THE EFFECT OF CERTAIN FACTORS UPON CHARACTERISTICS OF STORED PRECOOKED FROZEN BEEF AND PORK

by

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TABLE OF CONTENTS

INTRODUCTION 1
REVIEW OF LITERATURE 2
EXPERIMENTAL PROCEDURE 4
RESULTS 18
DISCUSSION OF RESULTS 34
SUMMARY 39
ACKNOWLEDGMENTS 42
REFERENCES 43
APPENDIX 45

INTRODUCTION

The freezing of cooked foods is one of the newer technological developments of the frozen food industry. Not until 1942 was there any volume pack of precooked frozen foods; by 1945, in spite of wartime scarcities, there were 22 food processors packing a sizeable quantity of precooked items. The expediency of war brought to light many useful applications of precooked foods; for example, the Maxson Food Systems, Inc. used a method of preparing plate meals of precooked foods suitable for reheating and serving on navy transports. In peacetime the demand for them continues. Commercial users, such as hotels and restaurants, forsee economical possibilities of standard quality, saving of time and labor, and reduction of waste for them in the field. In keeping with this increased demand for precooked foods, retail outlets are now available in certain areas in specialty shops dealing only with frozen foods, and in department stores offering this service to their customers. The Waldorf-Astoria Hotel in New York City is planning national distribution of frozen cooked foods prepared by its famous chefs.

Precooked meats are naturally contenders for popularity in this promising field, but to date, relatively little research has been conducted concerning them, and there exists an uncertainty as to the changes which will take place in frozen cooked meats as compared with uncooked. The purpose of this study was in general to determine if precooked frozen meat can be reheated to retain quality comparable to freshly cooked meat, and specifically to determine the effect of methods of packaging, thawing, and reheating upon the palatability, shear, press fluid, percentage losses, and rancidity of precooked frozen beef and pork.

REVIEW OF LITERATURE

Technical information pertaining to the reheating of precooked frozen foods, particularly meats, is scarce because of the recent advent of such products in the frozen food industry. New products are being developed constantly and are mentioned in the trade journals, but little mention is made of the problems concerning their preparation, freezing, and reheating. Tressler (1946) stated that the absence of any difficulty with precooked foods on the market to date has been due to the fact that such foods have moved rapidly from producer to consumer. As the business grows, the products will have to be subjected to longer storage periods, and then complaints may arise. It is for this reason that he emphasized the urgent need for immediate research on the best methods of preparing and freezing precooked foods. Hutchings and Evers (1945) have pointed out the need for quality control, for the future of the industry depends on consumer acceptance, which in turn depends on a high quality product. One of the essential factors to be considered under quality is freedom from bacterial contamination, because precooked foods serve as an excellent medium for the growth of Staphylococci aureus, the source of many cases of food poisoning.

Woodroof and Atkinson (1945) published results of their study at the Georgia Agricultural Experiment Station on precooked foods, including meats. Fried meats such as steaks, chicken and pork chops held in frozen storage lost crispness and gradually developed a "warmed-over" flavor. It was suggested that if such meats are frozen, they should be covered with gravy, sauce or oil. Large cuts cooked by boiling, roasting, or baking were satisfactorily preserved by freezing when adequately wrapped. To reduce air exposure to the minimum, such meats should be wrapped in as large pieces as possible and cut immediately before serving. Cooked meats for freezing should contain as little fat or seasoning as possible. Wilmeth (1945), who conducted studies on precooked beef steaks and roasts, and pork chops and roasts, concluded that all of the precooked frozen meat was acceptable and palatable. There were conceivable advantages in using such meats in certain food establishments, but the amount of time required for reheating was a limiting factor.

Tressler (1946) enumerated as one of the greater difficulties encountered in freezing precooked foods the fact that the fat is more likely to oxidize, hydrolyze, and become rancid.

This recent literature shows that the tentative work done with precooked frozen meats indicates a promising future for the product if minor problems can be worked out through diligent research.

EXPERIMENTAL PROCEDURE

The meat used in this experiment consisted of beef porterhouse and sirloin steaks, beef rib roasts, pork loin roasts, and pork loin chops. The beef was cut from a grade AA carcass handled by a local slaughtering house. The pork was purchased from John Morrell and Company, a meat packing plant in Topeka, Kansas, in the form of two loins which were cut into roasts and chops under personal supervision. All meats were obtained in paired cuts to eliminate as much variability as possible.

Initial Treatment

Fourteen pairs of steaks which had been cut in the spring of 1945, double-wrapped in locker paper, and stored in a local freezer locker plant, were removed from storage in the fall of 1945. The steaks had been numbered from 28 to 41, right and left, for purposes of identity; those numbered 28-34 were sirloin steaks one inch thick, and numbers 35-41 represented porterhouse steaks one and one-fourth inches thick. Each steak was weighed on a torsion balance when taken from 0° F. storage, and thawed overnight at refrigerator temperature of 35-39° F. to an internal temperature of 28-30° F. The thawed meat was unwrapped, a fat sample weighing approximately 25 grams removed from each piece for rancidity tests, and the meat again weighed. A meat thermometer was inserted as nearly as possible in the center of the longissimus dorsi muscle of the steak. The meat was then placed on a weighed broiler and the broiler, steak and thermometer weighed. These were then placed in an electric broiling oven preheated to 350° F. so that the meat was approximately three inches from the broiling unit. When the internal temperature of the meat reached approximately 125° F., the meat was turned and allowed to continue broiling on the other side to a temperature of 137° F., the rare stage of beef (Committee on Preparation Factors, National Live Stock and Meat Board). The cooking time was noted and the meat, broiler and drippings were weighed to determine evaporation loss, the broiler and drippings were weighed to find the loss from drippings, and the meat alone was weighed to check the total cooking loss and percentage total cooking loss.

Up to this point all of the steaks were treated exactly the same. At this time one steak from each pair was selected alternately for testing immediately after cooking for palatability, mechanical shear, and press fluid. A fat sample was removed from the cooked steak, wrapped, and tested for rancidity at the same time as the uncooked sample from the same steak. A group of six judges, members of the Department of Food Economics and Nutrition, comprised the palatability committee for scoring the meat according to a grading chart for cooked meat compiled by the Committee on Preparation Factors, National Live Stock and Meat Board. The tenderloin muscle was used for tasting when feasible. In some instances it was not large enough and had to be supplemented with samples from the longissimus dorsi muscle. The samples were numbered and each judge received the same section as nearly as possible each time.

The tenderness of the meat was tested by shearing a core in the Warner-Bratzler modified shear apparatus. Since the thickness of the steaks limited the length of the core, several cores were cut from the longissimus dorsi muscle of each steak to permit at least five trials, the average of which was recorded. A sketch of the steak was made to show approximate positions of these cores so that the tests could be duplicated on the paired steak when taken from storage.

The remaining portion of the longissimus dorsi muscle was stripped of all visible fat and ground three times in a Universal meat chopper preparatory to extracting the press fluid. Duplicate 40-gram samples of the ground meat were used to determine the press fluid by means of a Carver Laboratory press. Each sample was packed into the cylinder in four equal layers divided by filter paper, the bottom one being enforced with a double thickness of cheesecloth, and the top being sealed from leakage around the cylinder plunger by means of a tight-fitting hard rubber gasket. Pressure was applied gradually until the maximum of 16,000 pounds was attained at the end of 15 minutes. The resulting press fluid was collected in a graduated centrifuge tube which permitted direct reading of the amounts of serum, fat, and total press fluid obtained. The amounts from the two samples were averaged to give the reported results.

The extent of rancidity of the fat was measured by determining the free fat acid content and peroxide number of each sample. The fat was extracted with ethylene chloride according to the procedure developed by Conrad, Kansas Agricultural Experiment Station. The free fat acid determination was made by titrating a measured amount of fat in solution against a standard base, and was expressed as milligrams of potassium hydroxide per gram of fat. The Lea method was used for determining the peroxide number which was expressed as milliliters of 0.002 normal thiosulfate per gram of fat.

The remaining steaks were prepared for packaging and storage. Each steak was placed in a moisture-proof cellophane bag made to conform to the contour of the meat, and the drippings were poured around the meat. The package was heat-sealed and weighed. An outer wrapping of locker paper was used to give additional protection, and the packaged meat was then placed in storage. The uncooked fat sample that had been removed previously from the steak was stored at the same time.

The six rib roasts, weighing from 7.5 to 11.0 pounds, likewise cut and stored in the spring, were removed in the fall and prepared for roasting. Each roast was weighed before and after thawing, unwrapped, and weighed again. A hole was drilled into the center of the thickest muscle, and a test tube containing a small amount of oil was inserted in this hole as a receptacle for the thermocouple used to determine the internal temperature of the meat. The roast was placed in a weighed pan, fat side up, weighed again, and then put into an electric oven preheated to 300° F. The meat was roasted to a temperature of 140° F. as registered by the thermocouple, the time required for roasting being noted. When done, the meat, pan, and drippings were weighed as taken from the oven to determine evaporation losses. The roast was removed to a weighed platter so that the weight of the drippings could be determined, as well as the weight of the meat alone. Since a large roast will continue to cook even after it is removed from the oven, a meat thermometer was inserted in the roast, and when the maximum temperature of the roast was attained, the weights of the meat and drippings were again noted. From the weights recorded, calculations were made concerning losses due to evaporation and drippings in and out of the oven, total cooking losses, and percentages of these losses.

Portions of three of the roasts were immediately tested for palatability, mechanical shear, and press fluid in the manner described for the beef steaks. Fat samples were taken from the cooked roasts to be tested for rancidity. Certain portions of the inside fat from several of the roasts were noted to be rancid by taste, so three additional samples of this fat were collected and analyzed.

The remaining portions of the three roasts (approximately half) were boned, weighed, and wrapped in cellophane and locker paper to be frozen and stored for future testing. The three other roasts were boned and divided in half. One half was cut into slices about one-fourth inch thick, weighed, wrapped with the drippings, and stored at 0° F. The other half of the boned roast, approximately two inches thick, was packaged unsliced in drippings and stored.

The pork roasts consisted of one pair from the shoulder end weighing approximately five pounds each, and a pair from the loin end weighing slightly less. The four roasts were prepared for cooking soon after procurement, and since they were not frozen, thawing was unnecessary. The meat was weighed, a weighed meat thermometer inserted, and the roast placed fat side up in a weighed roasting pan. Just before placing in an electric oven preheated to 350° F., the pan, meat, and thermometer were weighed. The pork roasts were cooked to the well-done stage, 185° F., the temperature recommended for pork by the Committee on Preparation Factors, National Live Stock and Meat Board. The time required for roasting was noted, and the meat when done was removed from the oven and weighed. The meat was weighed again when the roast reached its maximum temperature.

The loin end pair of roasts were each cut into three equal and weighed. Evaporation losses were calculated by taking into account the evaporation occurring during searing and braising; the weight of the drippings in the pan accounted for the loss by drippings. The chops from both the right and left loins were divided into groups of three in the following manner: Group I contained chops 1, 5, 9; Group II, 2, 6, 10; Group III, 3, 7, 11; and Group IV, 4, 8, 12.

One of the eight groups of pork chops was tested immediately for palatability and press fluid in a manner similar to that for pork roasts except that the chops were not thick enough for the shear test.

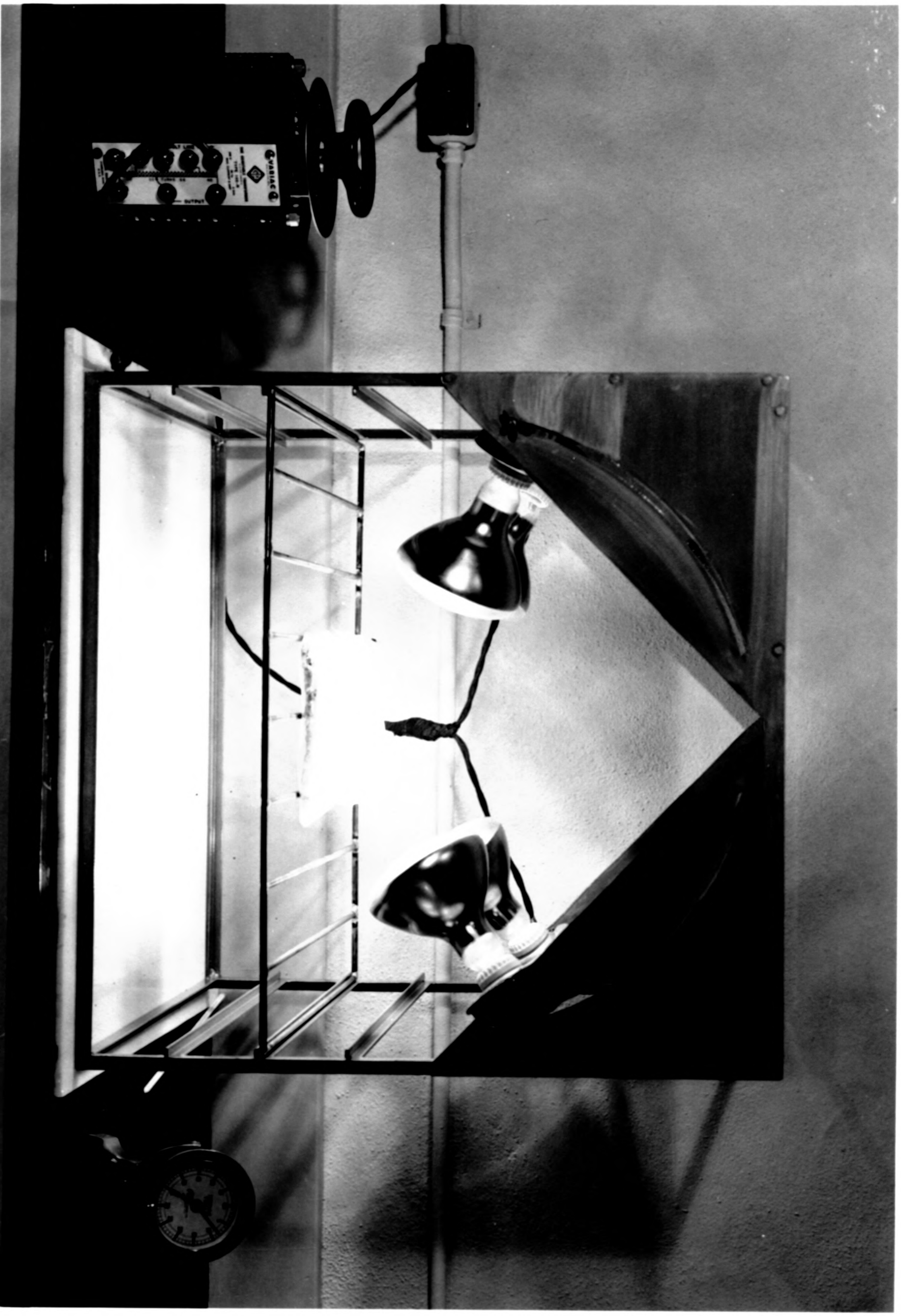
The remaining pork chops were double-wrapped and stored at 0° F. Four groups were packed in drippings, three were packed dry.

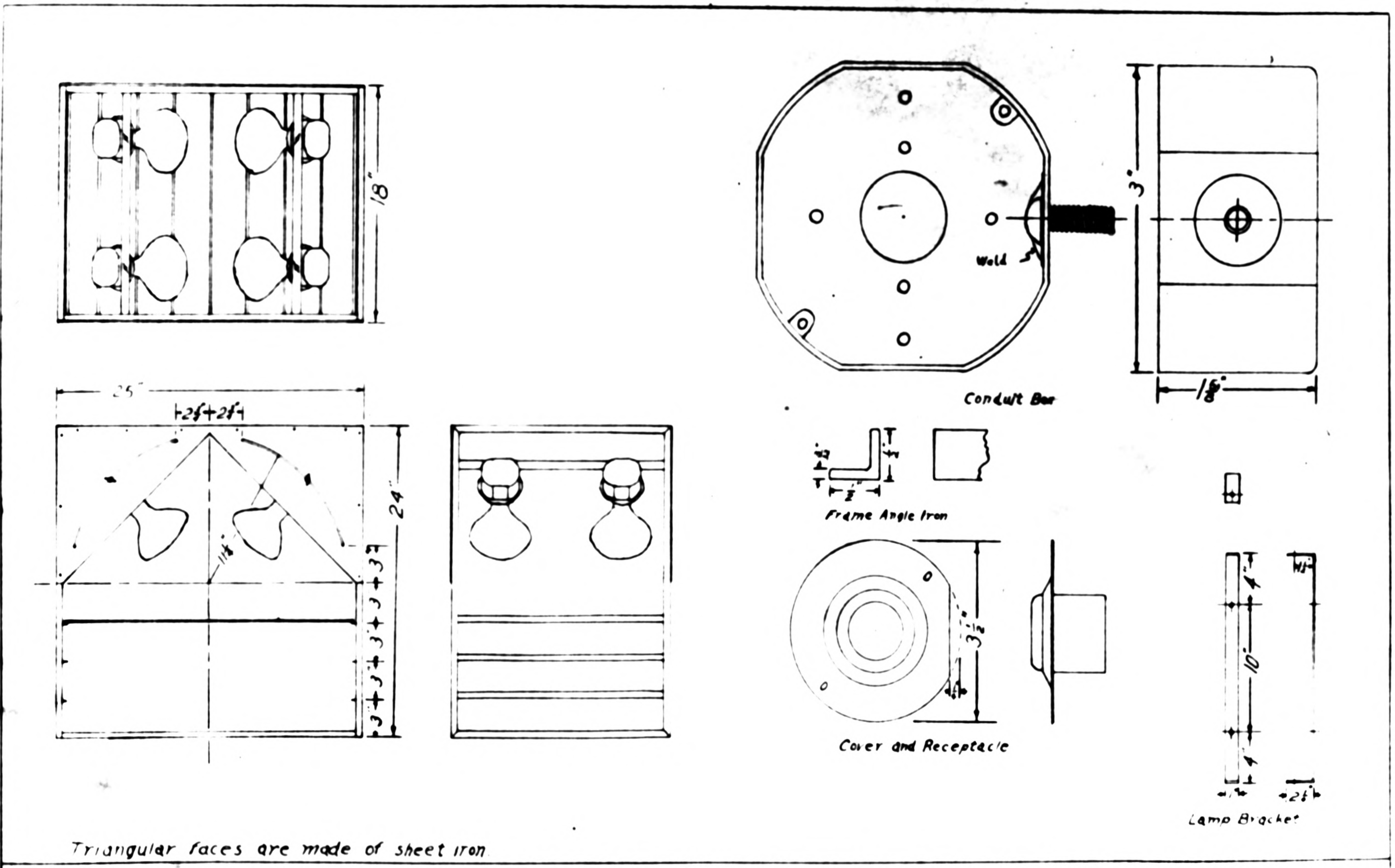
Reheating

Finding a suitable method for reheating the meat that had been precooked and frozen presented a problem. Wilmeth (1945), confronted with the same problem while conducting studies on precooked beef and pork, reheated the meat in a double boiler, and in an oven set at temperatures varying between 300-400° F. depending on the kind of meat. She concluded that the double boiler method seemed to be successful for most of the meats as far as palatability and percentage losses were concerned, but that the time required for reheating was prohibitive. In an effort to reduce the time, the possibilities of using infrared heat radiation which possesses an extremely high rate of sustained heat transfer were considered. Although infrared radiation is being used extensively for industrial purposes, no data could be found pertaining to its use for heating foods. A survey of existing infrared equipment on the market revealed no satisfactory apparatus for the purpose of reheating precooked meats, so a special infrared oven was designed and constructed (Plates I and II) with the cooperation of Professor O. D. Hunt, Department of Electrical Engineering, Kansas State College.

It was not known what the requirements of the oven would be until actual experiments had been carried out, so the oven was designed to give the utmost in flexibility of adjustment. Goodell (1942), in an article concerning infrared heat transfer for industrial use, said that by directing the energy in a crisscross pattern at a 45° angle to the oven axis, it is possible to approach uniform heating of any exposed surface regardless of position and over a considerable range of working distances. To achieve this angle adjustment, two 250-watt infrared bulbs were mounted on an arm of strap iron, affixed to a slot in the form of an arc at each end by means of wing-tip bolts, to permit adjustment of the bulbs on any angle at any point on the arc. In addition, the bulb housings were bolted to the arm so as to allow swivel adjustment of each infrared bulb. Two such units described above comprised the heat source of the oven. They were mounted in such a way that the four bulbs could be

Plate I





Scales
1½ in=1ft. ½ in=1in full

Infrared Oven

Designed by C.D.Hunt
Drawn by D.D.Kalen

used together as one unit for heating a surface, or separated and used two on each side, or at any position between the two extremes. The oven was constructed so that a rack could be placed at varying distances from the infrared lamps. A device was arranged for supporting meat perpendicular to the oven rack when desired. Since infrared light is transformed into heat energy only when absorbed, the oven was not enclosed; it was believed that the additional benefits to be derived from convection heating were not warranted for the short amount of time the meat would be in contact with the infrared rays. Should this be desirable, though, enclosure would be a simple matter.

After ten and one-half months storage at 0° F., the precooked frozen steaks were taken out and reheated one at a time by two methods; i.e., in a double boiler and in the infrared oven. The steaks were weighed while hard frozen in the cellophane package after the outer wrapping of locker paper had been removed. Seven steaks, chosen at random, were placed in the weighed top pan of a double boiler. The meat was placed over boiling water, covered, and heated as rapidly as possible. After it had thawed sufficiently, a meat thermometer was inserted and, when the internal temperature reached approximately 140° F., the meat was removed from the heat. The time required for reheating was noted. The pan and meat were weighed, the meat removed from the cellophane package and weighed alone, and the pan and drippings weighed. The steaks were then tested for palatability, mechanical shear and press fluid as before. A fat sample was taken from the reheated steak and analyzed for rancidity.

The seven remaining steaks were reheated by means of the infrared oven. Each steak was placed on a weighed tray which was placed on the highest shelf of the infrared oven. The meat was supported vertically between the four infrared bulbs, two on each side, focused to cover the area of the meat as adequately as possible. The oven was turned on and the power adjusted at 220 volts by means of a variac transformer and voltmeter. A thermometer was inserted when the meat had thawed, and the time necessary to reheat the meat to 140° F. was recorded. When done, the meat and tray were removed and weighed; the meat was taken out of the cellophane and weighed; and the tray and drippings were weighed. Tests identical to those for the steaks reheated by the double boiler method were conducted.

The percentage cooking, reheating, and total losses were calculated for all the steaks, and cooking time was figured on the basis of minutes per 100 grams. The percentage cooking losses were determined by adding the losses incurred as evaporation and drippings, and dividing by the weight of the fresh meat. The percentage reheating losses were determined by subtracting the weight of the reheated meat from the weight of the freshly cooked meat and dividing by the weight of the freshly cooked meat. Reheating and cooking losses combined equal the percentage total losses.

The precooked roast beef was removed after eight and one-half months storage at 0° F. In order to study the effects of packaging only one method of reheating, namely infrared, was used. The outer wrapping was removed from the roasts, the meat weighed and placed on a tray in the infrared oven. Again the bulbs were adjusted to cover the meat adequately, the thermometer was inserted after the meat had thawed sufficiently to permit penetration, and the time required to reheat the beef to 140° F. was noted. After reheating, the meat was weighed and losses noted. Samples were prepared for the palatability committee, cores were cut from the unsliced roasts for testing the shear, and press fluid was measured for all of the roasts. Three samples of fat for rancidity tests were also taken.

The pork roasts were stored five and one-half months before removing for reheating. The infrared method of reheating was used so that the effects of packaging with and without drippings could be determined. The smaller size of the pork roasts as compared to the beef roasts and steaks necessitated an adjustment in the infrared oven; the meat was placed on the second highest shelf, and all four bulbs were focused down on the meat from approximately a 45° angle, rather than two bulbs on either side of the meat. The procedure was much the same as for beef roasts; the outer wrappings were removed, the meat was weighed, reheated to 140° F., weighed again, and time required for reheating was recorded. Tests for palatability, shear, and press fluid were made and three samples of cooked fat were taken for rancidity tests.

The pork chops were removed after five and one-half months storage. Three groups (three chops per group) were reheated by the double boiler method, and four by infrared. Previous work done with precooked pork chops by Wilmeth (1945) indicated that the reheated product surpassed freshly cooked chops in palatability, but the time required for reheating by this method was too long to be practical. To decrease the time, the chops were separated before reheating, or else separated when sufficient thawing had occurred to permit separation. In the double boiler method, the chops were completely unwrapped, weighed, and placed in the weighed top of the double boiler. They were placed over boiling water, covered, and allowed to reheat until a meat thermometer inserted in the middle of the eye muscle registered 150° F. The meat and pan were weighed when removed from the heat, and the meat alone was also weighed. For infrared reheating, the chops were placed on a weighed tray and covered with cellophane to prevent excessive drying. Tray and meat were weighed when the internal temperature reached 150° F., and the meat alone was weighed. The time required for both these methods was carefully noted and compared. One chop in each group was used for the palatability test, and the lean meat from the other two chops was ground for press fluid.

RESULTS

The data accumulated in the experimental procedure were assembled and examined statistically wherever possible, or by comparing averages. The results are presented in tabular form accompanied by suitable explanation and discussion.

Statistical analyses of the paired steak data in Table 1 show that the judges rated precooked frozen steaks reheated by both infrared and double boiler methods consistently significantly less desirable in aroma (t=6.10, 6 degrees freedom, P less than .01), flavor of fat (t=6.07, P less than .01), and flavor of lean (t=3.13, P approximately .02) than freshly broiled steaks, although the reheated steaks were by no means undesirable. Apparently there was not much difference between the acceptability of steaks reheated with infrared as compared with the double boiler method. The differences in tenderness and juiciness as detected by the judges and also by mechanical means (shear resistance and press fluid) between fresh and reheated steaks did not exceed experimental error.

A comparison of steaks reheated by infrared and double boiler methods, Table 2, reveals some facts concerning percentage cooking, reheating, and total losses. The initial cooking losses range from 23.30 percent to 44.63 percent, averaging 37.08 percent for those steaks later reheated by the double boiler method, and 29.88 percent for those reheated by infrared. The reheating losses vary from 10.07 percent to a gain of 0.85

Table 1. Palatability and mechanical data for fresh cooked and precooked frozen steaks thawed by infrared and in double boiler.

Pair	Palatability data[1]										Mechanical data			
	Desirability													
	Aroma		Fat		Lean		Tenderness		Juiciness		Shear (pounds)		Press fluid (ml.)	
	fresh[2]	infra[3]	fresh	infra	fresh	infra	fresh	infra	fresh	infra	fresh	infra	fresh	infra
28	6.4	4.4	5.6	3.6	6.6	4.4	4.4	3.8	6.2	4.6	22.7	19.7	14.2	10.6
29	6.2	5.2	6.0	4.8	6.6	6.2	4.4	5.6	5.4	6.4	17.0	17.5	9.5	11.1
31	6.2	4.8	5.4	4.2	6.4	5.2	5.8	5.2	5.8	5.6	20.4	19.8	8.5	12.4
32	6.0	5.6	5.6	4.4	6.0	5.8	5.6	6.2	6.2	6.0	18.3	16.7	15.0	12.2
33	6.6	5.4	6.6	5.0	6.6	6.0	6.0	6.2	6.2	6.2	16.9	14.4	15.2	10.7
34	6.6	5.2	5.2	5.0	6.6	5.0	6.0	5.8	5.8	5.6	19.2	14.7	12.8	11.8
38	6.8	6.0	6.4	5.0	6.6	6.4	5.8	6.4	5.4	5.8	14.2	15.9	14.2	11.9
Av.	6.40	5.22	5.83	4.57	6.49	5.57	5.43	5.60	5.86	5.74	18.4	16.9	12.8	11.5
	fresh	d.b.[4]	fresh	d.b.	fresh	d.b.	fresh	d.b.	fresh	d.b.	fresh	d.b.	fresh	d.b.
30	6.4	5.2	5.8	4.2	6.2	5.2	6.0	5.2	6.0	5.0	20.1	19.3	8.1	7.2
35	6.0	6.0	5.6	4.4	6.0	5.6	6.2	4.6	5.8	4.6	19.9	16.9	3.4	11.3
36	6.6	5.6	5.6	3.8	7.0	5.6	6.8	6.2	6.2	5.6	12.0	10.9	9.5	11.6
37	6.8	6.0	5.8	5.8	6.8	5.8	6.6	6.6	6.6	5.0	14.5	12.6	8.5	12.0
39	6.4	5.4	5.9	5.0	6.2	5.8	5.0	5.4	5.6	4.8	13.0	15.0	17.4	11.4
40	6.2	5.8	6.2	6.0	6.6	6.0	5.2	5.0	6.0	5.2	12.0	13.6	14.6	10.3
41	6.0	5.2	5.2	4.8	6.0	5.2	4.8	4.4	5.8	5.2	11.4	11.7	14.2	12.8
Av.	6.34	5.60	5.73	4.85	6.40	5.60	5.80	5.34	6.00	5.05	14.7	14.3	10.7	11.0

1 Highest possible score 7.0.
2 Freshly broiled steaks.
3 Steaks reheated by infrared.
4 Steaks reheated by double boiler.

Table 2. Percentage cooking and reheating losses for broiled steaks.

Initial cooking losses		Reheating losses		Total losses	
(percent)					
d. b.	infra	d. b.	infra	d. b.	infra
34.39	29.61	1.93	10.02	36.32	39.63
38.22	30.53	1.26	5.27	39.48	35.80
33.58	29.61	4.80	+0.85	38.38	28.76
34.82	23.30	6.25	1.65	41.24	24.95
35.41	26.94	8.70	6.60	44.11	33.52
38.47	28.25	7.13	10.07	45.60	38.32
44.63	40.91	4.46	5.22	49.09	46.13
37.08	29.88	4.96	5.43	42.03	35.30

percent; the infrared-treated steaks, however, averaged a 5.43 percent loss, only one-half percent more than the double boiler method loss of 4.96 percent. When total losses are considered; i.e., initial plus reheating losses, the averages are 42.03 percent and 35.30 percent for the double boiler and infrared methods repectively, a difference of 6.73 percent. In order to account for the discrepancy among the initial cooking losses, all 28 steaks were grouped according to position of cut; steaks numbered 28 to 34 were classed as sirloin, while those numbered 35 to 41 were classed as porterhouse. When the data were examined from this standpoint, Table 3, the sirloin steaks averaged a 28.53 percent loss and the porterhouse steaks 38.26 percent, a difference of nearly ten percent. Since six out of seven of the steaks reheated by infrared were sirloins and all but one of those reheated by double boiler were porterhouse steaks, it becomes apparent that the difference manifested between the total losses is due largely to the steak rather than the reheating treatment.

The time required for cooking and reheating the steaks is shown in Table 4 in relation to the weight of the meat. The steaks averaged 1482 grams, three and one-fourth pounds, and 1539 grams, three and one-third pounds. The initial cooking time averages were 38 and 32 minutes; those steaks later reheated by the double boiler method were predominantly porterhouse steaks, one-fourth inch thicker than the sirloin steaks, which may account for the fact that they required six minutes

Table 3. Percentage cooking losses for sirloin and porterhouse steaks.

	Sirloin	:	Porterhouse
		(percent)	
	29.61		38.22
	26.88		37.06
	30.11		33.55
	30.53		37.89
	31.85		37.87
	34.39		34.82
	30.62		35.60
	29.61		40.91
	23.67		35.41
	23.30		38.29
	26.92		30.47
	24.67		40.71
	28.99		44.63
	28.25		42.28
Average	28.53		38.26
Combined average		33.40	

Table 4. Initial cooking and reheating time for broiled steaks.

	Initial weight (gram)		Initial cooking		Reheating (min.)		Reheating rate (min./100g.)	
	d. b.	infra	d. b.	infra	d. b.	infra	d. b.	infra
	1429	1368	32	28	53	37	4.45	3.30
	1662	1410	40	33	102	27	7.55	2.35
	1621	1594	39	32	56	24	4.20	1.75
	1348	1719	35	30	82	36	7.20	2.40
	1524	1690	36	30	75	34	5.90	2.30
	1431	1538	38	29	73	27	6.25	2.05
	1664	1453	42	43	75	41	6.80	3.60
Av.	1482	1539	38	32	74	32	6.05	2.54

more initial cooking time on the average. Steaks reheated in the double boiler required an average of 74 minutes or nearly double the initial cooking time, while the steaks reheated by infrared averaged 32 minutes, exactly the same as the initial cooking time. When figured on the basis of minutes per 100 grams, the reheating rate then averaged 6.05 minutes per 100 grams for the double boiler method, and 2.54 minutes per 100 grams for the infrared method.

Table 5 shows the extent of rancidity of four fat samples taken from each pair of steaks as measured by free fat acid content and peroxide value. Fat samples were analyzed (1) before cooking, (2) after cooking, (3) after storing, uncooked, and (4) after cooking, storing, and reheating. The results recorded are the averages of two determinations for each sample. Peroxide values did not begin to appear in any of the samples until cooking, storing and reheating had taken place. There was no significant difference between the free fat acid content of the fat before and after cooking ($t=1.176$, 6 degrees freedom, $P=.30$). The uncooked fat before and after storage differed significantly ($t=3.822$, P less than .01) as well as the cooked fat and the reheated fat ($t=3.208$, P less than .02). The free fat acid content of reheated beef fat decreased exponentially as the peroxide value increased; i.e., there was a significant negative correlation between the free fat acid content and the logarithm of the peroxide value ($r= -.6779$, 5 degrees freedom, P less than .01).

Table 5. Rancidity of broiled steaks as indicated by free fat acid and peroxide values.

Free fat acid[1]				Peroxide[2]
Before cooking	After cooking	After storage	After reheating	After reheating
1.33	1.31	0.75	0.39	4.26
1.11	1.32	0.72	0.45	5.16
1.39	1.13	0.68	0.56	3.18
1.15	0.80	0.66	0.63	0.59
1.03	0.95	0.56	0.55	1.04
1.52	1.11	0.53	0.64	0.50
1.32	0.93	0.75	0.60	0.76
1.40	1.61	0.74	0.76	0.84
1.46	1.86	0.78	0.78	0.31
2.10	1.28	0.99	0.44	0.69
0.76	0.48	0.73	0.45	1.80
1.43	0.79	0.70	0.51	1.19
1.40	1.11	0.91	0.57	3.76
1.12	1.51	0.68	0.47	1.76
Av. 1.32	1.15	0.72	0.56	1.84

[1] mg. KOH/g. fat.
[2] ml. 0.002 N thiosulfate/g. fat.

Comparison of the three different treatments given roast beef, Table 6, that is, freshly cooked meat, reheated sliced meat, and reheated unsliced meat, reveals generally consistent results in the palatability test. In rating the intensity and desirability of aroma, flavor of fat, and flavor of lean, the judges favored the freshly cooked meat in most instances. They rated the reheated unsliced meat next highest with a few exceptions, and the reheated sliced meat lowest. Even the meat receiving the lowest rating was quite acceptable in palatability. The palatability committee thought that the freshly cooked meat was juicier than the two reheated meats which they judged to be equal; however, the actual press fluid content showed the freshly cooked meat to be juicier than the reheated sliced meat, while the reheated unsliced meat was considerably less juicy.

Rancidity test results for the fat from freshly cooked roasts, and sliced and unsliced roasts after storage and reheating are shown in Table 7. Since part of the fresh samples seemed to taste rancid, a second group of samples composed of rancid-tasting fat was analyzed in the same manner; one sample proved to have a fairly high free fat acid content, but none of the samples showed any peroxide value. After storage, the sliced meat from two roasts had a free fat acid content below that of the freshly cooked meat, and a comparatively high peroxide value. The third roast showed an increased fat acid content, and an insignificant peroxide value. The fat

Table 6. Palatability and press fluid data for fresh cooked and precooked, frozen sliced and unsliced roast beef.

Cut	Aroma: Fresh	Aroma: Sliced	Aroma: Unsl.	Flavor of fat: Fresh	Flavor of fat: Sliced	Flavor of fat: Unsl.	Flavor of lean: Fresh	Flavor of lean: Sliced	Flavor of lean: Unsl.
				Intensity*					
R1	-	4.8	4.8	-	4.8	5.0	-	4.8	6.0
L1	5.2	-	5.4	6.5	-	5.6	6.2	-	4.8
R2	5.5	-	5.0	4.8	-	5.6	5.7	-	4.8
L2	-	4.8	5.6	-	5.4	5.2	-	5.0	5.4
R3	-	5.0	5.8	-	4.2	5.0	-	5.2	5.6
L3	5.4	-	5.4	4.6	-	5.0	6.0	-	5.4
Av.	5.4	4.9	5.3	5.3	4.8	5.2	6.0	5.0	5.3
				Desirability*					
R1	-	4.4	5.8	-	4.8	4.8	-	5.8	6.2
L1	6.5	-	5.4	4.0	-	4.4	6.5	-	6.2
R2	6.2	-	4.6	5.2	-	3.8	6.7	-	4.8
L2	-	5.0	5.4	-	4.0	3.8	-	4.4	5.0
R3	-	4.2	5.4	-	4.4	5.6	-	5.0	6.0
L3	6.4	-	4.8	5.8	-	5.0	5.0	-	5.8
Av.	6.4	4.5	5.2	5.0	4.4	4.6	6.4	5.1	5.6
	Tenderness*			Juiciness*			Press fluid (ml.)		
R1	-	4.6	5.0	-	4.6	4.8	-	10.8	8.8
L1	5.5	-	4.2	6.0	-	3.8	12.8	-	10.2
R2	5.8	-	5.4	6.0	-	5.6	13.1	-	5.0
L2	-	5.4	4.2	-	5.4	5.4	-	9.7	4.9
R3	-	5.2	5.0	-	4.8	4.6	-	10.7	6.5
L3	5.6	-	4.4	6.4	-	5.2	14.7	-	11.9
Av.	5.6	5.1	4.6	6.1	4.9	4.9	13.5	10.4	7.9

* Palatability data. Highest possible score 7.0.

Table 7. Rancidity of roast beef as indicated by free fat acid and peroxide values.

	Free fat acid*	Peroxide**
	Fresh	
I[1]	.805	0
	.646	0
	.321	0
II[2]	.603	0
	.993	0
	.367	0
	Sliced	
	.502	4.76
	.522	5.54
	.532	0.43
	Unsliced	
	.456	1.10
	.674	2.38
	.528	1.15

1 Original samples.
2 Additional samples.

* mg. KOH/g. fat.
** ml. 0.002 N thiosulfate/g. fat.

from the unsliced roasts gave slightly different results; the free fat acid content for the first roast was lower than the fresh, for the third it was higher, and for the second it was nearly the same. Two of the roasts gave peroxide values which were less than half of the values given by the sliced meat.

The reheating time for frozen roast beef in the infrared oven varied considerably because of the differences in weight and size of the packaged meat. The three sliced beef roasts required an average of 4.1 minutes per 100 grams for thawing and reheating; this rate would approximate 36 minutes for a two-pound package of slices. The unsliced meat required a longer reheating period, an average of 6.5 minutes per 100 grams, although in one instance the rate was as high as 12.9 minutes per 100 grams. For a two-pound unsliced roast, the reheating time would be 58 minutes.

The effect of packaging precooked pork roasts dry and with drippings as compared to freshly cooked meat is shown in Table 8. The freshly cooked pork ranked consistently high in desirability of aroma, flavor of fat, and flavor of lean. The roasts packed in drippings were second highest in the majority of scores, while those packed dry were lowest but the difference was slight. In the scores for tenderness and juiciness, the freshly cooked meat excelled, followed by the pork packed dry, and then the pork packed in drippings. The mechanical tests for tenderness and juiciness corroborated the judges' decision.

Table 8. Palatability and mechanical data and reheating rates for roast pork packaged dry and in drippings.

Cut	Palatability data*								Mechanical data		Reheating rate
	Intensity			Desirability			Tenderness	Juiciness			
	Aroma	Fat	Lean	Aroma	Fat	Lean			Shear (lbs.)	Press fluid (ml.)	(min./100g.)
Fresh											
L6	5.8	5.8	5.6	6.8	6.6	6.2	6.6	6.0	15.8	7.25	-
Dry											
R1	5.8	5.4	5.4	5.0	5.0	6.0	6.0	5.0	16.2	8.50	15.4
R2	5.0	4.2	4.8	5.8	4.8	6.0	5.4	4.0	11.0	7.75	16.9
R3	5.0	5.2	5.4	6.0	4.0	5.6	6.2	4.6	13.0	7.35	16.1
L9	5.6	5.4	6.0	5.4	4.6	5.2	6.2	6.6	16.2	7.60	14.7
L10	5.4	5.2	6.0	4.4	4.2	4.6	5.6	6.2	16.2	8.00	13.1
Av.	5.4	5.1	5.5	5.3	4.5	5.5	5.9	5.3	14.5	7.85	15.2
Drip											
L4	5.0	4.8	5.2	6.0	5.4	6.2	5.8	5.0	12.4	7.85	14.5
L5	5.2	5.4	5.2	5.4	5.0	6.2	5.0	4.4	11.4	6.10	14.1
R8	5.6	5.6	6.0	5.4	5.2	5.6	5.6	5.6	13.4	6.60	13.1
Av.	5.3	5.3	5.5	5.6	5.2	6.0	5.5	5.0	12.4	6.85	13.9

* Highest possible score 7.0.

The time required to reheat the frozen pork roasts averaged 14.5 minutes per 100 grams by infrared, Table 8. This amounted to 13.9 minutes per 100 grams for the meat boned and packed in drippings, and 15.2 minutes per 100 grams for the meat packed dry with the bone. The average pork roast boned and packed in drippings weighed slightly more than a pound and required 50 minutes to reheat. The roasts packed dry with the bone averaged one and one-fifth pounds and required 80 minutes.

Rancidity tests were made on two fat samples from the meat that had been packed dry, and one from that packed in drippings, Table 9. The free fat acid content of all three samples was approximately the same, and apparently bore no relation to the peroxide value. For the meat packed dry, one fat sample yielded a very small peroxide value, while the value for the other was more than eleven times greater. The peroxide value for the fat packed in drippings was half way between the other two values.

Table 10 shows the scores of the pork chops that were freshly braised compared with those reheated by infrared and double boiler methods. The freshly braised chops received the highest rating in every instance, closely followed in desirability by the chops subjected to each of the other treatments. They were also graded by the palatability committee as more tender and juicy. The only significant difference between the two methods of reheating appeared to be in the time required for reheating; the double boiler method required an average of 11 minutes per 100 grams and the infrared, 5.75 minutes per 100 grams. For packages of three chops weighing from 350 to 387 grams, the double boiler method averaged 43 minutes, and the infrared, 28 minutes.

Table 9. Rancidity of roast pork as indicated by free fat acid and peroxide values.

	Free fat acid*	Peroxide**
I[1]	.392 .437	0.22 2.88
II[2]	.444	1.15

1 Packed dry.
2 Packed in drippings.

* mg. KOH/g. fat.
** ml. 0.002 N thiosulfate/g. fat.

Table 10. Palatability and press fluid data and reheating rate for braised pork chops.

Cut	Palatability data*								Press fluid	Time
	Intensity			Desirability			Tender-ness	Juici-ness		
	Aroma	Fat	Lean	Aroma	Fat	Lean			(ml.)	(min./100g.)
Fresh										
RIII	5.8	6.2	6.0	6.6	6.8	6.6	6.4	5.2	-	-
Double Boiler										
LI	5.0	4.8	4.8	5.0	6.2	6.0	5.4	3.8	4.75	13.3
LIV	4.4	4.2	5.4	5.6	5.2	6.0	5.0	3.8	6.00	9.5
RI	5.0	4.4	5.0	5.2	6.4	6.0	5.4	4.2	5.15	10.3
Av.	4.8	4.5	5.1	5.3	5.9	6.0	5.3	3.9	5.30	11.0
Infra-red										
LII	4.6	4.6	4.4	5.6	5.0	5.2	4.8	3.6	5.60	5.10
RIV	5.0	5.4	5.8	5.4	6.2	6.4	5.8	4.8	6.15	6.10
LIII	4.4	5.4	4.6	5.6	5.8	5.8	5.0	4.0	5.40	5.30
RII	4.6	4.8	5.0	5.8	6.0	6.0	4.2	4.2	4.70	6.50
Av.	4.6	5.0	4.9	5.6	5.8	5.8	4.9	4.2	5.46	5.75

* Highest possible score 7.0.

DISCUSSION OF RESULTS

From the data concerning the thawing and reheating of precooked frozen beef steaks, it seems apparent that such steaks are less desirable than freshly broiled steaks. This finding is in accord with Wilmeth (1945) who noted that reheated precooked steaks were slightly less desirable. Coupled with this quality factor to make precooked steaks impractical was the amount of time required for reheating. Wilmeth found that the reheating time for steaks in the oven or double boiler was two to three times longer than the initial broiling time. By using the infrared oven it was possible to cut down the reheating time from 74 minutes per average steak (double boiler method, recommended by Wilmeth) to 32 minutes without any significant difference in palatability. Although the time was shortened to equal the initial cooking time, it was still not short enough to justify the precooking of steaks.

The difference of nearly ten percent between the initial cooking losses for sirloin and porterhouse steaks might be due to the different proportion of fat present on each type of cut. No references can be found to bear out this opinion; in fact, data for beef roasts (Alexander and Clark, 1939) indicate that although dripping losses were greater for fatter roasts, the evaporation losses were less.

The rancidity study on the fat samples taken from the steaks revealed some interesting facts, but interpretation of the data is necessarily superficial because the complex chemical reactions that take place when a fat becomes rancid are only partly understood. The susceptibility of fat to oxidation is influenced by the degree of unsaturation, molecular structure, and position of double bonds in the chain. The multiplicity of storage conditions, temperature, time, surface exposure, bacterial contamination, and enzymic activity also have their effect on the ultimate rancidity of a given fat. No one chemical test can measure successfully all the factors that contribute to rancidity, nor can any tasting panel agree perfectly in sensitivity and consistency in reporting differences and preferences in odor and flavor. Therefore it is impossible to define limits determining rancidity. It is generally agreed that one of the first stages of breakdown occurring in fats prior to rancidity is the formation of peroxides; thus the peroxide value of a fat measures its incipient rancidity. In most of the fat from the beef steaks, peroxide numbers did not appear until after the meat had undergone considerable storage and definitely had a rancid taste. The peroxide values occurring in the fat samples which had been precooked, stored for ten months, and reheated ranged from 0.31 to 5.16 cc. thiosulfate per gram; no explanation could be found for this variation. Lea (1938) states that fats which have been exposed to conditions leading to production of considerable quantities of free acid are usually also rancid, so the measure of the free fat acid content of a fat might help to indicate the presence of rancidity. In the fat samples from the beef steaks, there was a pronounced decline in the free fat acid content as the fat, both cooked and uncooked, aged. The free fat acid content of the reheated fat samples gave a good negative correlation with the peroxide values of the same samples. This was contrary to what was expected in view of Lea's statement that a high free acid content is associated with rancidity. However, so many factors are capable of contributing to the free acid content of a fat that it is difficult to make any explanation of these results.

The results of the work done with precooked frozen beef roasts, both sliced and unsliced, conform to the recommendation offered by Woodroof and Atkinson (1945) that meats such as roasts should be wrapped in as large pieces as possible to cut down air exposure. In this study, the palatability committee preferred the meat that had been frozen unsliced to that sliced. Press fluid extractions showed the sliced meat to be juicier, probably because slicing allowed better penetration of the drippings throughout the meat. The sliced meat also reheated at a faster rate. Due to the larger amount of surface exposure in the sliced meat, it might be expected that the fat from the sliced roast would be more rancid. Two out of three peroxide values indicated such a trend, but the data are insufficient to make any definite conclusions.

A precooked beef roast can be prepared so that it is palatable when reheated after frozen storage; roasts packed in large pieces are more desirable than those sliced. The time required for reheating with infrared is not excessive, approximately five minutes per 100 grams.

The fact that such precooked roasts can successfully meet quality and time factors leads to exciting speculation for their future uses. Simpson (1946) cited possible uses for precooked foods such as roasts in institutional kitchens. In chain restaurants where the chief dishes are cooked and frozen in a large central kitchen, the advantages to be gained are as follows: (1) only one or two highly skilled and highly paid chefs are necessary in the central kitchen instead of one in every restaurant, (2) cooking failures due to inexperienced or overworked help are eliminated, and a more standard product is achieved, (3) the smaller restaurants can offer more varied menus, and (4) in the long run, the cost will be less. In any institutional kitchen, precooked meats would be of major assistance in reducing peak loads, and in the conservation of left-overs, roasts remaining from necessary overproduction could be frozen rather than wasted or incorporated into the menu a day or two later. The success of such freezing of precooked meats would depend on the care and accuracy of the key work, suitable procedures for quick freezing and freezer storage, and efficient methods of transportation.

The reheated pork roasts which had been packed in drippings rater higher in flavor than those packed dry, in the opinion of the judges, but the roasts packed dry excelled in tenderness and juiciness. Wilmeth (1945) found little difference between pork packed dry and in drippings, but that packed dry did have a slightly more favorable score. The reheating rate was nearly three times longer than that of the beef roasts; the great difference may have been due to the fact that the pork roasts, although small, were thicker than the beef roasts. After five and one-half months of storage, there was very little rancidity detectable, either by the palatability committee or chemical tests.

The instances in which it would be desirable to precook pork roasts would be the same as for beef, but because of the time factor involved, there would be less advantage. The pork could be packaged in thinner pieces, but then it might be subject to greater oxidative factors; beef roasts, because of their larger over-all size, are more readily adapted to thinner packaging.

The freshly braised pork chops received a slightly higher palatability score than the reheated pork chops, contrary to the results of Wilmeth, who found the reheated chops more favorable. The time required for reheating, which Wilmeth found prohibitive - 92 minutes in the oven and 99 minutes in the double boiler - was cut down considerably by separating the chops as soon as possible after thawing had started and allowing them to reheat individually. This method reduced the time to 43 minutes for a group of three chops in the double boiler and 28 minutes in the infrared oven. With this shortened time and the small difference in palatability, precooked frozen pork chops might conceivably have some value. Since the initial cooking of pork must be long enough to insure it against the viability of the trichinosis organism, the reheating needs only to be long enough to warm the meat, and in some institutions, a shorter heating time before serving may be desirable.

SUMMARY

Four types of meat - beef steaks, beef roasts, pork roasts and pork chops - were precooked, frozen, stored, and reheated with varying degrees of success.

The method of reheating - infrared versus double boiler - was studied in connection with the beef steaks. Although the infrared method was twice as fast as the double boiler method, it required as much time as the initial cooking and did not produce an equally palatable product. Thus there was no conceivable advantage in precooking steaks.

Beef roasts, on the other hand, presented the most promising picture. The reheated product received a satisfactory palatability rating, and the reheating time in the infrared oven, compared to the initial roasting time, was quite reasonable. These roasts were packaged both sliced and unsliced, and although the reheating time was shorter for the sliced meat, the unsliced meat had the more desirable flavor when reheated. Many possibilities exist for the advantageous use of precooked frozen roast beef, especially in the institutional fields.

The quality of precooked pork roasts when reheated was generally quite high, but the reheating time by the infrared oven was not particularly time-saving. The roasts that had been boned and packed with drippings were judged to be more desirable in flavor by the palatability committee and required less reheating time, but those packed dry, with the bone in, were more tender and juicy. In some instances, precooked frozen pork roasts might possess advantages over the freshly prepared roasts.

The precooked frozen pork chops were even more palatable than the pork roasts, and the reheating time, especially by infrared, was not excessive. Precooked pork chops give a satisfactory reheated product with conceivable future uses.

As for methods of reheating, the infrared oven seemed to be fairly satisfactory, and certainly much quicker than the double boiler method. The thickness of the package of meat is most likely a determining factor in the rate of reheating, and should be considered when reheating efficiency is desired.

Reheating losses were at a minimum throughout the experiment.

In general, the packaging methods most successful include meat that is packed in as large pieces as possible in drippings.

The storage time was approximately ten months for beef and five months for pork. Both kinds of meat held up well under their respective storage periods at 0° F. The beef was probably nearer the limit of storage than the pork, as indicated by the rancidity tests. However, this may have been influenced by the fact that the beef had been stored frozen for five months before initial cooking.

The results of this study show that beef steaks and roasts, and pork roasts and chops can be satisfactorily reheated to produce acceptable products, although not on a par with freshly cooked meat. There seem to be some possible future uses for these precooked meats in the growing frozen food industry of today.

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APPENDIX

MEAT COOKING RECORD

Grading Chart for Cooked Meat

Cooking Laboratory No._______ Sample No. _______ Kind ____________ Date ____________

FACTOR	PHASE	7	6	5	4	3	2	1	REMARKS
Aroma	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	neutral	undes.	undes.	
Texture (Grain)	Intensity	very fine	fine	m. fine	s. coarse	coarse	very coarse	ext. coarse	
Flavor of Fat	Intensity	very pro.	pro.	m. pro.	s. pro	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	neutral	s. undes.	undes.	
Flavor of Lean	Intensity	very pro.	pro.	m. pro.	s. pro.	per.	s. per.	imper.	
	Desirability	very des.	des.	m. des.	s. des.	neutral	s. undes.	undes.	
Tenderness	Intensity	very tender	tender	m. tender	s. tough	tough	very tough	ext. tough	
Juiciness	Quantity of juice	very juicy	juicy	m. juicy	s. dry	dry	very dry	ext. dry	
	Quality of juice	very rich	rich	m. rich	s. rich	per.	s. per.	imper.	

Color of Lean

1. Light red
2. Dark pink
3. Light pink
4. Pinkish brown
5. Light brown
6. Dark brown

Color of Fat

1. White
2. Creamy white
3. Grayish cream
4. Grayish white
5. Yellowish brown
6. Yellow
7. Amber

Key to Abbreviations

pro. - pronounced
m. - moderately
s. - slightly
imper. - imperceptible
des. - desirable
undes. - undesirable
ext. - extremely
per. - perceptible

____
Signature of Judge

Sheet 8 MEAT COOKING RECORDS Date________________

SUMMARY OF SCORES FROM GRADING CHARTS FOR COOKED MEAT

Cooking laboratory serial number_______ Kind of meat______________
Animal number__________________________ Cut of meat_______________

Judges		INTENSITY							DESIRABILITY		
							Juciness				
Names	Symbols	Aroma	Texture	Flavor of fat	Flavor of lean	Tender-ness	Quality	Quantity	Aroma	Flavor of fat	Flavor of lean
Total											
Average											

Comments: