DEVELOPMENT OF IRRADIATED RESTRUCTURED LAMB

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INTRODUCTION

RADIATION sterilization has been successfully used to produce meats and meat products suitable for storage at room temperature. Irradiated beef, pork, chicken and ham products of high acceptance have been produced that were shelf stable for several years. Heiligman (1965) reported that irradiated bacon, pork and chicken were acceptable after 25 months of storage at 21°C. Wierbicki, et al. (1976) reported similar results with irradiated ham.

Irradiation processing at cryogenic temperatures has been the primary technological advancement responsible for the production of high quality irradiated meats. Low temperature irradiation has been beneficial in reducing the radiation induced changes in the sensory characteristics and chemical properties of the meat. (Snyder 1960, Wadsworth and Shults 1966 and Shults and Wierbicki 1974a).

Harlan et al. (1967) observed a linear decrease in the intensity of irradiation off-flavor of beef as the temperature during irradiation was decreased from +20°C to -196°C. Shults and Wierbicki (1974a) found no significant differences in the sensory quality of beef irradiated at -196°C and -80°C; significant differences were found for higher irradiation temperatures. Merritt et al. (1975) reported similar results on the volatiles associated with flavor changes in irradiated meats.

Grecz et al. (1971) reported that as the irradiation temperature was lowered, C. botulinum spore resistance increased and a corresponding increase in total dose was necessary to obtain sterility. Irradiation dose and temperature effects on both quality and microbiological factors have to be taken into account when developing irradiation processing conditions. To date a sterilizing irradiation dose has not been determined for lamb.

The effects of condensed phosphates on the water-holding capacity and meat swelling properties of fresh and cured meats has been reported by many investigators (Grau, et al. (1953), Mahan (1961), Shults et al. (1976), Wierbicki et al. (1975). Much of this earlier work was performed using fresh and cured pork due to the important role played by condensed phosphates in the production of cured pork products.

Recent research has demonstrated the importance of the condensed phosphates in fresh and cooked meats. The use of sodium tripolyphosphate, alone or in combination with sodium hexametaphosphate has been allowed (0.5% level) by the U.S. Department of Agriculture in cooked beef and fresh beef prepared for further cooking. Shults and Wierbicki (1972 and 1973) showed that tetrasodium pyrophosphate had the greatest effects on the water-holding capacity and meat swelling properties of pork, chicken, and beef muscle. However, it was found that when phosphates were used in combination with sodium chloride, lower concentrations of phosphates could be used. In the case of pyrophosphate and tripolyphosphate optimal effects of the pH, swelling, and water-holding capacity were achieved with 0.3% concentration when used with 3% NaCl (Shults and Wierbicki 1974). In irradiated meats, NaCl and phosphates are important for their role in developing a binding mechanism for meat chunks caused by the migration of dissolved proteins to the surface of the meat, which on denaturation acts as a binder.

The use of lamb meat in research on irradiation processing has been minimal. Agarwal (1972) reported that lamb irradiated at 1.0 Mrad (10 kGy) was shelf stable and an acceptable item. Irradiation in combination with partial dehydration produced an acceptable product free of C. botulinum toxin during 2-3 months of unrefrigerated storage. Rao (1974) also reported that a freeze-desication and irradiation-combination process produced a product capable of nonrefrigerated storage up to 90 days when an irradiation dose of 1.0 Mrad was used. However, 1.0 Mrad cannot be considered a 12-D sterilizing dose for C. botulinum.

The studies summarized in this paper investigated the effects of additives (sodium chloride and food grade phosphates) on the meat swelling, pH, and water-holding capacity (WHC) of lamb meat. The effects of irradiation temperature, dose and dose rate on the sensory properties of restructured lamb rolls were also investigated.

MATERIALS AND METHODS

THE RAW material used in these experiments was USDA graded Choice leg of lamb. The lamb legs were deboned and trimmed of all surface and intramuscular fats and cut into 225 to 450 chunks.

The water-holding capacity (meat shrinkage) was determined by the modified method of Wierbicki et al. (1957). The meat swelling (water-binding capacity) was determined by the method of Wierbicki et al. (1962).

The additives used for determination of WHC, pH, and meat swelling were sodium chloride (0, 0.5, 1.0, 1.5, 2.0, 4.0, 6.0, and 10.0 percent) and five combinations of food grade phosphates:

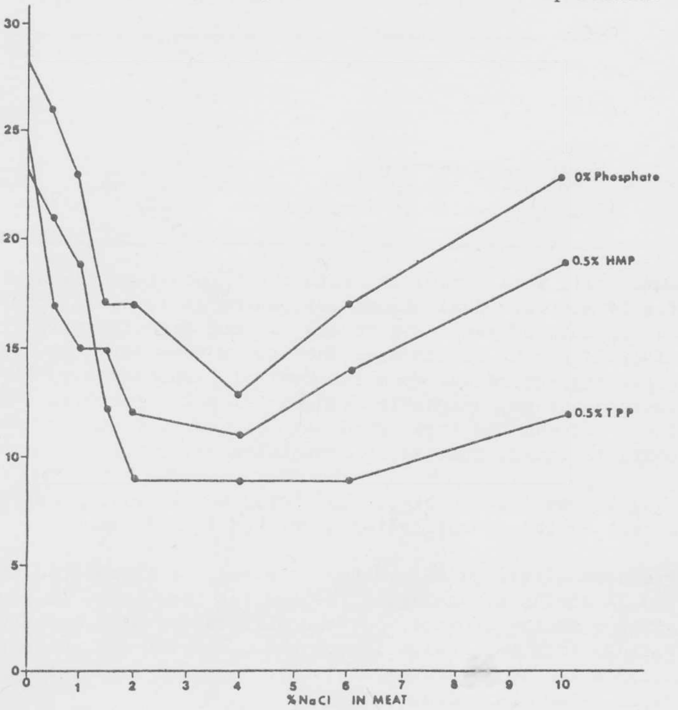
1. Sodium tripolyphosphate (TPP)
2. Sodium hexametaphosphate (HMP)
3. Combination of TPP and HMP
4. Tetrasodium pyrophosphate (PP)
5. Combination of TPP, PP, and sodium acid pyrophosphate

Phosphate addition levels were 0, 0.25, 0.5 and 1.0 percent.

For the studies on effects of irradiation on lamb product, restructured lamb rolls were used. The lamb meat was mixed in a mechanical mixer with 0.75% NaCl and 0.5% sodium tripolyphosphate (TPP). The meat was stuffed into size 6.5 fibrous, regenerated cellulose casings and formed into rolls. The meat was enzyme inactivated using dry heat (cookhouse) until an internal temperature of 71° - 76°C was obtained. The meat was cooled overnight at 5°C and then sliced into 595 ± 5 gm sections prior to vacuum packaging into metal containers for gamma irradiation. The lamb for electron irradiation processing was sliced into 13 mm slices and packaged in flexible pouches, 92.5 x 175 mm. The pouch consisted of three layers: medium density polyethylene as the food contactant, aluminum foil (middle layer), and Nylon 6 (outside layer).

Irradiation Processing

Samples were given total doses of 35, 47, and 55 k Gray (kGy) + 18% dose spread at irradiation temperatures of 0°C, -30°C and -80°C ±10°C. Dose rate of the gamma source was 14 Gy/sec. The linear accelerator utilized 10 mev electrons and a dose rate of 10^6 Gy per second.



Evaluation

All samples were subjected to sensory evaluation by trained technological panels of 7 to 8 panelists. The panelists evaluated for the sensory characteristics: discoloration, off-odor, mushiness, and irradiation flavor. The ratings for the sensory characteristics were made using an intensity scale of 1 to 9 with 1 denoting "none" and 9 being "extreme."

Preference ratings were obtained using trained technological panels. Indications of preference were made on a hedonic scale of 1 to 9 with 1 being "dislike extremely" and 9 meaning "like extremely." A rating of 5, "neither like nor dislike," was considered the borderline in determining the acceptability of the product.

RESULTS AND DISCUSSION

EFFECT of additives on the WHC, pH and swelling of lamb meat. The increase of pork, beef and chicken muscles related to the addition of NaCl and food grade phosphates has been adequately demonstrated.

The effects of NaCl additions from 0 to 10% with and without 0.5% TPP and HMP are shown on Figure 1. These results are similar to beef, pork and chicken. The maximum effects were found at an addition level of 4%. As the additive levels were increased, WHC decreased at concentrations above 4%. The synergistic effect of NaCl and phosphate additions as reported by Mahan (1961) are evident from the data on Table 1.

TABLE 1 - Effect of Phosphate addition on the water holding capacity and pH of lamb muscle.

% Phosphate	0.25				0.5				1.0			
% NaCl	0		1.0		0		1.0		0		1.0	
	% Shrink	pH	% Shrink	pH	% Shrink	pH	% Shrink	pH	% Shrink	pH	% Shrink	pH
Sodium tripolyphosphate	26	5.8	23	5.7	25	5.8	22	5.8	14	6.1	17	6.0
Sodium hexametaphosphate	28	5.6	25	5.7	30	5.7	21	5.8	28	5.8	24	6.0
Sodium hexametaphosphate Sodium tripolyphosphate	28	5.8	22	5.8	20	5.9	17	5.9	15	6.1	13	6.1
Sodium tripolyphosphate Sodium acid pyrophosphate Tetrasodium pyrophosphate	29	5.7	22	5.7	25	5.9	14	6.0	16	6.1	15	6.0
Tetrasodium pyrophosphate	19	5.6	7	5.7	14	5.9	9	5.7	11	6.4	7	5.9

The effects of the various phosphates on the pH and WHC of lamb meat are demonstrated on Table 1. Phosphate concentrations were 0, 0.25, 0.5, and 1.0% with and without NaCl additions of 0 and 1.0%. The results show that HMP does not have any effect on the WHC in lamb and pyrophosphate had the greatest effect.

Meat swelling values for lamb with the phosphates with and without NaCl showed that PP and TPP samples has the greatest increase in swelling with addition of 1% NaCl. No differences were found between the two phosphate combination samples.

Effects of irradiation processing on lamb rolls. Studies on beef, pork and chicken (Shults et al (1972, 74a), Wierbicki et al. (1975) has shown that the phosphate level (TPP) added to the product can be reduced from 0.5% to 0.3% without any significant effect on the shrinkage or meat swelling. The salt level for restructured meat rolls used for irradiation processing was established at 0.75%. All the irradiated meat rolls used in the wholesomeness studies to determine the safety of irradiated meats has 0.75% NaCl and 0.375% (beef) or 0.3% TPP (pork, chicken) additions. For the studies on the effects of irradiation condition on lamb rolls, 0.75% NaCl and 0.5% TPP were used. Results of the study to determine differences between gamma and electron irradiation are listed on Table 2. The samples were evaluated for the off-characteristics after 1 and 6 months storage at 21°C. No significant differences were found between the irradiated samples at either storage time. Ratings for the sensory characteristics ranged from 2 (trace) to 3 (slight) indicating an acceptable product.

TABLE 2 Electron vs. gamma irradiation of lamb rolls

Sample	Sensory Characteristics: Discoloration	Off odor	Irradiation flavor	Mushiness
Gamma	1.9 ± 0.81	1.9 ± 0.99	2.0 ± 1.20	2.4 ± 1.29
Electron	1.7 ± 0.70	2.1 ± 0.99	2.0 ± 1.50	2.4 ± 1.50
Frozen Control	1.0 ± 0.00	1.0 ± 0.00	1.0 ± 0.00	1.6 ± 0.73
F ratio	3.21	3.25	2.33	1.33
Significance	NSD	NSD	NSD	NSD

Significant (P <0.05)

7 member panels Irradiation: 47 kGy at 30°C ± 10°C

Lamb rolls were irradiated with the ^{60}Cobalt source at 0, -30, and -80°C ± 10°C and stored at room temperature for 24 months. Evaluations were taken at 1, 6, 12 and 24 months. The data obtained for irradiated flavor of the irradiated samples were low and not significantly different from the control up to 12 months of storage. After 24 months of storage, the scores were very low, from trace (2) to below moderate (4), but they were significantly different from the control. Mushiness rating increased slightly with storage time. The scores were low and not objectionable, ranging from 2 (trace) to 4 (below moderate). Significant differences were not found between the irradiated samples, however, the samples irradiated at -80°C rated slightly lower in this characteristic, indicating protective effect of low dose irradiation on textured changes.

Evaluations for dicsoloration showed no significant differences among irradiated samples and storage had no effect on the discoloration. Ratings for off-odor were not significantly different.

Preference ratings showed that the samples irradiated at 0°C were below the acceptability level (5.0) after 6 and 24 months of storage. The samples irradiated at -80°C were rated higher than the other irradiated samples after 6 months storage, but the differences were not significant in comparison with other irradiated samples. Ratings from the evaluation of these samples did not establish any trends that could be associated with the irradiation temperature (Table 3). Samples irradiated at -30° and -80°C were rated in the acceptable range after 24 months storage at 21°C.

TABLE 3 Effect of irradiation dose on the preference of lamb.

Irrad Temp °C	Preference Ratings, Storage time (months): 1	6	12	24
0	5.7±1.16	4.5±1.26[a]	5.0±1.31	4.8±0.90[b]
-30	5.9±1.25	4.7±1.41[a]	5.1±1.07	5.5±0.87[a,b]
-80	5.7±1.16	5.5±0.96[a,b]	5.6±1.05	5.7±0.75[a,b]
Frozen Control	6.6±0.73	7.0±0.58[b]	6.6±1.29	6.7±0.47[a]
F ratio	1.03	4.85	2.21	6.26
Significance	NSD	LSD 1.52 .05	NSD	LSD =0.89 .05

Irradiation dose: 47 kGy, gamma source; 7-8 panelists.

Means in a column followed by the same letter are not significant (P< 0.05).

TABLE 4 Effects of irradiation dose on the sensory quality of preference of lamb

Irrad dose kGy	Discoloration	Off-Odor	Irrad. Flavor	Mushiness	Pref. Rating
35	2.4±0.7	2.1±1.0	2.4±1.5	2.1±1.0	6.1±0.6[a]
47	2.3±1.0	1.9±1.1	2.4±1.7	2.3±1.2	5.7±1.5[a]
55	2.3±0.7	1.6±0.7	2.1±1.3	2.7±1.5	5.7±0.7[a]
0 (frozen control)	1.4±0.7	1.0±0.0	1.0±0.0	1.9±0.6	7.3±0.5[b]
F Ratio	1.58	2.06	1.62	0.62	4.00
Significance	NSD	NSD	NSD	NSD	LSD = 1.1

-30°C irradiation temperature; 7 panelists.

Means in a column followed by the same letter are not significant (P<0.05).

To study the effects of total dose on the sensory characteristics of irradiated lamb, samples were processed at 35, 47, and 55 kGy, using the gamma source and stored for 3 months at 21°C. It is estimated, based on our experience with irradiated beef, that the 12D irradiation sterilizing dose for lamb will be within this dose range (35 to 55 kGy at -30° ± 10°C). No significant differences were found among the irradiated samples for both the irradiation flavor and mushiness characteristics. This held true in ratings for both discoloration and off-odor. Ratings for each of the characteristics were low indicating an acceptable quality. (Table 4) Preference ratings were not significant; however, the sample irradiated at 35 kGy was rated slightly higher.

Preference ratings from technological panels showed no significant difference among the irradiated samples. It is obvious that in the dose range of 35 to 55 kGy, no differences in the effects of irradiation on lamb can be expected. When a 12D sterilizing dose for C. botulinum is determined, the quality of the lamb product will not be adversely affected if the sterilizing dose is within this range at -30° ± 10°C product temperature during irradiation. Lamb is not a priority product in the National Food Irradiation Program and no additional research in this area is planned at the present time. However, the results reported in this paper have shown that an acceptable irradiated lamb product can be produced.

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