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Effects of Freezing and Frozen Storage on Palatability of Beef, Pork, and Lamb Preroasted at Low Temperatures

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SUMMARY

Sensory evaluations were conducted on U.S. Good and U.S. Utility grades of beef round, cooked at 85°C to an internal temperature of 71°C; pork loin, cooked at 82°C to an internal temperature of 74°C; and leg of lamb, cooked at 82°C to an internal temperature of 71°C. All species of meat were prepared as whole roasts, packaged in aluminum foil with and without drippings, and as slices of roasts. Slices were either untreated, covered with gravy, or dipped in antioxidant. Two types of packaging, aluminum foil trays and boil-in-pouch bags, were used for slices of meat prepared by each of these three treatments. Pork and beef were rated more desirable when the prerosted meat was sliced, covered with gravy, and packaged in boil-in-pouch bags for freezer storage than when prepared by the other package-treatment combinations. Gravy was the only treatment that had a marked beneficial effect on palatability of sliced cooked lamb. However, mean panel scores for aroma, flavor, and general acceptability of pork and lamb prepared by low temperature cookery indicated that the meat was desirable after the 12 months of frozen storage (-19° to -22°C). This was also true for beef except for whole roasts packaged with drippings and untreated slices in aluminum foil trays.

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INTRODUCTION

Maintenance of high quality is essential to the success of convenience foods. A major concern in producing these foods is practicality of precooking and handling procedures. It was the purpose of this study to evaluate the palatability of pork, lamb, and two grades of beef cooked at low oven temperatures and subjected to freezer storage for periods up to one year. Treatments included whole roasts packaged in aluminum foil, with and without drippings, and slices of roasts untreated, covered with gravy, or dipped in antioxidant and packaged in aluminum foil trays or boil-in-pouch bags.

Cover (1943) observed that beef roasts were always tender when rate of heat penetration was slow. In agreement with this, Bramblett *et al.* (1959) found that U. S. Standard grade beef rounds wrapped in aluminum foil were more tender when cooked at 63°C than when cooked at 68°C. In addition, meat cooked at the lower temperature was juicier and better in texture and appearance than that cooked at 68°C, but there was no significant difference in flavor scores for the beef cooked at the two temperatures. In later work, utilizing the same oven temperatures for two grades of beef, differences were found between muscles in cooking losses, amount of press fluid, shear values, and sensory scores for tenderness and juiciness (Bramblett and Vail, 1964). In contrast to these studies, Marshall *et al.* (1960) concluded that low oven temperatures (93°C, 107°C, 121°C) were impractical for U.S. Choice grade top rounds of beef roasted to internal temperatures of 60°C, 70°C, and 80°C. When effects of freezing on the quality of beef cooked at low temperature were evaluated, some loss of quality occurred but the meat was still acceptable at 12 months (Bramblett *et al.*, 1965).

METHODS AND MATERIALS

Both sensory and chemical analyses were conducted on beef, pork, and lamb cooked at low temperatures and subjected to frozen storage. Adjacent slices of meat which were treated alike were used for these analyses. Only the results of sensory analysis are reported herein.

Preparation of Beef

Twenty-four top rounds of beef, six pairs each of U.S. Good and U.S. Utility grade, were used in this study. Each round was cut into two roasts (anterior and posterior), wrapped in heavy duty aluminum foil, and cooked to an internal tem-

perature of 71°C in a smokehouse (85°C). Twelve slices, ¼ inch thick, were obtained from each of these roasts. Of four adjacent slices of meat from each roast which were randomly assigned to treatment-storage combinations, two were put in one package and two in another. One of these two packages was assigned to chemical analyses and the other to sensory testing. The unsliced roasts also were assigned randomly to treatment-storage combinations. The eight treatments were replicated according to the following schedule:

1. Whole roasts (W)
 - a. Frozen in heavy duty aluminum foil cooking wrap containing the meat drippings (D).
 - b. Roasts removed from drippings and rewrapped in heavy duty aluminum foil (ND).
2. Sliced cooked beef packaged in the entrée section of aluminum foil trays and in boil-in-pouch bags (Polyethylene-Saran-Mylar-Laminated bag, International Kenfield Distributing Co., Chicago, Ill.), evacuated before heat sealing (S).
 - a. Packaged without further treatment, control (C).
 - b. Covered with ½ cup gravy (G) (Tables 1 and 2).
 - c. Dipped in antioxidant solution (1 g sodium tripolyphosphate and 0.27 g sodium ascorbate made to 100 ml with distilled water) for 30 seconds and drained for 10 seconds (A).

The schedule for evaluation of the meat was as follows: immediately after packaging, after one day, three, six, nine, and twelve months of frozen storage (-19 to -22°C).

To prepare meat for sensory evaluation, packages were heated as follows:

1. Unfrozen samples (immediately after packaging).
 - a. Boil-in-pouch bags: 2 minutes in 3 quarts water (82°C).
 - b. Aluminum foil trays: 3 minutes in oven (218°C).
 - c. Whole roasts: Sliced, covered with aluminum foil, heated 3 minutes in oven (218°C).
2. Frozen samples.
 - a. Boil-in-pouch bags: 15 minutes in 3 quarts water (82°C).
 - b. Aluminum foil trays: 35 minutes in oven (218°C).
 - c. Whole roasts: sliced, covered with aluminum foil, heated 30 minutes in oven (177°C).

Preparation of Pork

Twelve pairs of pork loins were selected for this study. Half of the loins were cut into two pieces (anterior and posterior) and assigned randomly to the whole roast treatment-storage combinations for cooking. The other loins were left whole for cooking. All roasts were wrapped in heavy duty aluminum foil and roasted in a smoke house (82°C) to an internal temperature of 74°C.

TABLE 1 -- INGREDIENTS AND PROCEDURE FOR PREPARING GRAVY

Ingredients	Amount
Low-methoxyl pectin ¹	1.0 g
Water	13.0 ml
Rendered suet (0.02% BHA added)	9.0 g
Waxy rice flour ²	12.0 g
201 Mix (Table 2)	4.0 g
Meat broth ³ (broth: water, 1:1)	180.0 ml
Calcium chloride (0.009N)	34.0 ml

Procedure

1. Sprinkle pectin on water. Disperse by stirring. Hold in water bath (60°C) 15 min.
2. Stir flour and 201 Mix into rendered suet.
3. Add meat broth and calcium chloride solution.
4. Heat to 87°C with minimum stirring.
5. Stir in hydrated pectin.

¹Low-methoxyl pectin, Lot no. 3466, Sunkist Growers, Research Department, Carona, Calif.

²Nu Formula Flour, Rice Products Co., Inc., 275 Post Street, San Francisco, Calif.

³Meat cubes, browned, then cooked in water (118 ml/lb of meat) 20 min at 15 psi. Fat removed from broth before straining and diluting with water.

TABLE 2 -- INGREDIENTS¹ FOR 201 MIX

Ingredients	Amount
Monosodium glutamate	7.0 g
Onion powder	1.0 g
Pepper (white)	0.3 g
Caramel color ²	1.3 g
Salt	11.1 g

¹Particle size, Wiley mill screen No. 60.

²B-C caramel color, Sethness Caramel Powder Co., 1013 West Webster, Chicago, Ill.

After cooking, the whole loins were cut into 36 $\frac{1}{4}$ inch thick slices. Of six adjacent slices of pork from each roast which were randomly assigned to treatment-storage combinations, two were put in each of three packages. One of these three packages was assigned to sensory testing and the other two to chemical analyses.

The entire experiment was replicated according to the following schedule:

1. Whole pork loin roasts treated the same as beef.
2. Sliced cooked pork loin packaged as for beef.

The schedule for the evaluation of the pork, the reheating of samples, and the taste panel procedures were the same as described for beef.

Preparation of Lamb

Eighteen pairs of boned legs of lamb were studied. Six pairs of legs of lamb were cut into two pieces (anterior and posterior) and these were assigned randomly to the whole roast treatment-storage combinations. The remaining 12 pairs of legs of lamb were left whole. All roasts were wrapped in heavy duty aluminum foil and cooked in a smokehouse (82°C) to an internal temperature of 71°C. After cooking, the whole legs of lamb were cut into 18 $\frac{1}{4}$ inch thick slices. Of six adjacent slices of lamb from each roast which were randomly assigned to treatment-storage combinations, two were put in each of three packages. One of these three packages was assigned to sensory testing and the other two to chemical analyses.

The entire experiment was replicated according to the following schedule:

1. Whole roasts treated the same as beef.
2. Sliced cooked leg of lamb packaged as for beef.

The schedule for the evaluation of the lamb, reheating of the samples, and the taste panel training and procedures were the same as described for beef.

Sensory Evaluation

The taste panel consisted of six women, but due to the extended length of the study, the panel composition did not remain the same. When new judges were introduced, they were trained prior to participation in actual taste panels.

Taste panel members were trained in identification of the flavor and aroma of fresh and stored meat samples. Slurries made from freshly prepared meat and broth (1:2 by weight) and from meat and broth stored in a refrigerator for four days, were used as training aids. These slurries and mixtures of these (1:2 and 2:1, by weight) were presented to panel members at three judging sessions. On two days at the beginning of the study and one day before evaluation of meat from each storage period, training procedures simulated actual data collection sessions.

Samples for judges were cut from the central portion of the meat slices and were served individually in preheated 50-ml beakers covered with aluminum foil

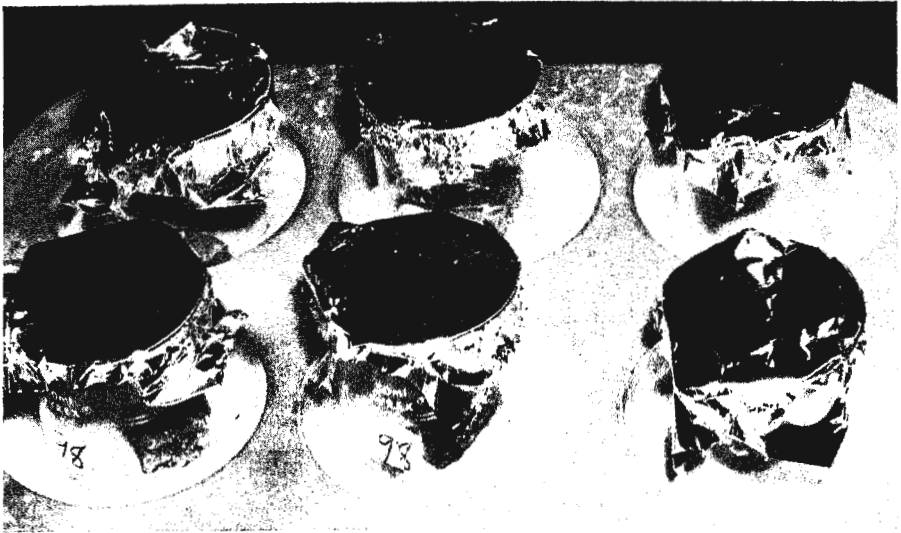


Figure 1. Equipment for transporting samples to judges.

(Fig. 1). Gravy was blotted from heated meat slices with paper towels before cutting portions for judges. Samples were served to judges seated in individual booths in a taste panel room.

At the beginning of each taste panel session, a warm-up sample of meat (representative of that storage period) was served to minimize bias toward the first judgment. Tap water at room temperature was provided for judges to rinse their mouths between samples. The meat prepared by the various treatments was randomized for order of judging. For beef, where there were 16 treatments, there was a 15-minute rest period between the first eight and last eight samples. Fig. 2 is a copy of the score sheet used for recording evaluations.

Statistical Analyses

Analyses of variance were determined for panel scores for palatability characteristics for beef, pork, and lamb. Sums of squares for the interactions and for the main effects of treatment were partitioned so that the amount of variation contributed by each factor could be determined. Mean scores involved in these significant orthogonal comparisons were examined for trends. The test for least significant difference was applied to determine significant differences between mean scores (Snedecor and Cochran, 1967). Analyses were made only where a judge's scores were complete for all storage periods. The sum of squares for judges and for judges and storage period interaction were pooled and called "Judges within storage period (J:SP)" in these analyses. This removed differences among judges from the error sum of squares.

Date

Judge Number

Sample

	9	8	7	6	5	4	3	2	1
	Extremely desirable	Very desirable	Moderately desirable	Slightly desirable	Neither desirable nor undesirable	Slightly undesirable	Moderately undesirable	Very undesirable	Extremely undesirable
Aroma									
Flavor									
Juiciness									
Tenderness									
General Acceptability									

Figure 2. Score sheet for sensory evaluation of meat.

RESULTS AND DISCUSSION

Sensory Evaluation of Beef

Immediately after packaging and prior to freezing, all samples were rated desirable in palatability as denoted by a mean panel score of 5.0 or above, except for tenderness of U.S. Good grade beef treated with antioxidant. In general, the panel ranked the meat desirable throughout the entire study (Tables 3, 4, 5, 6, 7).

The analyses of variance of panel scores for beef indicated highly significant ($P < 0.01$) interactions among storage period, grade, and treatment (SP x Gr x T) for all attributes. These significant interactions restricted interpretation which can be made concerning significant two-way interactions and main effects. However, mean scores were examined in detail to determine trends with meaningful and practical application (Tables 3, 4, 5, 6, 7, 8).

Influence of grade. In analyzing the role of grade on palatability, it was found that the mean scores for the various attributes of beef varied randomly

TABLE 3 -- MEANS¹ OF PANEL SCORES² FOR AROMA OF COOKED BEEF BEFORE AND AFTER FROZEN STORAGE (-19 to -22°C)

Treatments	Grade	Storage period				
		0 Day	1 Day	3 Months	6 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	Utility	5.7	5.7	5.2	5.2	5.7
Whole roast with drippings	Good	6.2	3.7	4.8	5.2	4.2
Whole roast without drippings	Utility	5.8	4.0	5.7	4.8	5.5
Whole roast without drippings	Good	7.2	4.8	5.2	4.3	5.7
<u>Slices</u>						
Control, boil-in-pouch	Utility	6.8	5.2	5.8	5.7	6.5
Control, boil-in-pouch	Good	5.5	5.7	6.2	5.5	6.5
Antioxidant, boil-in-pouch	Utility	5.7	5.5	5.7	6.0	6.0
Antioxidant, boil-in-pouch	Good	6.2	5.8	5.7	5.8	6.0
Gravy, boil-in-pouch	Utility	6.7	5.7	6.3	6.0	6.8
Gravy, boil-in-pouch	Good	6.0	6.2	6.3	6.2	6.7
Control, aluminum foil	Utility	6.3	4.8	5.7	4.8	4.7
Control, aluminum foil	Good	7.3	5.5	5.5	5.7	5.3
Antioxidant, aluminum foil	Utility	7.0	6.0	5.7	5.8	6.2
Antioxidant, aluminum foil	Good	5.7	5.8	5.8	5.8	6.3
Gravy, aluminum foil	Utility	6.0	5.3	5.8	5.7	7.2
Gravy, aluminum foil	Good	6.2	6.2	6.2	5.8	6.7

¹n=6, LSD_{0.05} = 0.90.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 4 -- MEANS¹ OF PANEL SCORES² FOR FLAVOR OF COOKED BEEF BEFORE AND AFTER FROZEN STORAGE (-19 to -22°C).

Treatments	Grade	Storage period				
		0 Day	1 Day	3 Months	6 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	Utility	6.0	5.2	5.0	6.2	6.3
Whole roast with drippings	Good	6.2	3.3	5.3	5.8	4.5
Whole roast without drippings	Utility	6.2	3.7	6.5	5.5	5.7
Whole roast without drippings	Good	7.9	5.3	5.3	5.5	6.7
<u>Slices</u>						
Control, boil-in-pouch	Utility	7.0	5.5	6.3	5.7	6.2
Control, boil-in-pouch	Good	5.7	6.5	5.5	5.7	6.2
Antioxidant, boil-in-pouch	Utility	6.2	6.2	5.8	6.5	6.2
Antioxidant, boil-in-pouch	Good	6.0	6.5	6.0	6.7	6.2
Gravy, boil-in-pouch	Utility	6.8	6.7	6.5	6.7	6.5
Gravy, boil-in-pouch	Good	6.3	7.0	7.3	6.7	7.0
Control, aluminum foil	Utility	5.5	5.3	5.8	4.7	4.3
Control, aluminum foil	Good	7.8	5.5	4.7	5.7	5.0
Antioxidant, aluminum foil	Utility	7.5	5.5	6.0	6.0	5.8
Antioxidant, aluminum foil	Good	6.7	6.3	6.2	6.3	6.2
Gravy, aluminum foil	Utility	6.2	6.2	6.0	5.8	7.0
Gravy, aluminum foil	Good	6.7	6.5	6.7	5.8	6.7

¹n=6, LSD_{0.05}=1.15.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 5 -- MEANS¹ OF PANEL SCORES² FOR TENDERNESS OF COOKED BEEF BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C).

Treatments	Grade	Storage period				
		0 Day	1 Day	3 Months	6 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	Utility	6.3	5.7	5.7	5.3	7.2
Whole roast with drippings	Good	5.3	4.7	5.3	5.5	6.2
Whole roast without drippings	Utility	6.3	5.0	6.3	5.7	6.3
Whole roast without drippings	Good	8.2	6.0	5.3	6.0	6.2
<u>Slices</u>						
Control, boil-in-pouch	Utility	7.0	5.7	7.2	5.0	5.8
Control, boil-in-pouch	Good	5.7	6.8	7.3	4.7	4.8
Antioxidant, boil-in-pouch	Utility	5.7	6.5	5.3	6.7	5.2
Antioxidant, boil-in-pouch	Good	4.8	5.5	6.8	5.8	4.7
Gravy, boil-in-pouch	Utility	6.8	6.8	6.8	6.0	6.5
Gravy, boil-in-pouch	Good	5.3	6.8	7.0	6.8	5.7
Control, aluminum foil	Utility	6.3	5.3	5.7	6.5	5.8
Control, aluminum foil	Good	7.5	4.2	5.3	4.8	3.3
Antioxidant, aluminum foil	Utility	7.8	4.7	5.7	6.0	6.0
Antioxidant, aluminum foil	Good	7.2	6.5	5.5	5.0	5.5
Gravy, aluminum foil	Utility	7.5	6.5	6.0	7.2	4.7
Gravy, aluminum foil	Good	7.2	6.3	6.7	5.0	5.5

¹n=6, LSD_{0.05}=1.00.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 6 -- MEANS¹ OF PANEL SCORES² FOR JUICINESS OF COOKED BEEF BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C).

Treatments	Grade	Storage period				
		0 Days	1 Day	3 Months	6 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	Utility	5.3	4.8	5.7	5.3	6.2
Whole roast with drippings	Good	6.2	4.0	4.8	6.2	5.0
Whole roast without drippings	Utility	6.7	4.2	5.7	6.5	5.8
Whole roast without drippings	Good	7.0	4.5	5.0	6.7	6.8
<u>Slices</u>						
Control, boil-in-pouch	Utility	6.3	5.3	5.8	5.0	5.5
Control, boil-in-pouch	Good	6.2	6.0	6.0	6.0	5.2
Antioxidant, boil-in-pouch	Utility	6.0	5.5	5.3	6.2	4.8
Antioxidant, boil-in-pouch	Good	5.8	5.2	6.0	7.0	5.3
Gravy, boil-in-pouch	Utility	6.0	5.8	6.2	6.3	5.5
Gravy, boil-in-pouch	Good	6.5	6.5	7.0	6.7	5.8
Control, aluminum foil	Utility	5.5	4.5	5.3	4.2	4.0
Control, aluminum foil	Good	7.8	4.5	5.0	4.5	3.8
Antioxidant, aluminum foil	Utility	7.3	4.3	5.0	5.5	5.2
Antioxidant, aluminum foil	Good	6.0	4.8	4.8	5.7	4.7
Gravy, aluminum foil	Utility	6.0	5.7	5.8	5.7	4.7
Gravy, aluminum foil	Good	6.8	5.3	5.8	5.3	6.3

¹n=6, LSD_{0.05}=0.98.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 7 -- MEANS¹ OF PANEL SCORES² FOR GENERAL ACCEPTABILITY OF COOKED BEEF BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C).

Treatments	Grade	Storage period				
		0 Day	1 Day	3 Months	6 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	Utility	5.7	5.3	5.0	5.5	6.5
Whole roast with drippings	Good	5.8	3.7	5.2	6.0	4.5
Whole roast without drippings	Utility	6.5	4.0	6.3	5.7	5.8
Whole roast without drippings	Good	7.8	5.0	5.2	5.8	6.5
<u>Slices</u>						
Control, boil-in-pouch	Utility	6.8	5.5	6.3	5.3	5.8
Control, boil-in-pouch	Good	5.7	6.2	5.8	5.7	5.7
Antioxidant, boil-in-pouch	Utility	5.7	6.0	5.3	6.3	6.7
Antioxidant, boil-in-pouch	Good	6.0	5.7	6.0	6.5	5.8
Gravy, boil-in-pouch	Utility	6.5	6.3	6.5	6.5	6.3
Gravy, boil-in-pouch	Good	6.2	6.7	7.2	6.7	6.7
Control, aluminum foil	Utility	5.5	5.2	5.8	4.3	4.3
Control, aluminum foil	Good	7.7	5.0	4.8	5.5	4.5
Antioxidant, aluminum foil	Utility	7.5	5.0	5.8	6.2	5.7
Antioxidant, aluminum foil	Good	6.5	5.8	5.8	5.8	5.8
Gravy, aluminum foil	Utility	6.2	6.0	5.8	6.2	6.2
Gravy, aluminum foil	Good	6.7	6.2	6.7	5.7	6.3

¹n=6, LSD_{0.05}= 0.99.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 8 -- ANALYSES OF VARIANCE FOR PANEL SCORES FOR PALATABILITY CHARACTERISTICS OF BEEF

Source of variation	Degrees of freedom	Mean square				
		Aroma	Flavor	Tenderness	Juiciness	General acceptability
Storage period (SP)	4	12.43**	9.04**	14.35**	23.35**	11.35**
Judges within storage period (J:SP)	25	5.16**	6.61**	12.36**	8.70**	7.98**
Grade (Gr)	1	0.03	2.00	10.21**	5.00*	1.01
Treatment (T)	7	9.07**	13.06**	6.23**	9.72**	10.70**
<u>Whole roast</u>						
Drippings (D) vs no Drippings (ND)	1	0.83	5.63*	5.21*	8.53**	9.08**
Whole roast (W) vs slices (S)	1	49.14**	29.18**	0.28	0.00	12.47**
<u>Slices</u>						
Control (C) vs [antioxidant (A) + gravy (G)]	1	7.61**	35.56**	10.27**	15.02**	27.22**
A vs G	1	4.27*	6.02*	16.02**	13.07**	10.42**
Package (P)	1	1.34	9.03**	2.03	28.34**	7.80**
P x [C vs (A+G)]	1	2.69*	3.20	6.05*	2.94*	4.67*
P x (A vs G)	1	2.02	2.82	3.75*	0.15	3.27*
SP x Gr	4	0.35	0.80	3.25**	0.95	0.48
Gr x T	7	2.15**	2.83**	2.16**	1.32	1.74*

TABLE 8 (Continued)

Source of variation	Degrees of freedom	Mean square				
		Aroma	Flavor	Tenderness	Juiciness	General acceptability
SP x T	28	1.81**	2.90**	5.52**	3.51**	2.59**
(D vs ND) x SP	4	1.83*	2.01	2.56*	1.53	2.08*
(W vs S) x SP	4	2.95**	8.69**	9.70**	9.16**	6.06**
[C vs (A + G)] x SP	4	2.76**	2.29	3.19**	3.73**	2.97**
(A vs G) x SP	4	1.10	1.87	9.02**	2.60**	1.79
P x SP	4	1.12	2.92*	15.02**	6.22**	3.88**
P x [C vs (A + G)] x SP	4	2.77**	1.58	4.82**	1.07	0.78
P x (A vs G) x SP	4	0.57	0.92	2.47*	0.22	0.58
SP x Gr x T	28	1.39**	2.40**	3.39**	1.75**	2.20**
Error	375	0.63	1.64	0.78	0.76	0.76
Total	479					
Coefficient of variation		13.80%	16.89%	14.78%	15.49%	14.90%

* P<0.05

** P<0.01

from storage period to storage period. There was no treatment where U.S. Utility or U.S. Good grade of beef was scored consistently higher than the other (Tables 3, 4, 5, 6, 7, 8).

Whole roasts. There were significant differences in flavor ($P < 0.05$), tenderness ($P < 0.05$), juiciness ($P < 0.01$), and general acceptability ($P < 0.01$) of whole roasts packaged with and without drippings. Mean scores were significantly higher only for flavor, juiciness, and general acceptability for roasts without drippings. Also, samples from whole roasts were scored significantly less desirable than sliced meat in aroma, flavor, and general acceptability. As storage time lengthened, mean scores for aroma and flavor of whole roasts declined more than those for slices. This trend was not evident for juiciness and general acceptability (Tables 3, 4, 5, 6, 7, 8).

Slices. Antioxidant- and gravy-treated samples of beef, were rated more desirable than the control slices for aroma, juiciness, and general acceptability except when tested before storage. Of the treated slices, the ones packaged with gravy were favored for all attributes (Tables 3, 4, 5, 6, 7, 8).

The influence of packaging on sliced cooked beef was shown by mean scores for samples subjected to freezing. The mean panel scores were significantly ($P < 0.01$) higher for flavor, juiciness, and general acceptability of samples of sliced beef packaged in boil-in-pouch bags than for samples in aluminum foil trays (Tables 3, 4, 5, 6, 7, 8).

Irrespective of storage period, the most desirable samples of sliced cooked beef were those packaged with gravy in boil-in-pouch bags. Also, over all storage periods, the least desirable samples were from the control slices packaged in aluminum foil (Tables 3, 4, 5, 6, 7, 8).

Sensory Evaluation of Pork

With one exception (mean score, 4.5, for tenderness of samples with gravy after nine months of storage) the sliced pork in boil-in-pouch bags was scored desirable (5.0 or above) for all attributes throughout the study. Of the other samples, where mean scores were below 5.0, there was no apparent relationship to either freezing or length of frozen storage (Tables 9, 10, 11, 12, 13).

The analyses of variance of panel scores for cooked pork indicated significant ($P < 0.01$) interactions under storage period and treatment (SP x T) for flavor, tenderness, juiciness, and general acceptability but not for aroma. However, certain trends with useful application were suggested by the magnitude of difference among mean scores (Tables 9, 10, 11, 12, 13, 14).

Although there were significant ($P < 0.01$) main effects of storage period, there was no tendency for palatability of pork to decrease as storage time progressed. This may be related to the change of two of the five judges for the evaluations at nine- and twelve-month storage periods (Tables 9, 10, 11, 12, 13, 14).

Whole roasts. No consistent preference for pork roasts with or without

TABLE 9 -- MEANS¹ OF PANEL SCORES² FOR AROMA OF COOKED PORK BEFORE AND AFTER FROZEN STORAGE (-19 to -22°C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	3.9	4.6	4.9	5.3	5.5	5.9
Whole roast without drippings	4.9	6.6	4.0	5.4	5.8	5.9
<u>Slices</u>						
Control, boil-in-pouch	5.3	5.6	6.2	5.4	6.2	6.2
Antioxidant, boil-in-pouch	5.0	5.1	5.4	6.0	6.4	6.4
Gravy, boil-in-pouch	6.0	5.8	6.7	6.3	5.9	6.9
Control, aluminum foil	4.1	4.5	4.9	4.6	6.1	5.2
Antioxidant, aluminum foil	5.6	5.0	5.7	5.3	6.2	6.4
Gravy, aluminum foil	5.9	5.4	5.9	6.1	6.0	6.7

¹n=10, LSD_{0.05} = 0.88.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 10 -- MEANS¹ OF PANEL SCORES² FOR FLAVOR OF COOKED PORK BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	3.6	4.7	6.0	6.1	5.7	6.8
Whole roast without drippings	4.3	4.7	4.9	5.4	6.4	6.2
<u>Slices</u>						
Control, boil-in-pouch	5.8	6.4	7.0	5.4	6.8	6.4
Antioxidant, boil-in-pouch	5.0	5.4	5.7	6.1	6.8	7.0
Gravy, boil-in-pouch	7.1	7.0	6.4	6.3	5.9	7.4
Control, aluminum foil	4.3	4.3	5.6	4.8	5.2	5.8
Antioxidant, aluminum foil	6.0	4.9	5.7	6.2	5.2	6.0
Gravy, aluminum foil	6.9	5.7	6.2	6.4	6.3	7.1

¹n=10, LSD_{0.05} = 1.03.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 11 -- MEANS¹ OF PANEL SCORES² FOR TENDERNESS OF COOKED PORK BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	STORAGE PERIOD					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	6.1	4.6	6.3	6.4	5.9	7.8
Whole roast without drippings	6.5	6.7	6.5	6.8	6.9	6.6
<u>Slices</u>						
Control, boil-in-pouch	6.9	6.5	5.9	7.1	5.1	7.4
Antioxidant, boil-in-pouch	6.7	5.5	7.2	5.6	7.3	6.8
Gravy, boil-in-pouch	6.8	6.5	6.9	6.2	4.5	7.4
Control, aluminum foil	5.7	6.4	5.5	3.4	4.1	5.9
Antioxidant, aluminum foil	5.6	6.6	4.0	5.4	5.1	6.3
Gravy, aluminum foil	7.4	6.0	4.1	4.5	5.0	6.7

¹n=10, LSD_{0,05} = 1.10.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 12 -- MEANS¹ OF PANEL SCORES² FOR JUICINESS OF COOKED PORK BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	5.9	5.5	5.2	6.0	5.9	6.3
Whole roast without drippings	6.1	5.3	4.5	3.9	6.1	5.9
<u>Slices</u>						
Control, boil-in-pouch	5.7	5.6	6.0	5.1	5.8	5.5
Antioxidant, boil-in-pouch	6.9	6.2	6.6	5.8	6.2	6.2
Gravy, boil-in-pouch	6.9	6.4	7.0	6.2	5.7	6.8
Control, aluminum foil	6.0	5.7	5.3	5.3	5.1	5.4
Antioxidant, aluminum foil	6.9	4.9	4.4	6.4	4.7	5.3
Gravy, aluminum foil	6.4	4.8	5.8	5.4	5.4	6.1

¹n=10, LSD_{0.05}=0.98.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 13 -- MEANS¹ OF PANEL SCORES² FOR GENERAL ACCEPTABILITY OF COOKED PORK BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	4.0	4.8	5.6	6.1	5.7	6.8
Whole roast without drippings	4.8	4.7	4.6	5.1	6.4	6.0
<u>Slices</u>						
Control, boil-in-pouch	5.5	6.0	6.4	5.6	6.6	6.3
Antioxidant, boil-in-pouch	5.6	5.7	5.8	5.9	6.9	6.7
Gravy, boil-in-pouch	6.8	6.7	6.6	6.3	5.9	7.2
Control, aluminum foil	4.5	4.9	5.4	4.7	5.1	5.7
Antioxidant, aluminum foil	6.0	5.3	4.8	6.2	5.1	6.1
Gravy, aluminum foil	6.9	5.6	5.5	5.6	6.0	6.8

¹n=10, LSD_{0,05}=0.94.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 14 -- ANALYSES OF VARIANCE FOR PANEL SCORES FOR PALATABILITY CHARACTERISTICS OF PORK

Source of	Degrees of freedom	Mean square				
		Aroma	Flavor	Tenderness	Juiciness	General acceptability
Replication	1	2.55	1.10	2.00	1.10	1.30
Judges within storage period (J:SP)	24	4.10**	5.26**	5.26**	10.05**	5.87**
Storage period (SP)	5	17.32**	16.04**	21.62**	8.52**	11.20**
Treatment (T)	7	14.96**	20.38**	18.72**	11.11**	15.65**
<u>Whole roast</u>						
Drippings (D) vs no Drippings (ND)	1	0.21	0.83	7.01*	7.50*	1.63
Whole roast (W) vs slices (S)	1	41.01**	34.53**	20.78**	7.08*	24.81**
<u>Slices</u>						
Control (C) vs [antioxidant (A) + gravy (G)]	1	25.31**	22.40**	2.57	15.02**	22.05**
A vs G	1	10.84**	31.54**	0.00	2.40	14.02**
Package (P)	1	14.40**	34.23**	96.10**	35.47**	42.03**
P x [C vs (A + G)]	1	12.01**	19.01**	3.61	10.27**	5.00*
P x (A vs G)	1	0.94	0.10	0.94	0.02	0.00
SP x T	35	1.50	3.73**	7.37**	2.95**	2.95**
(D vs ND) x SP	5	1.87	2.87	5.81**	3.68*	3.25*
(W vs S) x SP	5	2.38*	7.98**	8.60**	4.99**	5.71**
[C vs (A + G)] x SP	5	2.24	4.97**	2.25	2.17	4.06**
(A vs G) x SP	5	1.58	3.02	6.65**	2.45	2.12
P x SP	5	0.67	2.61	10.79**	4.18**	1.97
P x [C vs (A + G)] x SP	5	0.84	1.39	10.09**	0.83	0.74
P x (A vs G) x SP	5	0.90	3.28*	7.41**	2.39	2.62*
Error	407	1.02	1.37	1.58	1.26	1.15
Total	479					
Coefficient of variation		18.35%	23.38%	26.07%	21.83%	19.90%

* P<0.05

** P<0.01

drippings was found over the six evaluation periods. Even though the interaction between whole roasts versus slices and storage period [(W x S) x SP] was significant, mean scores for aroma, flavor, and general acceptability tended to be lower for samples from whole roasts than from slices. For these attributes, the differences were supported by the significantly ($P < 0.01$) lower means over all storage periods for whole pork roasts than for slices. This pattern was not true for juiciness (Tables 9, 10, 11, 12, 13, 14).

Slices. Of the sliced pork, samples with gravy were judged significantly ($P < 0.01$) higher in aroma, flavor, and general acceptability than those dipped in antioxidant. Mean scores for aroma for both of these treated samples were significantly ($P < 0.01$) higher than those for control slices. There was no difference in juiciness between the two treated samples of sliced pork but both were judged better than control samples (Tables 9, 10, 11, 12, 13, 14).

At all storage periods, sliced pork packaged in boil-in-pouch bags was rated significantly ($P < 0.01$) higher than that in aluminum foil for all attributes. The combined means for treated samples packaged in boil-in-pouch bags or in aluminum foil and the control samples packaged in boil-in-pouches were significantly higher in aroma ($P < 0.01$), flavor ($P < 0.01$), and general acceptability ($P < 0.05$) than the mean score for control samples packaged in aluminum foil trays. In comparing these four mean scores for juiciness, treated samples packaged in boil-in-pouch bags were favored. The preference for gravy-treated samples over antioxidant-dipped slices was not affected by packaging (Tables 9, 10, 11, 12, 13, 14).

Sensory Evaluation of Lamb

All mean panel scores for general acceptability of cooked slices of lamb stored frozen up to 12 months were above the acceptable level (5.0 or higher). With few exceptions, this also was true for aroma, flavor, tenderness, and juiciness of these samples. Most mean panel scores for the whole roasts were in the acceptable range (5.0 or higher) throughout the study (Tables 15, 16, 17, 18, 19).

The analyses of variance for lamb revealed significant interactions between storage period and treatment (SP x T) for all attributes except juiciness. Mean scores related to these interactions were examined to locate differences of practical importance (Tables 15, 16, 17, 18, 19, 20).

Although the main effects of storage period were significant for all palatability characteristics, there was no trend toward lower panel scores with increased storage time. This effect may be related to the change of three out of the four judges for the evaluations at the nine- and twelve-month storage period (Tables 15, 16, 17, 18, 19, 20).

Whole roasts. There was no significant difference between panel scores for any attribute of whole lamb roasts with and without drippings. The over-all mean score for aroma of samples of whole roasts was significantly ($P < 0.01$) lower than that for sliced lamb but the magnitude of difference among the means at

TABLE 15 -- MEANS¹ OF PANEL SCORES² FOR AROMA OF COOKED LAMB BEFORE
AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	5.1	5.0	5.4	4.8	5.1	5.6
Whole roast without drippings	6.4	5.9	4.1	4.8	6.0	6.1
<u>Slices</u>						
Control, boil-in-pouch	5.0	5.4	5.1	6.0	5.4	6.6
Antioxidant, boil-in-pouch	5.1	5.9	5.4	5.9	5.5	6.4
Gravy, boil-in-pouch	6.3	6.3	6.1	6.1	6.1	6.1
Control, aluminum foil	5.5	5.8	5.3	5.1	5.5	5.9
Antioxidant, aluminum foil	5.8	5.4	5.5	5.6	4.8	6.1
Gravy, aluminum foil	6.6	6.4	6.6	6.3	6.0	6.5

¹n=8, LSD_{0.05}=0.93.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 16 -- MEANS¹ OF PANEL SCORES² FOR FLAVOR OF COOKED LAMB BEFORE AND AFTER FROZEN STORAGE (-19 to -22°C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
Whole roast						
Whole roast with drippings	6.1	6.3	5.9	5.1	5.6	6.4
Whole roast without drippings	6.1	6.0	4.5	6.0	6.6	6.9
Slices						
Control, boil-in-pouch	5.3	5.5	4.9	5.5	4.9	7.1
Antioxidant, boil-in-pouch	4.8	6.4	5.3	6.3	5.9	6.5
Gravy, boil-in-pouch	6.6	6.5	6.8	5.9	7.3	6.6
Control, aluminum foil	5.3	5.8	4.8	5.3	5.9	5.5
Antioxidant, aluminum foil	6.3	5.6	5.9	6.5	5.1	6.0
Gravy, aluminum foil	7.4	7.0	7.6	6.4	6.6	6.4

¹n=8, LSD_{0.05}=1.25.

²Range of scores: 9, "like extremely" to 1, "dislike extremely."

TABLE 17 -- MEANS¹ OF PANEL SCORES² FOR TENDERNESS OF COOKED LAMB BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	5.9	6.8	6.0	5.8	5.5	6.1
Whole roast without drippings	6.9	6.0	4.3	7.4	6.3	7.3
<u>Slices</u>						
Control, boil-in-pouch	5.4	5.6	5.4	6.5	5.0	7.5
Antioxidant, boil-in-pouch	6.5	6.6	6.4	7.0	6.3	6.3
Gravy, boil-in-pouch	7.8	6.4	7.0	7.4	7.4	7.1
Control, aluminum foil	6.3	5.5	4.6	5.4	6.8	6.3
Antioxidant, aluminum foil	7.1	5.9	6.9	7.7	4.7	6.0
Gravy, aluminum foil	7.4	5.5	7.6	6.8	7.8	6.4

¹n=8, LSD_{0.05}= 1.25.

²Range of scores: 9, "like extremely" to 1, "dislike extremely".

TABLE 18 -- MEANS¹ OF PANEL SCORES² FOR JUICINESS OF COOKED LAMB BEFORE AND AFTER FROZEN STORAGE (-19 to -22° C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	7.3	6.6	5.0	6.4	6.1	6.3
Whole roast without drippings	6.8	5.9	4.9	6.0	6.3	7.0
<u>Slices</u>						
Control, boil-in-pouch	5.8	5.9	5.0	6.0	5.9	6.6
Antioxidant, boil-in-pouch	6.3	5.8	5.8	6.0	5.8	6.3
Gravy, boil-in-pouch	6.9	6.1	6.5	6.5	6.4	6.6
Control, aluminum foil	5.7	4.8	4.5	6.4	6.0	5.6
Antioxidant, aluminum foil	7.1	5.3	4.8	5.8	5.4	6.0
Gravy, aluminum foil	7.5	6.5	6.0	6.5	5.9	6.8

¹n=8, LSD_{0.05} = 0.98.

²Range of scores: 9, "like extremely", to 1, "dislike extremely".

TABLE 19 -- MEANS¹ OF PANEL SCORES² FOR GENERAL ACCEPTABILITY OF COOKED LAMB BEFORE AND AFTER FROZEN STORAGE (-19 to -22°C)

Treatments	Storage period					
	0 Days	1 Day	3 Months	6 Months	9 Months	12 Months
<u>Whole roast</u>						
Whole roast with drippings	6.3	6.4	5.8	5.8	5.8	6.1
Whole roast without drippings	6.4	5.9	4.4	6.1	6.6	6.8
<u>Slices</u>						
Control, boil-in-pouch	5.0	5.4	5.0	6.4	5.3	7.1
Antioxidant, boil-in-pouch	4.9	6.1	5.3	6.4	6.1	6.4
Gravy, boil-in-pouch	6.8	6.5	6.5	6.3	7.3	6.8
Control, aluminum foil	5.1	5.5	5.1	5.1	6.1	5.6
Antioxidant, aluminum foil	6.5	5.5	6.0	6.5	5.0	5.9
Gravy, aluminum foil	7.3	6.5	7.3	6.4	6.9	6.3

¹n=8, LSD_{0.05} = 1.10

²Range of scores: 9, "like extremely" to 1, "dislike extremely".

TABLE 20 - ANALYSES OF VARIANCE FOR PANEL SCORES FOR PALATABILITY CHARACTERISTICS OF LAMB

Source of variation	Degrees of freedom	Mean square				
		Aroma	Flavor	Tenderness	Juiciness	General acceptability
Replication	1	0.21	4.81	1.63	1.50	3.96
Judges within storage period (J:SP)	18	7.11**	10.08**	9.45**	14.42**	9.32**
Storage period (SP)	5	4.29**	3.99*	6.60**	14.12**	3.42*
Treatment (T)	7	7.52**	12.42**	11.15**	6.64**	9.88**
<u>Whole roast</u>						
Drippings (D) vs no drippings (ND)	1	3.38	0.38	2.67	0.51	0.01
Whole roast (W) vs slices (S)	1	14.90**	0.31	5.42	2.72	0.11
<u>Slices</u>						
Control (C) vs [antioxidant (A) + gravy (G)]	1	10.29**	46.13**	51.36**	16.34**	34.03**
A vs G	1	22.01**	37.63**	16.33**	22.01**	33.33**
Package (P)	1	0.00	0.42	1.84	2.92	0.13
P x [C vs (A + G)]	1	0.21	1.46	0.11	1.09	1.56
P x (A vs G)	1	1.88	0.63	0.33	0.88	0.02
SP x T	35	1.47*	2.81**	4.80**	1.45	2.71**
(D vs ND) x SP	5	3.25**	3.10	6.74**	1.14	2.76
(W vs S) x SP	5	2.61*	1.74	3.74**	1.73	2.13
[C vs (A + G)] x SP	5	0.81	2.48	7.38**	3.14**	2.48
(A vs G) x SP	5	1.08	4.71*	5.67**	0.29	3.20*
P x SP	5	1.27	3.38	2.66	1.90	4.13**
P x [C vs (A + G)] x SP	5	1.02	3.43	5.12**	1.60	3.42*
P x (A vs G) x SP	5	0.23	0.81	2.30	0.34	0.88
Error	317	0.91	1.63	1.63	1.01	1.26
Total	383					
Coefficient of variation		15.99%	27.16%	25.59%	16.69%	20.86%

* P<0.05

** P<0.01

each storage period varied. For the other attributes, there were no significant differences between mean scores for whole roasts and for sliced lamb (Tables 15, 16, 17, 18, 19, 20).

Slices. Samples of antioxidant- and gravy-treated slices of lamb were judged significantly ($P < 0.01$) higher than control slices for all attributes regardless of storage period. In addition, samples with gravy were preferred ($P < 0.01$) to those treated with antioxidant even though there were some significant interactions with storage. Palatability characteristics of sliced lamb were not affected significantly by packaging (Tables 15, 16, 17, 18, 19, 20).

General Discussion

In general, low temperatures (82-85°C) were suitable for preroasting pork, lamb, and U.S. Good and U.S. Utility grades of beef subjected to frozen storage. In the research by Marshall *et al.* (1960) on low temperature cookery, variability in time, formation of a crust on the surface, and a crumbly texture of the meat were major objections. These problems did not arise in this study. Preliminary work indicated that aluminum foil wrap was effective in preventing formation of outer crusts on the meat. Aluminum foil was superior to polymylar casing for this purpose. Bramblett and Vail (1964) reported that the appearance, flavor, and tenderness of U.S. Good grade rounds of beef wrapped in aluminum foil were superior when the oven temperature was 68°C rather than 93°C although the roasts cooked at the low temperature were less juicy. Pilot studies in our laboratory supported these findings on appearance and tenderness of U.S. Utility and U.S. Good grades of beef cooked at low temperature (82°C). Beef cooked to 71°C appeared well done, and was preferred to that cooked under pressure, in vacuum, or in nitrogen atmosphere.

The results of this study suggested that when using low temperature cookery for preparing pork and beef, it is preferable to slice the preroasted meat and to use the drippings for gravy to serve as a protective coating during frozen storage. Boil-in-pouch type packaging was preferable to the aluminum foil tray used, although type of packaging was not as essential to maintenance of palatability of lamb as it was of beef and pork.

Beef, pork, and lamb prepared by this method can be kept successfully for a 12-month period of frozen storage. This confirms results of research by Bramblett *et al.* (1965) for U.S. Good and U.S. Utility grades of beef cooked at 68°C and 93°C.

CONCLUSIONS

Based on results of this study, the following conclusions can be made:

1. Low temperatures (82 or 85°C) are appropriate for roasting pork, lamb, and beef prior to freezer storage (-19 to -22°C) up to 12 months.
2. For this method of cooking and storage, there was no consistent trend for U.S. Good grade to be rated more desirable than U.S. Utility grade beef.
3. Slicing the cooked pork and beef roasts and covering the slices with gravy is more desirable than leaving the roasts whole for frozen storage.
4. For sliced cooked pork and beef, boil-in-pouch (Polyethylene-Saran-Mylar-Laminated) bags are preferable to the entrée section of aluminum foil trays as packaging for freezer storage.

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