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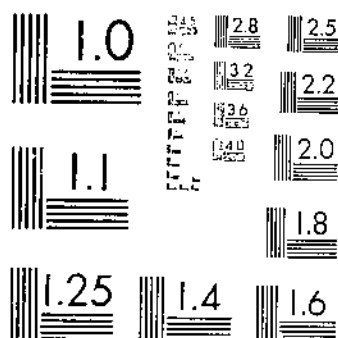
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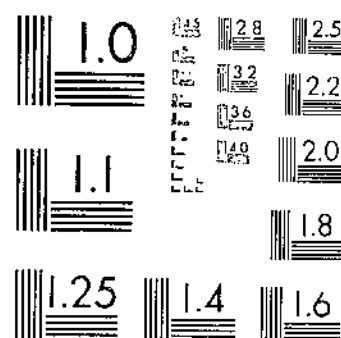
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SHRINKAGE AND HEAT PENETRATION DURING THE ROASTING OF LAMB AND MUTTON
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UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON D.C.

SHRINKAGE AND HEAT PENETRATION DURING
THE ROASTING OF LAMB AND MUTTON
AS INFLUENCED BY CARCASS GRADE,
RIPENING PERIOD, AND COOK-
ING METHOD¹

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INTRODUCTION

To the meat producer as well as to the consumer the cooking qualities of the different market grades are important. With lamb and mutton as with other meats, the thickness of the fat covering on a carcass is one of the chief points in determining grade. The grower of course tries to put the right degree of finish on his lambs so they will be neither too fat nor too thin. Grade is a matter of dollars and cents to him when he figures up his production costs and sells his lambs. But even for the grower the economic importance of grade does not send there. He needs to know for instance how much weight his very fat lamb loses in cooking and how much time is required to roast very small thin lamb. For in the long run such points make an impression on consumer demand and react on market prices.

¹ See Statement of Cooperation, p. 26.

² Prepared in consultation with other members of the U.S. Department of Agriculture publication committee of the cooperative meat investigations, O. G. Hankins (chairman), L. B. Burk, Paul E. Howe, H. C. McPhee, D. A. Spencer, and K. F. Warner. Acknowledgment is made to Elizabeth A. Engstrom and Meda K. Gates for laboratory and statistical assistance and to Lillian M. Grigg and Esther M. Lyerly for statistical assistance.

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As for consumers themselves, the value of such information to them is obvious. All classes—from hotel and restaurant keepers, to dietitians in institutions, to homemakers buying food for their own families—need definite facts on the selection and cooking of meats. Information that relates the finish of the raw cut to shrinkage of the cooked meat and time in the oven is part of the scientific basis of such a guide.

To distributors of dressed meat, and also to institutional managers who buy in large quantities and store in their own coolers, the effect of ripening or aging on cooking qualities of meat is a matter of interest. It is, of course, well known that ripening meat for several days makes it more tender. That ripening influences cooking shrinkage and the speed of cooking is not so well known, but it is also of economic importance in the handling of meat.

To research workers in meat cookery, knowledge of the influence of finish and ripening on shrinkage and speed of cooking is essential because these factors are inseparable from the meat itself. Unless research workers know how the character of meat affects its shrinkage and the rate of heat penetration, they cannot judge the merits of different methods of cooking and make sound recommendations to homemakers, institutional cooks, and manufacturers of cooking equipment. The fact that 750 legs of lamb roasted by one standard method showed a range in shrinkage from 7 to 25 percent of the weight of the raw meat, and in cooking time from 25 to 58 minutes per pound, is striking proof of the difference made by the character of the meat itself.

This bulletin represents an initial attempt to supply much-needed information on the factors that influence shrinkage and rate of heat penetration during roasting. It presents data on 7 different methods of roasting 1,185 legs of lamb and mutton, ranging in grade from Choice to Cull, and in ripening period from 2 to 24 days after slaughter. Included also are chemical analyses of 30 legs of lamb from Choice to Cull grade carcasses contributed by the Animal Husbandry Division of the Bureau of Animal Industry. Without attempting refined correlation methods these data were used as a basis for estimating what shrinkage may reasonably be expected and how much time to allow for roasting leg of lamb or mutton of a given grade and a certain ripening period when using a particular method.

The meat for these experiments was obtained through the cooperative meat investigations,³ a national project which affords a unique opportunity to study a large number of samples from animals of known history grown, slaughtered, chilled, and stored under controlled conditions. A large proportion of the meat samples was cooked by one standard method for palatability tests in connection with production experiments, and additional meat samples were used for the studies of cooking methods.

REVIEW OF LITERATURE

Although research in meat cookery has been under way in the United States for more than 30 years a review of the literature discloses no information on the shrinkage of lamb and mutton roasted

³ UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY. A STUDY OF THE FACTORS WHICH INFLUENCE THE QUALITY AND PALATABILITY OF MEAT. 76 pp., illus. 1927. [Mimeographed.]

by controlled methods up to 1931 when Weber, Loeffel, and Peters (7)⁴ published data on the shrinkage and cooking time of 66 legs of lamb all roasted by the standard method used in the cooperative meat investigations.⁵

These authors reported high correlation between carcass grade and fat content as indicated by analysis of the wholesale cut commonly referred to as the rack. The lamb carcasses of Choice grade showed on the average 44 percent fat in the rack; of Good grade, 35.5 percent; of Medium, 30.5 percent; of Common, 28 percent. There was, however, considerable variation within each grade, the data showing ranges of 15 percent in any grade and 30 percent in the Medium grade.

The cooking data reported by Weber and his associates show a range from 5.89 to 9.41 percent in evaporation losses, with most of the values falling between 8 and 9 percent. Drippings losses ranged from 3.03 to 7.83 percent and cooking time from 27 to 33 minutes per pound. These investigators concluded that while losses by evaporation bear no definite relation to the fatness of lamb, drippings losses are directly related to fatness—the fatter legs shrinking most—and that the cooking time per pound is slightly less for the fatter legs. Unfortunately they did not publish data on the shrinkage and cooking time of lamb of stated levels of fatness or of grade designation.

EXPERIMENTAL PROCEDURE

HISTORY OF SAMPLES

With the exception of nine pairs of lamb legs purchased in Washington, D.C., markets, all the samples discussed in this bulletin came from animals raised at Federal agricultural experiment stations or at the State agricultural experiment stations of Indiana, Maryland, Mississippi, New Mexico, New York (Cornell), Tennessee, and West Virginia.

For every animal raised in the experiment stations there was a record kept of breed, sex, age, and feeding ration. In all, the 1,167 legs of lamb and mutton of known history that were cooked represent 11 breeds. As to sex there were rams, wethers, and ewes. The lambs varied in age from 4 to 12 months. Nineteen different feeding rations were used.

After the animals were slaughtered, the carcasses were graded in accordance with the standards established by the Bureau of Agricultural Economics (1). In a total of 938 lamb carcasses there were 213 of Choice grade, 463 of Good, 171 of Medium, 41 of Common, 22 of Cull, and 28 of unrecorded grade. The nine mutton carcasses were distributed by grades as follows: Choice, 2; Good, 3; Medium, 3; Common, 1.

The legs of lamb and mutton were removed from the carcass where they joined the loin or just forward of the external angle of the ilium. They were then sawed apart, trimmed, and shaped up as if for the retail market. The fell was not removed.

The period of ripening the meat after slaughter ranged from 2 to 24 days, but most of it was aged from 4 to 9 days. Wide variation in ripening period was unavoidable in cases where as many as 100 or

⁴ Italic numbers in parentheses refer to Literature Cited, p. 25.

⁵ UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF HOME ECONOMICS AND BUREAU OF ANIMAL INDUSTRY. METHODS OF COOKING AND TESTING MEAT FOR PALATABILITY. 36 pp., illus. 1933. [Mimeographed.]

more lambs were slaughtered at a time, and a leg from each set aside for palatability tests, because the capacity of the cooking and judging laboratory was limited to eight legs a day. A special study of the effects of varying the period of ripening was made on paired legs from the same carcass in which one leg was cooked shortly after slaughter and the other leg held back for longer ripening.

ROASTING METHODS

All the legs of lamb and mutton were roasted by one of the following seven methods, differing from each other in oven temperatures and in the stage of doneness to which the meat was cooked as shown by a roast-meat thermometer.

Roasting method 1. By far the greatest number of samples was roasted by the standard laboratory method adopted for leg of lamb in connection with the cooperative meat investigations, since the meat was cooked for palatability tests as part of production experiments. According to this method, here designated as method 1, the leg of lamb or mutton was prepared for the oven without salt, pepper, or flour. Each leg was weighed, and then laid with the cut-flesh and pelvic-bone side up and the skin side down on a wire rack in a weighed roasting pan. A roast-meat thermometer was inserted to the center of the thickest portion of each leg and kept there throughout the cooking to show when the desired stage of doneness was reached. The leg, prepared in this way, was seared for 20 minutes at an average oven temperature of 265° C. after which the cooking was continued at 125° until the meat thermometer registered 76°, when the leg was removed from the oven and weighed. The meat was roasted entirely without a lid and without water added to the pan. The slow finish at 125° yields a uniformly cooked product deemed especially desirable for judging.

The other methods of roasting, held in most cases to be better adapted to household conditions, were based on method 1 but with the exception of method 7 varied from it in the use of higher oven temperatures or higher meat temperatures, resulting respectively either in faster cooking or more thoroughly cooked meat. At 76° C. lamb is between medium and well done and the juice is pink. Lamb is well done at 83° and is probably preferred this way by most people.

Roasting method 2. The meat was seared for 20 minutes at 265° C. as in method 1, but finished at 150°, to 76° internal temperature.

Roasting method 3. The meat was seared as in method 1 but finished at 175° C., to 76° internal temperature.

Roasting method 4. The meat was roasted at 175° C., without searing, to 76° internal temperature.

Roasting method 5. The meat was either seared as in method 1, or for 35 minutes at 250° C., and finished at 125°, to 83° internal temperature.

Roasting method 6. The meat was seared as in method 5 but finished at 175° C., to 83° internal temperature.

Roasting method 7. The meat was roasted at 125° C., without searing, to 76° internal temperature.

For all experiments the ovens were gas heated, indirect in action, ventilated, equipped with glass doors and temperature regulators. Portable thermometers in the same relative position in the several

ovens registered the oven temperatures, which were read through the glass doors.

The rate of heat penetration was determined by the number of minutes per pound required in cooking. Total time in minutes includes the searing period. The number of minutes per pound was calculated by dividing the total time by the weight in pounds of the uncooked leg.

DETERMINATION OF COOKING LOSSES

In these investigations shrinkage is defined as loss of weight during cooking. The shrinkage of each leg was determined as total loss of weight, and also as two fractions of the total, namely, the pan-drippings loss and the loss due to evaporation of water. Total shrinkage is the difference between the weight of the leg before cooking and immediately on removal from the oven. Drippings loss is the weight of the mixture of fat and juice which cooks out of meat and collects in the roasting pan. Loss of weight due to the evaporation of water is the difference between total loss of weight and the weight of the drippings. Unless otherwise indicated the shrinkage of each leg was calculated as percentage of the weight of the raw leg, trimmed, with the fell left on, and including bone.

While loss of weight of meat during cooking has value as such and can be discussed without reference to its fractions, it is frequently desirable to know what constituents of the meat went into the make-up of the loss of weight and how the original composition of the meat was modified. The only way to do this with precision is by chemical analysis of the meat, raw and cooked, and of the pan drippings. Fortunately, considerable work of this type was done by Grindley and Mojonnier (3) and more recently by McCance and Shipp (4), and while not on roast leg of lamb, the outstanding results on cooking losses are applicable to any kind of roasted meat. On the basis of principles established through chemical analysis it is possible to discuss the evaporation and drippings fractions of the loss of weight as approximations to losses of the chief constituents of meat during roasting.

McCance and Shipp distinguish between "shrink" and loss of weight. They define shrink as reduction in volume brought about by the action of heat on meat proteins. According to these authors, the loss of weight of flesh (beef and fish) during roasting is made up of water, fat, protein, and salts. The loss of weight due to evaporation accounts for nearly all of the water lost during roasting in dry air, that is, in an uncovered pan in a ventilated oven. The rest of the water is lost by dripping into the roasting pan. The pan drippings contain also fat, salts, and protein, but the loss of salts and protein is a small proportion of the loss of weight when flesh is roasted in dry air according to the results of chemical analysis. Most of the loss of weight is therefore due to loss of water and of fat.

On comparing the cooking losses obtained by the writers' methods with those determined by chemical analysis it appears that the evaporation fraction of the loss of weight is less than the true water loss but is a reasonably good approximation to it. Pan drippings usually are mainly melted fat, but it is probable that the composition of the drippings varies considerably, hence this fraction of the loss of weight has no definition in terms of exact amounts of fat, water, protein, and salts. Although exactness cannot be claimed for losses of meat constituents determined as evaporated water and as pan drip-

pings, the writers believe that when applied to meat as it is cooked by practical methods, these rough estimates of the water and fat loss have more value than loss of weight alone as a guide to the changes in volume, nutritive value, and palatability brought about by roasting.

The reduction in volume of meat on cooking is of considerable importance because it affects the appearance of the cooked cut and the number of servings obtainable from it. According to McCance and Shipp, loss of weight during cooking is a close measure of reduction in volume only for very lean meat, for which the loss is mostly water. The ordinary roast of course contains fat as well as lean and, as is well known, loses water and also melted fat during cooking. The presence of fat complicates the relationship between loss of weight and reduction in volume. Although the volume of servable meat in a roast may not be reduced appreciably by the melting out of a considerable portion of the fat, it may be affected noticeably by the loss of water. In order then to form a picture of volume changes, estimates of fat and water fractions of the loss of weight are needed, even if close relationships are not to be expected.

For studying changes in nutritive value through cooking losses, insofar as this is possible, estimates of water and fat fractions of the loss of weight, though rough, obviously have merit. Water loss does not represent loss of nutritive value, but it does affect the concentration of constituents left in the cooked meat. In this connection attention is called to the limitations of indirect determination of the food value of a piece of cooked meat, since Grindley and Mojonner (3) and also McCance and Shipp (4) state that little is known of the portion of the cooking losses contributed by skin and bone. Pan drippings made into gravies and sauces do not represent a loss of nutrients. Nevertheless under some circumstances it is desirable to know how much of the loss of weight went into pan drippings. This is particularly true when the drippings contain more fat than can be used. Under these conditions there is a loss of nutritive value. At the same time it is scarcely fair to attribute this waste to cooking because not all this fat would have been eaten even if it had been retained by the roast. Under any conditions excessively fat meat is wasty.

The palatability of a piece of cooked meat depends to some extent on its juiciness. Whereas loss of weight in itself may have little meaning as a guide to juiciness in determination of the palatability of meats, the evaporation fraction serves as an indicator of the quantity of juice, as at present judged by organoleptic tests.

PLAN OF EXPERIMENTS

When planning experiments to show the effect of grade of carcass, period of ripening, and method of cooking, on shrinkage and cooking time, everything possible was done to reduce the number of variables. In the studies of the influence of carcass grade the same cooking method was used on the same cut (the leg) from carcasses of different grades ripened to approximately the same extent. To show the influence of ripening or of cooking method, the meat samples were as nearly uniform as possible; that is, wherever possible paired legs from the same carcass were used, the left legs being treated one way and the right legs another. While such methods are tedious it is believed that they furnish the most information with the least

effort and that for comparing methods of cooking or otherwise handling meat, a small number of pairs is worth more than a much larger number of unrelated cuts. Preliminary to the tests on carcass grade, ripening period, and cooking method, 93 pairs of legs of lamb were cooked by method 1 to see how closely results on shrinkage and cooking time could be duplicated for the same meat, of the same ripening period, cooked by the same method.

Summing up, the order and arrangement of experiments were as follows:

1. Determination of allowance for error in data on shrinkage and cooking time as revealed by 93 pairs of lamb legs cooked by method 1.

2. Determination of the effect on shrinkage and cooking time of ripening 60 left legs of lamb 2 to 6 days and the 60 corresponding right legs 12 to 21 days, all cooked by method 1.

3. Determination of the effect of carcass grade on shrinkage and cooking time—first, for a large quantity of lamb grading from Choice to Cull cooked by method 1; then, for small groups of lamb of a range of grades cooked by methods 2, 3, 4, 5, and 6; and finally for mutton of several grades cooked by methods 1, 2, and 3.

4. Determination of the effect of cooking method on shrinkage and cooking time, using as far as possible pairs of legs of lamb and mutton for comparison of other methods with method 1.

EXPERIMENTAL ERROR IN DETERMINATION OF SHRINKAGE AND COOKING TIME

In order to decide from experimental data whether shrinkage and cooking time really are influenced by carcass grade, by ripening period, or by method of cooking, it is necessary first to determine what constitutes a significant difference in results. Of course, every determination of shrinkage and cooking time is subject to some error. It is, therefore, well to know how great this experimental error may be because unless differences between averages exceed their error they cannot be regarded as significant.

For a measure of error in the data the difference between duplicate determinations of shrinkage and cooking time was used. To make the duplicate determinations, corresponding left and right legs of lamb from the same carcass were cooked on the same day. Theoretically the right and left of each matched pair of lamb legs cooked on the same day by the same method should yield identical results. Where results are not identical the discrepancies are here regarded as due to error in the experiment. The study was conducted as follows:

The paired legs from 93 lamb carcasses were selected for the test. For each of 2 consecutive years the lamb was cooked by method 1 over a period extending from 5 to 18 days after slaughter. Data on shrinkage and cooking time were obtained separately for the left legs and for the rights. After cooking, the lamb legs were judged for palatability. Analysis of the data on palatability has been published by Spencer (5).

For each of the 93 pairs the difference between the left and the right leg was calculated on weight before cooking, shrinkage during cooking, and cooking time, and the differences averaged. For the 93 left legs and the corresponding rights the weights before cooking, the shrinkage during cooking, and the cooking time were averaged.

For each item, the difference between the averages was calculated and the standard error of the difference worked out according to the formula, $\sigma_M = \frac{\sigma}{\sqrt{n-1}}$ by the method which Fisher (2, pp. 112-114) quotes from "Student." The standard deviation, σ , is that of the series of differences between corresponding left and right legs calculated in the usual way as the root-mean-square of the deviations from the average of the series, and n is the number of samples used, 93. The data are presented in table 1.

TABLE 1.—Comparison of determinations of shrinkage and cooking time on corresponding left and right legs of lamb, each pair ripened the same period, and all cooked by the same method (method 1: seared 20 minutes at 265° C., finished at 125°, to 76° internal temperature)

Number and description of samples	Weight of uncooked leg	Shrinkage during roasting						Cooking time	
		Evaporation		Drippings		Total		Total	Per pound
	Grams	Grams	Percent	Grams	Percent	Grams	Percent	Minutes	Minutes
93, left.....	2,449	211	8.6	112	4.5	323	13.1	170	31.5
93, right.....	2,438	211	8.6	114	4.6	325	13.2	170	31.6
Difference.....	+11	0	0	-2	-1	-2	-1	0	-1
Standard deviation.....	±63.1	±41.2	±1.76	±24.6	±.987	±57.3	±2.39	±19.7	±3.98
Standard error.....	±6.6	±4.3	±.18	±2.0	±.10	±6.0	±.25	±2.1	±.42

According to Fisher two averages are not significantly different unless the difference between them is at least twice its standard error. In no case were the averages of the 93 pairs of duplicate determinations significantly different. However, according to the values found for standard errors in this study the averages of duplicate determinations of shrinkage and cooking time made on 93 pairs of legs of lamb could vary by chance alone up to 0.36 percent evaporation, 0.20 percent drippings loss, 0.50 percent total shrinkage, and 0.84 minutes per pound cooking time. These values are held to be significant differences between two averages, each of which is based on 93 samples.

Since 93 is an unusually large number of samples in experiments on cooking method, the standard errors for 20 and for 10 were calculated by dividing the standard deviations as found for the 93 by the square root of 19 and of 9, respectively. Following are the standard errors calculated for averages of 20 samples: Weight of uncooked leg, ± 14.5 grams; weight lost by evaporation, ± 9.5 grams, ± 0.40 percent; weight lost by pan drippings, ± 5.7 grams, ± 0.22 percent; total loss of weight, ± 13.1 grams, ± 0.55 percent; cooking time, ± 4.5 minutes, ± 0.91 minutes per pound. For averages based on 10 samples, the calculated standard errors are as follows: Weight of uncooked leg, ± 21.0 grams; weight lost by evaporation, ± 13.8 grams, ± 0.58 percent; weight lost by pan drippings, ± 8.2 grams, ± 0.32 percent; total loss of weight, ± 19.1 grams, ± 0.80 percent; cooking time, total ± 6.6 minutes, ± 1.33 minutes per pound. Allowance up to twice these standard errors should be made for experimental error when comparing averages based on 20 or 10 samples, respectively.

In generalizing from the results the writers realize that if data were available on an infinite number of groups of the composition of those studied, differences between duplicate determinations of shrinkage and

cooking time could not be expected to be exactly the same as those found in this experiment. At the same time these measures of experimental error are believed to be reasonable. They are useful throughout this bulletin as checks on the significance of differences to be ascribed to carcass grade, ripening, or method of cooking. Such checks are, of course, particularly helpful in judging the significance of results when averages are the only data reported, as frequently happens.

The experimental error as estimated may seem large. Much of the variation in shrinkage and cooking time between left and right legs was due to the manner in which they were shaped up as retail cuts, for if the fat covering over the inside round was stripped off more closely from one leg than the other there was a greater difference in the shrinkage and cooking time than when both were trimmed off to about the same extent. Slower cooking and increased shrinkage are direct results of excessive trimming. Apparently other factors also are involved in the differences between data from corresponding left and right legs cooked on the same day by the same method.

It is emphasized that this study covers but one method of roasting pairs of legs of lamb. Whether allowances for experimental error would need to be as large with other cooking methods cannot be stated but since the low oven temperature of 125° C. exaggerates the role of factors in the meat itself that retard heat penetration, smaller experimental error might be expected if higher oven temperatures were used.

SHRINKAGE AND RATE OF HEAT PENETRATION AS INFLUENCED BY PERIOD OF RIPENING OF THE MEAT

During the course of the study to determine experimental error in the data on shrinkage and cooking time, it became apparent that the length of time lamb legs are ripened after slaughter affects the cooking losses and the rate of heat penetration. Therefore, lest differences due to ripening be erroneously attributed to carcass grade or to cooking method, a special study was made of this.

Sixty pairs of lamb legs were chosen and the lefts cooked within 2 to 6 days after slaughter, while the corresponding rights were held from 8 to 18 days longer. All the legs were cooked by method 1 already described. The cooked meat was judged for palatability and the effect of ripening on the tenderness was reported by Warner and Alexander (6).

The data on shrinkage and cooking time for the corresponding left and right legs were handled as described on page 7, and the results are shown in table 2.

TABLE 2.—Effect of ripening on shrinkage and cooking time of pairs of legs of lamb, averaged for lefts and rights ripened for different periods, and all cooked by the same method (method 1: seared 20 minutes at 265° C., finished at 125°, to 76° internal temperature)

Number and description of samples	Aging period	Interval between tests	Weight of uncooked leg	Shrinkage during roasting			Cooking time
				Evaporation	Drip- plings	Total	
	Days	Days	Grams	Grams	Grams	Grams	Minutes
3, left.....	4	3	1,927	192	69	261	166
3, right.....	12		1,871	154	78	232	154
3, left.....	3	0	2,420	270	150	420	268
3, right.....	12		2,271	175	102	276	184
8, left.....	3	10	2,379	264	143	406	207
8, right.....	13		2,303	209	132	341	193
5, left.....	4	10	2,114	220	113	332	181
5, right.....	14		2,095	203	108	311	181
6, left.....	6	10	1,880	178	87	265	160
6, right.....	16		1,800	100	81	240	152
8, left.....	2	17	2,338	256	144	401	191
8, right.....	19		2,122	152	117	269	151
8, left.....	3	17	2,280	217	117	334	180
8, right.....	20		2,024	174	91	268	156
11, left.....	4	17	2,025	197	91	287	173
11, right.....	21		1,832	137	82	218	140
3, left.....	3	18	2,424	251	134	385	193
3, right.....	21		2,222	155	126	281	169
Average (60, left).....	4	13	2,171	223	115	338	184
Average (60, right).....	17		2,042	169	101	270	162
Difference.....			+129	+54	+14	+68	+22
Standard error of difference.....			±13.4	±5.3	±3.1	±7.2	±2.6

Testing the significance of the differences between the averages of 60 left and 60 right legs, the value t (2) was calculated for each factor by dividing the difference by the respective standard error. Since in every case t exceeded 2.576 and since for samples larger than 30 only one value in a hundred will exceed 2.576 by chance, the differences between the averages are clearly significant.

On comparing the results in table 2 with those in table 1 it can safely be stated that longer ripening made the differences and that lamb lost less in weight during roasting and took less time to cook as the ripening increased. However, since the meat lost weight all the time it was in cold storage, there was less to cook the longer the ripening continued. This fact has to be considered in showing the effect of ripening on shrinkage as percentage of raw weight and on cooking time as minutes per pound.

To show the effect of so many days' additional ripening, as for example the average interval of 13 days in table 2, on the percentage of shrinkage and on the number of minutes per pound required to cook the lamb, the base should be the raw weight of the corresponding paired legs when the first set was cooked. The right legs were not weighed at the time the lefts were cooked. However, table 1 shows that left and right legs of lamb did not differ significantly in raw weight when the same ripening was given to both. So, for an approximation of the effect of 13 days' additional ripening as reflected in percentage of shrinkage during cooking, the average raw weight of 60

left legs ripened 4 days, namely 2,171 grams, was taken as the base for the 60 rights also, and the following results were obtained: Evaporation loss, 10.3 and 7.8 percent; drippings loss, 5.3 and 4.7 percent; total loss, 15.6 and 12.4 percent. Similarly, the cooking time as minutes per pound was reduced from 38 to 34 by the extra 13 days of ripening given to the right legs.

While this method of calculating brings out most forcefully that increased ripening reduces cooking shrinkage and cooking time, percentage of shrinkage and cooking time in minutes per pound are usually figured on the basis of the raw weight of a piece of meat at the time it is cooked. Comparing the relative shrinkage and rate of heat penetration of 60 left legs of lamb ripened 4 days and 60 corresponding right legs ripened 17 days on the basis of the raw weight of each group at the time it was cooked, respectively 2,171 and 2,042 grams, the following values were found: Evaporation loss, 10.3 and 8.2 percent; drippings loss, 5.3 and 5.0 percent; total loss, 15.6 and 13.1 percent; cooking time, 38 and 36 minutes per pound. This method of calculation also showed that as lamb was ripened longer it shrank relatively less during roasting and cooked faster in proportion to its weight.

The figures also showed a greater reduction in the evaporation loss during roasting than in the drippings loss as ripening progressed. This is reasonable because the meat dried out in storage and its water content became lower. When cooked, the 60 legs of lamb ripened 4 days weighed on the average 1,833 grams and the corresponding 60 ripened 17 days weighed 1,772 grams. The difference between the roasts when cooked, 61 grams, was less than before cooking, which was 129 grams.

SHRINKAGE AND RATE OF HEAT PENETRATION AS INFLUENCED BY GRADE OF CARCASS

For detailed studies on the influence of carcass grade on shrinkage and cooking time, the writers chose from production experiments a sample of 749 legs of lamb, including 168 of Choice, 389 of Good, 142 of Medium, 32 of Common, and 18 of Cull grade. From the statistical standpoint larger samples of Common and Cull grades would be preferable, but the production experiments yielded only a small proportion of lambs in these lower grades.

Included in this sample of 749 are 32 left legs from the 93 pairs in table 1, 13 lefts from the 60 pairs in table 2, 8 lefts from the pairs cited below, and 696 lefts not discussed elsewhere in this bulletin.

The ripening period for the 749 legs ranged from 2 to 24 days after slaughter, with from one-half to two-thirds of the legs ripened from 4 to 9 days and only one-seventh beyond 15 days. When averaged for the Choice, Good, Medium, Common, and Cull grades, the ripening periods were, respectively, 9, 10, 11, 10, and 10 days.

All 749 legs were cooked by method 1 already described. Data on shrinkage and cooking time averaged for the five different grades are given in table 3. The standard errors were calculated by the formula,

$\sigma_M = \frac{\sigma}{\sqrt{n-1}}$ The standard deviation, σ , in this table is the square root of the sum of the squared deviations from the mean divided by the number of legs cooked, n .

TABLE 3.—The effect of carcass grade on shrinkage and cooking time of legs of lamb when roasted to specified internal temperatures

METHOD 1. OVEN: 205° C. FOR 20 MINUTES, 125° FOR FINISH. MEAT: 70°

Carcass grade	Samples	Weight of uncooked leg	Shrinkage during roasting		Cooking time per pound
			Evaporation	Drippings	
	Number	Grams	Percent	Percent	Minutes
Choice.....	108	2,489±24.9	9.1±0.14	0.3±0.11	34.3±0.27
Good.....	380	2,250±27.8	8.9±.09	5.3±.07	34.1±.17
Medium.....	142	1,895±32.1	8.9±.14	3.7±.11	34.6±.27
Common.....	32	1,498±63.2	9.3±.29	2.3±.18	37.3±.72
Cull.....	18	1,117±58.0	10.2±.44	1.2±.09	40.9±1.38

METHOD 2. OVEN: 205° C. FOR 20 MINUTES, 150° FOR FINISH. MEAT: 70°

Choice.....	1	2,285	10.8	8.3	27.0
Good.....	1	2,288	6.2	6.3	27.6
Common.....	2	1,412	11.4	2.8	31.9

METHOD 3. OVEN: 205° C. FOR 20 MINUTES, 175° FOR FINISH. MEAT: 70°

Choice.....	2	2,556	10.8	7.1	20.2
Good.....	2	2,230	11.2	7.4	22.1
Medium.....	3	1,646	11.8	4.1	25.4
Common.....	1	902	11.2	1.6	31.2
Cull.....	3	1,027	11.8	1.3	20.4

METHOD 4. OVEN: CONSTANT AT 175° C. MEAT: 70°

Choice.....	5	2,265	13.8	6.7	27.3
Good.....	5	2,236	14.5	6.5	28.9
Medium.....	7	1,791	13.6	5.7	20.4
Common.....	4	1,199	13.6	2.7	32.5
Cull.....	4	945	9.3	2.0	34.4

METHOD 5. OVEN: 205° C. FOR 20 MINUTES, 125° FOR FINISH. MEAT: 83°

Choice.....	3	2,367	19.2	8.0	60.4
Good.....	5	2,080	18.8	7.7	64.4

METHOD 6. OVEN: 205° C. FOR 20 MINUTES, 175° FOR FINISH. MEAT: 83°

Choice.....	3	2,340	18.7	8.2	26.9
Good.....	5	2,097	20.0	7.2	26.1

Additional tests of the influence of carcass grade on shrinkage and cooking time were made on smaller groups of both lamb and mutton, using other methods of cooking. The lamb legs of different carcass grades, cooked by method 2 were ripened for 4 to 5 days. Those cooked by method 3 were ripened, respectively, for Choice through Cull grades, 8, 8, 9, 7, and 7 days. Of the 25 legs of lamb cooked by method 4, 6 were purchased at a Washington, D.C., market and their ripening periods were not known, but for the remaining 19 the ripening periods averaged as follows: 4 Choice grade, 8 days; 3 Good, 8; 5 Medium, 9; 3 Common, 7; 4 Cull, 8. Of the lamb legs cooked by methods 5 and 6 those of Choice grade were ripened 8 days and of Good grade 7 days. Data are shown in table 3.

Table 4 presents the data for mutton of different grades cooked by methods 1, 2, and 3. Of those cooked by method 1, ripening periods averaged 7 days for the Choice grade, 7 for Good, 5 for Medium, and 5 for Common. Mutton legs cooked by method 2 were ripened 4, 5, 4, and 5 days, respectively, for Choice, Good, Medium, and Common grades. Ripening periods for mutton legs cooked by method 3 averaged 9 days for Choice grade, 8 for Good, and 6 for Medium.

TABLE 4.—*The effect of carcass grade on shrinkage and cooking time of legs of mutton when roasted to specified internal temperatures*

METHOD 1. OVEN: 265°C. FOR 20 MINUTES, 125° FOR FINISH. MEAT: 76°

Carcass grade	Samples	Weight of uncooked leg	Shrinkage during roasting		Cooking time per pound
			Evaporation	Drippings	
	Number	Grams	Percent	Percent	Minutes
Choice.....	2	3,494	10.8	6.1	30.2
Good.....	3	3,140	10.2	4.0	27.6
Medium.....	3	2,740	13.0	3.1	32.7
Common.....	1	2,969	14.2	.4	34.4

METHOD 2. OVEN: 205° C. FOR 20 MINUTES, 150° FOR FINISH. MEAT: 76°

Choice.....	1	3,537	14.0	8.1	28.2
Good.....	1	3,242	15.2	4.7	25.6
Medium.....	1	2,693	14.4	2.7	26.1
Common.....	1	2,846	20.0	1.0	27.1

METHOD 3. OVEN: 205° C. FOR 20 MINUTES, 175° FOR FINISH. MEAT: 76°

Choice.....	1	3,259	14.8	6.7	18.0
Good.....	2	3,028	15.6	4.7	19.9
Medium.....	2	2,873	15.2	3.5	19.9

The significance of differences between the grades in the first section of table 3 was determined by the method of Fisher (2, p. 108). To compare any two means the standard errors were first squared to obtain the variances. In making use of the proposition that the variance of the difference of two independent variates is equal to the sum of their variances, the two variances were added. Then extracting the square root of this sum the standard error of the differences between the means was obtained, and from this t calculated as usual. For significant results t should be at least 2. In the other experiments reported in tables 3 and 4 the number of samples in each grade was very small, so the standard errors of the means were not calculated. Instead, the data for the different grades were examined to see if they seemed to show the same trend as the larger samples and then the differences between grades were roughly checked by comparing them with the allowances made for experimental error of 10 samples as determined on page 8.

With few exceptions, the data in tables 3 and 4 show the same general trend in the relation of carcass grade of lamb and mutton to shrinkage and cooking time independent of the method of cooking.

Drippings loss, in percentage, was definitely related to carcass grade. Choice grade lamb and mutton lost the most as drippings, and as the carcass grade became poorer the drippings loss decreased. In table 3, method 1, where there are many samples in each grade the decline in drippings loss was from 1 to 1.6 percent from grade to grade below Choice. These differences are significant, but the slight differences between drippings losses of Choice and Good grade lamb when cooked by methods 3, 4, and 5 are not in themselves significant.

Shrinkage due to evaporation loss was not consistently related to carcass grade. In table 3, method 1, the data show that Choice, Good, Medium, and Common grade lamb did not differ significantly in evaporation loss, but that Cull grade lamb lost slightly more. The next largest sample was the 25 legs of lamb roasted by method 4. The data for this comparison of grades indicate no significant difference in evaporation loss of Choice, Good, Medium, and Common grade lamb. Here again Cull grade lamb differed from the other grades, but this time it lost less than they did by evaporation.

The rate of heat penetration was influenced by the carcass grade where each grade was reasonably well represented. According to the data in table 3 there was no significant difference in the number of minutes per pound required to roast Choice, Good, and Medium grade lamb by method 1, but Common and Cull grade lamb took longer to cook in proportion to the weight. The same result is suggested by the data on 25 legs roasted by method 4. In the other grade comparisons in tables 3 and 4 results are not considered significant because of the small number of samples.

Since the same method of cooking was used in each group of carcass grade comparisons shown in tables 3 and 4, and since the ripening periods were kept much the same on the average, the causes of variation in shrinkage and cooking time associated with carcass grade are not to be sought in cooking method or in ripening. According to Weber and his associates (7) the fatness of lamb determines the fat loss on cooking. Of course the legs that were cooked could not be analyzed for fat content. The corresponding uncooked legs were not analyzed either. However, there was recorded at the time of cooking a visual estimate of the relative fatness of each leg of lamb and mutton. These judgments of "finish" were made by the writers, following the system started in 1927 by D. A. Spencer of the Animal Husbandry Division of the Bureau of Animal Industry. On the basis of appearance the legs of lamb ranged in fatness from an extremely large amount to none visible and were graded in five classes. When the finish grades of the legs were compared with the official grades for the carcasses for 924 lambs, a sample which included many of those discussed here, the coefficient of linear correlation was $+0.78 \pm 0.009$, indicating that the visible fat on the leg was closely related to the carcass grade of lamb.

Data on the fat and water content of a small number of lamb legs from Choice, Good, Medium, Common, and Cull grade carcasses have been contributed by the Animal Husbandry Division of the Bureau of Animal Industry and are summarized in table 5.

TABLE 5.—*Water and fat content of lamb legs of Choice, Good, Medium, Common, and Cull grades determined by chemical analysis and expressed as percent of weight as purchased*

Carcass grade	Samples	Water content		Fat content	
		Average	Range	Average	Range
	Number	Percent	Percent	Percent	Percent
Choice.....	7	51.8	48.6-54.8	18.2	15.2-21.4
Good.....	9	53.7	49.8-57.5	14.7	11.6-17.5
Medium.....	7	54.4	49.2-58.5	11.6	10.2-13.4
Common.....	2	53.9	52.9-54.9	8.2	8.1-8.4
Cull.....	5	55.2	52.0-58.1	4.7	1.4-7.4

According to these data the fat content of leg of lamb as purchased varies directly with the carcass grade. The higher the grade the more fat there is in the leg. The water content of leg of lamb as purchased varies less consistently with carcass grade, but from these data appears to be greater for Cull lamb than for Choice.

On comparing drippings and evaporation loss of leg of lamb of the different carcass grades as shown in table 3 respectively with the fat and water content as shown in table 5, it appears that composition determines what the character and relative amount of the shrinkage will be, other things such as ripening and cooking method being equal.

The range in water and fat content of lamb leg in table 5 indicates considerable variation within grades, consequently it is to be expected that shrinkage also will vary within grades. A good deal of variation existed in each grade as shown by the standard error of the means of the large samples (table 3). Averages based on a small number of samples therefore cannot be expected to be the same as if a large number had been used.

It is unsatisfactory to attempt to explain the rate of heat penetration by the chemical composition of meat. The weight of a leg of lamb as well as the fat and water content undoubtedly influences the number of minutes per pound required to cook it. There appears to be a considerable range in fat content and in weight over which these factors do not influence the rate of heat penetration, as for example in Choice, Good, and Medium grades. However, with a sharp decrease in fat content and in weight, such as found in either Common or Cull lamb, the speed of cooking declines.

As far as it is possible to make comparisons, the results are in general accord with those reported by Weber, Loeffel, and Peters (7).

SHRINKAGE AND RATE OF HEAT PENETRATION AS INFLUENCED BY THE METHOD OF COOKING

Seven methods of roasting lamb and mutton were employed, including five different oven temperatures and two meat temperatures, or stages of doneness. These methods have already been described (p. 4). In comparative tests methods 2 to 7 were always checked against method 1, since it is the one by which the largest number of samples were cooked. Wherever possible, both legs from the same carcass were used, the leg from one side cooked in one way and the corresponding leg in another on the same day. This arrangement keeps the composition of the meat essentially the same for each comparison of two methods of cooking and so reduces the number of variables in an experiment:

OVEN-TEMPERATURE VARIATIONS

As already stated, for method 1 lamb or mutton was seared for 20 minutes at an average oven temperature of 265° C., then the cooking continued very slowly at 125° until the thermometer inserted in the meat registered 76°. From the 749 legs of lamb roasted by this method and summarized in table 3, the 18 Cull grade legs were omitted as not representative of the lamb ordinarily found on the market. This leaves 731 of Choice through Common grade, ripened for an average of 10 days. Shrinkage data and cooking time were averaged for these 731 samples and are presented graphically in figures 1 and 2,

group A. Data for three other groups of legs of lamb cooked by this method are also shown in figures 1 and 2, B, C, and D. These groups contain, respectively, 20, 8, and 21 legs of lamb, in part the mates of samples reported in table 3. Table 6 contains data on another group

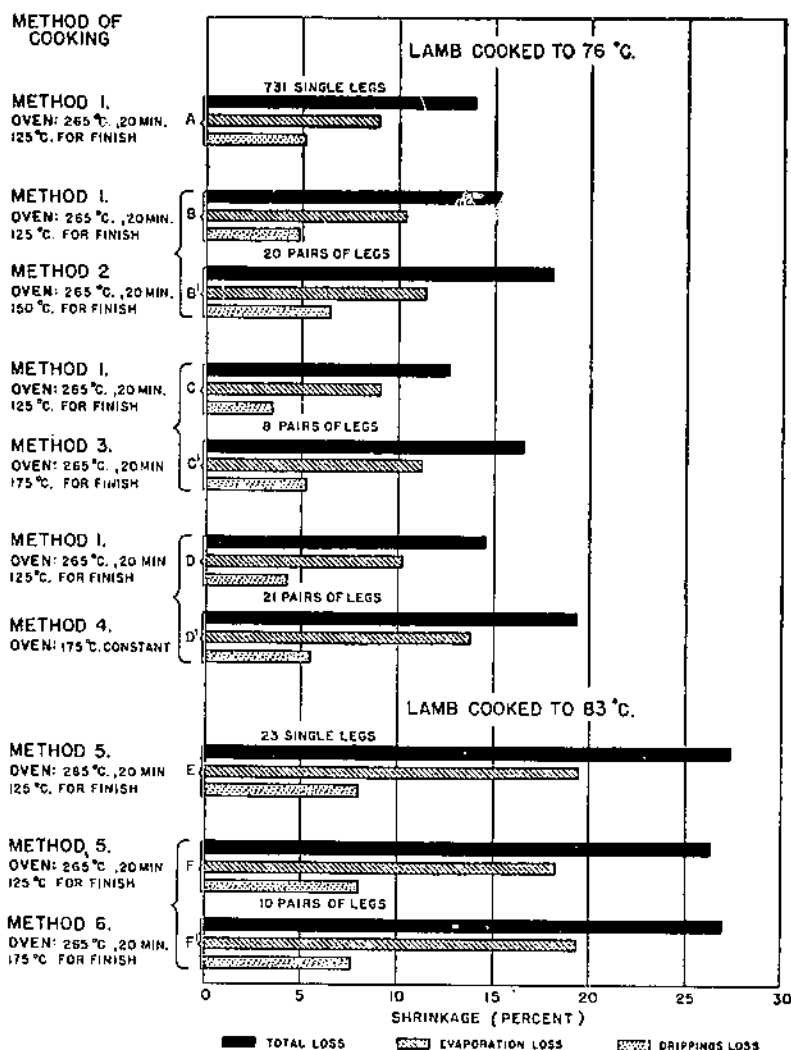


FIGURE 1.—Average shrinkage of several lots of lamb legs during roasting as affected by variations in oven temperature and in cooking to different stages of doneness. The losses are expressed as percent of the weight of the uncooked cut.

of legs of lamb cooked by method 1. Since the pairs of legs were cooked to compare different oven temperatures they are discussed in detail below.

Nine left legs of mutton were cooked by method 1 as reported in table 4. The ripening period ranged from 4 to 9 days, averaging 6. When the figures for shrinkage and cooking time were averaged the following results were obtained: Evaporation loss, 11.7 percent;

drippings loss, 3.8 percent; total loss, 15.4 percent; minutes per pound, 30.6.

Method 2 employs the same searing and the same meat temperature as method 1, but for the oven temperature uses 150° C. for the finish. The two methods were compared on pairs of legs of lamb and mutton to show the effect on shrinkage and cooking time when the finishing oven temperature was raised from 125° to 150°. Twenty pairs of legs of lamb and four pairs of legs of mutton were cooked by these two methods. Four pairs of the lamb legs came from graded carcasses (table 3). The remaining 16 pairs were from ungraded carcasses,

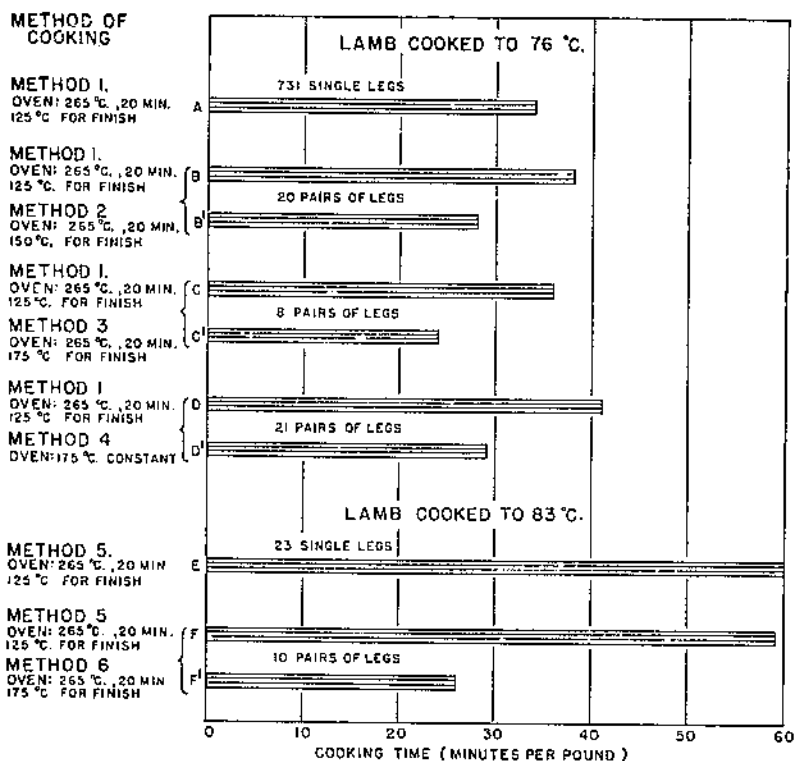


FIGURE 2.—Average time required for heat to penetrate lamb legs roasted by various methods and to various degrees of doneness. The cooking time is expressed as minutes per pound of the uncooked cut.

but finish grades assigned in the cooking laboratory indicated that all were of a moderate to a very high degree of fatness, except 1 pair which probably would have been graded Common. The ripening period ranged from 4 to 9 days, and averaged 7. Shrinkage and cooking time of the 20 pairs of legs were averaged for the two methods of cooking and are shown graphically in figures 1 and 2, as groups B and B'.

Of the four pairs of mutton legs, the left legs cooked by method 1 are reported with five others in the first section of table 4, and their mates cooked by method 2 appear in the second section of the table. The ripening period ranged from 4 to 5 days. Following are the averages, respectively, for the four pairs of legs of mutton cooked by

methods 1 and 2: Evaporation loss, 13.4 and 16.1 percent; drippings loss, 3.6 and 4.1 percent; total loss, 16.9 and 20.3 percent; minutes per pound, 32.8 and 26.8.

According to method 3 lamb and mutton were seared the same as in method 1 and cooked to the same stage, 76° C., but the finishing oven temperature was 175° instead of 125°. Eleven pairs of lamb legs and five pairs of mutton legs were cooked by these two methods to show the effect on shrinkage and cooking time of raising the oven temperature from 125° to 175° for the finish after searing. Table 3 reports data on the 11 legs of lamb cooked by method 3. Omitting the 3 pairs of Cull grade samples, the remaining 8 pairs averaged 8 days ripening. Shrinkage and cooking time for the 8 pairs cooked, respectively, by methods 1 and 3 are shown graphically in figures 1 and 2, groups *C* and *C'*. The 3 pairs of Cull grade lamb legs were ripened 7 days on the average. Shrinkage and cooking time for these 3 pairs of Cull grade legs cooked by methods 1 and 3 averaged, respectively, as follows: Evaporation loss, 11.3 and 11.8 percent; drippings loss, 0.7 and 1.3 percent; total loss, 12.0 and 13.1 percent; minutes per pound, 49.4 and 26.4.

Of the five pairs of legs of mutton the right legs cooked by method 3 were reported in the third section of table 4, and the lefts cooked by method 1 included in the first section of the same table. The ripening period averaged 7 days. The shrinkage and cooking time for the five pairs of mutton legs cooked by methods 1 and 3 averaged, respectively, as follows: Evaporation loss, 10.4 and 15.2 percent; drippings loss, 3.9 and 4.6 percent; total loss, 14.3 and 19.8 percent; minutes per pound, 28.9 and 19.5.

Method 4 employed a constant moderate oven temperature, 175° C. without searing, and the lamb was cooked to 76° internal temperature. Twenty-five pairs of legs of lamb were used to compare method 4 with method 1. Table 3 contains data on the 25 legs that were cooked by method 4. When the 4 pairs of Cull grade lamb legs were omitted, the ripening period of the remaining 21 pairs averaged 8 days so far as information is available (p. 12). The data for shrinkage and cooking time were averaged for the 21 left legs cooked by method 1 and for their mates cooked by method 4 and are shown graphically in figures 1 and 2, as groups *D* and *D'*. When the four pairs of Cull grade lamb legs, ripened 8 days, were averaged to show shrinkage and cooking time for the two methods of roasting, the following results were obtained, respectively, for method 1 and method 4: Evaporation loss, 10.6 and 9.3 percent; drippings loss, 1.8 and 2.0 percent; total loss, 12.4 and 11.3 percent; minutes per pound, 43.4 and 34.4.

Prior to the adoption of the standard laboratory method for palatability tests lamb was cooked well done to 83° C. (method 5). By this method the legs were seared either for 35 minutes at 250° or for 20 minutes at 265°. Since the two searing methods did not appear to affect the shrinkage differently, no distinction is made here. After searing, the finishing oven temperature was 125°. Twenty-three single legs of lamb were cooked by this method. Eleven legs were from carcasses graded Choice, Good, Medium, and Common. The remaining 12 were not graded. The ripening period for 21 of the 23 legs ranged from 3 to 10 days, averaging 7. The shrinkage and cooking time were averaged for the 23 legs, and the results are shown

graphically in figures 1 and 2, as group *E*. The 10 single legs of lamb cooked by method 5, for which shrinkage and cooking time are shown graphically in figures 1 and 2, group *F*, are included in the group of 23 and are discussed in detail below.

According to method 6 lamb was seared the same as by method 5 and cooked to the same stage, 83° C., but the finishing oven temperature was 175°. Ten pairs of legs of lamb were roasted by methods 5 and 6 to show the effect on shrinkage and on cooking time caused by raising the oven temperature for the finish from 125° to 175° for well-done lamb. Eight pairs were from carcasses graded Choice and Good (table 3) and were ripened for an average of 8 days. The remaining two pairs were from ungraded carcasses of unknown ripening period. The data for shrinkage and cooking time of the 10 pairs were averaged for the two methods of cooking and are shown graphically in figures 1 and 2, as groups *F* and *F'*.

According to method 7 lamb was cooked the same as in method 1 except that it was not seared. Ten pairs of legs of lamb were roasted by methods 1 and 7 to show the effect of searing on shrinkage and cooking time. Eight pairs were from Good grade carcasses and ripened for an average of 8 days. The remaining two pairs were from carcasses graded Medium, but since they were purchased at a market their ripening period was not known. The data for shrinkage and cooking time of the 10 pairs were averaged for the two methods of cooking and are shown in table 6.

TABLE 6.—*Effect of searing on shrinkage and cooking time of paired lamb legs when roasted to 76° C. internal temperature*

Roasting method and oven temperature	Number and description of samples	Weight of uncooked leg	Shrinkage during roasting			Cooking time per pound
			Evaporation	Drip-pings	Total	
Method 1: 205° C. for searing; 125° for finishing.	10, left.....	Grams 2,058	Percent 10.8	Percent 4.9	Percent 15.7	Minutes 39.3
Method 7: 125° C. entire time.....	10, right.....	2,091	8.4	3.4	11.8	44.7
Difference.....		-33	+2.4	+1.5	+3.9	-5.4
Standard error of the difference.....		±18.0	±.44	±.27	±.63	±1.77

Before discussing the effect of varying the oven temperature, attention is called to the data for the four groups of lamb legs in figures 1 and 2, designated as *A*, *B*, *C*, and *D*, and the seared group in table 6. Although all were cooked by method 1, they show discrepancies in shrinkage and also in cooking time as minutes per pound. If the groups *B* and *D* and the seared group in table 6 had been ripened 10 days on the average instead of 7 or 8, it is believed that the shrinkage and cooking time would have been nearer to the values shown for group *A*. The shrinkage of group *C* was unaccountably low for lamb ripened 8 days.

To show the effect of varying the oven temperature on the shrinkage and cooking time of lamb and mutton, the means of the paired samples in groups *B* and *B'*, *C* and *C'*, *D* and *D'*, and *F* and *F'*, also for the two groups each of Cull grade lamb and of mutton of several

grades, and for the seared and unseared groups in table 6, were tested for significant differences as described on page 7. In addition, the differences between means were further checked by comparing them with allowances for experimental error (p. 8).

Results showed that for lamb and mutton of Choice through Common grade when cooked to an internal temperature of 76° C., the higher oven temperatures employed in methods 2 and 3 caused greater shrinkage than method 1 and cooked the meat more quickly.

On comparing method 4 with method 1 (groups *D* and *D'*), lamb of Choice through Common grade roasted at a constant moderate oven temperature, 175° C., shrank more than when it was first seared at 265° and then finished at 125°. This finding is significant. The data in table 6 show that searing itself not only does not decrease the shrinkage of roasts as was once thought, but actually increases it, with the drippings loss increased proportionately more than the evaporation loss. In the case of method 1 and method 4, however, a method that included searing caused less shrinkage than a constant temperature roasting method. The data in groups *D* and *D'* suggest that method 4 gave higher average temperature than method 1. From these results it appears that in roasting meat shrinkage is affected more by average oven temperature than by initial searing.

Cull grade lamb again proved different from the higher grades, this time in response to variations in oven temperature during roasting. Whereas Choice, Good, Medium, and Common grade lamb when cooked to 76° C. internal temperature shrank more as the oven temperature was raised from 125° to 175°, Cull lamb treated similarly did not shrink significantly more at the higher temperatures. It appears that the time in the oven had some effect on the shrinkage, since Cull lamb took proportionately much longer to cook at 125° than at higher oven temperatures.

For lamb of Choice and Good grades cooked to 83° C., raising the oven temperature from 125° to 175° for the finish after searing did not increase the shrinkage significantly according to the comparison of methods 5 and 6 in groups *F* and *F'*, figure 1. This is a different result from the comparison of methods 1 and 3, although in the two experiments the same oven temperatures were contrasted. The finding with respect to lamb cooked to 83° is significant because it is contrary to the general belief that a low oven temperature always holds down the shrinkage of meat. That the long time required to cook lamb well done in a very slow oven decidedly affected the shrinkage is clear from the data in groups *F* and *F'*, figure 2.

MEAT TEMPERATURE VARIATIONS

Method 5 and method 1 differ only in the stage to which lamb is cooked, respectively 83° and 76° C. Although there were no pairs of legs of lamb cooked by these two methods there were several groups containing unrelated samples, namely, groups *A*, *B*, *C*, or *D* for method 1 and *E* or *F* for method 5.

Similarly the shrinkage and cooking time of group *C'* cooked by method 3 can be compared with those of the unrelated group *F'* cooked by method 6, figures 1 and 2. These two methods also differ only in the stage to which lamb is cooked, respectively 83° C. for method 6 and 76° for method 3.

Statistical treatment is not necessary to show the obvious effects on shrinkage and cooking time brought about by varying the stage of doneness or internal meat temperature. For the two groups *C'* and *F'*, however, the cooking time was compared by Fisher's method (2, pp. 114-118). The difference between the means was further checked by comparison with allowances made for experimental error (p. 8).

According to the results, lamb roasted well done, 83° C., shrink much more than lamb roasted only to the medium-to-well-done stage, 76°. The increase in the shrinkage associated with raising the meat temperature from 76° to 83° was almost 100 percent when the low oven temperature of 125° was used for finishing after searing, as in methods 1 and 5. Figure 2 shows that the cooking time was also greatly increased; in fact in many individual cases it was doubled. These groups, as already noted, were made up of unpaired legs of lamb, so they differed in composition, hence the difference in shrinkage and cooking time cannot be ascribed entirely to method of cooking. In addition there were some cases where the grade composition was not known. This probable dissimilarity makes it impossible to estimate how much of the difference might be attributed to grade, but it is believed to be relatively small.

Similarly, an allowance should be made for the effect of the composition of the meat on the shrinkage and cooking time for lamb cooked to 83° C. and only to 76° when the oven temperature was moderate, or 175°, for the finish after searing, as in methods 6 and 3. In this case the data for lamb cooked to 83° showed a 60 percent increased shrinkage over lamb cooked to 76°. With the higher oven temperatures used in methods 6 and 3, little longer time is required to raise the meat temperature from 76° to 83°. In groups *C'* and *F'* of figure 2, the difference between the means is insignificant, but since the groups were small and the legs were not paired, the results are not conclusive for cooking time.

RESULTS OF EXPERIMENTS ON COOKING METHOD

Summing up these experiments on the effect of method of cooking on the shrinkage of lamb and mutton, the results show that the oven temperature, the stage of doneness, and the length of time required to bring the meat to any particular stage of doneness all combined to influence the shrinkage during roasting. The lower the oven temperature, the longer was the time required to cook the meat to a particular stage of doneness, as would be expected. The more thoroughly the meat was cooked, the longer was the time required, as would also be expected. Low oven temperatures held down shrinkage except when the time required was excessively long in proportion to the weight of the roast. The lower the oven temperature the less was the shrinkage of lamb cooked medium to well done, 76° C., except for the small lean legs of Cull grade lamb. They required proportionately much longer time to cook in a very slow oven (125° after searing) than in a moderate oven (175° after searing) and showed no significant difference in shrinkage. Also for lamb cooked well done (83°) shrinkage was not significantly different at these same oven temperatures because 1 hour per pound was required when 125° was used as the finish after searing, whereas only half as long was needed when seared roasts were finished at 175°.

ESTIMATING SHRINKAGE AND COOKING TIME OF LAMB AND MUTTON ON THE BASIS OF EXPERIMENTAL RESULTS

Of special interest to meat producers and to those consumers who are looking for pointers on selection is the shrinkage expected of the different grades of lamb. According to information from the Division of Livestock, Meats, and Wool of the Bureau of Agricultural Economics, the bulk of the market supply of lamb reaches the consumer 7 to 10 days after slaughter and consists of Choice, Good, and Medium grades with the greatest number falling in the lower third of the Good grade.

The data in table 3 indicate that for 168 legs of Choice grade lamb ripened for an average of 9 days, prepared for roasting with the fell on and without seasoning, and roasted by method 1, in 95 percent of trials the average total loss of weight would fall between 15 and 16 percent. Similarly for 389 Good grade lamb legs ripened for an average of 10 days, the total loss of weight would be about 14 percent, and for 142 legs of Medium grade lamb aged 11 days on the average, from 12 to 13 percent. It is roughly estimated for lamb of Common and Cull grades when ripened for an average of 10 days and cooked by method 1 that the total loss of weight will fall between 11 and 12 percent.

The time required to cook Choice, Good, and Medium grade lamb legs by method 1 is estimated to average 34 to 35 minutes per pound, but varies considerably for individual legs. It is exceedingly difficult to predict cooking time for low-grade lamb when this method of cooking is used, but 40 to 45 minutes per pound is reasonable.

There were so few legs of lamb in each of the several carcass grades when other methods of cooking were used, as appears in table 3, that estimates by grades are not attempted.

Having shown that ripening has a definite effect on shrinkage and cooking time, the writers offer here estimates of shrinkage and cooking time based on averages of five groups of legs of lamb cooked by method 1 at different periods of ripening. The ripening periods averaged 4, 8, 10, 11, and 17 days, respectively, for 60 samples (table 2), 51 (from groups B, C, and D, figs. 1 and 2 and the seared group in table 6), 731 (table 3 and group A, figs. 1 and 2), 93 (table 1), and 60 (table 2). From the data it is estimated that for 60 legs of lamb including 29 Choice grade, 26 Good, 3 Medium, and 2 Common, ripened 4 days and cooked by method 1, shrinkage may be expected in 95 percent of trials to vary from 15 to 16 percent. Similarly for 51 legs of lamb ranging in grade from Choice to Common, averaging between Good and Medium and ripened 8 days, the shrinkage is estimated at 14 to 15 percent; for 731 legs of lamb ranging in grade from Choice to Common (table 3), averaging Good grade, and ripened for an average of 10 days, at 14 percent; for 93 legs of lamb made up of 21 of Choice, 50 of Good, 21 of Medium, and 1 of Common grade, ripened for an average of 11 days, at 13 percent; and for 60 legs of lamb mainly Choice to Good, as already noted, ripened for an average of 17 days, at 13 percent.

Cooking time as minutes per pound is estimated for groups of the composition of the above, respectively at 38 to 39, 37 to 39, 34 to 35, 31 to 32, and 35 to 37. The estimates for lamb ripened 11 and 17 days are not believed to be typical. However, they serve well to call attention to the fact that although longer ripening makes lamb cook

faster, there are other factors involved also, and it is not possible to make close estimates for individual legs on the basis of a certain number of days of ripening. In fact, so far no satisfactory basis has been found for close estimates of cooking time for individual legs of lamb roasted by method 1. Because this is so, method 1 is difficult even for the laboratory and is not recommended for household use. However, since it is the method by which the largest number of samples has been cooked, it is the basis for estimating the shrinkage and cooking time for the other methods. With the exception of methods 5 and 7, the others are held to be more practical.

For the general market supply of leg of lamb roasted by methods 2, 3, 4, 5, 6, and 7, estimates of shrinkage and cooking time are very rough because they are based on small samples, respectively groups *B'*, *C'*, *D'*, *E'* and *F'* in figures 1 and 2 and the unseared group in table 6. When method 2 is used, the shrinkage is predicted to range between 15 and 18 percent and the cooking time from 25 to 27 minutes per pound on the average.

For leg of lamb roasted by method 3 shrinkage is estimated at 17 to 20 percent and cooking time at 23 to 24 minutes per pound. However, since the shrinkage figures are based on only eight pairs which showed rather low cooking losses, they are believed to be smaller than should occur in the long run. The estimated cooking time, on the other hand, is believed to be too high.

For lamb roasted by method 4 shrinkage is estimated at 17 to 20 percent and cooking time at 24 to 26 minutes per pound on the average. Incidentally, as between methods 3 and 4, if meat of the same composition were used, the searing in method 3 would be expected to increase shrinkage 3 to 5 percent, and to decrease the cooking time about 5 minutes per pound.

For leg of lamb cooked well done, 83° C., by methods 5 and 6, shrinkage is estimated at 25 to 30 percent, whether the finishing temperature after searing is 125° or 175°. Cooking time is estimated at 1 hour per pound for method 5 and half an hour per pound for method 6.

For leg of lamb roasted by method 7 shrinkage is estimated at 10 to 11 percent and cooking time at 39 to 41 minutes per pound.

The number of mutton samples was too small to provide a reliable basis for predicting shrinkage and cooking time, but as far as can be judged from the data leg of mutton will shrink somewhat more than leg of lamb of the same grade and cook more quickly in proportion to its weight. This is contrary to a general belief that larger pieces of meat shrink proportionately less than do small ones, but is in accord with the belief that very large cuts cook faster in proportion to their weight.

SUMMARY AND CONCLUSIONS

The influence of carcass grade, period of ripening, and method of cooking on the shrinkage (loss of weight) and rate of heat penetration during roasting was determined in a series of experiments on 1,185 legs of lamb and mutton, including Choice, Good, Medium, Common, and Cull grades, ripening periods of from 2 to 24 days after slaughter, and seven different cooking methods. Studies on cooking method included variations in oven temperature and varia-

tions in the stage of doneness to which lamb was cooked as determined by a roast-meat thermometer. Oven temperature was raised from 125° C. to 175° for the finish after 20 minutes searing at 265°, and the effects on shrinkage and cooking time compared, and constant-temperature roasting at 125° and at 175° was compared with the sear at 265° plus finish at 125°. Also the lamb was cooked to two stages: 76°, medium to well done, and 83°, well done.

A preliminary study was made to determine what is a significant difference in shrinkage and cooking-time data for averages of 10, 20, and 93 legs of lamb roasted by the standard laboratory method used for palatability tests in the cooperative meat investigations.

The higher the grade of lamb and mutton the greater was the shrinkage, due mainly to the rendering out of more fat into the drippings from the better finished high-grade meat. Since pan drippings are usually made into gravies and sauces they do not necessarily represent a loss of nutritive value. Although drippings sometimes contain more fat than can be used, this excess fat should not be looked upon as cooking waste because it probably would not have been eaten even if it had been retained by the roast. Whereas drippings loss decreased with grade, the water lost by evaporation during roasting did not follow grade consistently. Choice, Good, and Medium legs of lamb cooked more rapidly in proportion to their weight than lamb of Common and Cull grades.

Increasing the length of the ripening period after slaughter decreased the cooking shrinkage and shortened the time required to roast leg of lamb. As the ripening period of lamb increased beyond 2 days after slaughter, the cooking shrinkage became smaller and the rate of heat penetration more rapid. The decrease in loss of weight in the oven is of special interest because it offsets to some extent the loss of weight in the cooler during storage. No studies were made on fuel consumption in relation to ripening, but of course with faster heat penetration there would be less fuel required per pound of meat cooked.

Among the studies on oven-temperature variations as influencing shrinkage, the comparisons of the constant low and constant moderate temperature methods with a method that includes an initial sear and a slow finish are of special interest. The average oven temperature for the combination of 265° C. for 20 minutes searing and 125° for finishing was higher than 125°, the constant low temperature used. There was a difference of 4 percent in the shrinkage of lamb legs roasted by these two methods and the smaller loss was associated with the lower average cooking temperature. That is to say, the unseared legs shrank less. In contrast, the average oven temperature for the combination of 265° for 20 minutes searing and 125° for finishing was lower than 175°, the constant moderate temperature used. Again there was a difference of 4 percent in the shrinkage of lamb legs roasted by the two methods, and the smaller loss was associated with the lower average cooking temperature, which however in this case included an initial sear. This time the unseared legs shrank more. This goes to show that searing in itself does not reduce shrinkage, as was once thought, but actually makes a roast lose more weight, though the extra loss is mainly fat. The significance of these results lies in the fact that it is the average oven tem-

perature which has more influence on shrinkage than does the initial sear.

As a whole the studies show that the lower the oven temperature the smaller was the shrinkage of leg of lamb cooked to the medium-to-well-done stage (76° C.). At the lowest oven temperature used, constant 125°, the shrinkage averaged 12 percent and the cooking time 45 minutes per pound. When lamb legs were first seared, and then finished at different oven temperatures, at the lowest finishing temperature, 125°, the meat shrank 13 percent, while at the highest, 175°, the shrinkage averaged 17 percent. The cooking time ranged from an average of 36 to an average of 24 minutes per pound, respectively.

In contrast when leg of lamb was cooked well done (83° C.) by these same oven temperatures, 125° and 175° following searing, the shrinkage was not significantly different, averaging 27 percent. The cooking time averaged 60 minutes per pound by the former method and 25 by the latter. Without doubt the time influenced the shrinkage.

These tests on the influence of cooking method showed that the stage to which leg of lamb was cooked made more difference on the shrinkage than the oven temperature that was chosen. The results bring out an important point in meat cookery with respect to controlling shrinkage: The stage of doneness to which meat is cooked in roasting may make more difference on the shrinkage than the specific oven temperature used. This is a good argument for the use of a roast-meat thermometer in addition to an oven thermometer because the meat thermometer shows when the desired stage of doneness is reached and prevents overcooking and excessive shrinkage.

On the basis of experimental data estimates of shrinkage and cooking time were worked out to apply to lamb and mutton as the consumer is likely to find it on the market, when cooked by the methods described in this bulletin.

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