period in days | Roast Numbers | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | 125°C | | |
| | | | | | | Difference | |
| Grade | Weight pounds | | 125°C | 225°C | More tender | Slight | Decided |
| Choice | 46 | 7 | 203L | 204R | 4 | 3 | 1 |
| | 54 | 7 | 206R | 205L | 0 | 0 | 0 |
| | | Total | | | 4 | 3 | 1 |
| Good | — | 7 | 144R | 143L | 8 | 6 | 2 |
| | — | 7 | 145L | 146R | 2 | 1 | 1 |
| | 36 | 7 | 287L | 288R | 3 | 1 | 2 |
| | 38 | 7 | 290R | 289L | 3 | 3 | 0 |
| | 34 | 7 | 315L | 316R | 9 | 7 | 2 |
| | 38 | 7 | 318R | 317L | 7 | 5 | 2 |
| | | Total | | | 32 | 23 | 9 |
| Medium | 29 | 6 | 299L | 300R | 4 | 0 | 4 |
| | 30 | 6 | 302R | 301L | 3 | 1 | 2 |
| | 34 | 6 | 331L | 332R | 1 | 0 | 1 |
| | 38 | 6 | 334R | 333L | 6 | 4 | 2 |
| | 39 | 7 | 347L | 348R | 3 | 2 | 1 |
| | 40 | 7 | 350R | 349L | 4 | 4 | 0 |
| | | Total | | | 21 | 11 | 10 |

**of lamb roasts cooked to an internal temperature of 76°C (well-done).**

| Tenderness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of judgments by paired eating method | | | | | | | | Weighted adjectives average per roast | |
| No difference | 225°C | | | Total N | For statistical treatment | | | | |
| | More tender | Difference | | | More tender | | Ratio $n_s/N$ | | |
| | | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | 125°C | 225°C |
| 2 | 0 | 0 | 0 | 6 | 5.0 | 1.0 | | 3.8 | 3.5 |
| 2 | 4 | 4 | 0 | 6 | 1.0* | 5.0* | | 4.5 | 4.5 |
| 4 | 4 | 4 | 0 | 12 | 6.0 | 6.0 | 0.5000 | 4.2‡ | 4.0‡ |
| 1 | 3 | 2 | 1 | 12 | 8.5 | 3.5 | | 2.3 | 1.9 |
| 0 | 8 | 5 | 3 | 10 | 2.0* | 8.0* | | 2.1 | 2.7 |
| 0 | 3 | 2 | 1 | 6 | 3.0 | 3.0 | | 2.0 | 2.0 |
| 1 | 2 | 1 | 1 | 6 | 3.5 | 2.5 | | 2.3 | 2.3 |
| 8 | 2 | 2 | 0 | 19 | 13.0 | 6.0 | | 4.0 | 3.6 |
| 2 | 6 | 3 | 3 | 15 | 8.0 | 7.0 | | 2.5 | 2.6 |
| 12 | 24 | 15 | 9 | 68 | 38.0 | 30.0 | 0.5588 | 2.5‡ | 2.5‡ |
| 1 | 1 | 1 | 0 | 6 | 4.5 | 1.5 | | 2.5 | 1.7 |
| 0 | 3 | 2 | 1 | 6 | 3.0 | 3.0 | | 2.5 | 2.3 |
| 2 | 9 | 5 | 4 | 12 | 2.0* | 10.0* | | 2.5 | 3.3 |
| 3 | 3 | 2 | 1 | 12 | 7.5 | 4.5 | | 2.6 | 1.8 |
| 2 | 7 | 4 | 3 | 12 | 4.0* | 8.0* | | 2.2 | 3.2 |
| 4 | 4 | 2 | 2 | 12 | 6.0 | 6.0 | | 4.0 | 4.0 |
| 12 | 27 | 16 | 11 | 60 | 27.0 | 33.0 | 0.4500 | 2.7‡ | 2.7‡ |

*Majority of the paired judgments in these roasts were in favor of the high oven temperature.
‡Mean.

**Table D. The time and gas required to cook roasts well-done**

| Carcass | | Class | Ripening period in days | Roast number | 125°C | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Weight of roast | | Internal temperature | | Time in oven minutes | |
| U. S. grade | Chilled weight pounds | | | | Grams | Pounds | Initial °C | Removal °C | Total | Per pound |
| 9th, 10th, and 11th ribs of beef | | | | | | | | | | |
| Prime | 630 | Steer | 10 | 233L | 5335 | 11.8 | 6 | 80 | 435 | 36.9 |
| Choice | 500–600 | Steer | 11 | 38R | 4292 | 9.5 | 8 | 80 | 439 | 46.2 |
| | | — | 11 | 59L | 3509 | 7.7 | 8 | 80 | 307 | 39.9 |
| | | Steer | 10 | 67L | 3692 | 8.1 | 6 | 80 | 325 | 40.1 |
| | | Steer | 10 | 72R | 3896 | 8.6 | 6 | 80 | 356 | 41.4 |
| | | Steer | 10 | 99L | 3674 | 8.1 | 7 | 80 | 310 | 38.3 |
| | 400–500 | Steer | 10 | 29L | 3460 | 7.6 | 7 | 80 | 340 | 44.7 |
| | | Heifer | 11 | 39L | 4297 | 9.5 | 6 | 80 | 395 | 41.6 |
| | | — | 10 | 58R | 3506 | 7.7 | 8 | 80 | 340 | 44.1 |
| | | Heifer | 11 | 65L | 3300 | 7.3 | 6 | 80 | 290 | 39.7 |
| | | Steer | 10 | 78R | 3075 | 6.8 | 8 | 80 | 325 | 47.8 |
| | | Steer | 10 | 98R | 3348 | 7.4 | 7 | 80 | 348 | 47.0 |
| Good | 594 | Steer | 10 | 184R | 4795 | 10.6 | 4 | 80 | 415 | 39.2 |
| | 564 | Steer | 10 | 185L | 4717 | 10.4 | 5 | 80 | 383 | 36.8 |
| Medium | 500–600 | Cow | 11 | 152R | 5565 | 12.3 | 7 | 80 | 410 | 33.3 |
| | | Steer | 10 | 200R | 4287 | 9.5 | 2 | 80 | 392 | 41.3 |
| | | Steer | 10 | 201L | 4100 | 9.0 | 2 | 80 | 410 | 45.6 |
| | 345 | Steer | 11 | 177L | 2670 | 5.9 | 6 | 80 | 267 | 45.3 |
| Common | 500–600 | Steer | 10 | 192R | 3287 | 7.2 | 1 | 80 | 320 | 44.4 |
| | | Steer | 10 | 193L | 4502 | 9.9 | 1 | 80 | 366 | 37.0 |
| | | Steer | 11 | 212R | 3623 | 8.0 | 0 | 80 | 395 | 49.4 |
| | | Steer | 11 | 213L | 3340 | 7.4 | 1 | 80 | 285 | 38.5 |
| | | Steer | 10 | 220R | 3850 | 8.5 | 5 | 80 | 348 | 40.9 |
| | | Steer | 10 | 221L | 3052 | 6.7 | 7 | 80 | 286 | 42.7 |
| | 430 | Cow | 11 | 153L | 3152 | 6.9 | 9 | 80 | 360 | 52.2 |
| Mean | ..... | ..... | 10.4 | ..... | 3853 | 8.5 | 5.3 | 80 | 354 | 42.2 |
| Round-bone chuck of beef | | | | | | | | | | |
| Prime | 630 | Steer | 10 | 231L | 3977 | 8.8 | 8 | 80 | 455 | 51.7 |
| Choice | 500–600 | — | 7 | 52R | 2874 | 6.3 | 10 | 80 | 414 | 65.7 |
| | | Steer | 14 | 80R | 2779 | 6.1 | 8 | 80 | 319 | 52.3 |
| | | Steer | 6 | 92R | 2947 | 6.5 | 8 | 80 | 457 | 70.3 |
| | 400–500 | Steer | 6 | 70R | 2750 | 6.1 | 8 | 80 | 433 | 71.0 |
| Good | 594 | Steer | 9 | 180R | 3423 | 7.5 | 7 | 80 | 561 | 74.8 |
| | 564 | Steer | 9 | 181L | 3368 | 7.4 | 6 | 80 | 490 | 66.2 |
| Medium | 593 | Steer | 9 | 195L | 3678 | 8.1 | 8 | 80 | 615 | 75.9 |
| | 587 | Steer | 9 | 198R | 3147 | 6.9 | 7 | 80 | 565 | 81.9 |
| | 322 | Steer | 10 | 171L | 2475 | 5.5 | 6 | 80 | 455 | 82.7 |
| | 345 | Steer | 10 | 174R | 2546 | 5.6 | 6 | 80 | 502 | 89.6 |
| Common | 512 | Steer | 9 | 187L | 2912 | 6.4 | 8 | 80 | 570 | 89.1 |
| | 579 | Steer | 9 | 190R | 2973 | 6.6 | 8 | 80 | 556 | 84.2 |
| | 521 | Steer | 9 | 207L | 3250 | 7.2 | 5 | 80 | 618 | 85.8 |
| | 575 | Steer | 9 | 210R | 3105 | 6.8 | 5 | 80 | 517 | 76.0 |
| | 520 | Steer | 9 | 215L | 2511 | 5.5 | 2 | 80 | 473 | 86.0 |
| | 503 | Steer | 9 | 218R | 2475 | 5.5 | 4 | 80 | 451 | 82.0 |
| Mean | ..... | ..... | 9.0 | ..... | 3011 | 6.6 | 6.7 | 80 | 497 | 75.6 |

**at constant oven temperatures of 125°C and 225°C.**

| | | 225°C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gas* | | Roast number | Weight of roast | | Internal temperature | | Time in oven minutes | | Gas* | |
| Cubic feet | Cost cents | | Grams | Pounds | Initial °C | Removal °C | Total | Per pound | Cubic feet | Cost cents |
| | | 9th, 10th, and 11th ribs of beef | | | | | | | | |
| 33.5 | 2.3 | 234R | 5592 | 12.3 | 2 | 80 | 217 | 17.6 | 45.2 | 3.1 |
| — | — | 37L | 4417 | 9.7 | 6 | 80 | 180 | 18.6 | — | — |
| — | — | 60R | 3553 | 7.8 | 10 | 80 | 135 | 17.3 | — | — |
| — | — | 68R | 3767 | 8.3 | 8 | 80 | 160 | 19.3 | — | — |
| — | — | 71L | 3581 | 7.9 | 6 | 80 | 156 | 19.7 | — | — |
| — | — | 100R | 3923 | 8.6 | 8 | 80 | 176 | 20.5 | — | — |
| — | — | 30R | 3526 | 7.8 | 7 | 80 | 155 | 19.9 | — | — |
| — | — | 40R | 4179 | 9.2 | — | 80 | 186 | 20.2 | — | — |
| — | — | 57L | 3700 | 8.2 | 9 | 80 | 156 | 19.0 | — | — |
| — | — | 66R | 3133 | 6.9 | 8 | 80 | 135 | 19.4 | — | — |
| — | — | 77L | 3041 | 6.7 | 8 | 80 | 139 | 20.7 | — | — |
| — | — | 97L | 3530 | 7.8 | 8 | 80 | 159 | 20.4 | — | — |
| 32.8 | 2.2 | 183L | 5082 | 11.2 | 6 | 80 | 197 | 17.6 | 43.0 | 2.9 |
| 29.3 | 2.0 | 186R | 4336 | 9.6 | 5 | 80 | 168 | 17.5 | 34.2 | 2.3 |
| — | — | 151L | 4778 | 10.5 | 9 | 80 | 185 | 17.6 | — | — |
| 31.1 | 2.1 | 199L | 3958 | 8.7 | 2 | 80 | 177 | 20.3 | 36.7 | 2.5 |
| 31.5 | 2.1 | 202R | 4770 | 10.5 | 0 | 80 | 173 | 16.5 | 36.5 | 2.5 |
| 20.2 | 1.4 | 178R | 2441 | 5.4 | 4 | 80 | 113 | 20.9 | 22.9 | 1.5 |
| 26.0 | 1.8 | 191L | 3395 | 7.5 | 3 | 80 | 146 | 19.5 | 31.5 | 2.1 |
| 29.5 | 2.0 | 194R | 4032 | 8.9 | 5 | 80 | 155 | 17.4 | 32.1 | 2.2 |
| 31.6 | 2.1 | 211L | 4011 | 8.8 | 0 | 80 | 180 | 20.5 | 40.1 | 2.7 |
| 22.9 | 1.5 | 214R | 3469 | 7.6 | 2 | 80 | 145 | 19.1 | 32.0 | 2.2 |
| 28.1 | 1.9 | 219L | 3974 | 8.8 | 5 | 80 | 168 | 19.1 | 35.3 | 2.4 |
| 19.4 | 1.3 | 222R | 3121 | 6.9 | 6 | 80 | 129 | 18.7 | 26.7 | 1.8 |
| — | — | 154R | 3091 | 6.8 | 11 | 80 | 120 | 17.6 | — | — |
| 28.0 | 1.9 | ..... | 3856 | 8.5 | 5.8 | 80 | 160 | 19.0 | 34.7 | 2.4 |
| | | Round-bone chuck of beef | | | | | | | | |
| 37.7 | 2.5 | 232R | 4548 | 10.0 | 8 | 80 | 120 | 12.0 | 27.8 | 1.9 |
| — | — | 51L | 3814 | 8.4 | 8 | 80 | 131 | 15.6 | — | — |
| — | — | 79L | 3562 | 7.8 | 8 | 80 | 124 | 15.9 | — | — |
| — | — | 91L | 3463 | 7.6 | 8 | 80 | 125 | 16.4 | — | — |
| — | — | 69L | 2879 | 6.3 | 8 | 80 | 125 | 19.8 | — | — |
| 43.9 | 3.0 | 179L | 3579 | 7.9 | 10 | 80 | 119 | 15.1 | 26.4 | 1.8 |
| 38.5 | 2.6 | 182R | 3265 | 7.2 | 6 | 80 | 129 | 17.9 | 27.8 | 1.9 |
| — | — | 196R | 3467 | 7.6 | 6 | 80 | 140 | 18.4 | — | — |
| 43.5 | 2.9 | 197L | 3391 | 7.5 | 7 | 80 | 138 | 18.4 | 29.3 | 2.0 |
| 34.3 | 2.3 | 172R | 2626 | 5.8 | 8 | 80 | 129 | 22.2 | 27.1 | 1.8 |
| 37.4 | 2.5 | 173L | 2510 | 5.5 | 5 | 80 | 119 | 21.6 | 23.5 | 1.6 |
| — | — | 188R | 2800 | 6.2 | 7 | 80 | 115 | 18.5 | — | — |
| 42.0 | 2.8 | 189L | 3188 | 7.0 | 6 | 80 | 133 | 19.0 | 27.8 | 1.9 |
| 47.6 | 3.2 | 208R | 2567 | 5.7 | 6 | 80 | 120 | 21.1 | 25.4 | 1.7 |
| — | — | 209L | 3375 | 7.4 | 7 | 80 | 144 | 19.5 | — | — |
| 37.0 | 2.5 | 216R | 2687 | 5.9 | 4 | 80 | 123 | 20.8 | 26.5 | 1.8 |
| 35.1 | 2.4 | 217L | 2677 | 5.9 | 6 | 80 | 116 | 19.7 | 25.7 | 1.7 |
| 39.7 | 2.7 | ..... | 3200 | 7.0 | 6.9 | 80 | 126 | 18.3 | 26.7 | 1.8 |

*Preheating of ovens not included.

**Table D. The time and gas required to cook roasts well-done**

| Carcass | | Class | Ripening period in days | 125°C | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Weight of roast | | Internal temperature | | Time in oven minutes | |
| U. S. grade | Chilled weight pounds | | | Roast number | Grams | Pounds | Initial °C | Removal °C | Total | Per pound |
| **Rump of beef** | | | | | | | | | | |
| Choice | 500–600 | Steer | 9 | 28R | 3603 | 7.9 | 8 | 80 | 468 | 59.2 |
| | | Steer | 10 | 33L | 3894 | 8.6 | 7 | 80 | 485 | 56.4 |
| | | — | 10 | 56R | 3323 | 7.3 | 8 | 80 | 335 | 45.9 |
| | | Steer | 9 | 64R | 3215 | 7.1 | 7 | 80 | 419 | 59.0 |
| | | Steer | 13 | 76R | 3627 | 8.0 | 8 | 80 | 483 | 60.4 |
| | | Steer | 9 | 96R | 3512 | 7.7 | 8 | 80 | 385 | 50.0 |
| | 400–500 | Heifer | 10 | 36R | 3382 | 7.5 | 6 | 80 | 375 | 50.0 |
| | | Steer | 9 | 73L | 2744 | 6.0 | 7 | 80 | 463 | 77.2 |
| | | Steer | 9 | 94R | 3450 | 7.6 | 8 | 80 | 489 | 64.4 |
| Mean | | | 9.8 | | 3417 | 7.5 | 7.4 | 80 | 434 | 58.1 |
| **Half-ham of pork** | | | | | | | | | | |
| | 202 | Barrow | 7 | 156R | 4986 | 11.0 | 7 | 84 | 461 | 41.9 |
| | 172 | Gilt | 7 | 158R | 4905 | 10.8 | 7 | 84 | 408 | 37.8 |
| | 151† | Barrow | 7 | 131L | 4107 | 9.1 | 4 | 84 | 337 | 37.0 |
| | 130† | Barrow | 7 | 133L | 3777 | 8.3 | 6 | 84 | 294 | 35.4 |
| | 197 | Barrow | 8 | 125L | 4432 | 9.8 | 4 | 84 | 365 | 37.2 |
| | 196 | Barrow | 8 | 128R | 4618 | 10.2 | 6 | 84 | 356 | 34.9 |
| | 156 | Barrow | 7 | 121L | 3975 | 8.8 | 1 | 84 | 359 | 40.8 |
| | 125 | Gilt | 7 | 124R | 3314 | 7.3 | 0 | 85 | 358 | 49.0 |
| | 185 | Barrow | 7 | 303L | 5533 | 12.2 | 7 | 84 | 443 | 36.3 |
| | 171 | Barrow | 7 | 306R | 5203 | 11.5 | 4 | 84 | 405 | 35.2 |
| | 186 | Barrow | 6 | 319L | 5847 | 12.9 | 10 | 84 | 470 | 36.4 |
| | 199 | Gilt | 6 | 322R | 5046 | 11.1 | 9 | 84 | 390 | 35.1 |
| | 171 | Gilt | 7 | 335L | 4946 | 10.9 | 6 | 84 | 441 | 40.5 |
| | 170 | Barrow | 7 | 338R | 5465 | 12.0 | 4 | 84 | 393 | 32.8 |
| | 159 | Barrow | 6 | 351L | 4529 | 10.0 | 6 | 84 | 434 | 43.4 |
| | 155 | Barrow | 6 | 354R | 4132 | 9.1 | 7 | 84 | 363 | 39.9 |
| Mean | | | 6.9 | | 4676 | 10.3 | 5.5 | 84 | 392 | 38.4 |
| **Leg of lamb** | | | | | | | | | | |
| Choice | 46 | Wether | 7 | 203L | 2215 | 4.9 | 6 | 77 | 231 | 47.1 |
| | 54 | Wether | 7 | 206R | 2761 | 6.1 | 3 | 76 | 272 | 44.6 |
| Good | — | Wether | 7 | 144R | 1997 | 4.4 | 8 | 76 | 178 | 40.5 |
| | — | Ewe | 7 | 145L | 2426 | 5.3 | 10 | 76 | 222 | 41.9 |
| | 36 | Wether | 7 | 287L | 2111 | 4.7 | 11 | 76 | 195 | 41.5 |
| | 38 | Wether | 7 | 290R | 2161 | 4.8 | 6 | 76 | 189 | 39.4 |
| | 34 | Ewe | 7 | 315L | 1622 | 3.6 | 9 | 76 | 155 | 43.1 |
| | 38 | Ewe | 7 | 318R | 1615 | 3.5 | 12 | 76 | 145 | 41.4 |
| Medium | 29 | Wether | 6 | 299L | 1646 | 3.6 | 11 | 76 | 185 | 51.4 |
| | 30 | Wether | 6 | 302R | 1712 | 3.8 | 10 | 76 | 179 | 47.1 |
| | 34 | Wether | 6 | 331L | 1915 | 4.2 | 12 | 76 | 185 | 44.1 |
| | 38 | Wether | 6 | 334R | 2141 | 4.7 | 11 | 76 | 179 | 38.1 |
| | 39 | Wether | 7 | 347L | 2439 | 5.4 | 10 | 76 | 221 | 40.9 |
| | 40 | Wether | 7 | 350R | 2156 | 4.7 | 10 | 76 | 200 | 42.6 |
| Mean | | | 6.7 | | 2066 | 4.6 | 9.2 | 76 | 195 | 43.1 |

†Warm weight of carcass.

**at constant oven temperatures of 125°C and 225°C—Continued.**

| | | 225°C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Gas* | | Roast number | Weight of roast | | Internal temperature | | Time in oven minutes | | Gas* | |
| Cubic feet | Cost cents | | Grams | Pounds | Initial °C | Removal °C | Total | Per pound | Cubic feet | Cost cents |
| | | | | Rump of beef | | | | | | |
| — | — | 27L | 3731 | 8.2 | 8 | 80 | 125 | 15.2 | — | — |
| — | — | 34R | 3989 | 8.8 | 6 | 80 | 148 | 16.8 | — | — |
| — | — | 55L | 3372 | 7.4 | 7 | 80 | 114 | 15.4 | — | — |
| — | — | 63L | 3376 | 7.5 | 8 | 80 | 130 | 17.3 | — | — |
| — | — | 75L | 3783 | 8.3 | 10 | 80 | 114 | 13.7 | — | — |
| — | — | 95L | 4136 | 9.1 | 8 | 80 | 131 | 14.4 | — | — |
| — | — | 35L | 3708 | 8.2 | 6 | 80 | 130 | 15.8 | — | — |
| — | — | 74R | 3304 | 7.3 | 10 | 80 | 113 | 15.5 | — | — |
| — | — | 93L | 3829 | 8.4 | 8 | 80 | 124 | 14.8 | — | — |
| — | — | ..... | 3692 | 8.1 | 7.9 | 80 | 125 | 15.4 | — | — |
| | | | | Half-ham of pork | | | | | | |
| 35.0 | 2.3 | 155L | 5390 | 11.9 | 10 | 84 | 220 | 18.5 | 44.8 | 3.0 |
| 31.2 | 2.1 | 157L | 5702 | 12.6 | 8 | 84 | 190 | 15.1 | 39.1 | 2.6 |
| 26.5 | 1.8 | 132R | 4079 | 9.0 | 6 | 84 | 169 | 18.8 | 34.6 | 2.3 |
| 23.4 | 1.6 | 134R | 4078 | 9.0 | 7 | 84 | 176 | 19.6 | 35.0 | 2.4 |
| 27.5 | 1.9 | 126R | 4234 | 9.3 | 5 | 84 | 153 | 16.5 | 30.3 | 2.0 |
| 27.2 | 1.8 | 127L | 5420 | 11.9 | 6 | 84 | 197 | 16.6 | 39.8 | 2.7 |
| — | — | 122R | 4147 | 9.1 | 1 | 84 | 187 | 20.5 | — | — |
| — | — | 123L | 3219 | 7.1 | 0 | 84 | 178 | 25.1 | — | — |
| 32.8 | 2.2 | 304R | 5536 | 12.2 | 7 | 84 | 225 | 18.4 | 45.3 | 3.1 |
| 29.7 | 2.0 | 305L | 4946 | 10.9 | 6 | 84 | 200 | 18.3 | 29.5 | 2.0 |
| 38.3 | 2.6 | 320R | 5830 | 12.9 | 7 | 84 | 237 | 18.4 | 39.0 | 2.6 |
| 30.9 | 2.1 | 321L | 5367 | 11.8 | 8 | 84 | 205 | 17.4 | 40.8 | 2.8 |
| 34.9 | 2.4 | 336R | 5353 | 11.8 | 6 | 84 | 218 | 18.5 | 47.6 | 3.2 |
| 32.5 | 2.2 | 337L | 5506 | 12.1 | 4 | 84 | 218 | 18.0 | 45.2 | 3.1 |
| 33.2 | 2.2 | 352R | 4904 | 10.8 | 5 | 84 | 200 | 18.5 | 43.4 | 2.9 |
| 27.9 | 1.9 | 353L | 4159 | 9.1 | 6 | 84 | 183 | 20.1 | 36.1 | 2.4 |
| 30.8 | 2.1 | ..... | 4867 | 10.7 | 5.8 | 84 | 197 | 18.6 | 39.3 | 2.7 |
| | | | | Leg of lamb | | | | | | |
| 17.5 | 1.2 | 204R | 2235 | 4.9 | 5 | 78 | 107 | 21.8 | 21.4 | 1.4 |
| 21.0 | 1.4 | 205L | 2889 | 6.4 | 3 | 76 | 140 | 21.9 | 28.3 | 1.9 |
| — | — | 143L | 1978 | 4.4 | 8 | 76 | 82 | 18.6 | — | — |
| — | — | 146R | 2344 | 5.2 | 8 | 76 | 102 | 19.6 | — | — |
| 14.1 | 1.0 | 288R | 2106 | 4.6 | 12 | 76 | 86 | 18.7 | 17.1 | 1.2 |
| 13.1 | 0.9 | 289L | 2270 | 5.0 | 8 | 76 | 90 | 18.0 | 17.1 | 1.2 |
| — | — | 316R | 1646 | 3.6 | 10 | 76 | 70 | 19.4 | — | — |
| — | — | 317L | 1611 | 3.5 | 12 | 76 | 67 | 19.1 | — | — |
| 13.6 | 0.9 | 300R | 1702 | 3.7 | 8 | 76 | 81 | 21.9 | 16.1 | 1.1 |
| 12.6 | 0.9 | 301L | 1724 | 3.8 | 10 | 76 | 87 | 22.9 | 16.0 | 1.1 |
| — | — | 332R | 1921 | 4.2 | 10 | 76 | 72 | 17.1 | — | — |
| — | — | 333L | 2099 | 4.6 | 10 | 76 | 77 | 16.7 | — | — |
| — | — | 348R | 2421 | 5.3 | 10 | 76 | 106 | 20.0 | — | — |
| 15.4 | 1.0 | 349L | 2225 | 4.9 | 9 | 76 | 91 | 18.6 | 17.8 | 1.2 |
| 15.3 | 1.0 | ..... | 2084 | 4.6 | 8.8 | 76.1 | 90 | 19.6 | 19.1 | 1.3 |

*Preheating of ovens not included.

**Table E. The relationship of tenderness ratio to various**

| Carcass | | Class | Ripening period days | Roast numbers | | Weight of roast (pounds) | | Initial Internal temperature | |
|---|---|---|---|---|---|---|---|---|---|
| Grade U. S. | Weight pounds | | | 125°C | 225°C | 125°C | 225°C | 125°C | 225°C |
| 9th, 10th, and 11th rib roasts of beef | | | | | | | | | |
| Choice | 500–600 | Steer | 11 | 38R | 37L | 9.5 | 9.7 | 8 | 6 |
| Choice | 500–600 | — | 11 | 59L | 60R | 7.7 | 7.8 | 8 | 10 |
| Choice | 400–500 | Steer | 10 | 78R | 77L | 6.8 | 6.7 | 8 | 8 |
| Choice | 400–500 | Steer | 10 | 98R | 97L | 7.4 | 7.8 | 7 | 8 |
| Common | 500–600 | Steer | 10 | 192R | 191L | 7.2 | 7.5 | 1 | 3 |
| Choice | 400–500 | Heifer | 11 | 39L | 40R | 9.5 | 9.2 | 6 | — |
| Good | 564 | Steer | 10 | 185L | 186R | 10.4 | 9.6 | 5 | 5 |
| Medium | 500–600 | Steer | 10 | 200R | 199L | 9.5 | 8.7 | 2 | 2 |
| Common | 500–600 | Steer | 11 | 212R | 211L | 8.0 | 8.8 | 0 | 0 |
| Medium | 500–600 | Steer | 10 | 201L | 202R | 9.0 | 10.5 | 2 | 0 |
| Common | 500–600 | Steer | 10 | 220R | 219L | 8.5 | 8.8 | 5 | 5 |
| Common | 500–600 | Steer | 10 | 193L | 194R | 9.9 | 8.9 | 1 | 5 |
| Choice | 400–500 | — | 10 | 58R | 57L | 7.7 | 8.2 | 8 | 9 |
| Medium | 345 | Steer | 11 | 177L | 178R | 5.9 | 5.4 | 6 | 4 |
| Common | 500–600 | Steer | 11 | 213L | 214R | 7.4 | 7.6 | 1 | 2 |
| Choice | 500–600 | Steer | 10 | 67L | 68R | 8.1 | 8.3 | 6 | 8 |
| Choice | 500–600 | Steer | 10 | 72R | 71L | 8.6 | 7.9 | 6 | 6 |
| Common | 430 | Cow | 11 | 153L | 154R | 6.9 | 6.8 | 9 | 11 |
| Prime | 630 | Steer | 10 | 233L | 234R | 11.8 | 12.3 | 6 | 2 |
| Good | 594 | Steer | 10 | 184R | 183L | 10.6 | 11.2 | 4 | 6 |
| Choice | 400–500 | Steer | 10 | 29L | 30R | 7.6 | 7.8 | 7 | 7 |
| Common | 500–600 | Steer | 10 | 221L | 222R | 6.7 | 6.9 | 7 | 6 |
| Choice | 400–500 | Heifer | 11 | 65L | 66R | 7.3 | 6.9 | 6 | 8 |
| Choice | 500–600 | Steer | 10 | 99L | 100R | 8.1 | 8.6 | 7 | 8 |
| Medium | 500–600 | Cow | 11 | 152R | 151L | 12.3 | 10.5 | 7 | 9 |
| Mean | | | 10.4 | | | 8.5 | 8.5 | 5.3 | 5.8 |
| Round-bone chuck roasts of beef | | | | | | | | | |
| Prime | 630 | Steer | 10 | 231L | 232R | 8.8 | 10.0 | 8 | 8 |
| Choice | 500–600 | Steer | 14 | 80R | 79L | 6.1 | 7.8 | 8 | 8 |
| Choice | 500–600 | Steer | 6 | 92R | 91L | 6.5 | 7.6 | 8 | 8 |
| Choice | 400–500 | Steer | 6 | 70R | 69L | 6.1 | 6.3 | 8 | 8 |
| Good | 594 | Steer | 9 | 180R | 179L | 7.5 | 7.9 | 7 | 10 |
| Good | 564 | Steer | 9 | 181L | 182R | 7.4 | 7.2 | 6 | 6 |
| Medium | 593 | Steer | 9 | 195L | 196R | 8.1 | 7.6 | 8 | 6 |
| Medium | 587 | Steer | 9 | 198R | 197L | 6.9 | 7.5 | 7 | 7 |
| Medium | 345 | Steer | 10 | 174R | 173L | 5.6 | 5.5 | 6 | 5 |
| Common | 512 | Steer | 9 | 187L | 188R | 6.4 | 6.2 | 8 | 7 |
| Common | 579 | Steer | 9 | 190R | 189L | 6.6 | 7.0 | 8 | 6 |
| Common | 521 | Steer | 9 | 207L | 208R | 7.2 | 5.7 | 5 | 6 |
| Common | 575 | Steer | 9 | 210R | 209L | 6.8 | 7.4 | 5 | 7 |
| Common | 520 | Steer | 9 | 215L | 216R | 5.5 | 5.9 | 2 | 4 |
| Common | 503 | Steer | 9 | 218R | 217L | 5.5 | 5.9 | 4 | 6 |
| Medium | 322 | Steer | 10 | 171L | 172R | 5.5 | 5.8 | 6 | 8 |
| Choice | 500–600 | — | 7 | 52R | 51L | 6.3 | 8.4 | 10 | 8 |
| Mean | | | 9.0 | | | 6.6 | 7.0 | 6.7 | 6.9 |

**other factors in individual well-done roasts.**

| Time in oven (minutes) | | | Cooking losses | | | | | | | | | Tenderness ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Volatile (percentage) | | | Fat in drippings (percentage) | | | Total (percentage) | | | |
| 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | |
| 9th, 10th, and 11th rib roasts of beef | | | | | | | | | | | | |
| 439 | 180 | 259 | 16.7 | 24.1 | 7.4 | 11.1 | 16.4 | 5.3 | 28.6 | 41.9 | 13.3 | 1.0000 |
| 307 | 135 | 172 | 11.4 | 20.0 | 8.6 | 6.9 | 14.1 | 7.2 | 19.2 | 34.6 | 15.4 | 1.0000 |
| 325 | 139 | 186 | 17.4 | 24.5 | 7.1 | 4.0 | 8.3 | 4.3 | 23.1 | 33.5 | 10.4 | 1.0000 |
| 348 | 159 | 189 | 17.5 | 27.2 | 9.7 | 3.6 | 9.4 | 5.8 | 22.6 | 37.5 | 14.9 | 1.0000 |
| 320 | 146 | 174 | 16.4 | 26.7 | 10.3 | 4.3 | 7.2 | 2.9 | 22.1 | 34.9 | 12.8 | 1.0000 |
| 395 | 186 | 209 | 13.8 | 23.7 | 9.9 | 9.8 | 19.3 | 9.5 | 24.7 | 44.1 | 19.4 | 0.9667 |
| 383 | 168 | 215 | 12.9 | 21.8 | 8.9 | 8.8 | 15.6 | 6.8 | 23.1 | 38.7 | 15.6 | 0.9500 |
| 392 | 177 | 215 | 16.9 | 26.8 | 9.9 | 5.4 | 11.3 | 5.9 | 24.9 | 39.1 | 14.2 | 0.8500 |
| 395 | 180 | 215 | 21.1 | 33.3 | 12.2 | 1.5 | 2.1 | 0.6 | 24.7 | 36.4 | 11.7 | 0.8500 |
| 410 | 173 | 237 | 18.2 | 24.2 | 6.0 | 9.1 | 12.8 | 3.7 | 29.5 | 38.0 | 8.5 | 0.8000 |
| 348 | 168 | 180 | 18.9 | 29.7 | 10.8 | —— | —— | —— | 22.0 | 34.2 | 12.2 | 0.8000 |
| 366 | 155 | 211 | 15.8 | 24.1 | 8.3 | 5.1 | 9.6 | 4.5 | 22.5 | 34.7 | 12.2 | 0.7500 |
| 340 | 156 | 184 | 14.3 | 22.9 | 8.6 | 7.1 | 14.0 | 6.9 | 22.3 | 37.5 | 15.2 | 0.7500 |
| 267 | 113 | 154 | 16.0 | 25.8 | 9.8 | 3.6 | 2.6 | —1.0 | 19.9 | 30.2 | 10.3 | 0.7500 |
| 285 | 145 | 140 | 15.5 | 26.3 | 10.8 | 2.8 | 6.0 | 3.2 | 20.1 | 32.8 | 12.7 | 0.7222 |
| 325 | 160 | 165 | 15.2 | 26.1 | 10.9 | 5.0 | 11.7 | 6.7 | 21.3 | 38.7 | 17.4 | 0.6667 |
| 356 | 156 | 200 | 13.3 | 21.1 | 7.8 | 8.9 | 17.2 | 8.3 | 22.9 | 38.9 | 16.0 | 0.6667 |
| 360 | 120 | 240 | 16.7 | 23.7 | 7.0 | 7.6 | 10.2 | 2.6 | 25.6 | 34.8 | 9.2 | 0.5625 |
| 435 | 217 | 218 | 11.2 | 21.1 | 9.9 | 13.4 | 27.2 | 13.8 | 25.9 | 49.3 | 23.4 | 0.4375 |
| 415 | 197 | 218 | 11.9 | 22.7 | 10.8 | 9.0 | 18.2 | 9.2 | 22.4 | 42.1 | 19.7 | 0.4000 |
| 340 | 155 | 185 | 16.3 | 23.6 | 7.3 | 4.8 | 13.2 | 8.4 | 22.2 | 37.6 | 15.4 | 0.3750 |
| 286 | 129 | 157 | 18.7 | 26.5 | 7.8 | —— | —— | —— | 21.1 | 29.8 | 8.7 | 0.3500 |
| 290 | 135 | 155 | 13.1 | 24.5 | 11.4 | 4.8 | 10.9 | 6.1 | 19.1 | 36.2 | 17.1 | 0.1111 |
| 310 | 176 | 134 | 13.4 | 27.5 | 14.1 | 4.4 | 10.5 | 6.1 | 19.0 | 38.8 | 19.8 | 0.0833 |
| 410 | 185 | 225 | 15.5 | 25.9 | 10.4 | 8.6 | 15.2 | 6.6 | 25.4 | 42.1 | 16.7 | 0.0000 |
| 354 | 160 | 193 | 15.5* | 25.0* | 9.4 | 6.5 | 12.3 | 5.8 | 23.0* | 37.5* | 14.5 | |
| Round-bone chuck roasts of beef | | | | | | | | | | | | |
| 455 | 120 | 335 | 20.4 | 19.6 | 0.8 | 7.4 | 15.3 | 7.9 | 29.1 | 36.4 | 7.3 | 1.0000 |
| 319 | 124 | 195 | 22.2 | 22.2 | 0.0 | 1.9 | 9.1 | 7.2 | 26.5 | 32.6 | 6.1 | 1.0000 |
| 457 | 125 | 332 | 28.3 | 26.2 | —2.1 | 2.1 | 6.1 | 4.0 | 31.7 | 33.6 | 1.9 | 1.0000 |
| 433 | 125 | 308 | 28.8 | 27.4 | —1.4 | 1.3 | 3.6 | 2.3 | 31.7 | 32.5 | 0.8 | 1.0000 |
| 561 | 119 | 442 | 27.4 | 22.1 | —5.3 | 5.8 | 8.2 | 2.4 | 34.7 | 31.5 | —3.2 | 1.0000 |
| 490 | 129 | 361 | 26.2 | 26.9 | 0.7 | 4.2 | 8.8 | 4.6 | 31.9 | 37.0 | 5.1 | 1.0000 |
| 615 | 140 | 475 | 32.8 | 31.1 | —1.7 | 4.3 | 4.4 | 0.1 | 38.7 | 37.1 | —1.6 | 1.0000 |
| 565 | 138 | 427 | 31.5 | 29.5 | —2.0 | 4.0 | 5.7 | 1.7 | 37.4 | 36.5 | —0.9 | 1.0000 |
| 502 | 119 | 383 | 29.5 | 27.5 | —2.0 | 3.9 | 3.6 | —0.3 | 34.6 | 32.3 | —2.3 | 1.0000 |
| 570 | 115 | 455 | 31.2 | 27.7 | —3.5 | 5.1 | 3.2 | —1.9 | 38.0 | 32.6 | —5.4 | 1.0000 |
| 556 | 133 | 423 | 30.7 | 29.8 | —0.9 | 4.2 | 4.8 | 0.6 | 36.6 | 36.3 | —0.3 | 1.0000 |
| 618 | 120 | 498 | 35.9 | 30.5 | —5.4 | 0.8 | 0.9 | 0.1 | 38.7 | 33.2 | —5.5 | 1.0000 |
| 517 | 144 | 373 | 32.0 | 30.7 | —1.3 | 2.2 | 3.9 | 1.7 | 35.9 | 35.7 | —0.2 | 1.0000 |
| 473 | 123 | 350 | 31.6 | 31.4 | —0.2 | 1.8 | 1.7 | —0.1 | 35.0 | 34.5 | —0.5 | 1.0000 |
| 451 | 116 | 335 | 30.9 | 32.3 | 1.4 | 2.4 | 1.7 | —0.7 | 34.9 | 35.4 | 0.5 | 1.0000 |
| 455 | 129 | 326 | 25.9 | 30.7 | 4.8 | 2.5 | 4.5 | 2.0 | 29.9 | 36.3 | 6.4 | 0.8125 |
| 414 | 131 | 283 | 24.0 | 21.1 | —2.9 | 4.6 | 11.9 | 7.3 | 29.8 | 33.9 | 4.1 | 0.7143 |
| 497 | 126 | 371 | 28.8* | 27.5* | —1.2 | 3.4 | 5.7 | 2.3 | 33.8* | 34.6* | 0.7 | |

*These means are subject to the criticism that the temperature, humidity, and length of storage period varied considerably with the different pairs of roasts.

**Table E. The relationship of tenderness ratio to various**

| Carcass | | Class | Ripening period days | Roast numbers | | Weight of roast (pounds) | | Initial Internal temperature | |
|---|---|---|---|---|---|---|---|---|---|
| Grade U. S. | Weight pounds | | | 125°C | 225°C | 125°C | 225°C | 125°C | 225°C |
| **Rump roasts of beef** | | | | | | | | | |
| Choice | 500–600 | Steer | 9 | 28R | 27L | 7.9 | 8.2 | 8 | 8 |
| Choice | 500–600 | Steer | 10 | 33L | 34R | 8.6 | 8.8 | 7 | 6 |
| Choice | 500–600 | Steer | 13 | 76R | 75L | 8.0 | 8.3 | 8 | 10 |
| Choice | 400–500 | Steer | 9 | 73L | 74R | 6.0 | 7.3 | 7 | 10 |
| Choice | 400–500 | Steer | 9 | 94R | 93L | 7.6 | 8.4 | 8 | 8 |
| Choice | 500–600 | Steer | 9 | 64R | 63L | 7.1 | 7.5 | 7 | 8 |
| Choice | 400–500 | Heifer | 10 | 36R | 35L | 7.5 | 8.2 | 6 | 6 |
| Choice | 500–600 | — | 10 | 56R | 55L | 7.3 | 7.4 | 8 | 7 |
| Choice | 500–600 | Steer | 9 | 96R | 95L | 7.7 | 9.1 | 8 | 8 |
| Mean | | | 9.8 | | | 7.5 | 8.1 | 7.4 | 7.9 |
| **Half-ham roasts of pork** | | | | | | | | | |
| | 202 | Barrow | 7 | 156R | 155L | 11.0 | 11.9 | 7 | 10 |
| | 171 | Barrow | 7 | 306R | 305L | 11.5 | 10.9 | 4 | 6 |
| | 155 | Barrow | 6 | 354R | 353L | 9.1 | 9.1 | 7 | 6 |
| | 170 | Barrow | 7 | 338R | 337L | 12.0 | 12.1 | 4 | 4 |
| | 197 | Barrow | 8 | 125L | 126R | 9.8 | 9.3 | 4 | 5 |
| | 196 | Barrow | 8 | 128R | 127L | 10.2 | 11.9 | 6 | 6 |
| | 151 | Barrow | 7 | 131L | 132R | 9.1 | 9.0 | 4 | 6 |
| | 130 | Barrow | 7 | 133L | 134R | 8.3 | 9.0 | 6 | 7 |
| | 199 | Gilt | 6 | 322R | 321L | 11.1 | 11.8 | 9 | 8 |
| | 171 | Gilt | 7 | 335L | 336R | 10.9 | 11.8 | 6 | 6 |
| | 186 | Barrow | 6 | 319L | 320R | 12.9 | 12.9 | 10 | 7 |
| | 185 | Barrow | 7 | 303L | 304R | 12.2 | 12.2 | 7 | 7 |
| | 172 | Gilt | 7 | 158R | 157L | 10.8 | 12.6 | 7 | 8 |
| | 156 | Barrow | 7 | 121L | 122R | 8.8 | 9.1 | 1 | 1 |
| | 125 | Gilt | 7 | 124R | 123L | 7.3 | 7.1 | 0 | 0 |
| | 159 | Barrow | 6 | 351L | 352R | 10.0 | 10.8 | 6 | 5 |
| Mean | | | 6.9 | | | 10.3 | 10.7 | 5.5 | 5.8 |
| **Leg of lamb roasts** | | | | | | | | | |
| Choice | 46 | Wether | 7 | 203L | 204R | 4.9 | 4.9 | 6 | 5 |
| Medium | 29 | Wether | 6 | 299L | 300R | 3.6 | 3.7 | 11 | 8 |
| Good | —— | Wether | 7 | 144R | 143L | 4.4 | 4.4 | 8 | 8 |
| Good | 34 | Ewe | 7 | 315L | 316R | 3.6 | 3.6 | 9 | 10 |
| Medium | 38 | Wether | 6 | 334R | 333L | 4.7 | 4.6 | 11 | 10 |
| Good | 38 | Wether | 7 | 290R | 289L | 4.8 | 5.0 | 6 | 8 |
| Good | 38 | Ewe | 7 | 318R | 317L | 3.5 | 3.5 | 12 | 12 |
| Good | 36 | Wether | 7 | 287L | 288R | 4.7 | 4.6 | 11 | 12 |
| Medium | 30 | Wether | 6 | 302R | 301L | 3.8 | 3.8 | 10 | 10 |
| Medium | 40 | Wether | 7 | 350R | 349L | 4.7 | 4.9 | 10 | 9 |
| Medium | 39 | Wether | 7 | 347L | 348R | 5.4 | 5.3 | 10 | 10 |
| Good | —— | Ewe | 7 | 145L | 146R | 5.3 | 5.2 | 10 | 8 |
| Choice | 54 | Wether | 7 | 206R | 205L | 6.1 | 6.4 | 3 | 3 |
| Medium | 34 | Wether | 6 | 331L | 332R | 4.2 | 4.2 | 12 | 10 |
| Mean | | | 6.7 | | | 4.6 | 4.6 | 9.2 | 8.8 |

**other factors in individual well-done roasts—Continued.**

| Time in oven (minutes) | | | Cooking losses | | | | | | | | | Tenderness ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Volatile (percentage) | | | Fat in drippings (percentage) | | | Total (percentage) | | | |
| 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | |
| **Rump roasts of beef** | | | | | | | | | | | | |
| 468 | 125 | 343 | 21.8 | 23.0 | 1.2 | 4.6 | 6.9 | 2.3 | 27.3 | 30.5 | 3.2 | 1.0000 |
| 485 | 148 | 337 | 22.0 | 24.5 | 2.5 | 5.7 | 7.3 | 1.6 | 29.0 | 32.5 | 3.5 | 1.0000 |
| 483 | 114 | 369 | 22.2 | 19.4 | —2.8 | 6.2 | 8.5 | 2.3 | 29.7 | 28.8 | —0.9 | 1.0000 |
| 463 | 113 | 350 | 25.1 | 24.3 | —0.8 | 3.1 | 3.8 | 0.7 | 29.7 | 29.4 | —0.3 | 1.0000 |
| 489 | 124 | 365 | 27.6 | 23.4 | —4.2 | 2.1 | 4.4 | 2.3 | 31.7 | 28.9 | —2.8 | 1.0000 |
| 419 | 130 | 289 | 23.7 | 24.9 | 1.2 | 2.5 | 2.1 | —0.4 | 28.5 | 28.5 | 0.0 | 0.9500 |
| 375 | 130 | 245 | 16.3 | 19.7 | 3.4 | 5.2 | 10.0 | 4.8 | 22.7 | 30.7 | 8.0 | 0.9500 |
| 335 | 114 | 221 | 16.0 | 20.1 | 4.1 | 6.0 | 8.4 | 2.4 | 23.2 | 29.4 | 6.2 | 0.9167 |
| 385 | 131 | 254 | 19.6 | 23.6 | 4.0 | 3.7 | 4.6 | 0.9 | 24.8 | 29.3 | 4.5 | 0.5000 |
| 434 | 125 | 308 | 21.6* | 22.5* | 1.0 | 4.3 | 6.2 | 1.9 | 27.4* | 29.8* | 2.4 | |
| **Half-ham roasts of pork** | | | | | | | | | | | | |
| 461 | 220 | 241 | 16.4 | 27.6 | 11.2 | 5.6 | 9.6 | 4.0 | 26.8 | 38.9 | 11.1 | 1.0000 |
| 405 | 200 | 205 | 12.1 | 22.6 | 10.5 | — | — | — | 26.3 | 35.0 | 8.7 | 1.0000 |
| 363 | 183 | 180 | 14.3 | 24.6 | 10.3 | — | — | — | 28.7 | 36.7 | 8.0 | 1.0000 |
| 393 | 218 | 185 | 16.7 | 27.4 | 10.7 | — | — | — | 24.8 | 35.3 | 10.5 | 0.9286 |
| 365 | 153 | 212 | 13.3 | 22.8 | 9.5 | 6.7 | 8.2 | 1.5 | 25.3 | 32.1 | 6.8 | 0.9167 |
| 356 | 197 | 159 | 14.8 | 25.6 | 10.8 | 4.2 | 8.6 | 4.4 | 23.9 | 35.6 | 11.7 | 0.8750 |
| 337 | 169 | 168 | 14.3 | 24.5 | 10.2 | — | — | — | 26.4 | 35.8 | 9.4 | 0.8750 |
| 294 | 176 | 118 | 13.4 | 26.2 | 12.8 | — | — | — | 22.1 | 31.1 | 9.0 | 0.8750 |
| 390 | 205 | 185 | 13.0 | 22.7 | 9.7 | — | — | — | 25.0 | 35.5 | 10.5 | 0.8750 |
| 441 | 218 | 223 | 16.3 | 26.4 | 10.1 | — | — | — | 26.4 | 36.7 | 10.3 | 0.8333 |
| 470 | 237 | 233 | 14.7 | 25.2 | 10.5 | — | — | — | 26.3 | 35.6 | 9.3 | 0.7083 |
| 443 | 225 | 218 | 12.8 | 24.5 | 11.7 | — | — | — | 29.2 | 38.3 | 9.1 | 0.7000 |
| 408 | 190 | 218 | 17.4 | 23.9 | 6.5 | 6.1 | 9.0 | 2.9 | 28.1 | 34.2 | 6.1 | 0.6250 |
| 359 | 187 | 172 | 17.7 | 28.7 | 11.0 | 5.3 | 7.7 | 2.4 | 29.2 | 38.3 | 9.1 | 0.5909 |
| 358 | 178 | 180 | 18.2 | 28.2 | 10.0 | 5.2 | 8.9 | 3.7 | 27.9 | 38.7 | 10.8 | 0.2083 |
| 434 | 200 | 234 | 17.4 | 27.0 | 9.6 | — | — | — | 32.1 | 39.0 | 6.9 | 0.2000 |
| 392 | 197 | 196 | 15.2* | 25.5* | 10.3 | 5.5 | 8.7 | 3.1 | 26.8* | 36.1* | 9.2 | |
| **Leg of lamb roasts** | | | | | | | | | | | | |
| 231 | 107 | 124 | 13.5 | 22.2 | 8.7 | — | — | — | 19.1 | 31.8 | 12.7 | 0.8333 |
| 185 | 81 | 104 | 12.0 | 21.1 | 9.1 | — | — | — | 17.2 | 26.9 | 9.7 | 0.7500 |
| 178 | 82 | 96 | 9.5 | 22.0 | 12.5 | — | — | — | 13.8 | 26.3 | 12.5 | 0.7083 |
| 155 | 70 | 85 | — | — | — | — | — | — | — | — | — | 0.6842 |
| 179 | 77 | 102 | 10.5 | 18.2 | 7.7 | — | — | — | 14.4 | 21.1 | 6.7 | 0.6250 |
| 189 | 90 | 99 | 9.4 | 21.8 | 12.4 | — | — | — | 13.5 | 27.5 | 14.0 | 0.5833 |
| 145 | 67 | 78 | 7.5 | 17.1 | 9.6 | — | — | — | 11.3 | 23.1 | 11.8 | 0.5333 |
| 195 | 86 | 109 | 12.0 | 21.8 | 9.8 | — | — | — | 17.0 | 26.7 | 9.7 | 0.5000 |
| 179 | 87 | 92 | 10.6 | 20.5 | 9.9 | — | — | — | 15.5 | 27.7 | 12.2 | 0.5000 |
| 200 | 91 | 109 | 12.2 | 22.1 | 9.1 | — | — | — | 16.3 | 25.4 | 9.1 | 0.5000 |
| 221 | 106 | 115 | — | — | — | — | — | — | — | — | — | 0.3333 |
| 222 | 102 | 120 | 12.1 | 26.1 | 14.0 | — | — | — | 17.9 | 31.0 | 13.1 | 0.2000 |
| 272 | 140 | 132 | 13.0 | 24.9 | 11.9 | — | — | — | 25.8 | 38.6 | 12.8 | 0.1667 |
| 185 | 72 | 113 | 10.9 | 17.8 | 6.9 | — | — | — | 14.9 | 21.7 | 6.8 | 0.1667 |
| 195 | 90 | 106 | 11.1* | 21.3* | 10.1 | — | — | — | 16.4* | 27.3* | 10.9 | |

*These means are subject to the criticism that the temperature, humidity, and length of storage period varied considerably with the different pairs of roasts.

**Table F. Removal temperature, time and gas required to obtain medium-**

| Carcass | | Class | Ripening period days | 125°C | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Weight of roast | | Internal temperature | | | Time in minutes | | | |
| U. S. grade | Weight lbs. | | | Roast number | | | Initial °C | Removal °C | Maximum °C | In oven | | To reach maximum | |
| | | | | | Grams | Pounds | | | | Total | Per pound | Total | Per pound |
| 9th, 10th, and 11th ribs of beef | | | | | | | | | | | | | |
| — | 398 | Heifer | 10 | 244R | 2265 | 5.0 | 7 | 52 | 60† | 130 | 26.0 | 30 | 6.0 |
| Good | 650 | Steer | 11 | 238R | 5470 | 12.1 | 1 | 58 | 64† | 275 | 22.7 | 53 | 4.4 |
| | 519 | Steer | 9 | 239L | 4152 | 9.2 | 8 | 58 | 66† | 201 | 21.8 | 44 | 4.8 |
| | 503 | Steer | 8 | 346R | 4245 | 9.3 | 7 | 55 | 61 | 183 | 19.7 | 42 | 4.5 |
| | 510 | Steer | 9 | 376R | 3773 | 8.3 | 6 | 55 | 61 | 165 | 19.9 | 45 | 5.4 |
| | 579 | Steer | 8 | 379L | 4332 | 9.5 | 4 | 55 | 62 | 209 | 22.0 | 41 | 4.3 |
| | 412 | Heifer | 9 | 279L | 3370 | 7.4 | 8 | 55 | 61 | 160 | 21.6 | 38 | 5.1 |
| | 420 | Heifer | 9 | 282R | 3550 | 7.8 | 10 | 55 | 62 | 150 | 19.2 | 30 | 3.8 |
| | 499 | Steer | 8 | 343L | 3926 | 8.6 | 6 | 55 | 63 | 190 | 22.1 | 45 | 5.2 |
| Medium | 477 | Steer | 8 | 295L | 3695 | 8.1 | 6 | 55 | 62 | 178 | 22.0 | 42 | 5.2 |
| | 447 | Steer | 8 | 298R | 3266 | 7.2 | 6 | 55 | 62 | 164 | 22.8 | 31 | 4.3 |
| | 480 | Steer | 9 | 327L | 4007 | 8.8 | 3 | 55 | 63 | 194 | 22.0 | 51 | 5.8 |
| | 482 | Steer | 9 | 330R | 3382 | 7.5 | 4 | 55 | 63 | 170 | 22.7 | 35 | 4.7 |
| | 462 | Cow | 9 | 365L | 3725 | 8.2 | 8 | 56 | 64 | 180 | 22.0 | 35 | 4.3 |
| | 336 | — | — | 246R | 2150 | 4.7 | 10 | 54 | 63 | 146 | 31.1 | 34 | 7.2 |
| | 352 | Steer | 6 | 271L | 2479 | 5.5 | 5 | 55 | 62 | 150 | 27.3 | 35 | 6.4 |
| | 383 | Steer | 6 | 274R | 2614 | 5.8 | 6 | 55 | 63 | 145 | 25.0 | 40 | 6.9 |
| Common | 506 | Bull (?) | 7 | 278R | 4033 | 8.9 | 4 | 55 | 65 | 190 | 21.3 | 55 | 6.2 |
| | 489 | Steer | 9 | 253L | 3409 | 7.5 | 8 | 54 | 61 | 154 | 20.5 | 36 | 4.8 |
| | 466 | Steer | 9 | 256R | 3193 | 7.0 | 8 | 54 | 60 | 149 | 21.3 | 36 | 5.1 |
| | 499 | Steer | 8 | 260R | 3666 | 8.1 | 7 | 55 | 63 | 175 | 21.6 | 40 | 4.9 |
| | 416 | Steer | 7 | 275L | 2722 | 6.0 | 7 | 55 | 63 | 150 | 25.0 | 40 | 6.7 |
| | 416 | Cow | 9 | 311L | 3470 | 7.7 | 8 | 55 | 62 | 177 | 23.0 | 38 | 4.9 |
| | 421 | Cow | 9 | 314R | 2887 | 6.3 | 6 | 55 | 60 | 153 | 23.9 | 27 | 4.2 |
| | 420 | Cow | 9 | 362R | 2880 | 6.3 | 8 | 56 | 62 | 141 | 22.4 | 44 | 7.0 |
| Mean... | ..... | ..... | 8.2 | ..... | 3399 | 7.5 | 6.6 | 55.0 | 62.2 | 167 | 22.7 | 39 | 5.3 |

†Data from these roasts were not used in computing the means nor in the test for palatability.

**rare roasts of beef at constant oven temperatures of 125°C and 225°C.**

| Gas* | | 225°C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Roast number | Weight of roast | | Internal temperature | | | Time in minutes | | | | Gas* | |
| | | | | | Initial °C | Removal °C | Maximum °C | In oven | | To reach maximum | | | |
| Cubic feet | Cost cents | | Grams | Pounds | | | | Total | Per pound | Total | Per pound | Cubic feet | Cost cents |
| | | 9th 10th, and 11th ribs of beef | | | | | | | | | | | |
| 9.8 | 0.7 | 243L | 2744 | 6.0 | 8 | 46 | 65† | 80 | 13.3 | 47 | 7.8 | 15.4 | 1.0 |
| 22.9 | 1.5 | 237L | 5101 | 11.2 | 4 | 58 | 68† | 143 | 12.8 | 40 | 3.6 | 33.7 | 2.3 |
| 15.9 | 1.1 | 240R | 4164 | 9.2 | 10 | 58 | 73† | 123 | 13.4 | 47 | 5.1 | 26.1 | 1.8 |
| 14.6 | 1.0 | 345L | 4473 | 9.9 | 6 | 45 | 62 | 98 | 9.9 | 47 | 4.7 | 21.9 | 1.5 |
| — | — | 375L | 3955 | 8.7 | 6 | 45 | 65 | 99 | 11.4 | 61 | 7.0 | — | — |
| 16.5 | 1.1 | 380R | 4388 | 9.7 | 4 | 45 | 64 | 113 | 11.6 | 57 | 5.9 | 23.3 | 1.6 |
| — | — | 280R | 3476 | 7.7 | 8 | 44 | 61 | 75 | 9.7 | 45 | 5.8 | — | — |
| 11.8 | 0.8 | 281L | 3339 | 7.4 | 10 | 45 | 61 | 74 | 10.0 | 46 | 6.2 | 15.9 | 1.1 |
| 15.1 | 1.0 | 344R | 3943 | 8.7 | 6 | 45 | 63 | 93 | 10.7 | 47 | 5.4 | 20.8 | 1.4 |
| 13.4 | 0.9 | 296R | 3611 | 8.0 | 5 | 45 | 63 | 86 | 10.8 | 59 | 7.4 | 17.9 | 1.2 |
| 12.3 | 0.8 | 297L | 3053 | 6.7 | 6 | 45 | 65 | 80 | 11.9 | 54 | 8.1 | 15.5 | 1.0 |
| 14.4 | 1.0 | 328R | 3638 | 8.0 | 2 | 46 | 63 | 90 | 11.3 | 45 | 5.6 | 19.4 | 1.3 |
| 12.6 | 0.9 | 329L | 3598 | 7.9 | 4 | 45 | 63 | 87 | 11.0 | 48 | 6.1 | 17.8 | 1.2 |
| 14.7 | 1.0 | 366R | 3645 | 8.0 | 7 | 45 | 62 | 83 | 10.4 | 43 | 5.4 | 17.4 | 1.2 |
| 10.4 | 0.7 | 245L | 1816 | 4.0 | 9 | 45 | 64 | 69 | 17.3 | 37 | 9.3 | 14.7 | 1.0 |
| 21.7 | 1.5 | 272R | 2286 | 5.0 | 7 | 45 | 64 | 66 | 13.2 | 44 | 8.8 | 22.7 | 1.5 |
| 10.7 | 0.7 | 273L | 2692 | 5.9 | 7 | 45 | 65 | 78 | 13.2 | 47 | 8.0 | 15.5 | 1.0 |
| 14.8 | 1.0 | 277L | 4085 | 9.0 | 7 | 45 | 65 | 100 | 11.1 | 65 | 7.2 | 21.8 | 1.5 |
| 21.7 | 1.5 | 254R | 3114 | 6.9 | 8 | 45 | 63 | 77 | 11.2 | 38 | 5.5 | 15.9 | 1.1 |
| 21.0 | 1.4 | 255L | 3276 | 7.2 | 8 | 45 | 63 | 82 | 11.4 | 43 | 6.0 | 17.4 | 1.2 |
| — | — | 259L | 3919 | 8.6 | 7 | 45 | 63 | 95 | 11.0 | 50 | 5.8 | — | — |
| 10.8 | 0.7 | 276R | 2518 | 5.5 | 7 | 45 | 63 | 71 | 12.9 | 39 | 7.1 | 13.0 | 0.9 |
| 13.2 | 0.9 | 312R | 3168 | 7.0 | 7 | 46 | 62 | 81 | 11.6 | 44 | 6.3 | 16.6 | 1.1 |
| 12.2 | 0.8 | 313L | 3542 | 7.8 | 7 | 45 | 65 | 95 | 12.2 | 45 | 5.8 | 19.5 | 1.3 |
| 11.2 | 0.8 | 361L | 2705 | 6.0 | 8 | 45 | 64 | 71 | 11.8 | 39 | 6.5 | 14.9 | 1.0 |
| 14.4 | 1.0 | ..... | 3375 | 7.4 | 6.6 | 45.0 | 63.3 | 85 | 11.6 | 47 | 6.5 | 17.9 | 1.2 |

*Preheating of ovens not included.
†Data from these roasts were not used in computing the means nor in the tests for palatability.

**Table F. Removal temperature, time, and gas required to obtain medium-rare**

| Carcass | | Class | Ripening period days | 125°C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Weight of roast | | Internal temperature | | | Time in minutes | | |
| | | | | | | | | | | In oven | | |
| U. S. grade | Weight pounds | | | Roast No. | Grams | Pounds | Initial °C | Removal °C | Maximum °C | Total | Per pound | To reach maximum |
| Round-bone chuck of beef | | | | | | | | | | | | |
| Good... | 650 | Steer | 11 | 235L | 3516 | 7.8 | 8 | 58 | 58† | 169 | 21.7 | 0 |
| | 519 | Steer | 9 | 241L | 2370 | 5.2 | 6 | 62 | 62 | 171 | 32.9 | 0 |
| | 503 | Steer | 7 | 342R | 3316 | 7.3 | 11 | 63 | 63 | 200 | 27.4 | 0 |
| | 510 | Steer | 8 | 372R | 3998 | 8.8 | 10 | 63 | 63 | 252 | 28.6 | 0 |
| | 579 | Steer | 8 | 377L | 4230 | 9.3 | 6 | 63 | 63 | 304 | 32.7 | 0 |
| | 420 | Heifer | 9 | 286R | 2533 | 5.6 | 12 | 64 | 64 | 155 | 27.7 | 0 |
| | 499 | Steer | 7 | 339L | 3746 | 8.3 | 8 | 63 | 63 | 255 | 30.7 | 0 |
| | 490 | Steer | 8 | 369L | 3286 | 7.2 | 8 | 63 | 63 | 230 | 31.9 | 0 |
| Medium | 462 | Cow | 9 | 363L | 3158 | 7.0 | 8 | 63 | 63† | 224 | 32.0 | 0 |
| | 477 | Steer | 7 | 291L | 2718 | 6.0 | 5 | 63 | 63 | 183 | 30.5 | 0 |
| | 447 | Steer | 7 | 294R | 2213 | 4.9 | 7 | 63 | 63 | 163 | 33.3 | 0 |
| | 480 | Steer | 8 | 323L | 2697 | 5.9 | 11 | 63 | 63 | 191 | 32.4 | 0 |
| | 482 | Steer | 8 | 326R | 3329 | 7.3 | 10 | 63 | 63 | 197 | 27.0 | 0 |
| | 352 | Steer | 5 | 267L | 1977 | 4.3 | 10 | 63 | 63 | 145 | 33.7 | 0 |
| | 383 | Steer | 5 | 270R | 2288 | 5.0 | 10 | 63 | 63 | 156 | 31.2 | 0 |
| Common | 506 | Bull(?) | 5 | 266R | 2433 | 5.4 | 13 | 63 | 63 | 137 | 25.4 | 0 |
| | 489 | Steer | 8 | 249L | 2973 | 6.5 | 10 | 63 | 63 | 160 | 24.6 | 0 |
| | 466 | — | 8 | 252R | 2458 | 5.4 | 8 | 63 | 63 | 150 | 27.8 | 0 |
| | 499 | Steer | 8 | 262R | 2828 | 6.2 | 8 | 63 | 63 | 183 | 29.5 | 0 |
| | 416 | Steer | 4 | 263L | 2437 | 5.4 | 14 | 63 | 63 | 155 | 28.7 | 0 |
| | 412 | Cow | 8 | 355L | 2634 | 5.8 | 8 | 63 | 63 | 183 | 31.6 | 0 |
| | 420 | Cow | 8 | 358R | 3233 | 7.1 | 10 | 63 | 63 | 210 | 29.6 | 0 |
| | 335 | Steer | 5 | 367L | 2108 | 4.6 | 12 | 63 | 63 | 130 | 28.3 | 0 |
| Mean... | ..... | ..... | 7.1 | ..... | 2848 | 6.3 | 9.4 | 63.0 | 63.0 | 186 | 29.8 | 0 |

†Data from these roasts were not used in computing the means nor in the tests for palatability.

**roasts of beef at constant oven temperatures of 125°C and 225°C—Continued.**

| | | 225°C | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas* | | Roast number | Weight of roast | | Internal temperature | | | Time in minutes | | | Gas* | |
| | | | | | | | | In oven | | To reach maximum | | |
| Cubic feet | Cost cents | | Grams | Pounds | Initial °C | Removal °C | Maximum °C | Total | Per pound | | Cubic feet | Cost cents |
| | | Round-bone chuck of beef | | | | | | | | | | |
| 13.8 | 0.9 | 236R | 3353 | 7.4 | 7 | 58 | 58† | 86 | 11.6 | 0 | 17.7 | 1.2 |
| 12.9 | 0.9 | 242R | 2658 | 5.9 | 6 | 62 | 63 | 91 | 15.4 | 14 | 16.3 | 1.1 |
| —— | —— | 341L | 3442 | 7.6 | 8 | 63 | 63 | 93 | 12.2 | 0 | —— | —— |
| 19.7 | 1.3 | 371L | 3815 | 8.4 | 7 | 62 | 62 | 111 | 13.2 | 0 | 23.5 | 1.6 |
| —— | —— | 378R | 4570 | 10.1 | 6 | 62 | 62 | 118 | 11.7 | 0 | —— | —— |
| 11.1 | 0.7 | 285L | 2639 | 5.8 | 13 | 64 | 64 | 77 | 13.3 | 0 | 16.0 | 1.1 |
| 20.8 | 1.4 | 340R | 3350 | 7.4 | 8 | 63 | 65 | 96 | 13.0 | 13 | 20.7 | 1.4 |
| 17.8 | 1.2 | 370R | 3934 | 8.7 | 8 | 62 | 62 | 111 | 12.8 | 0 | 24.4 | 1.6 |
| 17.3 | 1.2 | 364R | 3293 | 7.3 | 8 | 63 | 66† | 108 | 14.8 | 17 | 23.1 | 1.6 |
| 13.1 | 0.9 | 292R | 2843 | 6.3 | 7 | 63 | 63 | 83 | 13.2 | 0 | 15.5 | 1.0 |
| —— | —— | 293L | 2500 | 5.5 | 7 | 63 | 63 | 72 | 13.1 | 0 | —— | —— |
| 13.7 | 0.9 | 324R | 3205 | 7.1 | 10 | 63 | 63 | 89 | 12.5 | 0 | 18.6 | 1.3 |
| 14.5 | 1.0 | 325L | 3081 | 6.8 | 10 | 63 | 63 | 70 | 10.3 | 0 | 14.1 | 1.0 |
| 10.4 | 0.7 | 268R | 2051 | 4.5 | 10 | 63 | 63 | 69 | 15.3 | 0 | 13.0 | 0.9 |
| 12.3 | 0.8 | 269L | 2210 | 4.9 | 10 | 63 | 63 | 61 | 12.4 | 0 | 12.3 | 0.8 |
| 10.8 | 0.7 | 265L | 2760 | 6.1 | 12 | 63 | 63 | 65 | 10.7 | 0 | 13.1 | 0.9 |
| 12.1 | 0.8 | 250R | 2441 | 5.4 | 8 | 63 | 63 | 62 | 11.5 | 0 | 13.8 | 0.9 |
| 14.2 | 1.0 | 251L | 2787 | 6.1 | 10 | 63 | 63 | 75 | 12.3 | 0 | 15.2 | 1.0 |
| 14.5 | 1.0 | 261L | 2511 | 5.5 | 8 | 65 | 65 | 70 | 12.7 | 0 | 13.3 | 0.9 |
| 10.2 | 0.7 | 264R | 2463 | 5.4 | 10 | 63 | 63 | 70 | 13.0 | 0 | 13.3 | 0.9 |
| 14.1 | 1.0 | 356R | 3023 | 6.7 | 7 | 64 | 64 | 105 | 15.7 | 0 | 22.2 | 1.5 |
| 16.1 | 1.1 | 357L | 3285 | 7.2 | 7 | 63 | 65 | 115 | 16.0 | 20 | 24.2 | 1.6 |
| —— | —— | 368R | 2174 | 4.8 | 13 | 62 | 62 | 65 | 13.5 | 0 | —— | —— |
| 14.0 | 0.9 | ..... | 2940 | 6.5 | 8.8 | 63.0 | 63.2 | 84 | 13.0 | 2 | 17.0 | 1.1 |

*Preheating of ovens not included.
†Data from these roasts were not used in computing the means nor in the tests for palatability.

**Table G. The results of individual tests for tenderness**

| Carcass | | Ripening period in days | Roast Numbers | | 125°C | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Difference | |
| U. S. Grade | Weight pounds | | 125°C | 225°C | More tender | Slight | Decided |
| 9th, 10th, and 11th ribs | | | | | | | |
| Good | 503 | 8 | 346R | 345L | 13 | 8 | 5 |
| | 510 | 9 | 376R | 375L | 4 | 2 | 2 |
| | 579 | 8 | 379L | 380R | 2 | 2 | 0 |
| | | Total | | | 19 | 12 | 7 |
| | 412 | 9 | 279L | 280R | 2 | 2 | 0 |
| | 420 | 9 | 282R | 281L | 7 | 5 | 2 |
| | 499 | 8 | 343L | 344R | 7 | 6 | 1 |
| | | Total | | | 16 | 13 | 3 |
| Medium | 477 | 8 | 295L | 296R | 2 | 2 | 0 |
| | 447 | 8 | 298R | 297L | 3 | 3 | 0 |
| | 480 | 9 | 327L | 328R | 6 | 5 | 1 |
| | 482 | 9 | 330R | 329L | 9 | 5 | 4 |
| | 462 | 9 | 365L | 366R | 0 | 0 | 0 |
| | | Total | | | 21 | 15 | 5 |
| | 336 | — | 246R | 245L | 3 | 2 | 1 |
| | 352 | 6 | 271L | 272R | 2 | 1 | 1 |
| | 383 | 6 | 274R | 273L | 9 | 0 | 9 |
| | | Total | | | 14 | 3 | 11 |
| Common | 506 | 7 | 278R | 277L | 7 | 5 | 1 |
| | 489 | 9 | 253L | 254R | 5 | 1 | 4 |
| | 466 | 9 | 256R | 255L | 9 | 2 | 7 |
| | 499 | 8 | 260R | 259L | 3 | 3 | 0 |
| | 416 | 7 | 275L | 276R | 1 | 1 | 0 |
| | 416 | 9 | 311L | 312R | 6 | 1 | 5 |
| | 421 | 9 | 314R | 313L | 11 | 8 | 3 |
| | 420 | 9 | 362R | 361L | 10 | 5 | 5 |
| | | Total | | | 45 | 21 | 24 |

**with paired roasts of beef cooked medium-rare.**

| Tenderness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of judgments by paired eating method | | | | | | | | Weighted adjectives average per roast | |
| No difference | 225°C | | | Total N | For statistical treatment | | | | |
| | More tender | Difference | | | More tender | | Ratio $n_s/N$ | | |
| | | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | 125°C | 225°C |
| 9th, 10th, and 11th ribs | | | | | | | | | |
| 2 | 2 | 1 | 1 | 17 | 14.0 | 3.0 | | 4.3 | 3.3 |
| 3 | 5 | 5 | 0 | 12 | 5.5* | 6.5* | | 4.7 | 4.6 |
| 1 | 12 | 4 | 8 | 15 | 2.5* | 12.5* | | 4.4 | 5.0 |
| 6 | 19 | 10 | 9 | 44 | 22.0 | 22.0 | 0.5000 | 4.5‡ | 4.3‡ |
| 1 | 5 | 4 | 1 | 8 | 2.5* | 5.5* | | 3.5 | 3.6 |
| 0 | 1 | 1 | 0 | 8 | 7.0 | 1.0 | | 4.8 | 4.5 |
| 2 | 6 | 5 | 1 | 15 | 8.0 | 7.0 | | 3.8 | 4.0 |
| 3 | 12 | 10 | 2 | 31 | 17.5 | 13.5 | 0.5645 | 4.0‡ | 4.0‡ |
| 1 | 5 | 3 | 2 | 8 | 2.5* | 5.5* | | 2.0 | 3.0 |
| 1 | 4 | 1 | 3 | 8 | 3.5* | 4.5* | | 2.6 | 2.6 |
| 3 | 6 | 5 | 1 | 15 | 7.5 | 7.5 | | 3.6 | 3.3 |
| 6 | 0 | 0 | 0 | 15 | 12.0 | 3.0 | | 4.0 | 3.6 |
| 0 | 12 | 5 | 7 | 12 | 0.0* | 12.0* | | 3.0 | 4.4 |
| 11 | 27 | 14 | 13 | 58 | 25.5 | 32.5 | 0.4397 | 3.0‡ | 3.4‡ |
| 3 | 6 | 5 | 1 | 12 | 4.5* | 7.5* | | 2.1 | 2.5 |
| 2 | 5 | 3 | 2 | 9 | 3.0* | 6.0* | | 3.0 | 3.2 |
| 0 | 0 | 0 | 0 | 9 | 9.0 | 0.0 | | 3.5 | 1.8 |
| 5 | 11 | 8 | 3 | 30 | 16.5 | 13.5 | 0.5500 | 2.9‡ | 2.5‡ |
| 4 | 0 | 0 | 0 | 11 | 9.0 | 2.0 | | 5.0 | 4.6 |
| 1 | 6 | 1 | 5 | 12 | 5.5* | 6.5* | | 3.3 | 2.9 |
| 1 | 2 | 0 | 2 | 12 | 9.5 | 2.5 | | 3.1 | 1.6 |
| 3 | 0 | 0 | 0 | 6 | 4.5 | 1.5 | | 4.7 | 4.5 |
| 2 | 8 | 5 | 3 | 11 | 2.0* | 9.0* | | 2.5 | 3.3 |
| 6 | 6 | 6 | 0 | 18 | 9.0 | 9.0 | | 3.6 | 3.2 |
| 0 | 7 | 6 | 1 | 18 | 11.0 | 7.0 | | 4.2 | 4.1 |
| 0 | 2 | 2 | 0 | 12 | 10.0 | 2.0 | | 2.8 | 2.0 |
| 13 | 31 | 20 | 11 | 89 | 51.5 | 37.5 | 0.5787 | 3.5‡ | 3.1‡ |

*The majority of the paired judgments in this roast were in favor of high oven temperature. These roasts were apparently distributed in random manner in all of the groups of roasts.
‡Mean of all roasts.

**Table G. The results of individual tests for tenderness**

| Carcass | | Ripening period in days | Roast Numbers | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | 125°C | | |
| | | | | | | Difference | |
| U. S. Grade | Weight pounds | | 125°C | 225°C | More tender | Slight | Decided |
| | | | Round-bone chuck | | | | |
| Good..... | 519 | 9 | 241L | 242R | 6 | 6 | 0 |
| | 503 | 7 | 342R | 341L | 2 | 1 | 0 |
| | 510 | 8 | 372R | 371L | 1 | 1 | 0 |
| | 579 | 8 | 377L | 378R | 4 | 2 | 2 |
| | | Total.... | ..... | ..... | 13 | 10 | 2 |
| | 420 | 9 | 286R | 285L | 2 | 2 | 0 |
| | 499 | 7 | 339L | 340R | 5 | 4 | 1 |
| | 490 | 8 | 369L | 370R | 5 | 5 | 0 |
| | | Total.... | ..... | ..... | 12 | 11 | 1 |
| Medium..... | 477 | 7 | 291L | 292R | 1 | 0 | 1 |
| | 447 | 7 | 294R | 293L | 3 | 0 | 3 |
| | 480 | 8 | 323L | 324R | 4 | 4 | 0 |
| | 482 | 8 | 326R | 325L | 5 | 2 | 3 |
| | | Total.... | ..... | ..... | 13 | 6 | 7 |
| | 352 | 5 | 267L | 268R | 2 | 2 | 0 |
| | 383 | 5 | 270R | 269L | 2 | 2 | 0 |
| | | Total.... | ..... | ..... | 4 | 4 | 0 |
| Common..... | 506 | 5 | 266R | 265L | 3 | 3 | 0 |
| | 489 | 8 | 249L | 250R | 2 | 1 | 0 |
| | 466 | 8 | 252R | 251L | 4 | 3 | 1 |
| | 499 | 8 | 262R | 261L | 3 | 3 | 0 |
| | 416 | 4 | 263L | 264R | 5 | 4 | 1 |
| | 412 | 8 | 355L | 356R | 3 | 3 | 0 |
| | 420 | 8 | 358R | 357L | 3 | 0 | 3 |
| | | Total.... | ..... | ..... | 20 | 14 | 5 |
| | 335 | 5 | 367L | 368R | 7 | 5 | 2 |

**with paired roasts of beef cooked medium-rare—Continued.**

| Tenderness | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number of judgments by paired eating method | | | | | | | | Weighted adjectives average per roast | |
| No difference | 225°C | | | Total N | For statistical treatment | | | | |
| | More tender | Difference | | | More tender | | Ratio $n_s/N$ | | |
| | | Slight | Decided | | 125°C $n_s$ | 225°C $n_t$ | | 125°C | 225°C |
| Round-bone chuck | | | | | | | | | |
| 1 | 1 | 1 | 0 | 8 | 6.5 | 1.5 | | 4.6 | 4.5 |
| 1 | 5 | 5 | 0 | 8 | 2.5* | 5.5* | | 4.8 | 4.8 |
| 4 | 5 | 5 | 0 | 10 | 3.0* | 7.0* | | 4.6 | 4.7 |
| 2 | 4 | 4 | 0 | 10 | 5.0 | 5.0 | | 4.7 | 4.5 |
| 8 | 15 | 15 | 0 | 36 | 17.0 | 19.0 | 0.4722 | 4.7‡ | 4.6‡ |
| 3 | 3 | 3 | 0 | 8 | 3.5* | 4.5* | | 4.9 | 4.9 |
| 3 | 0 | 0 | 0 | 8 | 6.5 | 1.5 | | 4.9 | 4.6 |
| 3 | 2 | 1 | 1 | 10 | 6.5 | 3.5 | | 4.5 | 4.5 |
| 9 | 5 | 4 | 1 | 26 | 16.5 | 9.5 | 0.6346 | 4.8‡ | 4.7‡ |
| 1 | 6 | 1 | 5 | 8 | 1.5* | 6.5* | | 2.4 | 3.6 |
| 2 | 3 | 1 | 2 | 8 | 4.0 | 4.0 | | 3.9 | 3.8 |
| 3 | 1 | 1 | 0 | 8 | 5.5 | 2.5 | | 4.5 | 4.4 |
| 1 | 2 | 2 | 0 | 8 | 5.5 | 2.5 | | 3.6 | 3.1 |
| 7 | 12 | 5 | 7 | 32 | 16.5 | 15.5 | 0.5156 | 3.6‡ | 3.7‡ |
| 3 | 3 | 3 | 0 | 8 | 3.5* | 4.5* | | 4.5 | 4.5 |
| 1 | 5 | 3 | 2 | 8 | 2.5* | 5.5* | | 3.6 | 3.9 |
| 4 | 8 | 6 | 2 | 16 | 6.0 | 10.0 | 0.3750 | 4.0‡ | 4.2‡ |
| 3 | 2 | 2 | 0 | 8 | 4.5 | 3.5 | 0.5625 | 4.9 | 5.0 |
| 2 | 4 | 3 | 1 | 8 | 3.0* | 5.0* | | 3.3 | 3.4 |
| 2 | 2 | 2 | 0 | 8 | 5.0 | 3.0 | | 3.3 | 3.0 |
| 3 | 0 | 0 | 0 | 6 | 4.5 | 1.5 | | 3.4 | 3.1 |
| 0 | 3 | 1 | 2 | 8 | 5.0 | 3.0 | | 3.4 | 3.8 |
| 3 | 4 | 2 | 2 | 10 | 4.5* | 5.5* | | 3.7 | 4.1 |
| 5 | 2 | 0 | 2 | 10 | 5.5 | 4.5 | | 3.6 | 3.5 |
| 15 | 15 | 8 | 7 | 50 | 27.5 | 22.5 | 0.5500 | 3.5‡ | 3.5‡ |
| 1 | 2 | 2 | 0 | 10 | 7.5 | 2.5 | 0.7500 | 4.0 | 3.4 |

*The majority of the paired judgments in this roast were in favor of high oven temperature. These roasts were apparently distributed in random manner in all of the groups of roasts.
‡Mean of all roasts.

**Table H. The relationship of tenderness ratio to various**

| Carcass | | Class | Ripening period in days | Roast numbers | | Weight of roast (pounds) | | Initial Internal Temperature | |
|---|---|---|---|---|---|---|---|---|---|
| Grade U. S. | Weight pounds | | | 125°C | 225°C | 125°C | 225°C | 125°C | 225°C |
| **9th, 10th and 11th rib roasts of beef** | | | | | | | | | |
| Good..... | 420 | Heifer.... | 9 | 282R | 281L | 7.8 | 7.4 | 10 | 10 |
| Common.. | 420 | Cow..... | 9 | 362R | 361L | 6.3 | 6.0 | 8 | 8 |
| Good..... | 503 | Steer..... | 8 | 346R | 345L | 9.3 | 9.9 | 7 | 6 |
| Common.. | 506 | Bull (?).. | 7 | 278R | 277L | 8.9 | 9.0 | 4 | 7 |
| Medium... | 482 | Steer..... | 9 | 330R | 329L | 7.5 | 7.9 | 4 | 4 |
| Common.. | 466 | Steer..... | 9 | 256R | 255L | 7.0 | 7.2 | 8 | 8 |
| Common.. | 499 | Steer..... | 8 | 260R | 259L | 8.1 | 8.6 | 7 | 7 |
| Common.. | 421 | Cow..... | 9 | 314R | 313L | 6.3 | 7.8 | 6 | 7 |
| Good..... | 499 | Steer..... | 8 | 343L | 344R | 8.6 | 8.7 | 6 | 6 |
| Medium... | 480 | Steer..... | 9 | 327L | 328R | 8.8 | 8.0 | 3 | 2 |
| Common.. | 416 | Cow..... | 9 | 311L | 312R | 7.7 | 7.0 | 8 | 7 |
| Good..... | 510 | Steer..... | 9 | 376R | 375L | 8.3 | 8.7 | 6 | 6 |
| Common.. | 489 | Steer..... | 9 | 253L | 254R | 7.5 | 6.9 | 8 | 8 |
| Medium... | 447 | Steer..... | 8 | 298R | 297L | 7.2 | 6.7 | 6 | 6 |
| Medium... | 336 | — | — | 246R | 245L | 4.7 | 4.0 | 10 | 9 |
| Medium... | 352 | Steer..... | 6 | 271L | 272R | 5.5 | 5.0 | 5 | 7 |
| Good..... | 412 | Heifer.... | 9 | 279L | 280R | 7.4 | 7.7 | 8 | 8 |
| Medium... | 477 | Steer..... | 8 | 295L | 296R | 8.1 | 8.0 | 6 | 5 |
| Common.. | 416 | Steer..... | 7 | 275L | 276R | 6.0 | 5.5 | 7 | 7 |
| Good..... | 579 | Steer..... | 8 | 379L | 380R | 9.5 | 9.7 | 4 | 4 |
| Medium... | 383 | Steer..... | 6 | 274R | 273L | 5.8 | 5.9 | 6 | 7 |
| Medium... | 462 | Cow..... | 9 | 365L | 366R | 8.2 | 8.0 | 8 | 7 |
| Mean..... | ..... | ..... | 8.2 | ..... | ..... | 7.5 | 7.4 | 6.6 | 6.6 |
| **Round-bone chuck roasts of beef** | | | | | | | | | |
| Good..... | 519 | Steer..... | 9 | 241L | 242R | 5.2 | 5.9 | 6 | 6 |
| Good..... | 499 | Steer..... | 7 | 339L | 340R | 8.3 | 7.4 | 8 | 8 |
| Common.. | 499 | Steer..... | 8 | 262R | 261L | 6.2 | 5.5 | 8 | 8 |
| Common.. | 335 | Steer..... | 5 | 367L | 368R | 4.6 | 4.8 | 12 | 13 |
| Medium... | 480 | Steer..... | 8 | 323L | 324R | 5.9 | 7.1 | 11 | 10 |
| Medium... | 482 | Steer..... | 8 | 326R | 325L | 7.3 | 6.8 | 10 | 10 |
| Good..... | 490 | Steer..... | 8 | 369L | 370R | 7.2 | 8.7 | 8 | 8 |
| Common.. | 466 | — | 8 | 252R | 251L | 5.4 | 6.1 | 8 | 10 |
| Common.. | 416 | Steer..... | 4 | 263L | 264R | 5.4 | 5.4 | 14 | 10 |
| Common.. | 506 | Bull (?).. | 5 | 266R | 265L | 5.4 | 6.1 | 13 | 12 |
| Common.. | 420 | Cow..... | 8 | 358R | 357L | 7.1 | 7.2 | 10 | 7 |
| Good..... | 579 | Steer..... | 8 | 377L | 378R | 9.3 | 10.1 | 6 | 6 |
| Medium... | 447 | Steer..... | 7 | 294R | 293L | 4.9 | 5.5 | 7 | 7 |
| Common.. | 412 | Cow..... | 8 | 355L | 356R | 5.8 | 6.7 | 8 | 7 |
| Good..... | 420 | Heifer.... | 9 | 286R | 285L | 5.6 | 5.8 | 12 | 13 |
| Medium... | 352 | Steer..... | 5 | 267L | 268R | 4.3 | 4.5 | 10 | 10 |
| Common.. | 489 | Steer..... | 8 | 249L | 250R | 6.5 | 5.4 | 10 | 8 |
| Good..... | 503 | Steer..... | 7 | 342R | 341L | 7.3 | 7.6 | 11 | 8 |
| Medium... | 383 | Steer..... | 5 | 270R | 269L | 5.0 | 4.9 | 10 | 10 |
| Good..... | 510 | Steer..... | 8 | 372R | 371L | 8.8 | 8.4 | 10 | 7 |
| Medium... | 477 | Steer..... | 7 | 291L | 292R | 6.0 | 6.3 | 5 | 7 |
| Mean..... | ..... | ..... | 7.1 | ..... | ..... | 6.3 | 6.5 | 9.4 | 8.8 |

**other factors in individual medium-rare roasts.**

| Time in oven + time to reach maximum (minutes) | | | Cooking losses* | | | | | | Tenderness ratio |
|---|---|---|---|---|---|---|---|---|---|
| | | | Volatile (percentage) | | | Total (percentage) | | | |
| 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | 125°C | 225°C | Dif. | |
| 9th, 10th and 11th rib roasts of beef | | | | | | | | | |
| 180 | 120 | 60 | 4.4 | 11.7 | 7.3 | 6.1 | 19.8 | 13.7 | 0.8750 |
| 185 | 110 | 75 | 6.0 | 13.4 | 7.4 | 8.1 | 18.5 | 10.4 | 0.8333 |
| 225 | 145 | 80 | 5.3 | 14.4 | 9.1 | 7.3 | 22.1 | 14.8 | 0.8235 |
| 245 | 165 | 80 | 5.0 | 13.8 | 8.8 | 6.6 | 19.8 | 13.2 | 0.8182 |
| 205 | 135 | 70 | 5.5 | 14.3 | 8.8 | 7.5 | 19.4 | 11.9 | 0.8000 |
| 185 | 125 | 60 | 5.6 | 16.0 | 10.4 | 6.2 | 18.1 | 11.9 | 0.7917 |
| 215 | 145 | 70 | 6.8 | 18.4 | 11.6 | 7.6 | 19.9 | 12.3 | 0.7500 |
| 180 | 140 | 40 | 5.0 | 14.8 | 9.8 | 9.1 | 32.1 | 23.0 | 0.6111 |
| 235 | 140 | 95 | 5.3 | 13.1 | 7.8 | 6.6 | 20.7 | 14.1 | 0.5333 |
| 245 | 135 | 110 | 5.8 | 16.1 | 10.3 | 7.3 | 20.5 | 13.2 | 0.5000 |
| 215 | 125 | 90 | 4.9 | 12.4 | 7.5 | 8.8 | 23.2 | 14.4 | 0.5000 |
| 210 | 160 | 50 | 4.9 | 15.1 | 10.2 | 6.1 | 21.2 | 15.1 | 0.4583 |
| 190 | 115 | 75 | 6.4 | 14.9 | 8.5 | 6.8 | 16.9 | 10.1 | 0.4583 |
| 195 | 134 | 61 | 6.1 | 13.9 | 7.8 | 7.1 | 18.3 | 11.2 | 0.4375 |
| 180 | 106 | 74 | 5.6 | 13.1 | 7.5 | 6.3 | 17.5 | 11.2 | 0.3750 |
| 185 | 110 | 75 | 5.2 | 14.0 | 8.8 | 5.6 | 16.1 | 10.5 | 0.3333 |
| 198 | 120 | 78 | 3.9 | 10.3 | 6.4 | 5.9 | 19.4 | 13.5 | 0.3125 |
| 220 | 145 | 75 | 4.9 | 12.0 | 7.1 | 7.0 | 21.3 | 14.3 | 0.3125 |
| 190 | 110 | 80 | 4.5 | 12.2 | 7.7 | 5.2 | 16.0 | 10.8 | 0.1812 |
| 250 | 170 | 80 | 6.2 | 13.0 | 6.8 | 9.4 | 24.4 | 15.0 | 0.1667 |
| 185 | 125 | 60 | 4.8 | 13.6 | 8.8 | 5.7 | 18.2 | 12.5 | 0.1000 |
| 215 | 126 | 89 | 7.0 | 13.1 | 6.1 | 9.7 | 21.5 | 11.8 | 0.0000 |
| 206 | 132 | 74 | 5.4† | 13.8† | 8.4 | 7.1† | 20.2† | 13.1 | |
| Round-bone chuck roasts of beef | | | | | | | | | |
| 171 | 105 | 66 | 10.3 | 18.4 | 8.1 | 12.8 | 23.7 | 10.9 | 0.8125 |
| 255 | 109 | 146 | 12.2 | 18.8 | 6.6 | 15.3 | 25.5 | 10.2 | 0.8125 |
| 183 | 70 | 113 | 8.5 | 14.6 | 6.1 | 9.6 | 16.7 | 7.1 | 0.7500 |
| 130 | 65 | 65 | 8.5 | 16.5 | 8.0 | 10.2 | 21.0 | 10.8 | 0.7500 |
| 191 | 89 | 102 | 9.9 | 17.2 | 7.3 | 11.8 | 21.3 | 9.5 | 0.6875 |
| 197 | 70 | 127 | 9.5 | 11.4 | 1.9 | 11.6 | 15.0 | 3.4 | 0.6875 |
| 230 | 111 | 119 | 11.7 | 18.7 | 7.0 | 14.5 | 27.1 | 12.6 | 0.6500 |
| 150 | 75 | 75 | 7.5 | 15.2 | 7.7 | 8.4 | 17.2 | 8.8 | 0.6250 |
| 155 | 70 | 85 | 9.7 | 16.2 | 6.5 | 11.5 | 19.2 | 7.7 | 0.6250 |
| 137 | 65 | 72 | 7.0 | 11.7 | 4.7 | 7.7 | 16.1 | 8.4 | 0.5625 |
| 210 | 135 | 75 | 11.4 | 23.7 | 12.3 | 13.3 | 27.7 | 14.4 | 0.5500 |
| 304 | 118 | 186 | 13.5 | 17.0 | 3.5 | 17.1 | 25.2 | 8.1 | 0.5000 |
| 163 | 72 | 91 | 11.4 | 15.1 | 3.7 | 14.2 | 18.8 | 4.6 | 0.5000 |
| 183 | 105 | 78 | 8.5 | 21.1 | 12.6 | 9.7 | 26.1 | 16.4 | 0.4500 |
| 155 | 77 | 78 | 9.3 | 18.4 | 9.1 | 12.2 | 23.0 | 10.8 | 0.4375 |
| 145 | 69 | 76 | 8.1 | 18.0 | 9.9 | 9.9 | 21.7 | 11.8 | 0.4375 |
| 160 | 62 | 98 | 8.1 | 15.3 | 7.2 | 8.8 | 17.1 | 8.3 | 0.3750 |
| 200 | 93 | 107 | 9.9 | 17.1 | 7.2 | 12.6 | 22.9 | 10.3 | 0.3125 |
| 156 | 61 | 95 | 6.0 | 11.5 | 5.5 | 7.0 | 16.4 | 9.4 | 0.3125 |
| 252 | 111 | 141 | 11.6 | 19.6 | 8.0 | 14.8 | 25.8 | 11.0 | 0.3000 |
| 183 | 83 | 100 | 8.6 | 16.2 | 7.6 | 10.4 | 21.2 | 10.8 | 0.1875 |
| 186 | 86 | 100 | 9.6† | 16.7† | 7.2 | 11.6† | 21.4† | 9.8 | |

*Fat in drippings was not measured for these roasts.

†These means are subject to the criticism that the temperature, humidity, and length of storage period varied considerably with the different pairs of roasts.