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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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DISCLAIMER

NOTICE

The Annual Report for the period June 16, 1971 through June 15, 1972 is submitted in four units, each covering a quarter of the report period.

These quarterly reports follow.

RA # VP # Paper 1

Paper I

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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Contract AT(11-1)-1689

United States Atomic Energy Commission

QUARTERLY REPORT

June 15, 1971 through September 15, 1971

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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II. ABSTRACT

Because of its greater solubility, a sodium metaphosphate glass (SMPG) (64% P_2O_5)was investigated for its effects on color and drip. High concentrations (30%) yielded sufficient phosphate uptake by large-cuts with dipping alone.

Preliminary results, however, indicate the metaphosphate glass is not effective in maintaining color.

III. PREFACE

This first quarterly report was prepared in accordance with the terms of Contract No. AT(11-1)-1689 . . Modification No. 3 - between the United States Atomic Energy Commission and Michigan State University.

The material included in this report under said contract is based on experimental work that is continuing. The interpretation is based upon current results and previous findings in this project.

When the product of a specific manufacturer is stated as having been used in the work described herein, this is not meant to imply an endorsement of said manufacturer, nor is it meant to imply that similar products made by other manufacturers are not suitable for the same use.

IV. SUMMARY

The principal activity of the first quarter was concerned with application methods for phosphate. A sodium metaphosphate glass (SMPG)[a/] with a high solubility in water (34% by weight), was used in these experiments.

Large beef cuts with weights from 3 to 4 pounds were treated with SMPG by dipping alone and by combined dipping and pumping. The meat was vacuum packaged, irradiated to 100 krad, and stored at 38 F for 18 days. At the end of the storage period, the treated meats were found to become brownish in color, and to have a fairly large drip loss.

Addition of ascorbic acid to the metaphosphate solution appeared to be beneficial in improving the eating quality, as judged by previous criteria employed, of the treated beef. However, it did not improve the raw color appearance in the presence of sodium metaphosphate glass.

Phosphate-treatment of beef with different sodium salts of phosphate, namely, sodium metaphosphate glass (SMPG), hexasodium metaphosphate, sodium tripolyphosphate, acid pyrophosphate and mixture of Na_2HPO_4 and NaH_2PO_4, showed that sodium tripolyphosphate was the only phosphate which was capable of producing purple color appearance of beef inside vacuum packages. All other phosphates failed to prevent browning of the meat in vacuum packages.

Among the muscles of beef round, eye of round (semitendinosus) seemed to be most sensitive to SMPG. This muscle formed a drip which was cloudy, probably due to protein precipitation. Meat treated with SMPG or with SMPG plus sodium ascorbate after 18 days vacuum storage plus three days in air at 38 F was held frozen at -10 F for 30 days. TBA values indicated no rancidity development.

a/ SMPG is the coded identification for a sodium metaphosphate glass containing 64% P_2O_5 and is used throughout the report.

V. INTRODUCTION

During the previous contract years, a procedure for centralized cutting was developed. This combined phosphate treatment, vacuum packaging, radiation-pasteurization and storage at 38 F for up to 18 days, (1)(2)(3). The various aspects of the above process such as drip control, color retention, packaging technique and microbiology were examined.

The current quarterly report covers primarily the application of metaphosphate for the retention of moisture and red color of larger beef cuts. A sodium metaphosphate glass (SMPG, 64%P_2O_5) was used in these experiments because of its high solubility in water, although sodium tripolyphosphate had proved to be effective agent in previous work. Addition of ascorbates to metaphosphate solution to aid in maintaining the reduced state of myoglobin was studied.

VI. EXPERIMENTAL

A. General Methods and Materials.

1. Drip loss measurement:

The weight of the meat sample was recorded immediately after phosphate treatment, and again at the end of storage period. In both cases the weight was recorded after draining. The drip loss is reported as a percentage of initial drained weight after dipping.

2. Color evaluation:

Meat color was usually scored visually in accordance with the following numerical grading system:

(1) uniform bright color
(2) generally bright color
(3) uniformly red, but not bright red
(4) red color, not bright, with areas of brown or purple
(5) brown in color with practically no red area

3. Phosphate uptake determination:

Sodium metaphosphates were used, but the total amount of phosphate was determined in the form of orthophosphate. After the meat was treated, a slice (not from the end) was cut off, ground and mixed well. A 5 gram aliquot was boiled with 5 ml of 95% magnesium nitrate solution until dryness and ashed in a muffle furnace at 550 C for 48 hours. The ashed sample was heated with 40 ml of dilute HNO_3 (1:4) to boiling. The amount of orthophosphate was determined according to the A.O A C. Method (4).

4. Total plate count:

The meat sample was a single sample, (10 to 20 grams) aseptically transferred to a sterilized Waring Blendor; 20 parts of sterile water were added and the mixture blended for 2 minutes. The resultant suspension was further diluted and total plate count was made using nutrient agar.

5. Sensory evaluation:

Samples for sensory panel evaluation in all cases were steaks about 3/4 inch thick. If the particular experiment involved large pieces of meat, these were cut into steaks for panel testing. The steaks were cooked at 325 F for 30 minutes in an air oven and were judged by a consumer-type taste panel on a 9-point hedonic scale. The scoring system was as follows:

Acceptable range:	Unacceptable range:
9 Excellent	4 Fairly bad
8 Very good	3 Bad
7 Good	2 Very bad
6 Fairly good	1 Poor
5 Marginal	

6. Packaging:

The vacuum packaging material was a laminate of polyester (Mylar) base with a thin coat of polyvinylidine chloride (Saran) applied to the outer surface and a heavier extrusion coat of polyethylene on the inner surface. The pouch was a product of the International Kenfield Distributing Company. The O_2-permeable film (polyvinyl chloride) was produced by the Goodyear Tire and Rubber Company. The vacuum packages were sealed with a Kenfield Vacuum Sealer.

7. Materials:

The meat employed in all experiments was beef. The particular grade and cuts are given in the details of each experiment.

The sodium metaphosphate glass (SMPG) was a phosphate blend manufactured by the Calgon Corporation, Pittsburgh, Penn. It contains 64% P_2O_5 and has a high solubility in water (34% by weight).

Other phosphates used in these experiments were commercial products manufactured by the Calgon Corporation.

Ascorbates used in these experiments were products of the Merck & Co., Inc. Rahway, N.J.

B. Treatment of large beef cuts with various concentrations of SMPG

Experiments 1 and 2:

The use of a mechanical pumping machine in the incorporation of desired amounts of metaphosphate solution was investigated. The principle and operation procedure for this machine were given previously (p 23, 1970 Annual Report). This approach was primarily concerned with thicker beef cuts having a weight of 3 pounds or more. Approximately 0.5% sodium metaphosphate by weight was to be added by a combination of dipping and pumping at different percentage weight gains from 2 to 5%. Dipping was necessary in order to ensure good coverage of the meat surface by the sodium metaphosphate solution.

MATERIAL AND METHOD

Commercial grade beef rounds were cut, trimmed and weighed before treatment. The weighed samples first were dipped in a 10% SMPG solution for 30 seconds, and their weight gains recorded. The dipped samples were then pumped with the SMPG solution to the desired weight gain to provide 0.5% added phosphate salt by using various concentrations of SMPG ranging from 10 to 33%. The dipped and pumped meats were drained on a screen for about ten minutes, and the final weight and percentage weight gain were recorded before packaging. Samples without any treatment or only dipped in 10% SMPG were used as controls.

After draining, the samples were vacuum-packaged, irradiated to 100 krad, and stored at 38 F for 18 days. At the end of storage period, the meats were evaluated with respect to drip loss, phosphate uptake and color appearance. The procedure was the same in Experiments 1 and 2.

RESULTS AND DISCUSSION

The percentage weight gain, percentage phosphate uptake, percentage drip loss and color score of the treated meats observed in duplicate Experiments 1 and 2 are recorded in Tables 1 and 2. The phosphate gain for each sample in general was satisfactory except in

the case of 10% dipping-only treatment. The drip loss ranged from 0.2 to 4.0%. Treatment with a low concentration of SMPG solution tended to result in more drip loss than that with concentrated ones. However, the drip loss in nearly all cases was lower than the percentage weight gain immediately after treatment with SMPG.

The higher drip loss from the samples treated with relatively dilute SMPG solutions might be attributed to the excessive amount of water pumped into the meat. Samples treated with concentrated SMPG solutions (samples 4 and 5) had relatively small amount of drip.

A similar trend also existed in the color stability of the samples during the period of holding in air. Samples 4 and 5 retained a better appearance than the rest of the samples, but actually were dull red in color. Concentrated SMPG solutions gave a better surface color. In fully browned samples, the depth of brown pigment did not exceed 2 mm, and the inner portion of the meat remained purple.

The advantage of using SMPG in the treatment was its high solubility. This made possible the incorporation of 0.5% phosphate salt at a low percentage weight gain, which was essential in complying with USDA requirements (assumed to be a maximum of 3%). Dipping alone without pumping might provide the needed amount of phosphate for thicker cuts. The capability of SMPG in preserving the color of fresh meat, however, had to be established.

Table 1. Irradiated large beef cuts, dipped and pumped with SMPG, vacuum stored at 38 F for 18 days followed by storage in air

Sample no. a/	Treatment	Weight gain %	Phosphate gain % b/	Drip loss %	Color score after air storage c/	
					1 day	2 days
	SMPG					
1	10%	4.52	.39	2.61	5	5
1'	"	4.11	.36	3.10	4	5
1"	"	4.92	.52	1.18	3	4
2	13%	3.82	.44	1.00	4	5
2'	"	3.66	.42	3.15	5	5
2"	"	3.73	.45	1.76	3	5
3	17%	3.74	.50	2.31	5	5
3'	"	2.68	.39	2.40	5	5
3"	"	2.30	.33	1.36	5	5
4	25%	1.67	.20	1.66	3	4
4'	"	2.38	.47	1.67	4	5
4"	"	1.99	.30	1.90	4	5
5	33%	2.68	.44	1.32	3	4
5'	"	2.04	.39	1.35	3	4
5"	"	1.68	.23	.43	3	5
6	10% dip	2.77	.13	1.67	5	5
6'	" only	1.95	--	--	5	5
6"	"	2.72	--	4.18	4	5
7	None		d/	1.73	5	5
7'	"		d/	1.40	4	5
7"	"		d/	.74	3	4

a/ Average weight 1460 grams.

b/ The phosphate is given as the actual weight of the added phosphate salt.

c/ For scoring system see VI A-2.

d/ The average P_2O_5 content of fresh beef (untreated) is 0.45%. The precise chemical nature of this phosphorus is not known.

Table 2. Irradiated large beef cuts, dipped and pumped with SMPG, vacuum stored at 38 F for 18 days followed by storage in air

no. [a]	Treatment	Weight gain %	Phosphate gain % [b]	Drip loss %	Color score after air storage [c] 1 day	Color score after air storage [c] 2 days
	SMPG					
1	10%	5.18	.42	.91	3	4
1'	"	4.07	.42	.70	4	4
1"	"	5.07	.52	.96	4	5
2	13%	4.72	.58	2.13	5	5
2'	"	3.68	.33	2.58	4	5
2"	"	3.65	.52	.94	4	5
3	17%	2.58	.39	1.22	3	5
3'	"	5.14	.50	.95	3	5
3"	"	2.42	.27	.15	3	5
4	25%	2.73	.52	.54	2	2
4'	"	2.00	.28	.51	3	4
4"	"	2.92	.39	.81	2	4
5	33%	1.72	.34	2.01	4	4
5'	"	2.79	.44	.23	4	5
5"	"	2.91	.41	1.17	2	2
6	10% dip	1.63	.20	2.86	3	5
6'	' only	1.06	.17	1.85	3	4
6"	"	1.16	.14	1.58	4	4
7	None		[d]	3.12	5	5
7'	"		[d]	3.73	5	5
7"	"		[d]	1.42	5	5

[a] Average weight, 1615 grams.

[b] See [b] Table 1.

[c] For scoring system, see VI, A-2.

[d] See [d] Table 1.

C. Treatment of large beef cuts with concentrated SMPG solutions with or without ascorbic acid:

Experiment 3:

Treatment of beef samples by dipping only was studied. Adequate phosphate gain would depend upon absorption of phosphate from the surface of the meat.

MATERIALS AND METHOD

Under similar experimental conditions as given in section B, large cuts of beef from the round with weights about 4 lbs each were treated with 20 and 30% SMPG solutions, and also with 20 and 30% SMPG solutions plus 0.4% ascorbic acid. The meats were dipped in these solutions, and pumping with 20% SMPG (no ascorbic acid) was employed as a supplemental measure only in the case of inadequate phosphate gain, namely less than 0.5% phosphate salt. After the storage period, the samples were judged by a consumer-type taste panel.

RESULTS AND DISCUSSION

The observed dipping time, weight gain after dipping and pumping, percentage phosphate gain, percentage drip loss and color score are reported in Table 3. Dipping in 20% SMPG solution for various times (0.5 to 3 minutes) did not permit a 0.5% phosphate gain. Hence additional phosphate was incorporated by pumping the 20% solution into the meats. On the other hand, samples dipped in 30% SMPG solutions did reach the desired level of phosphate gain and in these cases pumping was not required. It was noteworthy, however, that the meats did not take up equal amounts of phosphate during the same dipping period. This difference was most likely due to the difference in texture and composition of meat. Hence, adequate uptake of phosphate must be obtained by noting and adjusting the weight gain. A longer dipping time was detrimental to color stability due to leaching of pigment, although it permitted a greater phosphate gain.

Table 3. Irradiated large beef cuts, dipped in SMPG and ascorbate, and vacuum stored at 38 F for 18 days followed by storage in air

Sample no. [a]	Treatment	Dipping time	Weight gain after dipping %	Weight gain after pumping %	Phosphate gain % [b]	Drip loss %	Color score after air storage [c] 1 day	2 days	3 days
1	20% SMPG dipping & pumping	30 sec	1.34	2.72	.41	1.31	4	4	5
1'	"	60	.77	1.93	.41	1.46	3	4	4
1"	"	60	1.50	1.93	.42	.63	3	4	4
2	30% SMPG dipping	75	1.67		.39	.55	3	3	3
2'	"	30	1.34		.41	1.42	5	5	5
2"	"	30	1.62		.39	.64	4	5	5
3	20% SMPG + 0.4% ascorbate	30	.84	2.38	.47	1.37	3	3	4
3'	"	30	1.38	2.28	.47	.59	1	1	4
3"	"	30	1.15	2.73	.60	.46	1	4	3
4	30% SMPG + 0.4% ascorbate	45	1.56		.50	.38	2	4	5
4'	"	60	1.73		.33	1.83	1	2	4
4"	"	75	1.63		.52	.70	1	2	3
5	20% SMPG dipping & pumping	180	1.27	2.72	.64	1.26	5	5	5
5'	"	180	1.45	3.49	.69	.39	4	5	5
5"	"	180	1.53	2.17	.32	.69	1	3	3

a/ Average weight, 1946 grams.

b/ See b/ Table 1.

c/ For scoring system see VI, 2-A.

Both 20% and 30% SMPG solution gave similar reductions in drip losses. Average drip losses of 0.8% and 0.9% were found for 20% and 30% SMPG treatments, respectively.

The samples were purple while in the vacuum package, and all bloomed to red color after being exposed to air. However, the red color seemed to be dull in appearance. Samples treated with SMPG plus ascorbic acid had a better color than those treated with SMPG alone. The red color, in either case, tended to brown rapidly within 3 days. If the treated sample was cut open, the newly cut surface bloomed to a very bright red color, unlike the original surface color. The newly cut surface also had a more juicy appearance than did the treated surface.

One sample of each treatment, after being held in air at 38 F for 3 days (after 18 days of vacuum storage at 38 F) was subjected to a consumer-type taste panel for sensory evaluation. Steaks were made from each large-cut sample, and were judged by 20 panelists using a nine-point hedonic scoring system. The results (Table 4) showed that the samples treated with 30% SMPG plus 0.4% ascorbic acid received the highest scores in every respect. It was clear that the presence of a small amount of ascorbic acid in the metaphosphate solution was advantageous to the eating quality of beef. Significant differences in scores were observed in flavor, texture, juiciness and overall quality between samples treated with 30% SMPG and 30% SMPG plus 0.4% ascorbic acid.

The texture scores indicate that beef treated with 30% SMPG was more tender than that treated with 20% SMPG. A corresponding effect of the metaphosphate on juiciness was not observed.

EXPERIMENT 4:

The results obtained from Experiment 3 indicated that dipping a large piece of meat in a 30% SMPG solution containing 0.4% ascorbic acid could satisfactorily reduce the drip loss, maintain the eating

Table 4. Taste panel hedonic scores[a/] for treated irradiated large beef cuts after 18 days vacuum storage plus 3 days in air at 38 F

Sample no.	Treatment		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	20% SMPG dipping and pumping	Av	6.0	6.4	5.6	3.8[d/]	4.7[e/]	5.0[f/]
		Range	4-9	5-8	4-8	1-7	3-7	3-7
2	30% SMPG dipping only	Av	5.4[b/]	6.1	4.9[c/]	5.6[d/]	4.2[e/]	5.1[f/]
		Range	3-9	5-8	2-7	3-8	1-6	3-8
3	20% SMPG + 0.4% ascorbate dipping & pumping	Av	6.4	6.6	6.4[c/]	5.2[d/]	5.8[e/]	6.0
		Range	4-9	6-8	4-8	1-8	4-8	4-8
4	30% SMPG + 0.4% ascorbate dipping only	Av	6.9[b/]	6.8	6.7[c/]	6.8[d/]	6.1[e/]	6.7[f/]
		Range	5-9	5-8	4-9	5-8	3-9	5-9

a/ For scoring system, see IV, A-5.

b/ Significant difference in color between No. 2 and 4.

c/ Significant differences in flavor between No. 2 and 3, and 2 and 4.

d/ Significant differences in texture between No. 1 and 4, 3 and 4, and 1 and 2.

e/ Significant differences in juiciness between No. 1 and 4, 2 and 4, and 2 and 3.

f/ Significant differences in overall quality between No. 1 and 4, and 2 and 4.

quality and fairly well preserve the original fresh meat color. In this experiment, the beef cuts were dipped but not pumped in the treating solutions, and the results were compared with those of Experiment 3.

MATERIALS AND METHOD

Commercial grade beef round was used. The samples were dipped in 20% SMPG with or without addition of 0.4% sodium ascorbate for 2 minutes, or in 30% SMPG with or without ascorbate for 1 minute. The meats were packaged and stored in the manner as described previously. After the storage period, the percentage drip loss, color score and pH values of the drip and meat were recorded. TBA value as determined by the method of Tarladgis et al. (5) was measured on the first and third days of holding in air.

RESULTS AND DISCUSSION

The percentage weight gain after dipping, percentage drip loss, color score, pH values of drip and meat, and TBA values are listed in Table 5. The percentage weight gain was lower than obtained in Experiment 4 and varied considerably among samples. The lower percentage weight by dipping was probably due to the relatively high fat content of the particular beef used. Extensive fat marbling was noted before treatment. Drip loss was high among these samples, the lowest drip loss being 2.1%, and the highest 6.7%. Along with the large amount of drip, a large amount of protein was extracted and precipitated in the drip. The color of both the drip and meat surface was dark brown. In an attempt to explain the exudation and subsequent precipitation of protein, the pH values of both drip and meat were determined. They were found to fall mostly within the range of 5.5 to 6.0, which appeared to be a normal pH range for beef. However, the pH values of the drip were all slightly lower than those of the meat, but not low enough to cause protein precipitation. Another noteworthy phenomenon was that the drip solution was capable of oxygenating to a red color when exposed to the air.

Table 5. Irradiated beef steaks, dipped in SMPG and ascorbate, and vacuum stored at 38 F for 18 days followed by storage in air

Sample no.[a]	Treatment	Dipping time min.	Weight gain %	Drip loss %	Color score[b] 18 ± 1	pH of drip	pH of meat	TBA value 1 day air	TBA value 3 days air
1	20% SMPG	2	.81	6.2	5	5.50	5.79	.07	.30
1'	"	2	1.01	4.5	5	5.52	5.85	.10	.42
1"	"	2	.69	3.4	5	5.55	5.83	.28	.51
2	"	1	.38	4.4	5	5.65	5.82	.07	.17
2'	"	1	.67	2.1	5	5.67	5.97	.14	.12
2"	"	1	.49	3.7	5	5.57	5.90	.28	.25
3	20% SMPG + 0.4% ascorbate	2	.45	3.1	5	5.47	5.77	.41	.73
3'	"	2	.32	2.6	5	5.80	5.95	.37	.73
3"	"	2	.96	4.3	5	5.58	5.90	.49	.82
4	30% SMPG + 0.4% ascorbate	1	.35	6.7	5	5.48	5.82	.28	.72
4'	"	1	1.37	4.6	5	5.55	5.82	.37	.78
4"	"	1	.47	2.2	5	5.61	5.90	.37	.66

a/ Average sample weight 1532 g.

b/ For color scoring system see VI, A-5.

Based on the result of the TBA determinations, the extent of oxidative rancidity was judged to be insignificant. TBA values were slightly higher for those samples treated with SMPG plus sodium ascorbate than those treated with SMPG alone.

In this experiment, sodium ascorbate instead of ascorbic acid was used for the first time. Both reagents have similar reducing action, although 0.4% solutions have different pH's, (sodium ascorbate 6.6, ascorbic acid 3.1). In phosphate solutions and in meats these pH differences would not occur. Hence there should be similar action for both compounds.

D. Effect of freezing of beef after storage at 38 F for 18 days in vacuum plus 3 days holding in air:

Experiment 5:

MATERIALS AND METHOD

Eye of round (semitendinosus) of USDA choice grade beef was used in this study. The meat was sliced into 3/4 inch thick pieces and dipped in 10% SMPG or 10% SMPG plus 0.4% sodium ascorbate. The treated samples along with the control sample were vacuum-packaged, irradiated to 100 krad, and stored at 38 F for 18 days. The samples were then opened and held in fresh meat wrap for 3 days, followed by freezing at -10 F and holding at that temperature for 30 days in O_2-permeable film. A few untreated, unirradiated samples were frozen on the same day of the treatment until the end of the 30-day freezing period for the treated samples.

The TBA values of these samples were determined in duplicate at the first day after the treatment, at the end of the three day air storage and at the end of the 30-day freezing period. The odor and flavor of the first three samples were judged by 20 judges against fresh beef using a 7-point difference test at the first day after the vacuum storage (see Table 7 for scoring system).

RESULTS AND DISCUSSION

The TBA values for samples stored in vacuum for 18 days, then held in air for 3 days and frozen for 30 days are recorded in Table 6. The initial TBA values for these samples were low and remained low throughout the vacuum storage period as has been shown previously. Slightly higher TBA values were again observed in samples treated with SMPG plus ascorbate at the 3rd day of holding in air. At this point, a sensory evaluation on off-odor and off-flavor of these samples was obtained with 20 panelists (Table 7). On a 7-point scale, the P-A-I and P-I samples received 3.0 and 2.9 (slightly different from fresh beef control). The 0-I samples received a 2.2 score indicating only very slight difference from the fresh meat.

As has been noted in earlier work reported, these data suggest that the irradiation of phosphate-treated meats may result in a slight flavor change in beef. Freezing for 30 days after storage for 21 days at 38 F did not result in higher TBA values, indicating no fat oxidation on storage.

Color evaluation after the 38 F storage indicated severe browning of the meat plus the formation of a large amount of brown drip.

At the end of 18 days vacuum storage, the sample packages were visually checked. The beef slices were brown in the vacuum package, and the drip was cloudy. The untreated control samples, on the other hand, had a slight purple appearance and clear drip. The possibility of microbial outgrowth appeared unlikely in this case. This was supported by the fact that no spoilage odor was detected by the taste panel.

The cloudiness of drip apparently was due to the exudation of protein from the meat, the semitendinosus muscle in particular. This observation was checked in additional experiments. Similar treatments of the semitendinosus muscle always yielded similar results. If beef round muscle other than the semitendinosus were used, the drip was generally not so cloudy although the meat surface was still brown. The unfavorable effect of SMPG in accelerating browning was definite in these experiments.

Table 6. TBA values of the meats after 18 days of vacuum storage, 3 days of holding in air at 38 F and 30 days of freezing at -10 F

Sample no.	Treatment[a/]	TBA value		
		1st day	18 + 3	18 +3 +30
1	P-A-I	.12	1.25	.27
2	P-I	.14	.55	.39
3	O-I	.15	.71	.28
4	O-O			.37

a/ P-A-I = 10% SMPG + 0.4% ascorbate + irradiation.

P-I = 10% SMPG + irradiation.

O-I = Irradiation only.

O-O = Frozen at -10 F without irradiation.

Table 7. Difference in odor and flavor of three treated samples after 18 days of vacuum storage at 38 F.

Sample no.	Treatment[a/]	Difference score[b/] Off-odor	Off-flavor
1	P-A-I	1.8	3.0
2	P-I	2.0	2.9
3	O-I	1.9	2.2

a/ P-A-I = 10% SMPG + 0.4% ascorbate + irradiation.
P-I = 10% SMPG + irradiation.
O-I = Irradiation only.

b/ Scoring system: the samples were judged against fresh meat using the following scores:

1 = None
2 = Very slight
3 = Slight
4 = Moderate
5 = Strong
6 = Very strong
7 = Extreme

Experiment 6:

MATERIAL AND METHOD

USDA commercial grade round of beef including eye of round (semitendinosus) and the adjacent area were sliced into 1/2 inch thick steaks and treated with 10% SMPG, 10% SMPG plus 0.4% sodium ascorbate. The samples were packaged and stored at 38 F as described in Experiment 5. At the end of 18 days vacuum storage, TBA values of these samples were determined on 18 + 0, 18 + 1, 18 + 3 and 18 + 7 day, and a consumer-type of taste panel was carried out on 18 + 2 day.

RESULTS AND DISCUSSION

The TBA values as shown in Table 8 had a similar pattern to that shown in Table 6. Even after 7 days of holding in air, the TBA values were so low that sensory rancidity was not indicated.

Table 9 shows the taste panel results, using a nine-point hedonic scale. No significant difference occurred with regard to cooked color, odor and flavor. The P-A-I samples showed a higher score for juiciness as was observed in Experiment 4.

E. Study of the effect of several metaphosphates, ascorbates on color of fresh meat:

Experiment 7:

In the previous experiments reported above, repeated difficulties were encountered in bringing about a desirable color of the treated meat after storage. At least two factors were newly introduced in these experiments and could possibly account for the rapid deterioration of color, i.e., SMPG (sodium metaphosphate glass) and sodium ascorbate (in place of ascorbic acid). It was therefore necessary to examine these two reagents individually and to find out which one caused the problem.

Table 8. TBA values of the meats after 18 days of vacuum storage, and various days of holding in air at 38 F

Sample no.	Treatment[a/]	TBA value			
		18 + 0	18 + 1	18 + 3	18 + 7
1	P-A-I	2.32	.38	.19	.49
2	P-I	.94	.74	.22	.98
3	O-I	.23	.43	.54	.61
4	O-O	.15			

a/ P-A-I = 10% SMPG + 0.4% ascorbate + irradiation.

P-I = 10% SMPG + irradiation.

O-I = Irradiation only.

O-O = Fresh meat, not stored.

Table 9. Taste panel hedonic scores[a/] for vacuum storage plus 2 days in air at 38 F

Sample no.	Treatment[b/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-A-I	Av	6.3	5.5	5.6	6.6	6.9[c/]	5.8
		Range	4-9	3-8	3-9	3-9	5-9	4-8
2	P-I	Av	6.5	5.9	5.8	5.7	5.8[c/]	5.5
		Range	4-9	3-9	3-8	3-7	3-8	3-8
3	O-I	Av	6.4	5.8	5.3	6.2	6.2	5.9
		Range	4-8	4-9	3-7	4-9	4-8	4-8
4	O-O	Av	6.5	6.1	6.1	5.5	6.0	6.0
		Range	3-8	5-8	2-8	2-9	3-9	5-9

a/ For scoring system, see IV, A-5.

b/ P-A-I = 10% SMPG + 0.4% ascorbate + irradiation.
P-I = 10% SMPG + irradiation.
O-I = Irradiation only.
O-O = Fresh meat, not stored.

c/ Significant difference in juiciness between No. 1 and 2.

MATERIAL AND METHOD

Half-inch slices of commercial grade beef round were treated with various combinations of reagents including 10% SMPG, 10% SMPG plus 0.4% sodium ascorbate, 10% SMPG plus 0.4% ascorbic acid, 10% SMPG plus 0.2% each sodium ascorbate and ascorbic acid, 0.4% sodium ascorbate alone and 0.4% ascorbic acid alone. The pH value of each treating solution was recorded. The meats were vacuum-packaged, irradiated to 100 krad, and stored at 38 F for 8 days. The color appearance of each package was visually examined, and the pH values of meat and drip were measured.

RESULTS AND DISCUSSION

The color appearance of samples treated with various reagents is recorded in Table 10. Samples treated with 0.4% ascorbic acid alone had the most desirable color appearance. Other samples turned brown to different extents. It was noteworthy that 0.4% ascorbic acid had a much lower pH than other solutions, but the pH values of the treated meat and drip did not differ very much.

Based on these results, it seemed that both the SMPG and sodium ascorbate had an unfavorable effect on meat color. With the limited amount of work being done in this regard, no explanation could be offered as to why SMPG and sodium ascorbate tended to promote browning in vacuum.

Experiment 8:

After Experiment 7 was completed, various sodium salts of phosphate were evaluated. Comparison was made using the semitendinosus muscle.

MATERIAL AND METHOD

Slices of commercial grade eye of round (semitendinosus) were treated with the following reagents: 10% SMPG, 10% sodium hexametaphosphate, 10% sodium tripolyphosphate, 10% acid pyrophosphate, three mixtures of sodium monobasic phosphate and sodium dibasic phosphate with pH 6.2, 6.4 and 6.6, respectively. The samples were dipped, vacuum-packaged, irradiated and stored at 38 F for 18 days. Also included were two controls,

Table 10. pH values of meat and drip, color appearance in vacuum packaging after treatment with different reagents and storage at 38 F for 8 days

Sample no.	Treatment	pH			In vacuum appearance
		Solution	Meat	Drip	
1	10% PO_4[a/]	6.20	5.62	5.82	Brown
2	10% PO_4 + 0.4% NaAA[b/]	6.12	5.60	5.79	Purplish brown
3	10% PO_4 + 0.4% HAA[c/]	5.80	5.55	5.62	" "
4	10% PO_4 + 0.2% NaAA + 0.2% HAA	5.95	5.58	5.70	Brown
5	0.4% NaAA	6.55	5.58	5.50	Brown
6	0.4% HAA	3.05	5.59	5.48	Purple

a/ PO_4 = SMPG (sodium metaphosphate glass)

b/ NaAA = Sodium ascorbate

c/ HAA = Ascorbic acid

which received no phosphate treatment. At the end of 18 days vacuum storage, the packages were visually examined and their color appearances recorded.

RESULTS AND DISCUSSION

Table 11 shows the results obtained after 18 days of storage. Treatment with sodium tripolyphosphate resulted in a satisfactory purple appearance under vacuum, while the samples treated with SMPG, hexasodium metaphosphate and acid pyrophosphate showed complete browning of meat surface. Treatment with mixture of orthophosphates had no remarkable effect on meat color since those samples had an appearance similar to that of the untreated controls. When drip was examined, cloudiness with protein precipitate was observed in samples treated with SMPG and hexasodium metaphosphate. These results indicate that sodium tripolyphosphate is superior to other phosphates in the preservation of fresh meat color.

Table 11. Color appearance of meat (semitendinosus) in vacuum package after treatment with different phosphates and storage at 38 F for 18 days

Sample no.	Treatment	Color appearance in vacuum package	
		Meat	Drip
1	10% SMPG	Brown	Cloudy
2	10% hexasodium metaphosphate	Brown	Cloudy
3	10% sodium tripolyphosphate	Lt. purple	Not cloudy
4	10% acid pyrophosphate	Brown	" "
5	0.2M phosphate buffer[a/] (pH 6.2)	Brownish purple	" "
6	0.2M phosphate buffer[a/] (pH 6.4)	" "	" "
7	0.2M phosphate buffer[a/] (pH 6.6)	" "	" "
8	Control	" "	" "
9	Control	" "	" "

a/ Phosphate buffer was made of 0.2M of NaH_2PO_4 and 0.2M of Na_2HPO_4

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Paper 2

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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QUARTERLY REPORT

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II. ABSTRACT

Kena (64% P_2O_5 sodium metaphosphate glass) was studied using beef rounds of one-day and ten-day post mortem age. The beef rounds were treated with Kena solution, vacuum-packaged, irradiated to a dose of 100 krad and stored at 38 F for 18 days. The color appearance after exposure to air was dull red, and drip loss was higher in the one-day post mortem round than in the ten-day post mortem round. For both post mortem ages a non-spoilage odor developed after storage. The microbial populations were within the normal range.

The ability of Kena in keeping the red color of the stored meats at different pH's was investigated by adjusting the pH of Kena solution with ascorbates and sodium hydroxide. The results showed that Kena, at normal pH or higher pH, was not effective in helping maintain the reduced form of meat pigments after 18 days vacuum storage. At pH 9, however, Kena solution reduced the cloudiness of drip from the eye of round muscle.

These results indicate that despite its greater solubility in water, Kena is not suitable for protecting the color of fresh meats. Sodium tripolyphosphate is the best phosphate found to date.

III. PREFACE

The Quarterly Report was prepared in accordance with the terms of Contract No. AT(11-1)-1689 . . Modification No. 3 between the United States Atomic Energy Commission and Michigan State University.

The material included in this report under said contract is based on experimental work that is continuing. The interpretation is based upon current results and previous findings in this project.

When the product of a specific manufacturer is stated as having been used in the work described herein, this is not meant to imply an endorsement of said manufacturer, nor is it meant to imply that similar products made by other manufacturers are not suitable for the same use.

IV. SUMMARY

Beef slices and large beef cuts, obtained from beef round one day post mortem, were treated with 10 or 25% Kena solution, vacuum-packaged, irradiated to a dose of 100 Krad and stored at 38 F for 18 days. At the end of the storage period, the color appearance of the meat was dull red and turned brown rapidly in one day when exposed to air. The drip loss was high and an objectionable odor was detected from the treated samples, particularly the sliced samples.

The results of sensory evaluation using a 9-point hedonic scale indicated that the Kena-treated samples had poor scores in texture only. Differences in other aspects between the fresh meat sample and the Kena-treated samples were not significant.

A comparison was also made between beef round treated with Kena one day and 10 days post mortem. Beef rounds were trimmed and separated into five major portions prior to treatment. The pH of each was recorded. The drip loss from the 10-day post mortem round was lower than that from the one-day round after 18 days storage. The color appearance was not satisfactory for both rounds. The microbial population was between 1×10^4 to 1×10^5 per gram of meat.

Beef samples were treated with Kena solutions with addition of ascorbic acid or sodium ascorbate. The oxygenated beef turned dark red after storage in nitrogen atmosphere. Addition of ascorbates to the phosphate did not promote reduction of pigments in nitrogen atmosphere.

Beef samples were treated with 10% Kena solution with pH 6.1, 7.55, 9.4 and 11.0, vacuum-packaged, irradiated to a dose of 100 krad and

stored at 38 F for 18 days. The color of the meat surface became brown at the end of the storage period at all pH levels. Comparable samples treated with sodium tripolyphosphate (pH 9.1), 10% Na_2HPO_4, (pH 8.65) and 10% Na_3PO_4 (pH 12.7) were able to maintain purple color inside the vacuum package after storage, and bloomed to a bright red color upon exposure to air.

These results indicate that despite its greater solubility in water, Kena is not suitable for protecting the color of fresh meats. Sodium tripolyphosphate is the best phosphate found to date for treatment of fresh beef.

V. INTRODUCTION

Reducing enzymes in meat have been regarded as essential in bringing about the reduced purple color in an O_2-free environment. Some variability in beef in maintaining the reduced purple color had been observed and to study the effect of post mortem age, experiments using fresh beef with known post mortem age were carried out in this quarter. Beef one and ten days post mortem was treated with Kena solutions (64% P_2O_5 sodium metaphosphate glass manufactured by the Calgon Corporation). (The poor performance of this material as a color protector had not been determined at this time.)

In experiments reported in the previous quarterly report (1), vacuum packaged beef was found to turn brown after treatment with Kena, hexasodium metaphosphate and acid pyrophosphate and after storage for 18 days. Beef treated with sodium tripolyphosphate, however, was purple in vacuum packages and bloomed to a bright red color readily upon exposure to air. To determine if the favorable effect of sodium tripolyphosphate on color was due to its high pH, studies were conducted in which Kena solution was adjusted to different pH's with sodium hydroxide and tested for its efficiency in preserving the meat color. Other phosphates with higher pH's also were studied.

The ability of ascorbic acid and sodium ascorbate in maintaining the reduced pigments in a nitrogen atmosphere was studied.

VI. EXPERIMENTAL

A. General Methods: drip loss measurement, color evaluation, phosphate uptake determination, total plate count, sensory evaluation and packaging.

1. Drip loss measurement:

The weight of the meat sample was recorded immediately after phosphate treatment, and again at the end of the storage period. In both cases the weight was recorded after draining. The drip loss is reported as a percentage of initial drained weight after dipping.

2. Color evaluation:

Meat color was scored visually in accordance with the following numerical grading system:

(1) uniform bright color

(2) generally bright color

(3) uniformly red, but not bright red

(4) red color, not bright, with areas of brown or purple

(5) brown in color with practically no red area

3. Phosphate uptake determination:

Metaphosphates were used, but the total amount of phosphate was determined in the form of orthophosphate. After the meat was treated, a slice (not from the end) was cut off, ground and mixed well. A 5 gram aliquot was boiled with 5 ml of 95% magnesium nitrate solution until dryness and ashed in a muffle furnace at 550 C for 48 hours. The ashed sample was heated with 40 ml of dilute HNO_3 (1:4) to boiling. The amount of orthophosphate was determined according to the A.O.A.C. Method (2).

4. Total plate count:

The meat sample (10 to 20 grams) was aseptically transferred to a sterilized Waring Blendor, 20 parts of sterile water were added and the mixture blended for 2 minutes. The resultant suspension was further diluted and total plate count was made using nutrient agar. Incubation was at 77 F.

5. Sensory evaluation:

After the meat was stored in vacuum for 18 days, it was held for 3 days in an O_2-permeable film. At the end of the holding period, the meat slice about 3/4 inch thick was cooked at 325 F for 30 minutes in an air oven. The steak was judged by a consumer-type taste panel on a 9-point hedonic scale. The scoring was as follows:

Acceptable range		Unacceptable range	
9	Excellent	4	Fairly bad
8	Very good	3	Bad
7	Good	2	Very bad
6	Fairly good	1	Poor
		5	Marginal

6. Packaging:

The vacuum packaging material was a laminate of polyester (Mylar) base with a thin coat of polyvinylidine chloride (Saran) applied to the outer surface and a heavier extrusion coat of polyethylene on the inner surface. The pouch was a product of the International Kenfield Distributing Company. The O_2-permeable film (polyvinyl chloride) was produced by the Goodyear Tire and Rubber Company. The vacuum packages were sealed with a Kenfield Vacuum Sealer.

B. Treatment of beef round with known post mortem age:

It has been observed that different lots of meat displayed varying ability to retain good color on storage after phosphate treatment. One variable that had not been controlled in these earlier experiments was the post mortem age of the meat prior to treatment.

The following experiments were carried out with beef round of known post mortem age in an attempt to investigate the effect of post mortem age prior to treatment in terms of color, appearance, flavor,texture and juiciness of the treated beef.

Experiment 1: Treatment of one day post mortem beef round with Kena.

MATERIAL AND METHOD

USDA Standard grade beef round was purchased from a local meat packer one day after slaughter. The meat was trimmed and cut into 3/4 inch slices and into large cuts (approximately 3 to 4 lbs). The slices were dipped in 10 or 25% Kena solution from 30 to 45 seconds, and the large cuts were dipped in 25% Kena solution for 120 seconds. The samples were drained, weighed, vacuum-packaged, irradiated to a dose of 100 krad and stored at 38 F for 18 days. Drip loss and phosphate uptake, and visual color scores were recorded. Only samples with acceptable color were submitted to a consumer-type taste panel.

RESULTS AND DISCUSSION

In Table 1 are recorded the weight gains after dipping, drip loss, phosphate uptake and color scores. The color immediately after dipping turned toward the purple, even before vacuum packaging. The pH's of the untreated, the 10% and the 25% Kena dipped samples were 5.9, 5.9 and 6.1, respectively. After vacuum storage followed by exposure to air, the sliced

Table 1. One day post mortem beef after treatment[a/]

Sample No.[b/]	Treatment	Dipping time	Weight gain %	Drip loss %	Phosphate uptake %	Color score[c/] after air storage 18 + 1	18 + 2	18 + 3
1	10% Kena	30 sec	1.14	1.12	0.31	3	4	4
1'	"	45	1.38	2.72	0.32	3	4	4
1"	"	45	1.75	2.59	0.36	3	4	4
2	25% Kena	30	0.33	1.32	0.55	3	4	4
2'	"	30	0.27	0.55	0.64	3	4	4
2"	"	30	0.70	0.46	0.77	3	4	4
3	"	120	1.16	1.43	0.85	1	1	2
3'	"	120	0.65	3.57	0.49	1	2	2
3"	"	120	1.17	2.48	0.91	1	2	2
3'"	"	120	0.67	3.55	0.58	1	1	1

a/ Treatment consisted of phosphate dipping, vacuum packaging, irradiation to a dose of 100 krad and storage at 38 F for 18 days, followed by air storage.

b/ Sample 1's and 2's were slices and sample 3's were large cuts.

c/ Color scores were given after 18 days vacuum storage and 1 to 3 days exposure to air using scoring system described in VI, A-2.

samples showed severe browning; the larger cuts, however, retained their red color better. Weight gains and phosphate uptakes were not uniform within a given treatment, and in some cases, phosphate uptake exceeded 0.5%.

Drip losses were not consistent. Dipping beef slices in 25% Kena gave satisfactory drip losses; the other treatments gave losses too high to be satisfactory. The slice samples were not evaluated with a taste panel primarily because of unsatisfactory color. In addition, an unusual odor (not spoilage) was observed with these samples.

The large-cut samples were compared with fresh beef round of unknown age obtained from the Michigan State University Food Stores. The panel results are given in Table 2. A large difference in texture favoring the fresh meat was noted but may not be significant due to the fact that the samples were not from the same animal. On the other hand, the treated meat had a higher flavor score than the fresh one. On the basis of overall quality there was little difference.

Table 2. Taste panel scores[a/] obtained from one day post mortem beef after treatment[b/]

Sample No.	Treatment[c/]		Cooked color	Odor	Flavor	Texture	Moisture or juiciness	Overall quality
1	0-0	Av	7.1[d/]	6.4	5.2	6.1[e/]	6.3	5.7
		Range	6-9	4-8	3-8	2-8	3-8	3-8
2	P-I	Av	6.0[d/]	5.7	5.8	4.8[e/]	5.7	5.5
		Range	3-9	3-8	4-8	2-8	2-8	3-7

a/ 9-point hedonic scale, See VI A-5.

b/ Treatment consisted of phosphate dipping, vacuum-packaging, irradiation to a dose of 100 krad and storage at 38 F for 18 days, followed by 3 days air storage.

c/ Code of treatment: 0-0 = Fresh, no treatment, no irradiation.

P-I = 25% Kena, 100 krad irradiation.

d/ Significant difference in cooked color.

e/ Significant difference in texture.

Experiment 2: Comparison between beef rounds treated with Kena one day and ten days post mortem.

This experiment compared beef rounds treated one and ten days post mortem.

MATERIAL AND METHOD

Two USDA Standard grade beef rounds from the same carcass were obtained from a local meat packer one day after slaughter. One round was trimmed immediately and separated into five major portions, namely top round, biceps femoris, semitendinosus, shank and knuckle.

The pH value of each portion was recorded before treatment. Four slices from the top round and the bottom round were dipped for 45 seconds in 10% Kena solution. Likewise three large cuts were dipped for 45 seconds in 25% Kena solution. After draining, all were vacuum-packaged, irradiated to a dose of 100 krad and stored at 38 F for 18 days. After 10 days, the packages were opened and drip loss, color scores and total plate count of the samples were obtained. The eating quality of the samples also was judged by a taste panel using a 9-point scoring scale. The same experiment was repeated twice starting three and six days later but using only three slices from the same bottom round.

When the other beef round was nine days port mortem, it was trimmed and separated into the five similar portions as described above for the first round, and the pH of each portion was determined. A similar set of samples was treated as with the first beef round, and evaluation was carried out in the same manner after 18 days. Three days later (13 days post mortem), four slices of bottom round were obtained from the same round. Two slices were treated with 10% Kena and two with 10% TPP. These were packaged, stored and examined as described above for the first round.

RESULTS AND DISCUSSION

In Tables 3 and 5 are given pH values, weight gains after dipping, drip losses and color scores after storage for the two rounds. It is to be noted that both rounds were from the same animal .

The pH values of the different portions of each round are different from each other.. A comparison of the pH of the same portion in the two rounds reveals that the second round (10 days post mortem) always has the lower value. The pH value of a particular muscle is related to the initial glycogen content at the time of death and to the rate of post mortem glycolysis. The pH values obtained with these two rounds from the same animal suggest that glycolysis proceeds over many days post mortem. One might similarly expect other post mortem changes to proceed as meat is stored. Consequently there may well be an optimum time post mortem for phosphate and other treatments.

The color scores of the meat from the two rounds do not reveal a critical age of meat for treatment and in fact suggest that age post mortem is not damaging. The scores indicate severe color loss within the three day air-storage period and suggest that the Kena phosphate is not protecting the color.

The percentage weight gain after dipping was lower for the large cuts than for the slices. Weight gains were about the same for both rounds. However, the percentage drip loss was markedly lower for the second round than for the first (Tables 3 and 5). The average drip loss for all samples was 4.0% for the first round and 1.5% for the second.

Total plate counts indicated a satisfactory bacterial condition for both rounds. Sample 2 of the second round (Table 5) was a leaker. The high count of this sample (2×10^8 per gram) undoubtedly was due to this

Table 3. Initial pH, weight gain after dipping, drip loss, color score and total plate count of one day post mortem beef after treatment a/

Sample No. b/	Muscle	pH	Treatment	Weight gain after dipping %	Drip loss %	Color score c/ 18 + 1	18 + 2	18 + 3	Total plate counts per gram
1	Top round	6.14	10% Kena	0.96	2.2	4	4	5	
1'	"	6.14	"	1.22	5.9	1	3	5	2×10^4
1"	"	6.14	"	1.59	3.7	1	3	5	1×10^5
1'"	Biceps femoris	5.94	"	2.23	3.2	3	4	5	3×10^4
2	Top round	6.14	25% Kena	0.34	3.5	2	4	5	$< 10^4$
2'	Shank	5.94	"	0.69	7.4	2	3	5	2×10^5
2"	Knuckle	5.71	"	0.56	1.7	3	3	5	2×10^5

a/ Treatment consisted of phosphate dipping, vacuum-packaging, irradiation to a dose of 100 krad and storage at 38 F for 18 days.

b/ Sample 1's were slices and sample 2's were large cuts.

c/ 5-point visual scoring scale, See VI, A-2.

Table 4. Taste panel scores[a] of one-day post mortem beef after treatment[b]

Sample No.	Muscle		Cooked color	Odor	Flavor	Texture	Moisture or juiciness	Overall quality	Value of Warner-Bratzler shear test
1	Slice (top round)	Av	6.7	5.5	4.9	4.9[c]	6.1[d]	5.1[e]	14.0
		Range	5-9	3-9	2-9	2-9	6-9	4-9	
2	Large cut(top round)	Av	7.3	5.8	6.1	6.0	7.6[d]	6.5[e]	10.1
		Range	4-9	2-9	1-8	1-8	4-9	3-8	
3	Large cut(shank)	Av	7.1	6.0	6.3	7.4[c]	7.1[d]	6.7[e]	13.0
		Range	4-9	3-8	2-8	3-9	4-9	3-9	
4	Large cut(knuckle)	Av	6.5	5.5	5.5	6.1	6.9	5.9	14.6
		Range	4-9	2-9	1-9	4-9	5-9	3-9	

a/ 9-point hedonic scale, See VI, A-5.

b/ Treatment consisted of phosphate dipping, vacuum-packaging, irradiation to a dose of 100 krad and storage at 38 F for 18 days, and holding in air for 3 days.

c/ Significant difference in texture between No. 1 and 3.

d/ Significant difference in juiciness between No. 1 and 2, No. 1 and 3.

e/ Significant difference in overall quality between No. 1 and 3, No. 1 and 2.

Table 5. Original pH, weight gain after dipping, drip loss, color score and microbial population of 10 day post mortem beef after treatment a/

Sample No. b/	Muscle	pH	Treatment	Weight gain after dipping %	Drip loss %	Color score c/ 18 + 1	18 + 2	18 + 3	Total plate count per gram
1	Top round	5.58	10% Kena	2.0	2.4	2	2	4	1.8×10^4
1'	"	5.58	"	1.8	0.54	2	3	4	2×10^5
1"	"	5.58	"	1.7	2.4	2	3	4	3×10^5
1'"	Biceps femoris	5.72	"	2.0	- -	2	3	4	- -
2	Top round	5.58	25% Kena	0.63	- -	5	5	5	2×10^8 (spoiled)
2'	Shank	5.87	"	0.45	0.8	1	2	4	3×10^5
2"	Knuckle	5.60	"	0.69	1.34	2	3	4	3×10^5

a/ Treatment consisted of phosphate dipping, vacuum packaging, irradiation to a dose of 100 krad and storage at 38 F for 18 days.

b/ Sample 1's were slices and sample 2's were large cuts.

c/ 5-point visual scoring scale, see VI, A-2.

Table 6. Taste panel scores[a/] of 10 day post mortem beef after treatment[b/]

Sample No.	Muscle		Cooked color	Odor	Flavor	Texture	Moisture or juiciness	Overall quality	Value of Warner-Bratzler shear test
1	Slice (top round)	Av	6.2[c/]	5.6	5.3[d/]	5.0[e/]	5.6[f/]	5.4	16.8
		Range	5-8	3-8	3-7	2-7	4-8	4-7	
2	" "	Av	6.1[c/]	6.1	5.6	5.3	5.6[d/]	5.8	18.0
		Range	4-8	4-8	3-7	3-8	2-8	3-7	
3	Large cut (shank)	Av	6.2[c/]	6.1	6.0	6.8[e/]	7.1[f/]	6.2	23.3
		Range	4-8	5-7	1-8	5-9	6-9	1-8	
4	Large cut(knuckle)	Av	6.8[c/]	6.4	6.8[d/]	6.7[e/]	6.8	6.6	11.3
		Range	4-9	4-9	5-8	5-9	5-9	4-9	

a/ 9-point hedonic scale, See VI, A-5.

b/ Treatment consisted of phosphate dipping, vacuum-packaging, irradiation to a dose of 100 krad and storage at 38 F for 18 days, and holding in air for 3 days.

c/ Significant difference in cooked color between No. 4 and 1, No. 4 and 2, No. 4 and 3.

d/ Significant difference in flavor between No. 1 and 4.

e/ Significant difference in texture between No. 1 and 3, No. 1 and 4.

f/ Significant difference in juiciness between No. 4 and 1, No. 4 and 2.

circumstance. Evidence of sensory spoilage also was present in this sample.

Taste panel results are given in Tables 4 and 6. Among samples of the first beef round, a significant difference in eating quality was found only between slices and large cuts (Table 4). Significant differences were observed in texture and juiciness. The slice samples in general received the lowest scores in nearly every aspect. The Warner-Bratzler shear test (average of 7 to 10 readings) showed that the slice samples were slightly tougher than the large cuts.

Taste panel results for the samples of the second beef round (Table 6) again indicated that the slice samples were significantly different from the large cuts. Significantly lower scores were received in color, flavor, texture and juiciness by the slice samples. The Warner-Bratzler shear test, however, did not reflect the similar tendency in tenderness measurement. A very high value was obtained from the shank sample while the texture score of the shank sample was judged by the panel to be the best among four samples tested. This was due possibly to the presence of large connective tissue in the shank muscle. On the basis of the Warner-Bratzler shear test, the second round appeared to be slightly less tender than the first round.

Slice samples from the bottom round from the first round treated four and seven days post mortem and the slices from the bottom round from the second round treated 13 days post mortem were examined for color and drip after 18 days of storage after treatment. The observations are given in Table 7.

When Kena phosphate was used, these observations show a difference between the eye of the round (semitendinosus) and other muscles. The eye of the round showed more discoloration. Also the drip was cloudy. (See

Table 7. Surface color and drip appearance of beef slices treated after holding for 4, 7 or 13 days post mortem

Sample No.	Days of holding prior to treatment	Treatment[a/]	Surface color[b/]		Drip
			Non-eye of round	Eye of round	
1	4	10% Kena	Light purple	Brown	Cloudy
1'	"	"	"	Brown purple	"
1"	"	"	"	"	"
2	7	"	Purple	"	"
2'	"	"	"	"	"
2"	"	"	"	"	"
2'"	"	None	Light purple	Light purple	Dark clear
3	13	10% Kena	Purple	"	Less cloudy
3'	"	"	"	"	"
3"	"	10% TPP	"	Purple	Clear
3'"	"	"	"	"	"

a/ Treatment consisted of phosphate dipping, vacuum packaging, irradiation to a dose of 100 krad, and storage at 38 F for 18 days.

b/ Surface color was observed visually in the vacuum package.

Experiment 5, Quarterly Report, for the period June 16 through September 15, 1971). The samples treated with sodium tripolyphosphate 13 days post mortem did not show these differences. The meat color was satisfactory and the drip clear.

Based on the above results, it is suggested that the beef treated with Kena regardless post mortem age has not satisfactorily retained color, drip loss and flavor. Under the conditions studied, the post mortem age has no direct bearing on the color appearance of the treated beef.

C. Effect of pH on color of beef stored in nitrogen atmosphere or vacuum

Experiment 3: Treatment of oxygenated, or browned beef with solution of phosphates plus ascorbate

MATERIAL AND METHOD

Commercial grade fresh beef was cut into 1 inch square cubes, and divided into two groups; one was untreated, well-oxygenated bright red meat, and the other was brown in color obtained by treating with a 1% potassium ferricyanide solution. Phosphate solutions were prepared by adding 0.4% ascorbic acid or sodium ascorbate to a solution made of a mixture of NaH_2PO_4 and Na_2HPO_4, to yield final pH's of 4.8 and 6.2, respectively. Duplicate samples were dipped in the solution for one minute, and placed in a vacuum desiccator, which was then vacuumized and back-filled with nitrogen several times. After the meats were kept at room temperature for 24 hours, their appearance was examined visually.

RESULTS AND DISCUSSION

The results are given in Table 8. After 24 hours in nitrogen atmosphere, the oxidized brown meats failed to turn to a purple color. Addition of either ascorbic acid or sodium ascorbate did not bring about any reduction of the brown metmyoglobin produced by the potassium ferricyanide.

Table 8. Color appearance of red or brown meat treated with solutions of phosphates plus ascorbates and kept in nitrogen atmosphere

Sample No.	Meat color[a/] prior to treatment	Treatment[b/]	pH of solution	Meat color after treatment
1	Red	PB-AA	4.8	Dark red
2	Red	PB-SA	6.2	Dark red
3	Brown	PB-AA	4.8	Brown
4	Brown	PB-SA	6.2	Brown

a/ Red meat was untreated and well-oxygenated; brown meat was obtained by treatment with 1% potassium ferricyanide solution.

b/ Code of treatment:

PB, a phosphate buffer with pH 6.4, is a mixture of 13.25 ml of 0.2 M Na_2HPO_4 and 36.75 ml of 0.2 M NaH_2PO_4 diluted to 100 ml with distilled water.

PB-AA = Phosphate buffer plus 0.4% ascorbic acid.

PB-SA = Phosphate buffer plus 0.4% sodium ascorbate.

The oxygenated red meats also tended to darken in the nitrogen atmosphere. Neither ascorbic acid nor sodium ascorbate caused a reduction of the meat pigment to produce a purple color.

Experiment 4: Treatment of oxygenated beef with solution of Kena plus ascorbates

MATERIAL AND METHOD

Commercial grade fresh beef was cut into 1 inch square cubes. The cubes were dipped for 30 seconds in the treating solutions which were either 10% Kena, 10% Kena plus 0.4% sodium ascorbate or ascorbic acid. After draining for 15 minutes, the samples were placed in a vacuum desiccator, which was then vacuumized and refilled with nitrogen several times, and stored in a 38 F refrigerator. After 72 hours of storage the samples were visually observed.

RESULTS AND DISCUSSION

The results are given in Table 9. All three samples were dark red after storage in nitrogen atmosphere for 72 hours. A small amount of red color was regained after the meats were exposed to air. But the inner part of the meat was in the reduced condition and bloomed to a bright red color readily upon exposure to air. The treated surface appeared to lose its reducing characteristic in the nitrogen atmosphere. This atmosphere is similar to a vacuum in that it is anaerobic. Under the conditions employed in this experiment, Kena was not effective in maintaining the reduced state of the meat pigments.

Table 9. Color appearance of red meat treated with solutions of Kena plus ascorbates and kept in nitrogen atmosphere at 38 F

Sample No.	Meat color prior to treatment	Treatment[a/]	pH of solution	Meat color after treatment
1	Red	P-O	6.6	Dark red
2	Red	P-AA	6.2	Dark red
3	Red	P-SA	6.5	Dark red

a/ Code of treatment:

P-O = 10% sodium metaphosphate glass

P-AA = " " " plus 0.4% ascorbic acid

P-SA = " " " plus 0.4% sodium ascorbate

Experiment 5. Treatment of beef with Kena with different pH's, and with tripolyphosphate

The pH of Kena solutions as used is about 6.6. Sodium tripolyphosphate has a much higher pH, about 9.0. The objective of this experiment was to determine if Kena could become effective in color preservation by raising its pH.

MATERIAL AND METHOD

Two cuts of beef were obtained. One was eye of round (semitendinosus), and the other was adjacent to eye of round. Ten percent solutions of Kena were adjusted with NaOH to either pH 7.55 or 9.4. Ten percent tripolyphosphate (pH 9.1) was also prepared. Beef slices obtained from the two cuts were dipped in one of these solutions for 45 seconds, vacuum-packaged, irradiated to a dose of 100 krad and stored at 38 F for 18 days.

RESULTS AND DISCUSSION

The appearance of beef samples inside the vacuum packages was visually observed after 18 days of storage. Both the color of the meat surface and the appearance of drip were examined. The results are given in Table 10. The eye of round (semitendinosus muscle) again was found to be very susceptible to the Kena treatment. Browning of the meat surface and cloudiness of drip took place after vacuum storage at both pH 7.55 and 9.4. However, the drip was less cloudy at pH 9.4.

Samples treated with 10% TPP had a purple color and clear drip in the vacuum packages. Without phosphate treatment the meat color was brown.

Table 10. Surface color[a/] and drip appearance of beef treated with various phosphate solutions

Sample No.	Treatment[b/]	pH of solution	Eye of round		Non-eye muscle	
			Surface	Drip	Surface	Drip
1	10% Kena	7.55	Brown	Cloudy	Brown with some purple	Cloudy
2	"	7.55	Brown w/ some purple	"	"	Cloudy
3	"	9.4	"	Less cloudy	"	Cloudy
4	"	9.4	"	"	"	Clear
5	10% TPP	9.1	Purple	Clear	Purple	Clear
6	"	9.1	Brownish purple	"	Purple w/ some brown	Clear
7	Control		Brown	"	Brownish purple	Clear

a/ Surface color was observed in vacuum package.

b/ Code of treatment:

100 krad irradiation for each sample after phosphate dipping and vacuum packaging.

Kena = Sodium metaphosphate glass.

TPP = Sodium tripolyphosphate.

Experiment 6. Treatment of beef with Kena with different pH's, and with tripolyphosphate, Na_2HPO_4 and Na_3PO_4

MATERIAL AND METHOD

This experiment, similar to Experiment 3, was carried out with eye of beef round using the following solutions: 10% Kena adjusted with NaOH to Na_3PO_4 (pH 12.75).

RESULTS AND DISCUSSION

After 18 days of storage at 38 F, the samples were visually examined in vacuum packages (Table 11). All samples treated with 10% Kena had a brown surface color. The drip was cloudy at pH near 7 and was less cloudy at higher pH's. Na_2HPO_4 (pH 8.65), Na_3PO_4 (pH 12.75) and TPP (pH 9.1) yielded meat of a good purple color in the vacuum package.

While both Na_2HPO_4 and Na_3PO_4 were found to produce a satisfactory color in this experiment, previous work under this contract had demonstrated that best drip control is obtained only with TPP (3). Hence TPP is the material of choice.

Table 11. Surface color[a/] and drip appearance of semitendinosus muscle of beef treated with various phosphate solutions

Sample No.	Treatment[b/]	pH of solution	Appearance in vacuum package	
			Surface color	Drip
1	10% Kena	6.1	Brown	Cloudy
2	"	7.55	Brown	Cloudy
3	"	11.0	Brown with purple	Clear
4	"	11.0	Brown	Less cloudy
5	10% TPP	9.1	Purple	Clear
6	10% Na_2HPO_4	8.65	Purple	Clear
7	10% Na_3PO_4	12.75	Purple	Clear
8	Control		Brown	Clear

a/ Surface color was observed in vacuum package.

b/ Code of treatment =

100 krad irradiation for each sample after phosphate dipping and vacuum packaging.

Kena = Sodium metaphosphate glass.

TPP = Sodium tripolyphosphate.

VII. REFERENCES CITED

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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Contract AT(11-1)-1689

United States Atomic Energy Commission

QUARTERLY REPORT

December 16, 1971 through March 15, 1972

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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QUARTERLY REPORT

II. ABSTRACT

In this quarter, work was continued on the treatment of large beef cuts by means of dipping and pumping. The principal phosphate employed for these treatments was sodium tripolyphosphate.

With the use of a nearly saturated sodium tripolyphosphate solution, 13 to 14% (w/w), the treated and stored large beef cuts could maintain acceptable surface color inside the O_2-permeable film for 2 to 4 days. The favorable effect of drip control by TPP treatment was not found with the one-day post mortem beef. The eating quality of the treated beef was distinguished from the fresh reference samples by the taste panel, but was not objectionable to the panel.

At a dose of 200 krad, the intensity of irradiated flavor of beef at different dose rates, storage time and temperature of irradiation was also investigated. No significant difference due to dose rate or storage time was found.

III. PREFACE

The Quarterly Report was prepared in accordance with the terms of Contract No. AT(11-1)-1689 . . Modification No 3 between the United States Atomic Energy Commission and Michigan State University.

The material included in this report under said contract is based on experimental work that is continuing. The interpretation is based upon current results and previous findings in this project.

When the product of a specific manufacturer is stated as having been used in the work described herein, this is not meant to imply an endorsement of said manufacturer, nor is it meant to imply that similar products made by other manufacturers are not suitable for the same use.

IV. SUMMARY

One-day and 10-day post mortem beef rounds from the same carcass were cut into large cuts, treated with 13% sodium tripolyphosphate (TPP), vacuum-packaged, irradiated with a dose of 100 krad and stored at 38 F for 18 days. At the end of the storage period, the total plate count was determined, and the color appearance and eating quality of the sample also evaluated.

After TPP treatment, the one-day post mortem beef had a higher drip loss than the 10-day post mortem beef round. The effect of TPP treatment on drip control was not shown in the one-day post mortem round. Treatment of 10-day post mortem round with TPP resulted in a marked reduction of drip loss. Without TPP treatment, the drip loss was higher for the 10-day post mortem round than for the one-day post mortem round. When beef round had a high initial pH, the drip loss was relatively low.

The color appearance of the TPP treated beef rounds was generally acceptable. No difference in color was observed when the sample was held in the air either at 38 F or 33 F. The total plate counts were found to be 5×10^6 to 4×10^7 per gram of beef, and the highest counts were always found in the irradiated non-phosphated samples.

The eating quality of the treated beef samples was compared with that of the fresh reference samples. The fresh reference samples consistently had better flavor scores than the treated samples. In the absence of fresh reference sample, the TPP-treated samples appeared to receive higher scores in most quality respects than did the irradiated non-phosphated samples. Exception was found occasionally when the drip loss for both samples was very high (see Tables 5 and 6).

Beef round of unknown post mortem age was treated with TPP solution in the form of retail-cuts. The thin (3/4 in) and thick (3/2 in) cuts were dipped in 10 and 13.5% TPP solution, respectively. Other treatments, packaging and storage were the same as for the foregoing experiments. The average value of drip losses of the 13.5% TPP treated samples was 1.02%, that of the 10% TPP-treated samples was 2.42% and that of the irradiated-only samples was 1.58%. The higher drip losses from the 10% TPP-treated samples contradicted earlier results. The color appearance of the TPP-treated samples was better than that of the non-phosphated samples.

The treated and stored samples received lower panel scores than did the fresh reference sample, but only one significant difference was found (between fresh reference sample and irradiated-only sample).

Beef round steaks were dipped for 30 seconds in 10% sodium metaphosphate glass (SPMG, 64% P_2O_5) 10% SPMG plus 0.4% ascorbic acid, or 0.4% ascorbic acid alone, and vacuum-packaged along with the untreated samples. Three dose rates including 0.05, 0.1 and 0.2 krad/sec were used and a total dose of 200 krad was given to the irradiated samples. The samples were also irradiated at two different temperatures (50 and 72 F). The irradiated samples were stored for 1,7 and 14 days at 38 F, and the intensity of their irradiated flavor was examined by a selected taste panel.

The data indicated that the intensity of irradiated flavor was not detectable under all conditions tested with a total irradiation dosage of 200 krad, which is lower than the threshold level.

V. INTRODUCTION

The findings of previous work (see reports for the periods June 16 to September 15, 1971 and September 16 to December 15, 1971) indicated that sodium metaphosphate glass (SMPG, 64% P_2O_5) had a high solubility in water, but gave unsatisfactory results in the treatment of fresh beef. Among the metaphosphates tested, sodium tripolyphosphate (TPP) was the only metaphosphate which was effective in both drip control and retention of fresh meat color.

In this quarter, experiments were carried out with TPP. Beef rounds with known and unknown post mortem age were used. One-day post

mortem beef round was compared with 10-day post mortem beef round in terms of weight gain after dipping, drip loss, color appearance and total plate count. Retail-cuts were treated similarly and their eating quality was examined after storage.

The intensity of irradiated flavor of beef is related to the dose employed. For beef, the threshold level of irradiation dose is about 250 krad (1). At a dose of 200 krad, the effect of different dose rates and temperatures of irradiation on intensity of irradiated flavor was examined. The study covers the beef immediately after irradiation and after storage for 1 to 2 weeks. Two temperatures of irradiation, 50 F and 72 F, were studied.

VI. EXPERIMENTAL

A. General methods and materials

1. Drip loss measurement:

The weight of the meat sample was recorded immediately after phosphate treatment, and again at the end of storage period. In both cases the weight was recorded after draining. The drip loss is reported as a percentage of initial drained weight after dipping.

2. Color evaluation:

Meat color was usually scored visually in accordance with the following numerical grading system:

(1) uniform bright color

(2) generally bright color

(3) uniformly red, but not bright red

(4) red color, not bright, with areas of brown or purple

(5) brown in color with practically no red area

3. Phosphate uptake determination:

Sodium metaphosphates were used, but the total amount of phosphate was determined in the form of orthophosphate. After the meat was treated, a slice (not from the end) was cut off, ground and mixed well. A 5 gram aliquot was boiled with 5 ml of 95% magnesium nitrate solution until dryness and ashed in a muffle furnace at 550 C for 48 hrs. The ashed sample was heated with 40 ml of dilute HNO_3 (1:4) to boiling. The amount of orthophosphate was determined according to the A.O.A.C. Method (2).

4. Total plate count:

The meat sample was a single sample, (10 to 20 grams) aseptically transferred to a sterilized Waring Blendor; 20 parts of sterile water were added and the mixture blended for 2 min. The resultant suspension was further diluted and total plate count was made using nutrient agar.

5. Sensory evaluation:

Samples for sensory panel evaluation in all cases were steaks about 3/4 in thick. If the particular experiment involved large pieces of meat, these were cut into steaks for panel testing. The

steaks were cooked at 325°F for 30 minutes in an air oven and were judged by a consumer-type taste panel on a 9-point hedonic scale. The scoring system was as follows:

Acceptable range:	Unacceptable range:
9 Excellent	4 Fairly Bad
8 Very Good	3 Bad
7 Good	2 Very Bad
6 Fairly Good	1 Poor

5 Marginal

6. Packaging:

The vacuum packaging material was a laminate of polyester (Mylar) base with a thin coat of polyvinylidine chloride (Saran) applied to the outer surface and a heavier extrusion coat of polyethylene on the inner surface. The pouch was a product of the International Kenfield Distributing Company. The O_2-permeable film (polyvinyl chloride) was produced by the Goodyear Tire and Rubber Company. The vacuum packages were sealed with a Kenfield Vacuum Sealer.

7. Materials:

The meat employed in all experiments was beef. The particular grade and cuts are given in the details of each experiment.

The sodium metaphosphate glass (SMPG) was a phosphate blend manufactured by the Calgon Corporation, Pittsburgh, Penn. It

contains 64% P_2O_5 and has a high solubility in water (34% by weight).

Other phosphates used in these experiments were commercial products manufactured by the Calgon Corporation.

Ascorbates used in these experiments were products of the Merck & Co., Inc. Rahway, N.J.

B. Treatment of beef round of known post mortem age with sodium tripolyphophate

Experiment 1: Comparison of beef round treated with sodium tripolyphosphate one and ten days post mortem

MATERIALS AND METHOD

Two USDA Standard grade beef rounds of the same animal were obtained from a local packer one day after slaughter. One round was trimmed and cut immediately. Four large cuts of 3 to 4 lbs weight each including two pieces of bottom round and two pieces of top round were obtained. The pH of each portion was determined. After the initial weights were recorded, three samples were dipped in a 13% sodium tripolyphosphate (TPP) solution for 60 seconds. The weight gain after dipping was recorded after draining. The phosphate-treated large cuts along with one piece of untreated sample were vacuum-packaged, irradiated at 40°F with a dose of 100 krad and stored at 38°F for 18 days. At the end of the storage period, the vacuum packages were opened. Total plate count and drip loss were determined immediately. A slice sample

(not from the outmost layer) was taken from each large cut for determination of phosphate gain. Each large cut was divided into two pieces and wrapped in O_2-permeable film. One-half was stored at 38°F and the other half at 33°F for three more days. Surface color of beef samples was scored visually each day.

After three days holding in air, the stored samples were cut into steaks, cooked at 325°F until well-done and served to a consumer-type taste panel. A fresh beef sample from another round was prepared as a reference. The samples were scored using a 9-point hedonic scale.

The second round, after storage in a cooler for 9 days, was trimmed. Four large cuts including one piece each of bottom round, top round, knuckle and shank were obtained and were similarly treated as indicated for the first round.

RESULTS AND DISCUSSION

In Tables 1 and 3 are recorded pH's, weight gain and phosphate uptake after dipping, drip loss, color scores and total plate count after 18 days storage of the beef round treated with TPP one day and ten days post mortem, respectively. Both rounds had high pH's, ranging from 6.45 to 6.98 for the first round and from 6.50 to 7.03 for the second round. The difference in pH between different portions of each round was about 0.5 pH unit. Weight gains and phosphate uptakes varied from sample to sample. No direct relationship between the weight

gain and phosphate uptake could be established.

The drip losses were generally low for both rounds. The untreated sample had a much lower drip loss than the phosphate-treated samples in the first round, and the difference was not as great in the second round. The low drip loss of the untreated sample was probably due to its high natural pH. The effect of TPP on drip control was shown in the ten-day post mortem beef round.

The colors of the beef samples were quite satisfactory. Despite the high pH, no dark-cutter appearance was observed during three days holding in air. The samples stored either at 38°F or at 33°F had identical color appearance. The total plate count of the second round was slightly higher than the first round, but no spoilage was noted in either round. The relatively high counts of microorganisms (4.7×10^6 to 1.4×10^7 per gram of meat) could be critical if the meat was to be stored longer.

Since the beef round had a high pH before treatment, the pH's of samples after treatment and storage were checked again prior to the taste panel test as shown in Table 2. A pH of 6.8 was found in the treated and stored beef in contrast to pH 5.7 obtained from the fresh beef reference sample. This confirmed the observation that the two beef rounds used in this experiment had high pH's both before and after the storage period.

Taste panel scores for the first and second rounds are given in Tables 2 and 4, respectively. In the case of the first round, only one difference in juiciness scores between the phosphate-treated and untreated samples was found to be significant (Table 2). The scores of each quality aspect showed that the phosphate-treated sample had scores close to those of the fresh beef reference sample in color, flavor, juiciness and overall quality and higher than those of the irradiated non-phosphated samples in flavor, texture, juiciness and overall quality.

For the second round, significant differences were found in texture between the fresh reference sample and all of the treated samples. This textural difference obviously was attributable to the different source of the beef, since no significant textural differences were found among the treated samples. The phosphate-treated samples again received better scores in every quality aspect than the non-phosphated sample and had little difference from the fresh reference sample. While the phosphate-treated samples were slightly better in juiciness, the fresh reference sample appeared to be more acceptable in flavor.

Comparisons made between O-I-38 and O-I-33 samples in Table 2 and between P-I-38 and P-I-33 samples in Table 4 did not show any significant difference in all the quality aspects, nor did they indicate whether air storage at 33°F was more satisfactory than storage at 38°F.

Table 1. Initial pH, weight gain and phosphate uptake after dipping, drip loss, color scores[a/] and total plate count of beef treated one day post mortem[b/] and stored in vacuum at 38°F for 18 days followed by 3 days air storage at 38°F

Sample No.[c/]	Meat portion[d/]	Initial pH	Treatment	Weight gain after dipping	TPP uptake[e/]	Drip-loss after storage	Color score after air storage 1 day	2 days	3 days	Total plate count, no. per gram
1	B.R.	6.45	13% TPP	1.53%	0.10%	1.80%	1	1	2	4.7×10^6
2	B.R.	6.65	13% TPP	1.25%	0.14%	1.78%	1	1	2	6.5×10^6
3	T.R.	6.85	13% TPP	1.36%	0.14%	0.60%	1	1	2	5.0×10^6
4	T.R.	6.98	no TPP	--	--	0.39%	1	1	2	1.4×10^7

a/ See VIA-2 for color scoring system.

b/ Treatment consisted of dipping in 13% TPP for 60 seconds, vacuum-packaging, irradiation with a dose of 100 krad and storage for 18 days.

c/ The average weight of samples was 1619 g.

d/ B.R. = Bottom round; T.R. = Top round

e/ The phosphate uptake is expressed in terms of weight percentage TPP absorbed.

Table 2. Taste panel scores[a/] and pH's[b/] of beef treated one day post mortem and stored in vacuum at 38°F for 18 days followed by 3 days air storage at 33°F or 38°F

Sample No.	Treatment[c/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality	pH
1	P-I	Av.	6.3	5.9	5.8	6.2	6.7[e/]	6.3	6.8
		Range	4-8	3-8	3-8	1-8	5-9	3-8	
2	0-0	Av.	6.5	6.4	6.1	5.3	6.6	6.1	5.7
		Range	4-8	3-9	3-7	2-9	4-8	3-8	
3	0-I-38	Av.	6.2	5.9	5.1	5.6	5.9	5.6	6.8
		Range	1-9	3-8	1-7	1-8	4-8	3-8	
4	0-I-33	Av.	5.5	6.4	5.4	5.8	5.7[e/]	5.4	6.8
		Range	2-8	4-9	3-8	3-8	4-8	1-8	

a/ See VIA-5 for scoring system.

b/ pH's of the samples were determined after 3 days air storage.

c/ Code of treatment:

P-I = 13% TPP dipping, vacuum-packaging and irradiation with a dose of 100 krad and storage.

0-0 = Fresh reference sample, not stored.

0-I-38 = Vacuum-packaging, irradiation with a dose of 100 krad and storage for 18 days followed by 3 days air storage at 38°F.

0-I-33 = Vacuum-packaging, irradiation with a dose of 100 krad and storage for 18 days at 38°F followed by 3 days storage at 33°F

d/ Significant difference in juiciness between No. 1 and 4.

Table 3. Initial pH, weight gain and phosphate uptake after dipping, drip loss, color scores[a/] and total plate count of beef treated ten days post mortem[b/] and stored in vacuum at 38°F for 18 days followed by 3 days air storage at 38°F

Sample[c/] No.	Meat[d/] portion	Initial pH	Treatment	Weight gain after dipping	TPP[e/] uptake	Drip-loss after storage	Color score after air storage 1 day	2 days	3 days	Total plate count, no. per gram
1	B.R.	7.03	13% TPP	13.1%	0.41%	1.00%	1	2	3	2.0×10^7
2	T.R.	6.50	13% TPP	0.91%	0.31%	0.90%	1	2	3	1.6×10^7
3	Kn.	7.03	13% TPP	0.71%	0.19%	0.32%	1	2	3	1.2×10^7
4	Sh.	7.00	no TPP	--	--	0.89%	1	2	3	3.5×10^7

a/ See VIA-2 for color scoring system.

b/ Refer to b/ Table 1.

c/ The average weight of samples was 1670 g.

d/ Code of treatment: B.R. = Bottom round; T.R. = Top round; Kn. = Knuckle; Sh = Shank.

e/ Refer to e/ Table 1.

Table 4. Taste panel scores[a/] of beef treated ten days post mortem and stored in vacuum at 38°F for 18 days followed by 3 days air storage at 33°F or 38°F

Sample No.	Treatment[c/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	O-I	Av.	6.0	5.8	5.2	6.2[d/]	6.0	5.7
		Range	1-8	4-7	1-7	3-8	4-7	4-7
2	P-I-38	Av.	6.5	5.6	6.1	6.4[d/]	6.4	5.9
		Range	5-9	3-8	3-8	4-8	3-9	2-8
3	O-O	Av.	6.3	6.3	6.3	4.8[d/]	6.1	6.1
		Range	3-8	3-9	3-9	1-7	3-9	3-8
4	P-I-33	Av.	6.1	5.6	5.5	6.7[d/]	6.1	5.7
		Range	2-9	1-7	1-8	5-9	2-9	1-8

a/ See VIA-5 for scoring system.

b/ Refer to b/ Table 1.

c/ Code of treatment:

O-I = Vacuum-packaging, irradiation with a dose of 100 krad and storage.

P-I-38 = 13% TPP dip for 60 seconds, vacuum-packaging, irradiation with a dose of 100 krad and storage at 38°F for 18 days followed by air storage at 38°F for 3 days.

P-I-33 = Same as above except air storage at 33°F for 3 days.

O-O = Fresh reference sample (from a different animal), not stored.

d/ Significant differences in texture between No. 3 and 1; 3 and 2; and 3 and 4.

Experiment 2: Comparison of beef round treated with sodium tripolyphosphate one and ten days post mortem

MATERIALS AND METHOD

Two USDA Standard grade beef rounds were obtained from a local packer one day after slaughter. One round was immediately trimmed and four large cuts with weights from 3 to 4 lbs were obtained including one piece each from bottom round, top round, shank and knuckle. The pH and weight of each sample were recorded. Treatment was carried out in the same manner as in Experiment 1. Weight gain, phosphate uptake, drip loss, total plate count and color score were determined.

The second round was cut after 9 days storage in a cooler. Similar cuts with weights from 3 to 4 lbs were used. Treatment was carried out in the same manner as for the first round.

RESULTS AND DISCUSSION

The initial pH of the sample, weight gain and phosphate uptake after dipping, drip loss, color score and total plate count are given in Tables 5 and 7. The pH of the untreated beef was within a normal range, varying from 5.70 to 6.13 for the first round and from 5.40 to 5.75 for the second round. The difference between the highest and lowest pH was about 0.4 pH unit. Also, the pH range for the second round was generally lower than that for the first round. This agrees with the observation made in the previous experiment, namely, that the

post mortem beef may not reach a steady state within 24 hours post mortem. Biochemical changes may ensue for many days.

Both weight gain and phosphate uptake after dipping were relatively low, while drip loss was relatively high for both rounds. For the non-phosphated beef, the drip loss was higher for the second round than for the first round (2.10% versus 1.21%), but opposite results were obtained for the TPP-treated beef. An average drip loss of 3.82% was found from the first round and 1.67% from the second. This result indicated that the TPP treatment was effective in drip control only for the second round. A similar trend was observed in the last experiment and in the previous experiment using SMPG (Exp. 2 Quarterly report for the period September 16 to December 15, 1971). These observations suggest the possibility that one-day post mortem beef will suffer a higher drip loss if treated with phosphate and stored.

The second round received better raw color scores than the first round, but not much difference was observed between the phosphate-treated and untreated samples. It is noteworthy that in many instances, the color appearance of the non-phosphated beef was comparable with that of the TPP-treated beef. The color difference between the TPP-treated and untreated beef normally is not so obvious in large cuts as in small slices. However, TPP-treatment always provides a good surface color to beef after a period of vacuum storage.

The taste panel scores of both rounds are recorded in Tables 6 and 8. For the first beef round, significant differences were found mostly between the fresh reference sample and one of the TPP-treated samples (Samples 1 and 3). There was no doubt that Sample No. 1 was the poorest sample among four samples tested. It should be pointed out, however, that Sample No. 1 received a very low score in juiciness, which was not typical for the phosphate-treated sample.

Sample No. 1, although having a high score in juiciness, was also scored lower than the only irradiated or fresh reference sample in odor, flavor, texture and overall quality. The poor quality may be attributed to the large amount of drip loss after 18 days storage (3.82% for the phosphate-treated sample).

For the second beef round (Table 8), no significant difference was found between the phosphate-treated and untreated samples; only the fresh reference was superior to the stored irradiated samples. The data did not indicate whether the TPP-treated samples were definitely superior to the non-phosphated sample or not, since the TPP-treated samples had lower scores in juiciness than the non-phosphated sample and one of the TPP-treated sample (Sample No. 1) received lower scores than the non-phosphated sample in all aspects except flavor. No explanation can be offered to account for this irregularity.

Table 5. Initial pH, weight gain and phosphate uptake after dipping, drip loss, color scores[a/] and total plate count of beef treated one day post mortem[b/] followed by air storage

Sample[c/] No.	Meat[d/] portion	pH prior to Treatment	Treatment	Weight gain after dipping	TPP[e/] uptake	Drip loss after storage	Color score after air storage 1 day	2 days	3 days	Total plate count, no. per gram
1	T.R.	5.72	13% TPP	0.82%	0.16%	4.03%	2	2	3	6.0×10^6
2	B.R.	5.73	13% TPP	0.81%	0.19%	4.20%	3	3	4	9.0×10^6
3	Kn.	5.70	13% TPP	0.91%	0.23%	3.24%	2	2	3	3.0×10^6
4	Sh.	6.13	no TPP	--	--	1.21%	2	3	4	1.5×10^7

a/ See VIA-2 for color scoring system.

b/ Refer to b/ Table 1.

c/ The average weight of samples was 1880 g.

d/ T.R. = Top round; B.R. = Bottom round; Kn. = Knuckle; Sh. = Shank.

e/ Refer to e/ Table 1.

Table 6. Taste panel scores[a] of beef treated one day post mortem and stored in vacuum at 38 F for 18 days followed by air storage at 38 F for 3 days

Sample No.	Treatment[b]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I	Av	5.6[c]	5.6	4.8[d]	4.3[e]	4.6[f]	4.9[g]
		Range	3-7	2-7	1-7	1-7	1-8	3-7
1'	P-I	Av	6.6[c]	5.6	5.1	5.2	6.2[f]	5.2[g]
		Range	4-8	2-7	1-8	3-9	4-9	1-8
2	0-I	Av	6.2	6.0	5.8	5.6	5.7	6.0[g]
		Range	3-8	2-8	3-8	1-8	2-8	4-7
3	0-0	Av	6.4	6.4	6.4[d]	6.0[e]	6.1[f]	6.3[g]
		Range	4-8	5-8	3-8	2-9	4-8	4-8

a/ See VI A-5 for scoring system.

b/ Code of treatment:

P-I = 13% dipping for 60 sec, vacuum packaging, irradiation with a dose of 100 krad and storage.

0-I = Same as above except with no phosphate dipping.

0-0 = Fresh reference sample, not stored.

c/ Significant difference in cooked color between No. 1 and 1'.

d/ " " " flavor between No. 1 and 3.

e/ " " " texture between No. 1 and 3.

f/ " " " juiciness between No. 1 and 1', 1 and 3.

g/ " " " overall quality between No. 1 and 1', 1 and 2, and 1 and 3.

Table 7. Initial pH, weight gain and phosphate uptake after dipping, drip loss, color scores[a/] and total plate count of beef treated 10 day post mortem[b/], and stored in vacuum at 38 F for 18 days followed by air storage

Sample[c/] No.	Meat[d/] portion	pH prior to treatment	Treatment	Weight gain After dipping %	TPP[e/] uptake %	Drip loss after storage %	Color score after air storage			Total plate count
							1 day	2 days	3 days	
1	T.R.	5.40	14% TPP	1.15	.22	2.54	1	1	3	5×10^6
2	B.R.	5.50	"	.73	.31	1.76	1	1	3	3×10^6
3	Sh.	5.75	"	1.58	.60	.72	1	2	3	2×10^7
4	Kn.	5.75	No TPP			2.10	1	1	3	3×10^7

a/ See VI A-2 for color scoring system.

b/ Refer to b/, Table 1.

c/ The average weight of samples was 1558 g.

d/ Refer to d/, Table 5.

e/ Refer to e/, Table 1.

Table 8. Taste panel scores[a/] of beef treated 10 day post mortem and stored in vacuum at 38 F for 18 days followed by air storage at 38 F for 3 days

Sample No.	Treatment[b/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I	Av	6.5	6.4	6.1	6.0	6.0	6.2
		Range	4-9	3-9	2-8	4-8	3-9	4-8
1'	P-I	Av	6.3	6.0	5.4	5.1[d/]	5.9	5.3[e/]
		Range	4-9	3-8	3-7	3-7	3-9	3-8
2	0-0	Av	6.3	6.7	6.4[c/]	6.6[d/]	6.5	6.5[e/]
		Range	5-9	3-9	3-8	3-9	3-9	3-8
3	0-I	Av	6.1	6.1	5.1[c/]	5.6	6.4	5.4[e/]
		Range	2-8	2-8	1-9	3-8	3-9	3-8

a/ See VI A-5 for scoring system.

b/ Code of treatment:

P-I = 14% TPP dipping for 60 sec, vacuum-packaging, irradiation with a dose of 100 krad and storage in vacuum at 38 F for 18 days followed by air storage at 38 F for 3 days.

0-I = Same as above except no phosphate dipping.

0-0 = Fresh reference sample, not stored.

c/ Significant difference in flavor between No. 2 and 3.

d/ " " " texture between No. 1 and 2.

e/ " " " overall quality between No. 1' and 2, No. 2 and 3.

C. TREATMENT OF RETAIL-CUT BEEF WITH SODIUM TRIPOLYPHOSPHATE (TPP)

Experiment 3. Effect of TPP on the thin and thick retail-cuts

MATERIALS AND METHOD

USDA Choice grade round steaks with unknown post mortem age were obtained from the Michigan State University Food Stores. The round steaks were sliced into two thicknesses, 3/4 inch thick and $1\frac{1}{2}$ inch thick. Three pieces each of thick and thin cuts were dipped for 45 sec in 13.5% and 10% TPP, respectively. Two thin cuts were untreated. The pH of each sample was determined prior to and after phosphate-dipping. The TPP-uptake was determined after phosphate-dipping. The treated and untreated samples were vacuum-packaged, irradiated with a dose of 100 krad at 40 F, and stored at 38 F for 18 days. At the end of the storage period, the appearances of samples in the vacuum packages were visually examined. Drip loss was determined after the packages were opened. The samples were rewrapped with O_2-permeable film and stored at 38 F for 3 more days. During this period, the colors of the samples were noted. A consumer-type taste panel was held at the end of 3 days air-storage. The round steaks were cooked at 325 F until well-done and judged by 25 persons on a 9-point hedonic scale. The thick cuts were cut into half thickness for taste panel evaluation in order to obtain uniform thickness of all samples.

RESULTS AND DISCUSSION

The pH's of beef after dipping, phosphate uptake, drip loss and color scores are given in Table 9. The pH's of the phosphate-treated and untreated beef did not differ very much and fell mostly between 5.5 and 5.6. The beef steak before treatment had a bright red color and juicy appearance. After dipping in TPP solution, part of the muscle in a round steak started turning purple while other muscles remained red. The peripheral fat layer, however, turned yellowish brown after TPP dipping.

After 18 days vacuum storage at 38 F, various degrees of purple surface color were found in the vacuum packages. Among the muscles, semitendinosus, semimembranosus and adductor appeared to have lighter purple color than others. The general appearance of the vacuum packages was quite acceptable. The beef was tightly held by the film and no excessive drip could be seen. The peripheral fat layer was slightly dark but not objectionable.

The TPP-uptakes were higher than expected even though the dipping time was only 45 sec. Based upon the available data, it seems clear that the amount of phosphate uptake by beef cannot be regulated by merely adjusting the dipping time, nor can be monitored by merely noting the weight gain. Therefore, in order to abide strictly with the 0.5% maximum level, an efficient pumping method is required. Appropriate

Table 9. pH, phosphate uptake after dipping, drip loss and color scores[a/] of beef round steaks treated, irradiated and stored at 38 F for 18 days

Sample[b/] No.	Treat-[c/] ment	pH of meat after dipping	TPP[d/] uptake %	Drip loss after storage %	Color score after air storage		
					1 day	2 days	3 days
1	P-I-H	5.53	.95	1.15	1	2	2
1'	P-I-H	5.56	.60	.97	2	2	3
1"	P-I-H	5.58	.55	.95	1	2	4
2	P-I-L	5.60	.64	1.51	1	2	3
2'	P-I-L	5.61	.70	3.70	2	2	2
2"	P-I-L	5.60	.40	2.06	2	2	3
3	O-I	5.50	- -	1.74	2	3	4
3'	O-I	5.50	- -	1.42	4	4	4

a/ See VI, A-2 for color scoring system.

b/ 1 series - thick slices; 2 and 3 series - thin slices.

c/ Code of treatment:

P-I-H = 13.5% TPP dip, vacuum packaging, irradiation with a dose of 100 krad and storage at 38 F for 18 days, followed by air storage at 38 F for 3 days.

P-I-L = Same as above except 10% TPP dip.

O-I = Same as above except no TPP dip.

d/ Since the samples were treated with TPP solution, the phosphate uptake is expressed in terms of percentage sodium tripolyphosphate absorbed.

amounts of phosphate might be metered into the meat, followed by a spray of the surface.

The drip loss of the treated samples, as shown in Table 9, amounted to an average of 2.42% for the thin cuts and an average of 1.02% for the thick cuts. The average drip loss for the non-phosphated samples was 1.58%. The fact that the thick cuts yielded lower drip, and the thin cuts yielded higher drip than did the control is difficult to understand in view of earlier results.

The TPP-treated samples received better color scores than the non-phosphated samples during air-storage. Sometimes, a couple of spots on the phosphated sample rapidly turned brown and caused a down-grading of an otherwise acceptable sample. An example of such a case is sample No. 1 in Table 9.

The taste panel results are recorded in Table 10. There was only one significant difference found between the fresh reference sample and the irradiated non-phosphated sample in flavor (Sample No. 1 and 4). The scores showed that the phosphate-treated samples were better than the non-phosphated sample in all aspects but texture. Between the 13.5% and 10% TPP-treated samples, the 13.5% TPP-treated sample received slightly better scores than the 10% TPP-treated sample. This can be related to the fact that the 10% TPP-treated thin cut had higher drip loss than the 13.5% TPP-treated thick-cut.

Table 10. Taste panel scores[a/] of beef round steaks treated, irradiated and stored at 38 F for 18 days followed by air storage at 38 F for 3 days

Sample No.	Treatment[b/]		Cooked color	Odor	Flavor	Texture	Moisture or juiciness	Overall quality
1	0-0	Av	6.3	6.4	5.7[c/]	6.6	6.0	6.1
		Range	4-9	5-9	2-8	3-9	3-8	3-8
2	P-I-H	Av	7.0	6.7	6.4	6.4	6.5	6.4
		Range	4-9	5-9	4-9	3-9	4-9	5-9
3	P-I-L	Av	6.6	6.7	6.1	6.3	6.4	6.3
		Range	4-9	3-9	2-8	4-9	4-9	4-8
4	Fresh	Av	6.5	6.8	7.0[c/]	6.8	6.9	6.7
		Range	3-9	4-9	2-9	4-9	4-8	4-8

a/ See VI A-5 for scoring system. Scores are average values obtained from 25 judges.

b/ Treatment is same as b/ Table 9.

c/ Significant difference in flavor between No. 1 and 4.

D. EFFECT OF TEMPERATURE, DOSE RATE AND STORAGE TIME ON THE FLAVOR OF BEEF IRRADIATED WITH A DOSE OF 200 krad

Experiment 4. Irradiation of beef in vacuum at 50 F at dose rates of 0.05, 0.1 and 0.2 krad/sec.

USDA Commercial grade beef round was used. Beef slices about 1/2 in thick were dipped for 30 sec in one of the following solutions: 10% SMPG, 10% SMPG plus 0.4% ascorbic acid, and 0.4% ascorbic acid alone. The treated samples along with the untreated samples were vacuum-packaged and irradiated with ^{60}Co gamma radiation with a dose of 200 krad at 50 F. Three dose rates including 0.05, 0.1 and 0.2 krad/sec were used. The irradiated samples were stored at 38 F. Samples with different treatments and different dose rates were taken after 1, 7 and 14 days storage. After water cooking in a plastic bag for 30 min, the irradiated flavor intensity of each sample was rated by a trained expert panel (5 members) on a 5-point numerical scale (See Table 11 for a description of scoring system). A beef sample irradiated with 1000 krad was provided as a reference for the panel and a score "Irradiated Flavor Intensity" of 3 was assigned.

RESULTS AND DISCUSSION

The average values of the irradiated flavor intensity are given in Table 11. Most of the scores fluctuated between 1 and 2. There was no consistent pattern of progressive change with storage time or dose rate. The generally low scores indicated that the irradiated

flavor was not strong enough to be detected by the panelists. According to a previous study, the threshold for the irradiated flavor of beef without any treatment and irradiated at approximately 0.3 krad/sec (1) was 250 krad. The results in this experiment showed that at a dose of 200 krad over the dose rate range studied, the irradiated flavor in beef treated with 10% SMPG and/or 0.4% ascorbic acid was not detectable.

Experiment 5. Irradiation of beef in vacuum at 72 F at dose rates of 0.05, 0.1 and 0.2 krad/sec

USDA Commercial grade beef round were used. Beef slices about 1/4 in thick were dipped for 30 sec in one of the following solutions: 10% SMPG, 10% SMPG plus 0.4% ascorbic acid, and 0.4% ascorbic acid alone. The treated samples and the untreated sample were vacuum packaged and irradiated with ^{60}Co gamma radiation to a dose of 200 krad at 72 F. The same dose rates, storage time and storage temperature as in Experiment 4 were used. The samples were similarly judged by a 5-member trained expert panel. A reference sample with 1000 krad irradiation dose was provided with other samples.

RESULTS AND DISCUSSION

As shown in Table 12, the flavor intensity scores of these samples again fluctuate between 1 and 2. No correlation was observed between the intensity of irradiated flavor and the dose rate or the storage time at a dose of 200 krad. A comparison of the results obtained at 50 F and at 72 F (Tables 11 and 12) indicates that the flavor intensity difference was negligible under all conditions.

Table 11. Irradiated flavor intensity scores[a/] of beef irradiated at three dose rates at 50 F

Treatment[b/]	Days of storage	Scores at each dose rate		
		0.05 krad/sec	0.1 krad/sec	0.2 krad/sec
0-I	1	1.0	1.6	1.0
	7	1.4	1.4	2.2
	14	1.0	2.2	1.4
P-I	1	1.4	2.2	1.4
	7	1.0	2.2	1.6
	14	1.6	1.8	2.0
P-A-I	1	1.4	1.6	1.2
	7	1.2	1.4	1.8
	14	1.2	1.6	2.0
A-I	1	1.4	1.6	1.6
	7	1.6	1.8	1.2
	14	1.2	1.8	1.4

a/ Irradiated flavor intensity scoring system:

1. None
2. Slight
3. Moderate
4. Strong
5. Very strong

b/ Code of treatment:

0-I = 200 krad irradiation only.

P-I = 10% SMPG treatment and 200 krad irradiation.

P-A-I = 10% SMPG plus 0.4% ascorbic acid treatment and 200 krad irradiation.

A-I = 0.4% ascorbic acid treatment and 200 krad irradiation.

Table 12. Irradiated flavor intensity scores[a] of beef irradiated at three dose rates at 72 F

Treatment[b]	Days of storage	Scores at each dose rate		
		0.05 krad/sec	0.1 krad/sec	0.2 krad/sec
0-I	1	1.0	1.0	1.6
0-I	7	1.4	1.4	1.4
0-I	14	1.0	1.6	2.0
P-I	1	1.4	1.2	1.2
P-I	7	1.6	1.2	1.2
P-I	14	2.0	1.6	1.6
P-A-I	1	1.4	1.4	1.2
P-A-I	7	1.4	1.4	1.2
P-A-I	14	1.4	1.2	1.4
A-I	1	1.2	1.2	1.4
A-I	7	1.4	1.2	1.4
A-I	14	1.4	1.6	1.2

a/ and b/ refer to a/ and b/ Table 11.

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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United States Atomic Energy Commission

QUARTERLY REPORT

March 16, 1972 through June 15, 1972

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RADIATION PASTEURIZATION OF FRESH MEATS AND POULTRY

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II. ABSTRACT

Large pieces of beef were pumped with 13% TPP and the surface covered with 13% TPP by dipping or spraying. After being held for a period for TPP diffusion, the large piece was cut into smaller portions, vacuum-packaged, irradiated and stored at 38 F for 18 days. The TPP-treated samples in general had lower drip losses than non-phosphated samples, and drip losses were lower from large cuts then from slices. Eating quality of the TPP-treated samples was poorer than that of the fresh reference samples, particularly in texture, juiciness and overall quality. Among the treated and stored samples, no significant difference was found although the large cuts were rated higher than the slices.

Beef slices were treated with TPP or TPP plus ascorbic acid, vacuum-packaged, irradiated and stored at 38 F for 18 days, held in air for 3 days and

frozen at -10 F for 30 days. The eating quality of these treated samples and the frozen control samples were compared at the end of the entire storage period. The treated samples were not much different from the frozen control samples.

Lamb, pork and chicken could be successfully treated with 13% TPP dip. Color appearance of the treated samples was very satisfactory and the drip losses were markedly reduced by TPP-treatment. Eating qualities of lamb, pork and chicken after 18 days vacuum storage and 3 days air storage were scored by the taste panel favorably.

The panel scores showed that texture of these commodities, unlike beef, was not affected by TPP-treatment and storage. However, occasional off-odor was detected from the treated samples. It was suggested that careful handling was required to reduce the initial microbial counts.

The results of the microbiological studies showed that after irradiation the microbial counts were reduced by one to two log cycle. Microbial spoilage of the irradiated beef would ultimately occur. No evidence of new health hazard as a consequence of the irradiation procedure was found.

VIII. PREFACE

This quarterly report was prepared in accordance with the terms of Contract No. AT(11-1)-1689 . . Modification No. 3 - between the United States Atomic Energy Commission and Michigan State University.

The material included in this report under said contract is based on experimental work that is continuing. The interpretation is based upon current results and previous findings in this project.

When the product of a specific manufacturer is stated as having been used in the work described herein, this is not meant to imply an endorsement of said manufacturer, nor is it meant to imply that similar products made by other manufacturers are not suitable for the same use.

IV. SUMMARY

Four experiments were carried out, in that the large piece of beef was pumped with a nearly saturated sodium tripolyphosphate solution (13% by weight TPP solution) to a weight gain of two to less than three percent. The surface of beef was covered with TPP solution by either dipping or spraying. The TPP uptake determined after dipping and spraying did not exceed 0.5% of the total weight.

In the first two experiments, the large pieces of beef were pumped and dipped with 13% TPP, held at 33 F for 24 hours, and cut into smaller portions as slices or large cuts. An average drip loss of 2.41% was obtained from the three large cuts in the first experiment, while average drip losses of 2.19%, 1.72% and 3.46% were obtained from slices, large cuts and non-phosphated control, respectively, in the second experiment. The taste panel results indicated that the TPP-treated samples were slightly inferior to the fresh beef reference samples. Lower scores in texture, juiciness and overall quality were received by the treated samples. Among irradiated and stored samples, the difference in scores was not significant, but the large cuts tended to receive higher scores than the slices or samples being irradiated only. The higher scores might be associated with the lower drip loss of the phosphated large cuts.

In the next two experiments, the large pieces of beef were pumped and sprayed with 13% TPP, held at 38 F for 2 hours, and then cut into small portions

as slices or large cuts. An average drip loss of 2.79% was obtained from the three large cuts in the first experiment, while average drip losses of 2.30%, 1.71% and 2.65% were obtained from slices, large cuts and non-phosphated control, respectively, in the second experiment. The scores in flavor, texture and juiciness of the TPP-treated samples were lower than that of the fresh reference sample in the first experiment. Large differences between the treated samples and the fresh reference samples were again found in texture, juiciness and overall quality in the second experiment.

Beef slices were treated with TPP or TPP plus ascorbic acid, vacuum-packaged, irradiated with 100 krad and stored at 38 F for 18 days followed by 3 days air storage and 30 days frozen storage. Slight changes in TBA (Thio-barbituric acid) values after 18 + 3 days and 18 + 3 + 30 days storage were found, but no definite pattern of changes could be established. Addition of ascorbic acid to the TPP solution resulted in a higher TBA value than using TPP solution alone. Eating quality of these treated,irradiated, refrigerated and frozen samples was similar to the only-frozen control samples in two cases and slightly poorer than the only frozen control sample in another case. Freezing beef for 30 days after 18 days vacuum storage and 3 days air storage was possible based on these studies.

Lamb round was treated with TPP, vacuum-packaged, irradiated and stored at 38 F for 18 days followed by 3 days air storage. The weight gain and TPP uptake after dipping were satisfactory. The drip losses after 18 days storage ranged from .91 to 4.34% for the TPP-treated samples and 1.99 to 5.79% for the

non-phosphated samples. Reduction of drip loss by TPP-treatment was readily shown.

Color appearance of the TPP-treated and untreated lamb did not vary greatly and appeared acceptable. Flavor difference between different samples seemed to be tied with location of muscle more closely than the TPP treatment. This might be due to the stronger original odor of lamb. The texture and juiciness scores of the treated and stored samples were less affected than those of beef.

Pork samples were treated with TPP solution, vacuum-packaged, irradiated, or simply vacuum-packaged and frozen at -10 F or refrigerated at 28 F. After 18 days of storage, the color appearance of each sample was satisfactory except that the bone portion was dehydrated and turned brown. The drip losses of the stored pork samples were negligible. The eating quality of these pork samples was evaluated by a consumer-type taste panel. All samples received favorable scores in all aspects. Samples refrigerated at 28 F appeared to have the highest quality among all. The TPP-treated samples were more acceptable than the non-phosphated irradiated samples. Higher odor scores were given to the frozen samples.

Quartered chicken fryers were treated with 5 or 13% TPP solution, vacuum-packaged, irradiated and stored at 38 F. Control samples were frozen at -10 F and all kept for 18 days. Lowest drip loss was obtained from samples treated with 13% TPP (2.0%). Samples dipped for 60 minutes with 5% TPP tended

to have higher drip loss (2.52-3.81%), but the frozen chickens had the highest drip loss (3.94-4.07%). The taste panel scores indicated that the 13% TPP-treated chicken had better eating quality than other samples. But due to the high initial microbial load, the irradiated chickens tended to have off-flavor after storage for 18 days. The flavor score was affected if off-flavor was present. The texture and juiciness, on the other hand, were not affected by this treatment and storage.

Relative concentrations of beef pigments after an exposure were determined daily for four days. The untreated control samples showed very stable pigment concentrations with 12% metmyoglobin and 88% oxymyoglobin. The vacuum-packaged and irradiated samples had purple color appearance immediately after the treatment but was not greatly changed during the following days of air exposure. When the vacuum-packaged and irradiated samples were stored for 18 days, a large amount of metmyoglobin was produced in the non-phosphated sample, but less metmyoglobin was formed in the TPP-treated samples. During air exposure, the non-phosphated samples had less oxymyoglobin than the TPP-treated samples, and hence had a dull-red appearance and turned brown more rapidly. The beneficial effect of TPP treatment in maintaining the red color pigment, namely, oxymyoglobin was readily shown.

The microbiological studies indicated that irradiation with 100 krad could reduce the total counts by one to two log cycles. From the total count data, it was shown that microbial spoilage ultimately would occur, even with the

irradiated samples.

With vacuum-packaging and irradiation, the dominant outgrowth group of microorganisms are Lactobacilli and not Pseudomonas and Achromobacter. No evidence of new health hazard as a consequence of the irradiation procedure employed was found.

V. INTRODUCTION

During the third quarter of this contract year, beef round samples were treated with 13% sodium tripolyphosphate (TPP) successfully. To improve the effectiveness of TPP, a combination of pumping and dipping or pumping and spraying was employed to incorporate a higher level of TPP than by dipping alone. TPP solution was pumped with a pumping machine into large pieces of beef and subsequently held over a period prior to cutting into smaller portions.

Eating quality of TPP-treated and irradiated beef after 18 days vacuum storage at 38 F, holding in air at 38 F for 3 days and frozen storage at -10 F for 30 days were evaluated with both TBA value determination and sensory evaluation.

Experiments in this fourth quarter also include treatment of lamb, pork and chicken with 13% TPP dipping. This fulfills the last portion of the research proposal approved for the period from June 16, 1971 to June 15, 1972.

An objective measurement of relative pigment concentration was also carried out in this quarter. The fluctuation of the three meat pigments, namely myoglobin, oxymyoglobin and metmyoglobin, after air exposure was examined both before and after irradiation and storage under the experimental conditions usually employed.

Microbiological studies were conducted during the previous contract year and were summarized in this report.

VI. EXPERIMENTAL

A. General Methods and Materials

1. Drip loss measurement:

The weight of the meat sample was recorded immediately after phosphate treatment, and again at the end of the storage period. In both cases the weight was recorded after draining. The drip loss is reported as a percentage of initial drained weight after dipping.

2. Color evaluation:

Meat color was usually scored visually in accordance with the following numerical grading system:

(1) uniform bright color
(2) generally bright color
(3) uniformly red, but not bright red
(4) red color, not bright, with areas of brown or purple
(5) brown in color with practically no red area

3. Phosphate uptake determination:

Sodium metaphosphates were used, but the total amount of phosphate was determined in the form of orthophosphate. After the meat was treated, a slice (not from the end) was cut off, ground and mixed well. A 5 gram aliquot was boiled with 5 ml of 95% magnesium nitrate solution until dryness and ashed in a muffle furnace at 550 C for 48 hours. The ashed sample was heated with 40 ml of dilute HNO_3 (1:4) to boiling. The amount of orthophosphate was determined according to the A.O.A.C. Method (2).

4. Microbiological sample:

The meat cubes constituting the test sample were added in an aseptic manner to sterile 0.2% peptone solution, on the basis of one part of meat and nine parts solution. This mixture was blended for one minute in a sterilized Waring blendor. Aliquots of the blended mixture were employed for microbiological studies.

5. Sensory evaluation:

Samples for sensory panel evaluation in all cases were steaks about 3/4 inch thick. If the particular experiment involved large pieces of meat, these were cut into steaks for panel testing. The steaks were cooked at 325 F for 30 minutes in an air oven and were judged by a consumer-type taste panel on a 9-point hedonic scale. The scoring system was as follows:

Acceptable range:		Unacceptable range:	
9	Excellent	4	Fairly bad
8	Very good	3	Bad
7	Good	2	Very bad
6	Fairly good	1	Poor
5	Marginal		

6. Packaging:

The vacuum packaging material was a laminate of polyester (Mylar) base with a thin coat of polyvinylidine chloride (Saran) applied to the outer surface and a heavier extrusion coat of polyethylene on the inner surface. The pouch was a product of the International Kenfield Distributing Company. The O_2-permeable film (polyvinyl chloride) was produced by the Goodyear Tire and Rubber Company. The vacuum packages were sealed with a Kenfield Vacuum Sealer.

7. Materials:

The meat employed in all experiments was obtained from the Michigan State University Food Stores. The particular grade and cuts are given in the details of each experiment.

Sodium tripolyphosphate was of food grade quality obtained from the Calgon Corporation.

Ascorbates used in these experiments were products of the Merck & Company, Inc., Rahway, N.J.

B. Treatment of Beef Round with Sodium Tripolyphosphate (TPP) by Dipping and Pumping or Spraying and Pumping

Experiment 1: Dipping and pumping of a large piece of beef with 13% TPP and holding for 24 hours at 35 F prior to cutting and vacuum-packaging:

MATERIALS AND METHODS

U.S.D.A. Commercial grade beef round was secured from the Michigan State University Food Stores. From this was prepared a beef cut of about 10 lbs weight. This was dipped and pumped with 13% TPP solution so that approximately 0.5% TPP was incorporated into it. It was then wrapped in polyethylene film and kept at 33 F cooler overnight to allow the phosphate to distribute in the meat through diffusion. The large cut was converted into three thick cuts of approximately 3 lbs each, which were weighed, vacuum-packaged, irradiated with 100 krad at 40 F and stored at 38 F for 18 days.

At the end of this storage period, each package was drained, and drip loss determined. The thick cuts were rewrapped with O_2-permeable PVC film and kept at 38 F for 3 days. The general color appearance was observed visually and at the end of 3 days air storage the thick cuts were sliced into 3/4 inch steaks and evaluated by a consumer-type taste panel after broiling to well-done.

RESULTS AND DISCUSSION

The large piece of beef, having a weight of 4714 g, gained 2.88% of its weight after dipping and pumping with 13% TPP solution. After one day of storage, one large cut was sliced off the pumped beef and the surface of this cut examined visually. A number of purple spots were found, which were obviously caused by the added TPP. It indicated that the pumped TPP was quite concentrated at local areas after 24 hours storage. This large cut was cut after 24 additional hours storage and the cut surfaces again examined visually. The purple spots were not as visible as those after 24 hours storage.

Three large cuts were obtained from the remaining portion of the pumped beef. The amounts of added sodium tripolyphosphate were determined individually. The results are given in Table 1. It appears that the levels of phosphate in each large cut are not equal to each other, although the three large cuts are obtained from the same pumped beef. The drip loss after 18 days storage, however, was similar, with an average value of 2.41% (Table 1).

After three days air storage, the irradiated and stored samples were judged against the fresh beef samples, which were obtained fresh from the

Table 1. Phosphate uptake[a/] and drip loss of beef pumped and dipped with 13% TPP as a large cut, subsequently divided into portions and vacuum packaged, irradiated with 100 krad and stored at 38°F for 18 days followed by 3 days air storage

Portion[b/] No.	% TPP uptake shortly after dipping and pumping	% drip loss after storage
1	.27	2.22
1'	.45	2.64
1"	.40	2.44

a/ Phosphate uptake after dipping and pumping are expressed as percentage TPP retained by beef.

b/ The average weight of samples was 1229 g.

Michigan State University Food Stores. The taste panel scores are listed in Table 2. The treated samples received lower scores than the fresh reference samples in all aspects. Significant differences were found in texture, juiciness and overall quality.

Experiment 2: Dipping and pumping of a large piece of beef with 13% TPP and holding for 24 hours at 33 F prior to cutting and vacuum-packaging:

U.S.D.A. Commercial grade beef round was obtained from the Michigan State University Food Stores. Two large pieces of beef with weights of 8 to 10 lbs each were dipped and pumped with 13% TPP solution. After pumping and draining, the large cuts were wrapped and held at 33 F for 24 hours in the same manner as done in Experiment 1. For vacuum-packaging, one large cut was cut into four slices and another was cut into two thick cuts. Increase of phosphate in each piece was determined. A piece of non-phosphated large cut was vacuum-packaged without holding for 24 hours. All packages were irradiated with 100 krad and stored at 38 F for 18 days.

At the end of the storage period, drip losses of these samples were determined. Taste panel evaluation of the treated and stored samples was carried out with 20 untrained judges after three days air storage.

RESULTS AND DISCUSSION

The results of storage and taste panel are given in Tables 3 and 4. The weight gains for the two large pieces of beef were 2.60 and 2.71%, respectively. Determination of added TPP in each sample indicated that the TPP distribution in

Table 2. Taste panel scores[a] of phosphated, vacuum-packaged and irradiated beef after storage in vacuum for 18 days and in air for 3 days at 38 F (fresh beef used as reference sample)

Portion No.	Treatment[b]		Cooked Color	Odor	Flavor	Texture	Juiciness	Overall Quality
0	0-0 (Fresh)	Av	6.6	6.7	6.5	6.5[c]	6.9[d]	6.7[e]
		Range	4-9	4-8	4-9	4-8	4-8	5-8
1	P-I	Av	6.4	6.0	5.8	4.8[c]	5.6[d]	5.4[e]
		Range	4-8	2-8	3-8	1-8	3-9	3-8
1'	P-I	Av	6.9	6.7	6.8	6.4[c]	6.8[d]	6.7[e]
		Range	4-8	5-8	4-9	2-8	5-8	4-8
1''	P-I	Av	6.6	6.3	6.1	5.4	6.0	6.0
		Range	4-8	4-8	4-8	1-8	3-8	3-8

a/ For scoring system, see VI, A 5.

b/ Code: 0-0, Fresh beef reference sample, not stored.
P-I, See Table 1, caption.

c/ Significant differences in texture between 0 and 1, 1 and 1'.

d/ Significant differences in juidiness between 0 and 1, 1 and 1'.

e/ Significant differences in overall quality between 0 and 1, 1 and 1'.

Table 3. Phosphate uptake[a/] and drip loss of beef pumped and dipped with 13% TPP solution as a large cut and subsequently divided into portions and vacuum-packaged, irradiated with 100 krad and stored at 38 F for 18 days followed by 3 days air storage

Portion No.[b/]	Treatment[c/]	Kind of final cut	TPP uptake after dipping & pumping	Drip loss after storage
1	P-I	Slice	.57%	1.76%
1'	"	"	.27%	2.27%
1"	"	"	.50%	2.78%
1'"	"	"	- -	1.96%
2	P-I	Large cut	.39%	2.10%
2'	"	"	.39%	1.34%
3	O-I	Large cut	None	3.46%

a/ Refer to a/ Table 1.

b/ The average weights for each set of samples were Portions 1,1',1" and 1'":1118 g; Portions 2 and 2':1563 g; Portion 3:1646 g.

c/ Code of treatment:

P-I = 13% TPP dip and pump, held at 33 F for 24 hours, vacuum-packaged, irradiated with 100 krad and stored at 38 F for 18 days followed by 3 days air storage at 38 F.

O-I = Same as above except no phosphate treatment and holding period at 33F prior to vacuum packaging.

Table 4. Taste panel scores[a/] of phosphated, vacuum-packaged and irradiated beef after storage in vacuum for 18 days and in air for 3 days at 38 F

Sample No.	Treatment[b/] and cut		Cooked color	Odor	Flavor	Texture	Juici-ness	Overall quality
1	P-I	Av	5.7	5.4	5.1	5.5	5.1	5.4
	(slice)	Range	1-7	2-7	1-7	2-9	1-9	2-8
1'	P-I	Av	6.5	6.2	5.9	6.2	5.8	5.8
	(slice)	Range	2-9	2-9	1-9	2-9	2-8	3-9
2	P-I	Av	6.7	6.1	6.3	6.5	6.3	6.0
	(large cut)	Range	4-9	3-8	4-9	4-9	4-9	5-8
3	O-I	Av	5.5	5.6	5.9	5.5	5.3	5.3
	(large cut)	Range	2-8	3-8	3-8	3-8	3-8	3-8

a/ For scoring system see VI, A-5.

b/ Code of treatment: Refer to c/ Table 3.

beef was not homogeneous. The diffusion rate of TPP, therefore, could not secure an even distribution of TPP within 24 hours. Better results may be possible with a more easily controlled pumping device than that used in this work. The pH's of the beef before and after the TPP treatment were 5.83 and 6.20 respectively. The drip loss after 18 days storage averaged 2.19% for slices, 1.72% for large cuts and 3.46% for the non-phosphated sample.

The taste panel results (Table 4) showed that, although no significant difference was found among samples, the TPP-treated large cut received the highest scores in every respect and appeared to be the best one among samples tested. This can be related to the fact that it suffered the least drip loss. However, it should be pointed out that the average scores of each sample are all higher than the marginal score of 5.

Experiment 3: Spraying and pumping of a large piece of beef with 13% TPP and holding for 2 hours at 38 F prior to cutting and vacuum-packaging:

MATERIALS AND METHODS

A large piece of bottom round of U.S.D.A. Commercial grade beef obtained from the Michigan State University Food Stores was pumped and sprayed with 13% TPP solution. After draining briefly, it was covered with polyethylene film and kept in 38 F refrigerator for two hours. The overall increase of weight and TPP was determined. The large piece was cut into three thick cuts which were individually vacuum-packaged. After irradiation with 100 krad, the packages were stored at 38 F for 18 days and the drip loss was determined at the end of the storage time. A taste panel evaluation was made after three days air storage using 3/4 inch thick steaks of the treated beef along with fresh beef reference sample.

RESULTS AND DISCUSSION

The results are given in Tables 5 and 6. The weight gain and TPP uptake of the large piece of beef after pumping and spraying were 2.1 and 3.4%, respectively. The color appearance of the treated and stored samples was not quite bright red. This was because the color appearance of the starting material was not bright red. The drip losses of these samples averaged 2.79%, which was slightly higher than samples treated in the last two experiments.

The taste panel scores (Table 6) indicate that changes in texture and juiciness of the treated samples were greater than those of other quality aspects.

Table 5. Drip loss and color scores[a/] of beef pumped and sprayed with 13% TPP as a large cut, subsequently divided into portions and vacuum packaged, irradiated with 100 krad and stored at 38 F for 18 days followed by 3 days air storage

Portion No.[b/]	Percent drip loss after storage	Color score after air storage		
		1 day	2 days	3 days
1	1.60	3	3	4
1'	3.41	3	3	3
1"	3.36	3	3	4

a/ For scoring system, see VI, A-2.

b/ The average weight of samples was 1587 g.

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Table 6. Taste panel scores[a/] of phosphated vacuum-packaged and irradiated beef after storage in vacuum for 18 days and in air for 3 days at 38 F (fresh beef used as reference sample)

Sample No.	Treatment[b/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I	Av	6.0	6.3	5.5[c/]	4.3[d/]	4.9	5.0
		Range	4-8	3-8	2-7	1-7	2-7	3-7
1'	P-I	Av	6.2	6.5	5.7	4.5	4.9	5.3
		Range	3-8	4-8	2-8	1-7	1-9	2-7
2	0-0	Av	6.5	6.5	6.7[c/]	5.7[d/]	5.8	6.0
		Range	3-8	3-8	5-8	2-8	1-8	3-8
2'	0-0	Av	6.5	6.2	6.0	5.0	5.2	5.3
		Range	5-8	3-8	1-8	2-7	3-7	3-7

a/ For scoring system, see VI, A-5.

b/ Code of treatment:

P-I = See Table 5 caption.

0-0 = Fresh beef reference sample, not stored.

c/ Significant difference in flavor between No. 1 and 2.

d/ " " " texture between No. 1 and 2.

The treated and stored samples suffered a large amount of drip loss. The flavor and overall quality scores of the treated and stored beef were also slightly inferior to the fresh beef but only one flavor score of the treated sample was significantly lower than the fresh beef reference sample.

Experiment 4. Spraying and pumping of a large piece of beef with 13% TPP and holding for two hours at 38 F prior to cutting and vacuum-packaging:

MATERIALS AND METHODS

A U.S.D.A. Commercial grade bottom round secured from the Michigan State University Food Stores was used. One large cut was prepared without TPP treatment. The remaining bottom round was pumped with 13% TPP solution, and the meat surface was covered with 13% TPP solution by spraying. After a brief draining, the weight gain of the pumped portion was determined. It was then covered with polyethylene film and kept for two hours in a 38 F refrigerator. Three 3/4 inch thick slices and two large cuts with average weights of 570 g and 2082 g, respectively, were vacuum-packaged along with the non-phosphated cut. The packages were irradiated and stored at 38 F as previously done.

Drip losses were determined at end of 18 days vacuum storage. Color appearance of the samples was observed visually during the 3-day air storage. The eating quality of these samples was judged by a consumer-type taste panel with 20 judges.

RESULTS AND DISCUSSION

The results are given in Tables 7 and 8. A weight gain of 2.6% was obtained after pumping and spraying the beef with 13% TPP solution. Theoretically, about .34% TPP was added to the beef. As shown in previous experiments, however, the TPP level at different regions could be slightly higher or lower. The drip loss after 18 days storage averaged 2.30% for the treated slices, 1.71% for the treated large cuts and 2.65% for the non-phosphated sample. These results are very similar to those obtained in Experiment 2.

The color appearance of the TPP-treated samples was acceptable during the first three days air storage. The pH value of the beef before and after TPP-treatment was 5.55 amd 5.90, respectively. The non-phosphated sample, on the other hand, suffered more drip loss and turned brown more rapidly. The benefit of TPP treatment on color was very clear.

The taste panel results (Table 8) showed that the treated and stored samples received low scores in texture and juiciness. Their scores were significantly lower than those received by the fresh beef reference sample. Similar results were obtained in Experiment 3. The overall quality score of the fresh reference sample is also significantly higher than that of the treated samples. It should be pointed out that, in these experiments, the difference between the treated, stored samples and the fresh reference sample is more in texture and juiciness than in odor and flavor. It is not clear whether the phosphate treatment, or the irradiation, or the vacuum storage adversely affects texture and juiciness scores.

Table 7. Drip loss and color scores[a] of beef pumped and sprayed with 13% TPP solution and subsequently divided into portions and vacuum-packaged, irradiated with 100 krad and stored at 38 F for 18 days followed by 3 days air storage

Portion No.[b]	Treatment[c]	Kind of final cut	Drip loss after storage	Color score after air storage		
				1 day	2 days	3 days
1	P-I	Slice	2.09	2	2	3
1'	P-I	"	2.71	2	2	3
1"	P-I	"	2.10	2	2	3
2	P-I	Large cut	2.54	2	2	3
2'	P-I	"	.87	2	2	3
3	O-I	Large cut	2.65	3	4	4

a/ For scoring system, see VI, A-2.

b/ The average weights for each set of samples were as follows:

Portions 1, 1' and 1" - 570 g; Portions 2 and 2' - 2082 g; Portion 3 - 1923 g.

c/ Code of treatment:

P-I = See Caption of this table.

O-I = Same as above except no phosphate treatment and holding period at 38 F prior to vacuum-packaging.

Table 8. Taste panel scores[a/] of phosphated, vacuum-packaged and irradiated beef after storage in vacuum for 18 days and in air for 3 days at 38 F (fresh beef used as reference sample)

Sample No.	Treatment[b/] and cut		Cooked Color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I	Av	6.0	6.5	5.6	3.8[c/]	4.0[d/]	4.5[e/]
	(slice)	Range	1-8	4-8	3-8	1-8	1-8	2-7
2	P-I	Av	5.6	6.3	6.0	4.3[c/]	4.3[d/]	5.1
	(large cut)	Range	1-8	3-8	3-8	2-8	2-6	2-7
3	0-I	Av	6.2	6.5	5.5	4.1[c/]	4.7	4.9[e/]
	(large cut)	Range	2-9	5-9	2-8	1-8	2-8	1-8
4	0-0	Av	6.0	6.3	5.9	6.5[c/]	5.8[d/]	6.1[e/]
	(fresh)	Range	3-8	4-8	3-8	4-8	4-8	4-8

a/ For scoring system, see VI, A-5.

b/ Code of treatment:

P-I = See Table 5 caption.

0-I = Same as above, except no phosphate treatment and holding period prior to vacuum packaging.

0-0 = Fresh beef reference sample, not stored.

c/ Significant differences in texture between No. 1 and 4, No. 2 and 4, and No. 3 and 4.

d/ " " juiciness between No. 1 and 4, and No. 2 and 4.

e/ " " overall quality between No. 1 and 4 and No. 3 and 4.

C. Eating Quality of TPP-Treated and Irradiated Beef after Storage at 38 F for 18 days in Vacuum, holding in Air at 38 F for Three days and Freezing at -10 F for 30 Days

Experiment 5: Evaluation of eating quality of irradiated and stored beef using TBA (Thiobarbituric acid) value and taste panel scores as indicators:

MATERIALS AND METHODS

Nine pieces of U.S.D.A. Standard grade beef round 1/2 inch thick each were used in this experiment. Three slices were dipped in 13% TPP solution for 30 seconds, and three slices were not dipped. These samples were vacuum-packaged, irradiated with 100 krad and stored at 38 F for 18 days. Three more slices were vacuum-packaged and frozen at - 10 F for storage.

At the end of 18 days storage, the packages were opened, and representative samples taken for TBA value determination (22) after three days air storage. The remaining samples were frozen at -10 F for 30 more days. The frozen samples were thawed and the TBA values determined again. The eating quality of these samples was judged by a consumer-type taste panel with 20 judges.

RESULTS AND DISCUSSION

The TBA values and color scores of the samples are given in Table 9. The color appearances of the TPP-treated samples were better than those of the non-phosphated or frozen samples. The TBA values after 18 days vacuum storage and three days air storage at 38 F were generally low. However, the lowest TBA values were from the frozen samples. The TPP-treated samples had slightly

Table 9. TBA (Thiobarbituric acid) values[a] and color scores[b] of beef after 18 days vacuum storage, 3 days holding in air at 38 F and 30 days of frozen storage at -10 F

Sample No.	Treatment[c]	TBA value		Color score after air storage		
		18 + 3 days	18 + 3 + 30 days	1 day	2 days	3 days
1	P-I	.30	.28	1	1	1
1'	P-I	.60	.86	1	1	3
2	0-I	.50	.67	1	2	3
2'	0-I	1.0	1.35	2	3	3
3	0-F	.12	.21	2	3	3
3'	0-F	.12	.24	2	3	3

a/ TBA value is expressed as mg malonaldehyde per 1000 g meat.

b/ For color scoring system, see VI, A-2

c/ Code of treatment:

P-I = 13% TPP dip, vacuum packaged, irradiated with 100 krad, and stored at 38 F for 18 days followed by 3 days air storage and 30 days of frozen storage.

0-I = Same as above except no phosphate dip.

0-F = Frozen at 0 days without irradiation and phosphate treatment, sampled at 21 and 51 days.

lower TBA values than the non-phosphated samples. After 30 more days freezing storage, all samples tended to increase their TBA values slightly.

The taste panel scores are given in Table 10. The P-I samples received better scores than the O-I sample. A comparison between the TPP-treated samples and the frozen sample indicates that the P-I samples had higher texture and juiciness scores but lower flavor scores. Most obvious differences were found in juiciness and overall quality. Both the P-I and O-F samples were significantly better in juiciness than the O-I sample but only one P-I sample was significantly better in overall quality than the O-I sample.

Experiment 6: Evaluation of eating quality of irradiated and stored beef using TBA (Thiobarbituric acid) value and taste panel scores as indicator

MATERIALS AND METHOD

U.S.D.A. Commercial grade beef round was obtained from the Michigan State University Food Stores. As received, the pH of the beef was 5.85. Nine 1/2 inch thick slices were allowed to oxygenate for a few minutes before phosphate treatment. Three slices were treated with 13% TPP solution and irradiated along with three non-phosphated samples. Three slices were frozen and stored at -10 F.

The TBA value determination and the taste panel evaluation were carried out as described in Experiment 5.

RESULTS AND DISCUSSION

The TBA values and color scores are given in Table 11. The best color appearance of stored beef was again found from the P-I samples. During the TPP-treatment before storage, the surface of the TPP-treated beef became reddish purple rapidly. A difference in color between the TPP-treated and untreated beef was noticed after the treatment.

Table 10. Taste panel scores[a] of phosphated, vacuum packaged and irradiated beef after storage in vacuum at 38 F for 18 days followed by 3 days air storage and 30 days frozen storage at -10 F

Sample No.	Treatment[b]		Cooked color		Flavor	Texture	Juiciness	Overall quality
1	P-I	Av	6.2	5.7	5.4	5.4	5.5[c]	5.7[d]
		Range	4-8	3-7	1-8	1-7	3-7	3-7
1'	P-I	Av	6.0	5.9	5.3	5.4	5.4[c]	5.4
		Range	3-9	3-7	1-7	2-8	4-7	4-7
2	O-I	Av	6.1	5.5	5.0	4.2	3.9[c]	4.6[d]
		Range	3-9	2-7	2-7	1-7	2-6	3-7
3	O-F	Av	6.0	5.8	5.8	4.9	4.9[c]	5.4
		Range	4-8	3-7	1-8	1-7	3-8	1-8

a/ For scoring system, see VI, A-5.

b/ Code of treatment = Refer to c/, Table 9.

c/ Significant difference in juiciness between 1 & 2, 1' & 2, and 2 & 3.

d/ Significant difference in overall quality between 1 & 2.

Table 11. TBA (Thiobarbituric acid) value[a/] and color scores[b/] of beef after 18 days vacuum storage, 3 days holding in air at 38 F and 30 days of freezing at -10 F.

Sample No.	Treatment[c/]	TBA value		Color score after air storage		
		18 + 3days	18 + 3 + 30 days	1 day	2 days	3 days
1	P-I	.55	.24	1	2	3
1'	P-I	.35	.19	1	2	2
2	O-I	.96	1.11	1	2	2
2'	O-I	1.58	.59	2	2	3
3	O-F	.23	.14	2	2	3
3'	O-F	.23	.14	1	2	3

a/ TBA value is expressed as mg malonaldehyde per 1000 g meat.

b/ For color scoring system see VI, A-2.

a/ Code of treatment: Refer to c/, Table 9.

The TBA values of each sample follow the same pattern as that in Experiment 5 (Table 9). The frozen samples(0-F) had the lowest TBA values, while the 0-I samples had the highest TBA values. The change in TBA value after 30 days freezing storage was not significant in these samples.

The taste panel scores (Table 12) showed that the frozen sample received the highest scores in all quality aspects. The P-I samples in this case were not much different from the 0-I samples, and both received very low scores in flavor, texture and juiciness. However, since the total scores of the 0-F samples were not high, the actual difference in all quality aspects are not significant.

Experiment 7. Evaluation of eating quality of irradiated and stored beef using TBA value and taste panel scores as indicator:

MATERIALS AND METHODS

U.S.D.A. Commercial grade beef round was obtained from the Michigan State University Food Stores. Twelve 1/2 inch thick slices were prepared. Three slices were treated with 13% TPP solution and three with 13% TPP plus 0.4% ascorbic acid solution. The treated samples were vacuum-packaged along with three untreated slices. All were irradiated with 100 krad and stored at 38 F for 18 days. Three more slices were vacuum-packaged and frozen for the same period.

At the end of the storage period, all the samples were opened and rewrapped in O_2-permeable PVC film, and stored at 38 F for three days. The

Table 12. Taste panel scores[a/] of phosphated, vacuum-packaged and irradiated beef after storage in vacuum at 38 F for 18 days followed by 3 days air storage and 30 days freezing period

Sample No.	Treatment[b/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I	Av	5.3	5.8	5.2	3.9	4.1	4.7
		Range	2-7	4-8	2-7	1-6	1-5	2-7
1'	P-I	Av	5.0	5.3	4.9	3.9	4.1	4.5
		Range	1-7	4-8	1-7	1-7	1-6	1-7
2	O-I	Av	5.5	5.5	4.8	3.9	4.1	4.6
		Range	2-7	4-8	2-7	1-6	1-7	1-7
3	O-F	Av	5.7	6.0	5.8	4.6	4.8	5.6
		Range	4-7	4-8	4-8	1-7	1-7	2-7

a/ For scoring system, see VI, A-5.

b/ Code of treatment, Refer to c/, Table 9.

color appearance of the samples was observed during the three days air storage and the TBA values determined at the third day.

After three days air storage, the samples were frozen at -10 F for 30 days. The TBA values were again determined and the eating quality was evaluated by a teast panel of 20 judges.

RESULTS AND DISCUSSION

The TBA values and color scores after storage are given in Table 13. Relatively high TBA values were obtained for these samples after storage in vacuum for 18 days and in air for three days. After freezing at -10 F, TBA values in all samples increased. It should be noted, however, that the samples treated with both TPP and ascorbic acid had much higher TBA values than those treated with TPP alone. Similar results were obtained previously (pp 15-17, First Quarterly Report for the period from June 16, 1971 to September 15, 1971). It is believed that addition of ascorbic acid interferes with the TBA determination. A true oxidative change of the P-A-I apparently is not illustrated by the TBA determination. The TPP-treated samples also gave rise to lower TBA values than the non-phosphated irradiated samples.

The color scores indicated that samples treated with TPP, or TPP plus ascorbic had satisfactory color appearance after three days air storage at 38 F. Without phosphate treatment, the surface color tended to turn brown rapidly.

Table 13. TBA (Thiobarbituric acid) values[a] and color scores[b] of beef after 18 days vacuum storage, 3 days holding in air at 38 F and 30 days of frozen storage at -10 F

Sample No.	Treatment[c]	TBA value		Color score after air storage		
		18 + 3 days	18 + 3 + 30 days	1 day	2 days	3 days
1	P-I	1.53	2.28	1	1	1
1'	P-I	.49	.71	1	1	1
2	P-A-I	1.64	2.35	1	1	2
2'	P-A-I	1.63	2.94	1	1	1
3	O-I	2.18	2.15	1	2	3
3'	O-I	1.26	2.49	1	2	3

a/ TBA value is expressed as mg malonaldehyde per 1000 g meat.

b/ For color scoring system, see VI, A-2.

c/ Code of treatment - Refer to c/ Table 9.

P-A-I = 13% TPP plus 0.4% ascorbic acid as a dip.

The taste panel scores are given in Table 14. P-I and P-A-I samples had similar scores as 0-F, and all three samples had better quality scores than 0-I, the non-phosphated, irradiated sample. The odor and flavor scores of P-I and P-A-I were as good as those of 0-F although P-I and P-A-I had much higher TBA value than 0-F. Significant differences in texture and overall quality were found between 0-F and 0-I.

Table 14. Taste panel scores[a] of beef treated, irradiated and stored at 38 F for 18 days followed by 3 days air storage and 30 days frozen storage at -10 F

Sample No.	Treatment[b]	Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I	6.8	6.7	5.9	5.6	5.6	5.8
		4-8	5-8	3-8	3-8	3-8	4-7
2	P-A-I	6.8	6.6	5.8	5.8	6.0	5.8
		4-8	5-8	3-8	3-8	3-8	4-8
3	0-I	6.3	5.9	5.0[c]	4.5	5.2	5.1[d]
		4-8	3-8	3-8	1-7	2-7	3-8
4	0-F	6.5	6.5	6.2[c]	5.3	5.8	6.1[d]
		4-8	4-8	4-8	1-8	2-9	3-8

a/ For scoring system, see VI, A-5.

b/ Code of treatment: Refer to c/ Table 9 and Table 13.

c/ Significant difference in flavor between 3 and 4.

d/ " " " overall quality between 3 and 4.

D. Treatment of Lamb Round with Sodium Tripolyphosphate (TPP)

Experiment 8: 13% TPP dip of lamb round of unknown post-mortem age:

MATERIALS AND METHODS

U.S.D.A. Choice grade lamb legs of unknown post-mortem age were obtained from the Michigan State University Food Stores. The lamb rounds were trimmed of fat and separated into three major portions, viz. top round, bottom round and knuckle and the pH's of each portion determined. One set of samples was weighed, and dipped in 13% TPP solution for 45 seconds. After draining, the dipped samples were vacuum-packaged along with the non-phosphated samples. All were then irradiated with a dose of 100 krad at 40 F and stored at 38 F for 18 days. Phosphate contents of the treated and untreated samples were determined before packaging.

At the end of vacuum-storage, all packages were opened, rewrapped with O_2-permeable PVC film, and stored at 38 F for three days. The color appearance of each sample was observed visually during storage. After three days, the samples were cut into 1/2 inch steaks and evaluated by a consumer-type taste panel with 20 judges.

RESULTS AND DISCUSSION

The initial pH, weight gain and TPP uptake after dipping, drip loss and color scores are recorded in Table 15. Different pH's were found from different portions of lamb round. Knuckle had the highest pH among three meat portions. Similar differences in pH's were found also in beef round. After

Table 15. Initial pH, weight gain and phosphate uptake after dipping, drip loss, color scores[a/] of lamb stored in vacuum at 38 F for 18 days followed by 3 days air storage at 38 F

Sample[b/] No.	Meat[c/] portion	Initial pH	Treatment[d/]	Weight gain after dipping	TPP[e/] uptake after dipping	Drip loss after storage	Color score after storage 1 day	2 days	3 days
1	T.R.	5.74	P-I	1.09%	.19%	2.15%	1	1	1
1'	B.R.	5.85	P-I	1.98%	.27%	2.49%	1	1	2
1"	Kn.	6.40	P-I	1.54%	.25%	.91%	2	3	4
2	T.R.	5.70	0-I	- -	- -	3.59%	1	1	2
2'	B.R.	5.81	0-I	- -	- -	1.99%	1	1	1
2"	Kn.	6.14	0-I	- -	- -	4.58%	2	3	3

a/ For scoring system, see VI, A-2.

b/ The average weight of samples was 520 g.

c/ T.R. = Top round; B.R. = Bottom round; Kn = Knuckle.

d/ Code of treatment: P-I = 13% TPP dip for 45 seconds, vacuum-packaging, irradiation with 100 krad, storage at 38 F for 18 days followed by 3 days air storage.
0-I = Same as above except no phosphate dip.

e/ Phosphate uptake after dipping and pumping is expressed as percentage TPP retained by lamb.

dipping in 13% TPP solution for 45 seconds, the dipped samples gained from 1.09 to 1.98% of their original weights. The TPP uptake, however, was below 0.3%.

The drip loss of TPP-treated and untreated samples after 18 days of storage obviously were different. The TPP-treated samples had an average drip loss of 1.85%, while the non-phosphated samples had an average drip loss of 3.39%. Dipping with TPP solution, therefore, is advantageous to lamb round for three weeks storage.

The color appearance of the lamb round after storage was generally acceptable. The difference between the TPP-treated and untreated samples was not very great, probably because of the low pigment concentrations.

The taste panel scores as given in Table 16 showed no significant difference among samples. The non-phosphated knuckle sample (Sample 2) appeared to have the highest scores in all quality aspects, but other samples also scored better than marginal score, 5. Sensory evaluation of lamb with a group of taste panelists, some of whom do not eat lamb regularly, may have been less discriminating than an evaluation of beef.

Table 16. Taste panel scores[a/] of lamb treated and stored in vacuum at 38 F for 18 days followed by 3 days air storage at 38 F

Sample No.	Meat[b/] portion	Treatment[c/]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	B.R.	P-I	Av.	6.4	5.6	5.9	6.6	6.6	5.9
			Range	4-8	2-9	2-9	4-8	5-9	3-8
1'	Kn.	P-I	Av	5.8	5.6	5.9	6.3	6.6	5.8
			Range	4-8	4-8	2-9	4-9	5-8	3-8
2	B.R.	O-I	Av	6.4	5.7	5.4	6.2	6.2	6.0
			Range	4-8	3-7	3-8	4-8	4-8	4-8
2'	Kn.	O-I	Av	6.6	6.1	6.1	6.6	6.8	6.2
			Range	5-8	3-8	4-8	5-8	4-9	5-7

a/ For scoring system, see VI, A-5.

b/ B.R. = Bottom round; Kn = Knuckle.

c/ Code of treatment, see d/ , Table 15.

Experiment 9: 13% TPP dip of lamb round of unknown post-mortem age

MATERIALS AND METHODS

U.S.D.A. Choice grade lamb legs of unknown post-mortem age were obtained from the Michigan State University Food Stores. The lamb rounds were treated the same as described in Experiment 8.

Initial pH's, weight gain and TPP uptake after draining, drip loss and color scores after 18 days storage at 38 F were determined. An evaluation by a consumer-type taste panel was carried out after three days additional storage in air.

RESULTS AND DISCUSSION

The initial pH's, weight gains and TPP uptakes after dipping, drip losses and color scores are recorded in Table 17. The pH's of each meat portion were different by 0.4 to 0.5 pH unit. The knuckle again had the highest pH among the three portions. Weight gains varied from .91% to 2.14%, and TPP uptakes varied from .14% to .25%. The average drip loss after storage was 3.49% for the TPP-treated samples and 4.37% for the non-phosphated samples. The phosphate treatment resulted in a lower drip loss after storage, although the average drip losses for lamb rounds in this experiment were higher than those in Experiment 8.

Color appearance of the treated and untreated lamb was identical. The change in surface color of lamb was not significant in this experiment.

The taste panel results are given in Table 18. Scores in each quality aspect are generally higher than marginal score, 5. The P-I samples appeared to

Table 17. Initial pH, weight gain and phosphate uptake after dipping, drip loss, color scores[a] of lamb stored in vacuum at 38 F for 18 days followed by 3 days air storage at 38 F

Sample No.[b]	Meat portion[c]	Initial pH	Treatment[d]	Weight gain after dipping	TPP uptake after dipping[e]	Drip loss after storage	Color score after air storage		
							1 day	2 days	3 days
1	T.R.	6.02	P-I	.91%	.14	4.34	1	1	2
1'	B.R.	5.91	P-I	1.51%	.25	3.51	1	1	2
1"	Kn.	6.58	P-I	2.14%	.16	2.63	1	1	2
2	T.R.	6.00	0-I	- -	- -	5.79	1	1	2
2'	B.R.	5.70	0-I	- -	- -	2.41	1	1	2
2"	Kn.	6.23	0-I	- -	- -	5.00	1	1	2

a/ For scoring system, see VI, A-2.

b/ The average weight of samples was 584 g.

c/ T.R. = Top round; B.R. = Bottom round; Kn = Knuckle.

d/ Code of treatment - See d/ Table 15.

e/ Phosphate uptake after dipping is expressed as percentage TPP retained by lamb.

Table 18. Taste panel scores[a] of lamb treated and stored in vacuum at 38 F for 18 days followed by 3 days air storage at 38 F

Sample No.	Meat portion[b]	Treatment[c]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	B.R.	P-I	Av	6.1	6.1	6.6	6.7	6.4	6.7
			Range	4-8	4-8	4-8	5-8	4-8	5-8
1'	Kn	P-I	Av	6.3	6.8	6.8	7.0[d]	7.3[e]	6.7[f]
			Range	4-9	4-9	5-9	4-9	5-9	4-9
2	B.R.	O-I	Av	6.1	6.0	5.9	5.9[d]	6.0[e]	5.8[f]
			Range	3-9	4-9	4-8	3-9	3-8	4-8
2'	Kn	O-I	Av	6.4	6.1	6.1	6.7	7.2[e]	6.4
			Range	4-8	4-8	3-8	5-9	5-9	4-8

a/ For scoring system, see VI, A-5.

b/ B.R. = Bottom round; Kn = Knuckle.

c/ Code of treatment = Refer to c/, Table 15.

d/ Significant difference in texture between No. 1' and 2.

e/ " " " Juiciness between No. 1' and 2 and No. 2 and 2'.

f/ " " " overall quality between No. 1' and 2.

be more acceptable to the taste panel than the 0-I samples. Significant differences in texture, juiciness and overall quality were found between Sample 1' and 2. The knuckle samples received higher scores than the bottom round samples in both TPP-treated and untreated samples.

Summarizing the results of Experiment 8 and 9, it is concluded that TPP treatment is beneficial in reducing the drip loss and maintaining the color of lamb after storage. Both TPP treatment and irradiation do not affect the eating quality of lamb to any significant extent. While the texture of beef is affected by treatment and storage, that of lamb is less affected. This confirms the view that a process which is successful in stabilizing fresh beef also will be successful with meats from other species and justifies the concentration of effort on beef.

E. Treatment of Pork Chops with Sodium Tripolyphosphate

Experiment 10: 10% TPP dipping of pork with unknown post-mortem age

MATERIALS AND METHODS

Eighteen pieces of 1/2 inch thick pork chops were obtained from the Michigan State University Food Stores. The samples were weighed, and initial pH determined. Six pieces were dipped in 10% TPP solution for 30 seconds. The pH and TPP uptake after dipping were determined. These samples were individually vacuum-packaged along with six non-phosphated samples, irradiated with 100 krad at 40 F and stored at 38 F for 18 days. Three pieces were packaged and frozen at -10 F without any treatment and three more were packaged and kept at 28 F for 18 days. At the end of the storage, all packages were opened and rewrapped with O_2-permeable PVC film. Their color appearances were observed visually. The samples were evaluated by a consumer-type taste panel three days later.

RESULTS AND DISCUSSION

The pH's of the pork sample before and after TPP-treatment were 6.75 and 7.08, respectively. These values are abnormally high. About 0.3% TPP was absorbed after 30 second dipping in 10% TPP solution. After 18 days of storage at 38 F, the drip loss from both treated and untreated pork samples was negligible. The color appearance of all samples were identical, and the color change, if any, was not noticeable. Due to the high pH, the surface color appeared to be dark red. The cut surface of the TPP-treated bone became dehydrated and turned brown after storage.

Taste panel results are given in Table 19. All samples received favorable scores in all aspects. The 0-R (refrigerated at 28 F) samples appeared to have the highest quality among all. The P-I samples were better than the 0-I samples and had similar scores to the 0-F (frozen at -19 F) samples. However, no significant differences in quality were found among samples.

Experiment 11: 13% TPP dip of pork with unknown post-mortem age

MATERIALS AND METHODS

Eighteen pieces of 1/2 inch thick boneless pork chops were obtained from the Michigan State University Food Stores. The samples were handled and treated in the same manner as described in Experiment 10, except that the TPP dipping solution was 13%. pH's before and after TPP treatment, TPP uptake after dipping, color appearance and drip loss after storage were determined. A taste panel was carried out after three days air storage.

RESULTS AND DISCUSSION

The pH's of the pork sample before and after TPP-treatment were 5.65 and 5.90, respectively. These values are normal. The average TPP-uptake after 30 seconds dipping was .31%. As in Experiment 10, the color appearance of the pork sample after 18 days vacuum storage was satisfactory. Amount of drip loss was negligible.

The taste panel results are given in Table 20. The 0-R (refrigerated at 28 F) samples again received the highest scores in nearly all quality aspects. The frozen samples (0-F) had low scores in every aspect but odor. The TPP-treated P-I samples were scored better than the non-phosphated 0-I samples.

Table 19. Taste panel scores[a] of treated or untreated stored pork chops

Sample No.	Treatment[c] and no. of replicates[b]		Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I (6)	Av	6.5	6.2	6.2	6.7	6.5	6.4
		Range	3-8	3-8	2-8	4-8	4-8	4-8
2	0-I (6)	Av	6.6	5.9	5.9	6.5	6.2	6.1
		Range	4-8	2-8	2-8	4-8	4-8	3-8
3	0-F (3)	Av	7.1	6.6	6.1	6.4	6.7	6.5
		Range	5-8	1-8	1-8	1-8	5-8	1-8
4	0-R (3)	Av	6.5	6.6	6.3	6.8	6.9	6.5
		Range	4-8	4-8	3-8	4-8	5-8	3-8

a/ For scoring system, see VI, A-5.

b/ The average weight of samples was 195 g.

c/ Code of treatment:

P-I = 10% TPP dip for 45 sec, vacuum-packaging, irradiation with 100 krad and storage at 38 F for 18 days followed by 3 days air storage.

0-I = Same as above except n o phosphate dip.

0-F = Frozen at -10 F for 18 days followed by 3 days air storage at 38 F.

0-R = Vacuum storage at 28 F for 18 days followed by 3 days air storage at 38 F.

Table 20. Taste panel scores[a/] of treated or untreated stored pork chops

Sample No.[b/]	Treatment[c/] and no. of replicates	Cooked Color	Odor	Flavor	Texture	Juici-	Overall quality
1	P-I (6) Av	7.0	6.3	6.5	6.8	6.9	6.6
	Range	5-9	4-9	2-9	2-9	3-9	3-9
2	O-I (6) Av	6.3	6.3	6.5	6.7	6.3	6.5
	Range	3-9	3-9	2-9	2-9	3-9	3-8
3	O-F (3) Av	6.4	6.5	5.7	6.7	6.3	5.9
	Range	2-9	2-9	2-9	4-9	3-9	3-8
4	O-R (3) Av	6.4	6.2	6.5	7.1	7.3	6.8
	Range	3-9	3-9	2-9	3-9	3-9	3-9

a/ For scoring system, see VI, A-5.

b/ The average weight of samples was 206 g.

c/ Code of treatment: See e/ Table 19. TPP solution concentration 13% in Experiment 11.

In conclusion, pork chop, after TPP-treatment, irradiation with 100 krad and storage at 38 F for 18 days, does not produce noticeable amount of drip in packages, nor does it turn brown to a noticeable extent. Taste panel results indicated that pork chops stored at 28 F have better eating quality than those stored at 38 F after irradiation or frozen at -19 F. Samples treated with TPP and irradiated are more acceptable than the non-phosphated irradiated samples or frozen samples. The frozen samples, however, appear to gain higher scores in odor aspect.

F. Treatment of Chicken with Sodium Tripolyphosphate

Experiment 12: Dipping of chicken parts with 5% or 13% TPP

MATERIALS AND METHODS

Ice-packed chicken fryers of unknown history were obtained from the Michigan State University Food Stores. Each fryer was quartered into two leg portions and two wing portions. Each chicken part was weighed individually. The TPP-treatment was carried out with 13% TPP and 5% TPP solutions. To eliminate variations among chickens, half of the chicken parts from the same bird (1 leg and 1 wing) were treated with TPP and the other half untreated. Therefore, three leg portions and wing portions each (from three chickens) were dipped in 13% TPP solution for 45 seconds and vacuum-packaged individually, while the remaining half chicken including three leg portions and three wing portions were also vacuum-packaged without TPP treatment. Another set of three chickens was treated with 5% TPP solution for 60 minutes and vacuum-packaged in the same manner as

described for the 13% TPP dipping. The vacuum-packaged chicken parts were irradiated with 100 krad at 40 F and stored at 38 F for 18 days. Three more chickens were frozen at -10 F and stored for the same length of time. At the end of 18 days storage, all packages were opened and rewrapped with O_2-permeable PVC film. The drip loss and color appearance were examined. After three days storage at 38 F, the chicken parts were broiled at 325 F for 35 minutes and evaluated by a consumer-type taste panel with 20 judges.

RESULTS AND DISCUSSION

Due to the low initial pigment concentration in chicken, the color change of chicken was not critical. Both short and relatively long dipping period of TPP solution might be applicable to chicken treatment. Therefore, both 13% dipping for 45 seconds and 5% dipping for 60 minutes were tested. The results are given in Table 21.

After 18 days storage, the color appearances of all chicken samples did not vary greatly, and in general were quite acceptable. The drip losses from each treatment, however, varied to a certain extent. In samples treated with 13% TPP, drip losses ranged from 1.26% to 2.64% (average of six samples was 2.00%) with 5% TPP, drip losses ranged from 2.79% to 6.76% (average of six samples was 3.81%) with only irradiation, drip losses ranged from 1.50% to 5.10% (average of 12 samples was 2.68%), and in frozen samples, drip losses ranged from 3.22% to 6.11% (average of six samples was 3.94%) (Table 21). Higher drip losses were resulted from treatment with 5% TPP for 60 minutes. Dipping in 13% TPP solution

Table 21. Average drip losses and taste panel scores[a/] of chicken after treatment[b/] and vacuum storage for 18 days followed by 3 days air storage

Sample No.	Treatment and number of replicates	Average drip loss after storage %	Score	Cooked color	Odor	Flavor	Texture	Juici-ness	Overall quality
1	P-I (6)	2.00	Av	7.1	6.5	6.6	7.2	7.1	6.9
	13% TPP		Range	4-9	2-9	2-8	4-9	4-9	4-8
2	P-I (6)	3.81	Av	6.9	7.1	6.4	6.6	6.7	6.6
	5% TPP		Range	4-9	4-9	1-9	3-9	4-8	2-8
3	0-I (12)	2.68	Av	7.0	7.1	6.6	7.1	6.7	6.8
			Range	3-9	5-9	4-8	4-8	4-8	5-8
4	0-F (6)	3.94	Av	6.8	6.6	6.2	6.5	6.2	6.4
			Range	3-9	4-8	1-8	4-9	4-8	2-8

a/ For scoring system, see VI, A-5.

b/ Treatment:

P-I = 13% dip for 45 seconds or 5% TPP dip for 60 minutes, vacuum-packaging, irradiation with 100 krad and storage at 38 F for 18 days followed by 3 days air storage.

0-I = Same as above but no phosphate treatment.

0-F = Frozen storage at -10 F.

for 45 seconds, on the contrary, provided samples with the smallest drip losses after storage.

The taste panel scores are given in Table 21. Samples treated with 13% TPP received the highest scores in all quality aspects but odor. The irradiated non-phosphate samples were rated second best and slightly better than those treated with 5% TPP solution. The frozen samples (0 F) had the poorest scores among all samples. The scores received by these samples, in general, are better than marginal score 5. It was noteworthy that the texture scores of the TPP-treated chickens, unlike the TPP-treated beef, were always better than those of the non-phosphated samples.

Experiment 13: Dipping of chicken parts with 5% or 13% TPP

MATERIALS AND METHODS

This experiment is a replicate of the last experiment; materials and methods are as given for Experiment 12.

RESULTS AND DISCUSSION

The results are given in Table 22. The color appearances of all samples after 18 days vacuum storage and three days air storage were generally acceptable. Variation in color was not noticeable. Drip losses ranged from 0.71% to 3.51% (average of six samples was 1.99%) in samples treated with 13% TPP, ranged from 1.08% to 5.46% (average of six samples was 2.52%) in samples treated with 5% TPP, ranged from 1.92% to 6.98% (average of 12 samples was 3.37%) in irradiated non-phosphated samples and ranged from 3.19% to 4.81% (average of six samples was 4.07%)

Table 22. Average drip losses and taste panel scores[a/] of chicken after treatment[b/] and vacuum storage for 18 days followed by 3 days air storage

Sample No.	Treatment and number of replicates	Average drip loss after storage %	Score	Cooked color	Odor	Flavor	Texture	Juiciness	Overall quality
1	P-I (6)	1.99	Av	6.9	5.5	5.8	6.8	6.8	6.0
	13% TPP		Range	5-9	3-8	1-9	3-9	5-9	3-9
2	P-I (6)	2.52	Av	6.4	5.7	5.8	7.3	6.8	6.0
	5% TPP		Range	4-8	2-8	2-9	5-9	5-9	3-8
3	0-I (12)	3.37	Av	7.0	5.7	5.7	6.8	6.5	6.0
			Range	4-8	2-8	2-9	5-9	5-9	2-8
4	0-F (6)	4.07	Av	6.7	6.5	6.1	6.8	7.0	6.5
			Range	4-8	5-8	3-8	3-9	5-9	3-8

a/ For scoring system, see VI, A-5.

b/ Treatment:

P-I = 13% dip for 45 seconds or 5% TPP dip for 60 minutes, vacuum-packaging, irradiation with 100 krad and storage at 38 F for 18 days followed by 3 days air storage.

0-I = Same as above but no phosphate treatment.

0-F = Frozen storage at -10 F.

in samples frozen for 18 days (Table 22). Lower drip losses were again resulted from 13% TPP dip.

The taste panel results are shown in Table 22. No significant difference in scores was found among samples. But the frozen chicken was obviously superior to the other treated samples. Scores in odor and overall quality of the frozen sample were mugh higher than those of the treated samples. It should be pointed out that an off-flavor from the treated samples was noted during broiling. It was likely that the chickens used in this experiment might have had a high initial microbial count. Due to the highly perishable nature of the chickens, further experiments should be carried out using freshly dressed chickens.

G. Objective Measurement of Pigment Concentrations with a Bausch & Lomb 505 Reflectance Spectrophotometer:

Experiment 14: Change of relative concentrations of beef pigments during air storage at 38 F:

MATERIALS AND METHODS

U.S.D.A. Good grade eye-of-round of unknown history was obtained from Michigan State University Food Stores. The beef was cut into pieces 2.5 in by 2.5in and 1/2 in thick. After oxygenation in air, the slices were treated in the same manner as previously described. Six slices were dipped in 10% TPP solution for 45 seconds, vacuum-packaged, irradiated with 100 krad at 40 F. Six slices were treated the same way except there was no phosphate treatment. After irradiation, three vacuum-packaged samples from each treatment were opened and rewrapped with

O_2-permeable PVC film, and relative pigment concentrations were measured spectrophotometrically immediately after air exposure and daily for four days. Control samples in triplicate were also measured along with the treated samples.

The remaining three vacuum-packaged samples from each treatment were stored at 38 F for 18 days. At the end of the storage period, the pigment concentrations were measured in the same manner as the non-stored samples. Measurements were made immediately after air exposure and daily for four days.

The procedure used in the determination of relative pigment concentration was the same as the one used previously. For a detailed discussion of the method, see Annual Report of this contract for the period of Feb. 15, 1967 to Feb. 14, 1968 (20).

RESULTS AND DISCUSSION

The results are listed in Table 23. The pigment concentrations reported are averages of triplicated samples. The untreated control samples showed very stable pigment concentrations for the first four days. About 12 to 14% metmyoglobin was found in these samples, and myoglobin was entirely converted to oxymyoglobin. The vacuum-packaged and irradiated samples had purple color appearance immediately after the treatment. As shown in Table 23, the concentration of myoglobin was relatively high shortly after irradiation under vacuum, but after one day of air exposure, myoglobin was completely converted into oxymyoglobin. No difference was observed among the control samples and the irradiated samples up to the fourth day. On the fifth day, the concentration of metmyoglobin rapidly

Table 23. Relative concentrations of beef pigments upon exposure to air for 5 days after treatment[a/] or after treatment and storage

Days air storage	Treatment 0-0 Mb[b/]	0-0 MbO_2[c/]	0-0 MMb[d/]	0-I Mb	0-I MbO_2	0-I MMb	P-I Mb	P-I MbO_2	P-I MMb
	Pigment concentrations measured without vacuum storage								
1	0%	86%	14%	31%	58%	11%	24%	54%	22%
2	0	88	12	0	89	11	0	86	14
3	0	88	12	0	88	12	0	88	12
4	0	87	13	0	93	7	0	85	15
5	0	86	14	0	47	53	0	51	49
	Pigment concentration measured after 18 days vacuum storage at 38 F								
1				13	21	66	16	55	29
2				5	35	60	19	39	42
3				7	39	54	0	69	31
4				6	37	57	0	61	33
5				0	42	58	0	58	42

a/ Code of treatment:
P-I = Samples dipped in 10% TPP solution for 45 seconds, vacuum-packaged, irradiated with 100 krad.
0-I = Samples treated in the same manner as above except no phosphate dipping.
0-0 = Samples without any treatment and storage.

b/ Mb = Myoglobin

c/ MbO_2 = Oxymyoglobin

d/ MMb = Metmyoglobin

increased and the sample turned brown thereafter.

After the irradiated samples were stored at 38 F for 18 days, the proportion of metmyoglobin increased markedly. In the non-phosphated samples (0-I), metmyoglobin increased from 11% to 66% shortly after air exposure. In the subsequent days of air exposure, the amount of oxymyoglobin increased slightly at the expense of both myoglobin and metmyoglobin. However, the concentrations of metmyoglobin remained high.

The TPP-treated samples did not show very much difference from the non-phosphated samples if not stored. But after 18 days vacuum storage, the TPP-treated samples obviously had a much greater amount of oxymyoglobin and a much smaller amount of metmyoglobin than the non-phosphated samples. Upon air exposure for three days, the TPP-treated samples contained 69% oxymyoglobin and 31% metmyoglobin, which produced a bright red appearance, while the non-phosphated samples were a dull red due to high percentage of metmyoglobin (7% mb, 39% mbO_2 and 54% mmb). These objective measurements confirm earlier subjective color observations that TPP-treatment is beneficial in retaining the desirable surface color when meat is stored for a relatively long period. However, on exposure to air, the proportion of metmyoglobin increases gradually and the color becomes a dull red. Eventually it will become brown. Thus the treated and stored meat when exposed to air suffers the same color deterioration as untreated meat. This performance is considered desirable by the U.S.D.A. in order to avoid any consumer deception.

H. Microbiological Studies of Irradiated and Stored Beef

The procedure developed for the treatment of red meats and poultry is sufficiently different from past practices as to raise questions about its effect on the microbiological outgrowth pattern. Concerns of two kinds exist: a) the possibility of introducing a health hazard, and b) the alteration of the character of the ultimate spoilage of the product in a way as not to be recognized as spoilage by the consumer. For these reasons it was desirable to develop some information regarding the microbial outgrowth.

The objective of this study was to determine the presence or absence of certain organisms on beef after treatment and storage in accordance with the developed procedure.

Experiment 15: Microbial outgrowth flora of treated and stored beef:

MATERIALS AND METHODS

U.S.D.A. Good Grade beef of unknown post-mortem age was secured from the Michigan State University Food Stores. Trimmable outside fat was removed. Cubes approximately 1 X 1 X 3/4 inch were prepared from the eye of the round (semitendinosus muscle). In cubing the beef it was first firmed by partial freezing and then cut into 3/4 inch slices. The slices were placed on a wooden cutting board so constructed with knife guides as to permit easy cutting into cubes of one inch cross section. Two cubes were employed for test sample and together weighed approximately 25 grams.

The beef cubes were dipped for one minute in a 10% TPP solution and then drained for about 10 minutes. Two cubes were vacuum-packaged, irradiated with a dose of 100 krad, and stored at 40 F for 21 days.

Samples were taken at 0, 10 and 21 days. After 21 days of vacuum storage, one set of samples was re-packaged in an oxygen-permeable film (Plasticized Stretch Polyvinyl Chloride manufactured by Dow) and then stored at 40 F for five days. The oxygen-permeable film employed was a typical fresh meat film. Each variable was triplicated.

The microbiological analysis consisted of determination of total counts, characterization of representative isolates from total plate counts in terms of percentages of the following:

- Gram positive
  - Cocci
    - Catalase positive
    - Catalase negative
  - Rods - non-sporulating
    - Catalase positive
    - Lactobacillus
- Gram negative
  - Rods
- Yeasts
- Unknown

and determination of the presence of the following organisms: Salmonella, coliforms, and fecal coliforms, Coagulase positive Staphylococcus aureus and Clostridium perfringens. Procedures employed closely followed those given in the publication: "Microbiological Specifications and Testing Methods for Irradiated Foods" of the International Atomic Energy Agency (1).

Any difference from the I.A.E.A. methods was of a minor nature and generally was occasioned by the nature of the sample being examined. Such modifications were in accord with the U. S. Department of Agriculture methods (2) or those of the American Public Health Association (3).

Studies were confined to determination of natural flora. Except for checking methods, no product was inoculated with microorganisms.

RESULTS AND DISCUSSION

Total bacteria counts are given in Table 24. Coliforms found are reported in Table 25. Fecal coliforms found are reported in Table 26. Clostridium perfringens bacteria found are reported in Table 27. Salmonella bacteria found are reported in Table 28. Coagulase positive Staphylococcus aureus found are reported in Table 29.

An attempt was made to classify the organisms found on total count plates. Not all organisms were identified. Table 30 shows the findings.

The 0-day storage samples demonstrate the effect of irradiation in reducing the initial total count (Table 24). Counts of all samples increase with storage time. At 21 days the difference between non-irradiated and irradiated

Table 24. Total bacterial counts per gram of treated and stored beef

Days storage	Replicate No.	Treatment[a] 0-0	P-0	0-I	P-I
0					
Mesophiles	1	1.2×10^4	5.2×10^3	7.5×10	2.2×10^2
	2	1.2×10^5	2.4×10^5	1.3×10^3	8.1×10^3
	3	3.0×10^4	1.7×10^4	1.4×10^3	1.0×10^3
Psychrophiles	1	1.6×10^3	5.8×10^2	$< 5 \times 10$	2.5×10
	2	1.1×10^4	1.3×10^5	6.4×10^2	1.4×10^3
	3	1.3×10^4	1.2×10^4	1.4×10^2	1.3×10^2
10 (Vacuum)					
Mesophiles	1	8.7×10^7	1.1×10^7	2.0×10^2	4.0×10^3
	2	2.9×10^7	3.5×10^7	1.5×10^5	1.2×10^5
	3	1.1×10^7	3.4×10^7	3.2×10^3	4.2×10^5
Psychrophiles	1	9.1×10^7	1.2×10^7	$< 1.0 \times 10^2$	5.8×10^3
	2	3.2×10^7	3.9×10^7	4.6×10^4	5.6×10^5
	3	1.6×10^7	3.1×10^7	4.8×10^3	7.7×10^5
21 (Vacuum)					
Mesophiles	1	2.1×10^8	1.6×10^8	2.7×10^6	6.3×10^6
	2	1.8×10^8	2.7×10^8	1.1×10^7	3.0×10^7
	3	1.1×10^8	1.3×10^8	3.2×10^4	2.7×10^7
Psychrophiles	1	1.8×10^8	1.8×10^8	1.2×10^7	1.3×10^7
	2	1.8×10^8	4.6×10^8	1.2×10^7	5.8×10^7
	3	1.3×10^8	1.3×10^8	3.5×10^4	2.6×10^7
26 (21 Vac, 5 Air)					
Mesophiles	1	1.3×10^{10}	9.7×10^9	1.5×10^8	1.0×10^8
	2	5.0×10^9	2.3×10^9	1.0×10^9	5.6×10^8
	3	7.6×10^9	9.0×10^9	1.6×10^6	5.4×10^8
Psychrophiles	1	1.2×10^{10}	1.2×10^{10}	1.8×10^8	1.0×10^9
	2	6.8×10^9	2.6×10^9	1.9×10^9	2.2×10^9
	3	5.8×10^9	8.8×10^9	1.8×10^6	9.6×10^8

[a] Treatment code:
0-0 = No treatment
P-0 = TPP dip only
0-I = Irradiation only
P-I = TPP dip and irradiation

Table 25. Coliform bacteria in treated and stored beef

Days storage	Replicate No.	Organisms per gram (most probable number) Treatment[a/] 0-0	P-0	0-I	P-I
0 (Vacuum)	1	9.3	0.4	< 0.3	< 0.3
	2	4.3	46	< 0.3	< 0.3
	3	9.3	24	< 0.3	< 0.3
10 (Vacuum)	1	11,000	11,000	< 0.3	< 0.3
	2	0.9	0.4	< 0.3	< 0.3
	3	46	9.3	< 0.3	0.4
21 (Vacuum)	1	> 110,000	>110,000	< 0.3	< 0.3
	2	0.7	46,000	< 0.3	< 0.3
	3	2.3	700	< 0.3	> 1,100
26 (21 Vac; 5 air)	1	1,500,000	11,000,000	15	< 0.3
	2	0.4	1,500	< 0.3	< 0.3
	3	2.3	> 1,100,000	< 0.3	< 0.3

a/ Treatment code:

0-0 = No treatment

P-0 = TPP dip only

0-I = Irradiation only

P-I = TPP dip and irradiation

Table 26. Fecal coliform bacteria in treated and stored beef

Days storage	Rep. No.	Organisms per gram (most probable number) Treatment[a] 0-0	P-0	0-I	P-I
0 (Vacuum)	1	4.3	< 0.3	< 0.3	< 0.3
	2	< 0.3	< 0.3	< 0.3	< 0.3
	3	4.3	2.3	< 0.3	< 0.3
10 (Vacuum)	1	0.7	0.4	< 0.3	< 0.3
	2	< 0.3	< 0.3	< 0.3	< 0.3
	3	15.0	4.3	< 0.3	< 0.3
21 (Vacuum)	1	1.4	0.4	< 0.3	< 0.3
	2	< 0.3	< 0.3	< 0.3	< 0.3
	3	0.9	2.3	< 0.3	43
26 (21 Vac; 5 air)	1	< 0.3	< 0.3	< 0.3	< 0.3
	2	< 0.3	< 0.3	< 0.3	< 0.3
	3	0.4	0.4	< 0.3	< 0.3

a/ Treatment code:

0-0 = No treatment

P-0 = TPP dip only

0-I = Irradiation only

P-I = TPP dip and irradiation

Table 27. Clostridium perfringens bacteria in treated and stored beef

Days storage	Rep No.	Organisms per gram (most probable number) Treatment[a/] 0-0	P-0	0-I	P-I
0 (Vacuum)	1	< 5	< 5	< 5	< 5
	2	< 10	< 10	< 10	< 10
	3	< 10	< 10	< 10	< 10
10 (Vacuum)	1	< 10	< 10	< 10	< 10
	2	< 10	< 10	< 10	< 10
	3	< 10	< 10	< 10	< 10
21 (Vacuum)	1	< 10	< 10	< 10	< 10
	2	< 10	< 10	< 10	< 10
	3	< 10	< 10	< 10	< 10
26 (21 vac; 5 air)	1	< 10	< 10	< 10	< 10
	2	< 10	< 10	< 10	< 10
	3	< 10	< 10	< 10	< 10

a/ Treatment code:

0-0 = No treatment

P-0 = TPP dip only

0-I = Irradiation only

P-I = TPP dip and irradiation

Table 28. Presence of salmonella bacteria in 25 gram samples of treated and stored beef

Days storage	Rep No.	Treatment[a/] 0-0	P-0	0-I	P-I
0 (Vacuum)	1	None	None	None	None
	2	"	"	"	"
	3	"	"	"	"
10 (Vacuum)	1	"	"	"	"
	2	"	"	"	"
	3	"	"	"	"
21 (Vacuum)	1	"	"	"	"
	2	"	"	"	"
	3	"	"	"	"
26 (21 vac; 5 air)	1	"	"	"	"
	2	"	"	"	"
	3	"	"	"	"

a/ Treatment code:

0-0 = No treatment

P-0 = TPP dip only

0-I = Irradiation only

P-I = TPP dip and irradiation

Table 29. Coagulase positive Staphylococcus aureus bacteria in treated and stored beef

Days storage	Rep No.	Organisms per gram (most probable number) Treatment[a/] 0-0	P-0	0-I	P-I
0 (Vacuum)	1	> 100 < 1000	> 10 < 100	> 5 < 10	> 10 < 100
	2	< 10	< 10	< 10	< 10
	3	< 10	< 10	< 10	< 10
10 (Vacuum)	1	> 100 < 1000	< 10	> 10 < 100	< 10
	2	10	> 100 < 1000	> 10 < 100	< 10
21 (Vacuum)	1	> 1000 < 10,000	> 10 < 100	> 100 < 1000	< 10
	2	> 100 < 1,000	> 100 <1000	< 10	>10< 100
	3	< 10	< 10	< 10	< 10
26 (21 vac; 5 air)	1	< 10	> 10 < 100	> 10 < 100	< 10
	2	< 10	< 10	< 10	< 10
	3	<	< 10	< 10	< 10

a/ Treatment code:

0-0 = No treatment

P-0 = TPP dip only

0-I = Irradiation only

P-I = TPP dip and irradiation

Table 30. Classification of microorganisms from total count plates from treated and stored beef (percentages of total plate count)

Treatment	Days storage	Replication No.	Gram positive rods: Cocci Catalase Pos.	Gram positive rods: Cocci Catalase Neg.	Gram positive rods: Non-sporulating Catalase pos.	Gram positive rods: Lactobacillus Catalase neg.	Gram negative Rods	Yeasts	Unknown
0-0	0								
Mesophiles		1	36			2	43	0	18
		2	7	0	0	0	93	0	0
		3	7					0	93
Psychrophiles		1	8			3	36	0	53
		2	25	0	0	0	75	0	0
		3	0	0	1	0	99	0	0
	10 (vacuum)								
Mesophiles		1	0	0	0	2	98	0	0
		2					67	0	33
		3			1	2	96	0	1
Psychrophiles		1	0	15	0	0	85	0	0
		2	0	0	0	0	100	0	0
		3		8			90	0	2
	21 (vacuum)								
Mesophiles		1				7	77	0	16
		2			3	7	83	0	7
		3	25			2	69	0	4
Psychrophiles		1	0	0	0	27	73	0	0
		2				12	82	0	6
		3	29	0	0	16	55	0	0
	26 (21 vac; 5 air)								
Mesophiles		1				1	87	0	12
		2	0	0	6	0	94	0	0
		3	0	0	4	0	96	0	0
Psychrophiles		1					99	0	1
		2	7				76	0	17
		3		8			25	0	67

Table 30 (continued)

Treat-	Days	Replication No.	Gram positive rods: Cocci Catalase Pos.	Cocci Catalase Neg.	Non-sporulating Catalase pos.	Lactobacillus Catalase neg.	Gram negative Rods	Yeasts	Unknown
0-I	0								
Mesophiles		1	67	0	33	0	0	0	0
		2	64			9	18	0	9
		3	0	0	97	0	0	3	0
Psychrophiles		1							
		2					62	0	38
		3	0	0	0	8	92	0	0
	10 (vacuum)								
Mesophiles		1	25	0	0	50	0	25	0
		2	0	0	0	100	0	0	0
		3	3	0	0	97	0	0	0
Psychrophiles		1							
		2	0	0	0	98	2	0	0
		3	0	0	0	98	0	2	0
	21 (vacuum)								
Mesophiles		1	0	0	0	97	0	3	0
		2	0	0	16	84	0	0	0
		3	0	0	0	99	0	1	0
Psychrophiles		1	0	0	0	95	0	5	0
		2	0	0	0	99	1	0	0
		3							
	26(21 vac;5 air)								
Mesophiles		1	0	0	0	99	0	1	0
		2			27	26		0	47
		3	0	0	1	97	0	2	0
Psychrophiles		1	0	0	0	98	0	2	0
		2	33	0	0	66	1	0	0
		3	0	0	0	98	0	2	0

Table 30 (continued)

Treatment	Days storage	Replication No.	Gram positive rods: Cocci Catalase Pos.	Gram positive rods: Cocci Catalase Neg.	Gram positive rods: Non-sporulating Catalase pos.	Gram positive rods: Lactobacillus Catalase neg.	Gram negative Rods	Yeasts	Unknown
P-0	0								
Mesophiles		1	1	7			52	0	41
		2	6				78	0	16
		3	5	1	1		1	0	92
Psychrophiles		1					67	0	33
		2				1	45	0	54
		3	4		3	1	88	1	3
	10(vacuum)								
Mesophiles		1	0	0	0	16	84	0	0
		2	3		19	7	32	0	39
		3	0	0	47	3	50	0	0
Psychrophiles		1					65	0	0
		2	0	0	0	15	85	0	0
		3	0	15	5	24	56	0	0
	21(vacuum)								
Mesophiles		1				11	83	0	6
		2			8	8	74	0	10
		3			4	27	68	0	1
Psychrophiles		1	0	0		12	88	0	0
		2	0	0	0	27	73	0	0
		3	6		0	24	64	0	6
	26(21 vac;5 air)								
Mesophiles		1				1	91	0	8
		2	0	0	4	0	96	0	0
		3				6	92	0	2
Psychrophiles		1	0	0	0	3	97	0	0
		2	9	0	0	3	88	0	0
		3	0	0	0	12	88	0	0

Table 30. (Continued)

Treatment	Days storage	Replication No.	Gram positive rods: Cocci catalase Pos.	Cocci catalase Neg.	Non-sporulating Catalase pos.	Lactobacillus Catalase neg.	Gram negative Rods
P-I	0						
Mesophiles		1	60	0	0	0	40
		2	59				4
		3	0	0	79	7	0
Psychrophiles		1	0	0	100	0	0
		2			44		
		3	0	0	53	24	23
	10(vacuum)						
Mesophiles		1		23			
		2	3		1	95	
		3	0	0	80	20	0
Psychrophiles		1			7	14	
		2	68	0	9	5	18
		3	0	0	0	100	0
	21(vacuum)						
Mesophiles		1	0	0	0	100	0
		2	0	0	21	79	0
		3	0	0	0	99	0
Psychrophiles		1				99	
		2	28	0	0	57	15
		3			22	76	
	26(21 vac;5 air)						
Mesophiles		1	0	0	4	96	0
		2	0	0	0	83	17
		3	0	0	85	15	0
Psychrophiles		1	61	0	0	39	0
		2	16	0	0	83	1
		3	0	0	0	100	0

counts is about one log cycle (ca 10^8 vs. 10^7 organisms per gram). Five days additional storage in air increase the counts of all samples by an additional cycle.

From the total count data, it is clear that the microbial spoilage ultimately will occur, even with the irradiated samples. Levels of about 10^9 organisms per gram may be considered indicative of microbial spoilage and likely are to be attained after 26 plus days storage at 40 F.

There is no essential difference between mesophilic and psychrophilic counts. With the exception of one sample, coliforms and fecal coliforms were found to be present only in the non-irradiated samples (Tables 25 and 26). The ability of radiation to control these organisms under the storage conditions is striking.

Clostridium perfringens and Salmonella were not detected in any sample (Tables 27 and 28). The methods employed for detection of these organisms were checked by inoculated test packs with known organisms. Hence their absence in the test samples must be concluded and, as a consequence, no information on these two organisms was secured in this investigation.

Small numbers of Staphylococcus aureus (coagulase positive) were found in some samples (Table 29). Irradiation appeared to reduce the incidence of this organism but did not eliminate it. The very low counts obtained with the irradiated samples are noteworthy.

The classification of the organisms found on the total count plates (Table 30) reveals a number of interesting aspects of the effects of the proposed treatment. In general the irradiated samples tend to contain gram positive organisms, whereas gram negative rods predominate in non-irradiated samples. This observation is in accord with the findings of other investigators, both on meat and other products such as fish (4,5,6,7,8,9,10). Gram negative rod-type bacteria are more sensitive to radiation than gram positive organisms.

The proposed treatment procedure involves an extended period of anaerobic holding. Because of this growth is largely limited to anaerobes or facultative aerobes. To a large degree the anaerobic conditions account for the limited incidence of yeasts (5,8,9,10).

The classification gram positive includes cocci and rods. The irradiated samples contained no catalase negative cocci. Catalase positive cocci were found in all types of samples. These catalase positive cocci include coagulase positive Staphylococcus aureus, and as noted previously, the data of Table 29, indicate that in the irradiated samples these were present in small numbers. Other cocci include the staphylococci, micrococci and Sarcina. These cocci have no health significance, but can contribute to microbial spoilage.

The gram positive rods, catalase positive, all were non-sporulating. No spore-formers were found. These organisms occurred in all types of samples. This group could include Kurthia, Microbacterium, Corynebacterium and others. Some are lactic acid producers. They have been found in irradiated meats by other

investigators (5,6,8,9,10). Generally these organisms are not pathogenic. They can, however, contribute to spoilage.

Lactobacilli were found in all types of samples and predominate at the end of the storage period only in the irradiated samples. The lactobacilli are non-spore forming. They produce lactic acid. They grow well under anaerobic conditions and have been reported to exist in irradiated vacuum packaged meats and fish (5,8,9,10,11). They have no health hazard significance and contribute spoilage. The fact that they produce lactic acid and consequently lower the pH of the meat can have implications on the retarding of the growth of other organisms, e.g., Salmonella . A lowering of pH has been observed in other work carried out under this contract.

All gram negative organisms were rods. They occurred in all types of samples. They predominate, however, at the end of the storage period only in the non-irradiated samples. This is a principal difference between the non-irradiated and irradiated samples. As noted above, the dominant group of organisms in the stored irradiated samples is Lactobacillus. The gram negative rods include Pseudomonas, Achromobacter, Flavobacterium, Enterobacteriaceae, and others. Pseudomonas and Achromobacter are common meat contaminants and usually account for the typical spoilage of non-irradiated fresh meat (6,7,11,12). As the data indicate, they essentially are absent with the proposed procedure and storage conditions.

The grouping listed as "unknown" in Table 30 included organisms which could not be obtained in pure culture, or whose morphology was not consistent, or which otherwise were not amenable to identification procedures. These organisms all were bacteria. Some of these bacteria may fall into the ill-defined grouping of Achromobacter, Acinetobacter, Mima-Herellea, or Moraxella (6,13,14,15,16,17,18 and 19) but for the reasons already mentioned (inconsistent morphology and gram staining, etc.) classification was not attempted.

Based on the data of this study, it is clear that microorganisms survive the proposed process and in time grow out in sufficient number to lead to microbial spoilage. Other information obtained in work on this contract indicates that sensory spoilage occurs which can be recognized as such by consumers.

With irradiation and vacuum packaging the dominant outgrowth group of organisms are Lactobacillus and not Pseudomonas and Achromobacter, which normally predominate with aerobic stored non-irradiated meats. No evidence has obtained of a new health hazard as a consequence of the proposed procedure. One might say in fact that there is some possible lessening of the usual health hazards associated with fresh meats through the dominant outgrowth of lactobacilli and their lowering of the pH of the meat.

WMU:mmr

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