CHANGES IN NON-PROTEIN NITROGEN CONTENT AND THE SENSORY CHARACTERISTICS OF BEEF STEAKS AS AFFECTED BY THE HEAT TREATMENT

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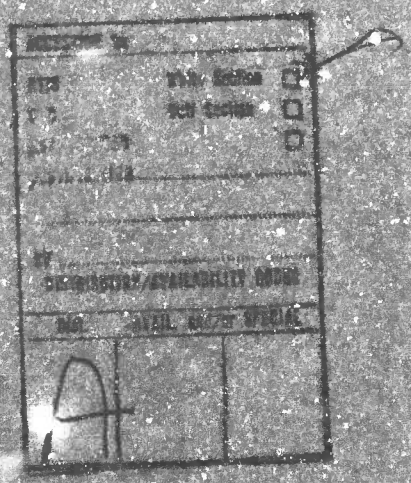

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The time temperature relationship for enzyme inactivation in beef steaks by heat treatments was evaluated by determination of increases in the non-protein nitrogen content and changes in the organoleptic qhality during storage. Cooking beef steaks at 55°C for up to 6 hours prior to irradiation was not adequate to inhibit proteolytic enzyme activity as evidenced by changes in sensory characteristics and by increases in non-protein nitrogen during storage. At 60°C, 180 minutes was not sufficient to reduct the changes in flavor and texture

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caused by enzymatic activity. To produce an irradiated beef steak in which non-protein nitrogen did not increase during storage at 21°C, pre-irradiation heat treatments required were 5 hours at 60°C, 30 minutes at 6[illegible]°C, 10 minutes at 71°C or 1 minute at 77°C.

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TECHNICAL REPORT

75-8-FEL

CHANGES IN NON-PROTEIN NITROGEN CONTENT AND THE SENSORY CHARACTERISTICS OF BEEF STEAKS AS AFFECTED BY THE HEAT TREATMENT

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July 1974

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FOREWORD

This report describes the research that was conducted on beef steaks heat treated at several temperatures and times. The objectives of this study were to determine the time - temperature relationship for enzyme inactivation as determined by changes in non-protein nitrogen (NPN) in storage and to evaluate the organoleptic quality of the steaks as affected by the different heat treatments.

Beef steaks cooked at 55°C for 6 hours and 60°C for 3 hours were rated unacceptable due to off-flavors and textural degradation. A temperature of 71° to 76°C appears essential for enzyme inactivation as shown in NPN values and technological data.

The work covered by this report was performed under project 1T762724A899, Food Technology, Technical Area, A899, Radiation Preservation of Food. The study was accomplished by the Irradiated Food Products Group, Radiation Preservation of Food Division, Food Engineering Laboratory.

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INTRODUCTION

The development of a fresh or fresh-like irradiated meat product that can be stored unrefrigerated has long been a goal of the irradiated meats program. Enzymes responsible for the deterioration of the meat on storage were studied, to provide information for accomplishing this goal. These enzymes were identified as the proteolytic enzymes by Doty and Wachter (1955). This enzyme activity caused increases in the non-protein nitrogenous constituents of the meat and resulted in the development of off-flavors and a degradation of its texture.

Early works showed that irradiation at sterilizing doses alone did not inactivate all the proteolytic enzymes in meat, (Doty and Wachter, 1955). Doty found little reduction in the activity of proteolytic enzymes in beef muscle irradiated at 5×10^5 rep. At a higher irradiation dose of 1.6×10^6 rep there was a reduction of approximately 50 percent in the proteinase activity in the beef muscle.

Early experiments to develop a non-thermal method for inactivating proteolytic enzymes were not successful. Ultrasonic vibrations were found ineffective (Landmann, 1958). Altering the chemical structures of the meats by addition of chemicals and changing the pH were also unsuccessful. Presently, the only reliable method found for inactivating proteolytic enzymes is by heat.

Pearson (1959) found beef heated to $77^{\circ}C$ internal temperature, before irradiation, was more acceptable after 3 and 6 months storage than beef heated to lower internal temperatures. Chiambalero et.al. (1959) deter-

mined a time-temperature relationship for heat inactivation of proteinases in beef; he found proteolytic enzymes in beef inactivated at internal temperatures of 60°C, when heated for 23 minutes; 66°C, when heated for 6 minutes; 71°C, when heated for 1.5 minutes and 77°C, when heated for 17 seconds. However, Landmann (1961) reported the proteolytic activity in beef cannot be completely destroyed unless a temperature of 60°C is held for 1 hour or longer. Artar (1960) also reported that beef should be heated to 71°C or 77°C internal temperature before irradiation to avoid any significant increases in the non-protein nitrogenous constituents in the beef. This is in agreement with the works of Cain (1955) and Drake (1957), who reported irradiated beef, pre-cooked to 71°C, did not undergo degradative changes during storage.

More recent investigation, using C-14 labeled hemoglobin as the substrate (Roth et.al., 1971) has shown that gamma irradiation alone destroys up to 75% of the proteolytic enzymes using 4 to 6 Mrad and the heat treatment (blanching) was more effective in this respect, especially when carried out at 70°C. A combination of irradiation (4.5 to 5.2 Mrad) plus blanching at 65 to 70°C destroys at least 95% of the proteolytic activity in beef (Losty et.al., 1973).

Previous research has not conclusively determined the time and temperature relationship for inactivating proteolytic enzymes in beef. Only one paper reports the effects of irradiation on the sensory characteristics of beef pre-cooked at the different temperatures and time intervals. Artar (1961) found that beef cooked to 77°C before irradiation had less irradiation flavor and was more acceptable than beef pre-cooked to lower internal temperatures.

The data available on the inactivation on enzymes in beef indicate a possibility of lowering the temperature required to inhibit the activity of the proteolytic enzymes. If this is so, the production of a fresh-like meat product can be achieved, since 60°C is below the temperature for denaturing meat pigment protein, myoglobin. However, the heating time of 60°C will have to be determined for controlling the proteolytic activity to the desired level.

To determine the feasibility of producing irradiated beef, enzyme inactivated at lower internal temperatures, several experiments were performed. The objectives of these experiments were to determine differences in the sensory characteristics and changes in the non-protein nitrogenous constituents of the irradiated beef.

MATERIALS AND METHODS

Loin Steaks

U. S. Choice beef loins, the Longissimus dorsi muscle, were sliced into 13 mm steaks weighing 110-120 grams each. The steaks were packaged in flexible pouches and immersed into a controlled temperature water bath. Fifteen to seventeen minutes were required before the internal temperature of the steaks were within 1-2°C of the temperature of the water bath. The steaks were cooked at the following temperatures and held for the specified time intervals after the desired internal temperatures were reached:

55°C: 30, 60, 120, and 360 minutes

60°C: 30, 60, 120, and 180 minutes

66°C: 10, 30, and 60 minutes

71°C: 1, 10, and 30 minutes

77°C: 1 minute

After cooking, the pouches were placed in an ice-water bath to cool the samples. The steaks were removed from the pouches and hermetically sealed at 16.6 k Pa of pressure in metal containers. These samples were irradiated to a total dose of 4.5 - 5.6 megarads at a controlled temperature of -40°C ± 10°C.

Round Steak

U. S. Choice top rounds, Semimembranosus muscle, were sliced into 13 mm steaks (110-120 grams) and packaged into flexible pouches. The pouches were placed in a controlled temperature bath and held at the following temperatures for the specified times after the desired internal temperatures were reached:

60°C: 180, 240, 300, and 360 minutes

66°C: 10, 20, 30, and 60 minutes

71°C: 5, 10, and 15 minutes

77°C: 1 minute

After cooking at each specific time interval, the pouches containing the steaks were immersed in an ice water bath for rapid cooling. The steaks were removed from the pouches and hermetically sealed at 16.6 k Pa of pressure in metal containers. The samples were irradiated to a total dose of 4.5 to 5.6 megarads and at a controlled temperature of -180°C ± 10°C. This cryogenic temperature was utilized in an attempt to minimize irradiation effects.

Top Round Steaks - Salt Added

U.S. Choice top rounds, Semimembranosus muscle, were pumped under pressure with a 10% salt solution to 10% added weight and allowed to soak in the solution for 24 hours at 5°C. The top rounds were sliced into 13 mm steaks (110-120 grams) and packaged in pouches. The pouches were

heated in a controlled water bath at the following temperature and for the specified times after the desired internal temperatures were reached:

66°C: 10, 20, 30, and 60 minutes

71°C: 5, 10, and 15 minutes

After heating, these samples were treated in the same manner as the top round steaks without the salt added.

Irradiation

All samples were irradiated in a Cobalt-60 source to a total dose of 4.5 to 5.6 megarads. Temperatures during irradiation were controlled in a cryogenic system using nitrogen either in a gaseous or liquid state. The temperatures during irradiation were controlled within a range of $\pm$ 10°C of the required temperature.

Technological Evaluation

All samples were evaluated by trained technological panels consisting of 6 to 8 "expert" panelists for sensory characteristics; off odor, discoloration, mushiness, irradiation flavor, dryness, and off flavors. These ratings were made on the 9-point intensity scale of 1 (none) to 9 (extreme). Indications of preference were rated on the hedonic scale of 1 (dislike extremely) to 9 (like extremely).

The results from these evaluations were analyzed statistically for multiple range test and analysis of variance. Significance was determined at the 95 percent confidence level.

Chemical Analysis

The samples were subjected to chemical analysis in accordance with standard AOAC procedures to determine the changes in the non-protein

nitrogenous constituents. The percent of non-protein nitrogen $\left(\frac{NPH}{N}\right) \times 100$ was used as a guide to determine the amount of degradation in the product during storage. The determination of the non-protein nitrogen is based on the amount of organic nitrogen contained in an aliquot of a trichloracetic acid filtrate. All samples were run in duplicate.

RESULTS AND DISCUSSION

Loin Steaks

The irradiated choice loin steaks were stored at 21°C and evaluated at 1 week and 3 months by technological panels. Intensity ratings for the characteristics of mushiness and off-flavor for all samples range from a trace (2) to slight (3) at the one week of storage. (Table 1). At three months storage samples cooked at 55°C were deteriorated to the extent that they were not suitable for organoleptic testing. The intensity ratings for mushiness and off-flavor of the samples irradiated at 60°C increased to a range of below moderate (4) to moderate (5). Whereas the irradiated samples cooked at 66°C and 71°C showed no increase in the intensity ratings of off-flavor during 3 months storage, they did show an increase in the intensity ratings for mushiness.

Preference ratings of all the samples were in the acceptable range at one week storage. At 3 months storage, the 60°C irradiated samples were rated unacceptable. Evaluation of the data indicate that the steaks must be cooked at 66°C or above to reduce the off-flavor formation and the degradation of texture on storage. Cooking at 55°C for 360 minutes and 60°C for 180 minutes was not sufficient and increases in the mushiness and off-flavor intensities were detected which resulted in unacceptable products.

The chemical analyses for non-protein nitrogen were performed after one year of storage at 21°C. Table 2 shows that the NPN values increased after 3 months of storage; storage up to one year resulted in only small increases of NPN except for the irradiated samples cooked at 55°C for 30 minutes.

The results show that a cooking temperature of 66°C for 60 minutes or 71°C for 1 minute is necessary to inhibit the increase of NPN in beef during storage. At 66°C for 30 minutes, increased NPN values were found, but not as high as those of the other irradiated samples.

Round Steaks

The U. S. Choice round irradiated steaks were evaluated by technological panels at 1 week, 3 months and 6 months of storage at 21°C. The results on Table 3 show the steaks cooked at 60°C were rated significantly higher in the intensity scores for off-odor, mushiness, and irradiation flavor. Preference ratings for the irradiated steaks cooked at 60°C were in the acceptable range, with the exception of the 60°C - 360 minutes sample, but were found significantly lower than other irradiated samples.

The data for the sensory characteristics of the irradiated steaks show that cooking at 60°C for periods up to 6 hours reduced the changes in the mushiness and off-flavor intensities. This reduction in mushiness and off-flavor intensity ratings indicated that the heat treatments were sufficient to decrease the enzymatic activity in the beef to a level where the degradation attributed to enzymes was not noticeable during 6 months of storage.

Results of the technological evaluation of beef steaks heated at 66°C for 10, 20, 30, and 60 minutes are listed in Table 4. Intensity ratings for mushiness show that steaks cooked for 10, 20, and 30 minutes had

significantly higher ratings than the non-irradiated control. Steaks cooked for 60 minutes were not significantly different from the control. No significant differences were found between the intensity ratings for the other sensory characteristics. All samples were rated in the acceptable range of 5.0 or above.

Sensory data and preference ratings for steaks cooked at 71°C for 5, 10, and 15 minutes are shown in Table 5. No significant differences were found among the sensory characteristics for all samples. Mushiness and off-flavor scores were in the range of 1 (none) to 2 (trace) indicating that enzymatic activity was not detected. Preference ratings were in the acceptable range and no significant differences were found.

The chemical analysis for the irradiated steaks stored at 21°C and 38°C are shown on Table 6. The irradiated samples, cooked at 71° and 77°C, 66°C for 30 and 60 minutes, and at 60°C for 300 and 360 minutes showed no increase in NPN at 6 months storage at 21°C. The NPN values for samples cooked at 60°C for 180 minutes and 240 minutes, and 66°C for 10 and 20 minutes, increased only slightly at 6 months storage. At 38°C storage, only the 71°C and 77°C cooked samples showed no increase in NPN values after 3 months. The increases in non-protein nitrogen values for the beef steaks cooked at 60°C and 66°C indicates that enzymes are not destroyed by the heat treatments and the enzymatic breakdown of the nitrogenous components of the meat is responsible for this increase in NPN.

These results on the time-temperature relationship of heat inactivation of enzymes indicated that for storage up to six months, a heat treatment of 60°C for 300 minutes, 66°C for 30 minutes, or 71°C for 5 minutes is

necessary for inhibition of the proteolytic enzymes. However, these treatments may not be sufficient to destroy all the enzymes in beef as indicated by results from the 38°C storage. Only samples heated to 71°C for 10 and 15 minutes and 77°C for 1 minute did not show any increase in NPN values at 38°C for 3 months. Losty et.al. (1973) using a C^{14} hemoglobin substrate analysis reported that a combination of heat (60-70°C) and irradiation (4.5-5.7 Mrads) may be expected to destroy at least 95% of the proteolytic activity in beef.

Top Round - Salt Added

Present procedures for preparation of beef steaks calls for pumping of the meat with various salt solutions prior to slicing into steak form. To determine the effects, if any, of the salt (sodium chloride) on the proteolytic activity of beef, U.S. Choice rounds were pumped with a 10% solution of NaCl. Salt concentration after pumping was approximately 1%. There were no significant differences in the sensory characteristics of the samples of beef steaks which had been pumped with the salt solution. (Tables 7 and 8). The ratings were in a range of 1 (none) to 3 (slight) intensity for all characteristics. Preference scores for the samples were all in the acceptable range and differences in the ratings were not statistically significant.

The NPN values for the irradiated samples (Table 9) were lower initially than for the non-salted samples (Table 6). Apparently, some of the initial NPN, naturally present in meat (7 to 9% of the total N) has been washed out by perfusion during the pumping of the raw beef with 10% NaCl solution to the 10% weight increase, the fact known to meat specialists. At 6 months storage at 70°C, all samples were found approximately the same in NPN values

except the steaks cooked at 66°C for 10 minutes. The salted samples cooked at 66°C for 10 and 20 minutes had lower NPN values at 6 months storage than steaks without the salt treatment cooked for the same times and temperatures.

The addition of salt to the steaks did not result in any noticeable improvements in the sensory characteristics of the irradiated steak when compared with ratings for non-salted steaks. The effect of NaCl addition on NPN values was also small. More work will be required to determine if salt additions will significantly reduce the temperature and time required for inhibiting the changes in non-protein nitrogenous contents of irradiated beef steaks. Also, the effect of salt in combination with Na-tripolyphosphate on the inactivation of proteolytic enzymes in meats should be investigated.

SUMMARY

Cooking beef steaks at 55°C for up to 6 hours prior to irradiation was not adequate to inhibit proteolytic enzyme activity as evidenced by changes in sensory characteristics and by increases in non-protein nitrogen during storage. At 60°C, 180 minutes were not sufficient to reduce the changes in flavor and texture caused by enzymatic activity.

To produce an irradiated beef steak in which non-protein nitrogen did not increase during storage at 21°C, pre-irradiation heat treatments required were 5 hours at 60°C, 30 minutes at 66°C, or 10 minutes at 71°C. At 38°C storage only samples heated to 71°C for 10 minutes or 77°C for 1 minute showed no changes in NPN during 3 months of storage.

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Table 1

Intensity Ratings for Mushiness and Off-flavor of Beef Steaks

Blanched at Several Temperatures and Time Intervals

Variable		Intensity Ratings				Hedonic Ratings	
		Mushiness		Off-flavor		Preference	
°C	Min	1 Week Storage	3 Months Storage	1 Week Storage	3 Months Storage	1 Week Storage	3 Months Storage
55	30	2.0	-*	2.2	-*	6.1	-*
55	60	1.8	-	2.1	-	6.5	-
55	120	2.8	-	2.4	-	6.0	-
55	360	2.4	-	2.4	-	6.4	-
60	30	2.8	4.0	2.0	3.8	6.5	3.6
60	60	2.0	4.4	2.5	4.6	6.5	3.9
60	120	3.7	4.2	3.0	3.8	5.7	4.4
60	180	3.9	4.4	2.8	4.4	6.0	3.5
66	10	2.8	3.6	2.1	2.6	5.7	5.0
66	30	2.1	3.6	2.9	2.2	6.7	5.0
66	60	2.1	3.0	2.4	2.2	6.4	5.4
71	1	1.9	3.9	2.4	2.1	6.3	4.9
71	10	1.8	3.9	2.5	1.9	6.8	4.9
71	30	2.7	3.5	2.5	1.8	6.4	5.5

* At 3 months storage, samples were too deteriorated for testing.

N = 3 panelists

Table 2

Changes in Non-Protein Nitrogen Content of Irradiated Beef Steaks

Temp °C	Time in Minutes	Storage Time (21°C) 0 Month N	0 Month NPN	0 Month % NPN[1/]	3 Months N	3 Months NPN	3 Months % NPN	6 Months N	6 Months NPN	6 Months % NPN	12 Months N	12 Months NPN	12 Months % NPN
55	30	2.90	.28	9.6	3.42	.58	16.9	3.33	.62	18.7	3.09	.76	24.9
55	60	2.88	.28	9.7	3.02	.50	16.6	2.78	.48	17.3	3.58	.70	19.5
55	120	3.05	.30	9.9	3.46	.57	16.5	3.44	.62	18.0	3.12	.55	17.6
55	360	2.91	.27	9.3	3.59	.48	13.4	3.13	.48	15.3	3.32	.53	15.9
60	30	3.45	.34	9.9	3.59	.57	13.9	3.20	.52	16.2	3.54	.62	17.5
60	60	3.12	.32	10.3	3.30	.46	14.4	3.32	.64	15.7	3.36	.56	16.7
60	120	3.19	.32	10.0	3.69	.53	15.4	3.43	.66	19.2	3.62	.58	16.0
60	180	3.62	.38	10.5	3.44	.47	13.7	3.32	.50	15.0	3.11	.50	16.1
66	10	3.66	.35	9.6	3.48	.43	12.4	3.54	.46	13.0	3.24	.42	12.9
66	30	3.31	.28	7.9	3.25	.32	9.8	3.46	.36	10.4	3.21	.30	9.3
66	60	2.97	.26	8.6	3.53	.35	9.9	3.17	.31	9.8	3.63	.31	8.5
71	1	3.34	.32	9.6	3.67	.33	9.0	3.47	.34	9.8	3.39	.23	6.8
71	10	3.53	.28	7.9	3.66	.36	9.8	3.80	.32	8.4	4.35	.33	7.6
71	30	4.11	.34	8.3	4.00	.37	9.0	4.12	.32	7.8	3.82	.25	6.5
77 [2/] control frozen	1	3.75	.28	7.9	4.10	.31	7.6	3.90	.31	8.0	3.55	.24	6.8

1/ Calculated as percent of total N.

2/ Stored at -29°C prior to analysis.

Table 3

Effects of Irradiation on the Sensory Characteristics of Beef Steaks

Cooked at Several Temperatures and Time Intervals

	Intensity Ratings						Hedonic Ratings
Sample	Discoloration	Off Odor	Mushiness	Irrad. Flavor	Dryness	Off Flavor	Preference
Non-irrad. Control 3/ 60°C	1.8	1.5	1.2 2/	1.2 2/	2.5	1.6	6.5 2/
180 min. 4/ 60°C	1.7	2.3	2.6	2.4	2.2	2.6	5.2
240 min. 4/ 60°C	1.7	2.8 1/	3.1	2.9	2.4	2.5	5.1
300 min. 4/ 60°C	2.2	2.5 1/	2.4	2.7	2.6	2.4	5.3
360 min. 4/	1.9	2.6 1/	2.5	2.6	2.7	2.1	4.9

N = 22

1/ Significantly different from the non-irradiated sample.
2/ Significantly different from the irradiated samples.
3/ Heated at 60°C for 180 minutes.
4/ Irradiated, 4.5-5.6 Mrad at -40 ± 10°C.

Significance ($P < .05$)

Table 4

Effects of Irradiation on the Sensory Characteristics of Beef Steaks Cooked at Several Temperatures and Time Intervals

Sample	Intensity Ratings						Hedonic Ratings
	Discoloration	Off-Odor	Mushiness	Irrad. Flavor	Dryness	Off-Flavor	Preference
Non-irrad. Control 2/ 66°C	1.8	1.5	1.2	1.2	2.5	1.6	6.5
10 min. 3/ 66°C	1.5	2.2	2.4 1/	1.8	2.3	1.9	5.7
20 min. 3/ 66°C	1.6	1.8	2.1 1/	1.6	2.1	1.9	6.1
30 min. 3/ 66°C	1.5	1.5	2.1 1/	1.6	2.6	1.5	6.1
60 min. 3/	1.8	1.5	1.7	1.4	2.5	1.6	6.3

N = 22

1/ Significantly different from the non-irradiated control.

2/ Heated at 60°C for 130 minutes.

3/ Irradiated, 4.5-5.6 Mrad at -40 ± 10°C

Significance ($P < .05$)

Table 5

Effects of Irradiation on the Sensory Characteristics of Beef Steaks Cooked at Several Temperatures and Time Intervals

	Intensity Ratings						Hedonic Ratings
Sample	Discoloration	Off-Odor	Mushiness	Irrad. Flavor	Dryness	Off-Flavor	Preference
71°C 5 min.	1.5	1.9	2.1	1.9	2.3	2.1	5.7
71°C 10 min.	1.7	1.9	1.8	2.1	2.3	1.7	5.8
71°C 15 min.	1.7	1.9	1.8	1.9	2.7	1.8	5.9

N = 22

No significant differences at the 5% level.

Table 6

Percent of Non-Protein Nitrogen in Irradiated Beef Steaks -

Time and Temperature Effects

Temp °C	Time in min.	Storage Time: 21°C, 0 Month N	NPN	%NPN 1/	21°C, 3 Months N	NPN	%NPN 1/	21°C, 6 Months N	NPN	%NPN 1/	38°C, 1 Month N	NPN	%NPN 1/	38°C, 2 Months N	NPN	%NPN 1/	38°C, 3 Months N	NPN	%NPN 1/
60	180	4.09	.36	8.8	4.20	.39	9.5	4.39	.43	10.0	4.17	.46	11.0	4.14	.57	13.8	4.36	.52	12.9
60	240	4.10	.35	8.5	4.37	.40	9.2	4.27	.46	10.8	3.93	.41	10.3	4.35	.54	12.4	3.46	.49	14.2
60	300	3.99	.33	8.3	4.12	.40	9.7	4.03	.29	7.1	4.16	.44	10.6	4.23	.55	13.0	4.03	.51	12.7
60	360	4.09	.34	8.3	4.09	.39	9.5	4.36	.41	9.4	4.06	.42	10.3	4.19	.50	11.9	4.15	.55	13.3
66	10	3.65	.34	9.3	4.21	.50	11.9	4.37	.53	12.1	3.27	.40	12.2	3.95	.60	15.2	4.07	.70	17.2
66	20	4.02	.35	8.7	4.19	.45	10.9	4.41	.45	10.2	3.99	.42	10.5	4.26	.54	12.7	4.04	.58	14.4
66	30	4.16	.33	7.9	4.15	.38	8.2	4.19	.34	8.1	4.18	.38	9.1	4.16	.46	11.1	4.40	.51	11.6
66	60	4.07	.35	8.5	4.18	.38	9.1	4.24	.35	8.2	3.88	.36	9.3	4.51	.47	10.4	4.50	.51	11.3
71	5	4.22	.33	7.8	4.33	.35	8.1	4.45	.30	6.7	4.09	.36	8.8	4.38	.38	8.7	4.17	.38	9.1
71	10	4.28	.32	7.5	4.33	.39	9.0	3.94	.26	6.6	4.16	.30	7.2	4.51	.38	8.4	3.79	.29	7.7
71	15	4.27	.29	6.9	4.41	.36	8.2	4.56	.36	7.9	4.36	.32	7.3	4.12	.34	8.3	3.89	.30	7.8
77	1	4.92	.33	8.3	4.44	.44	9.9	4.55	.35	7.7	4.50	.33	7.3	4.45	.35	7.9	4.50	.36	8.0
77 2/ non-irrad. control	1	4.12	.30	7.3	4.55	.36	7.9	4.80	.31	7.1	4.12	.30	7.3	4.83	.43	8.9	4.87	.38	7.8

1/ Calculated as percent total N.

2/ Stored at -29°C prior to analysis.

Table 7

Effects of Irradiation on the Sensory Characteristics

of Beef Steaks pumped with a Salt Solution

	Intensity Ratings						Hedonic Ratings
Variable	Discoloration	Off-Odor	Mushiness	Irrad. Flavor	Dryness	Off-Flavor	Preference
66°C 2/ 10 min.	1.8	2.1	2.3 1/	2.2 1/	2.2	2.2	5.7
66°C 2/ 20 min.	1.6	2.1	2.2 1/	2.1	2.1	2.1	6.0
66°C 2/ 30 min.	1.8	2.1	2.1 1/	2.1	2.7	2.3	6.0
66°C 2/ 60 min.	1.8	2.1	1.9	2.1	2.7	1.9	5.6
non-irrad.3/ control	1.4	1.5	1.0	1.1	2.7	1.5	6.6

N = 24

1/ Significantly different from the non-irradiated control samples.

2/ Irradiated at 4.5-5.6 Mrad at -180°C ± 10°C.

3/ Heated at 66°C for 10 minutes for the enzyme inactivation.

Significance ($P < .05$)

Table 8

Effects of Irradiation on the Sensory Characteristics

of Beef Steaks pumped with a Salt solution

Variable	Discoloration	Off-Odor	Mushiness	Irrad. Flavor	Dryness	Off-Flavor	Preference
71°C 2/ 5 min.	1.6	2.0	2.3 1/	2.3 1/	2.4	2.0	5.9
71°C 2/ 10 min.	1.8	2.4 1/	2.2 1/	2.1	2.1	2.6 1/	5.7
71°C 2/ 15 min.	1.6	2.3 1/	2.0	2.2 1/	2.3	2.3	6.2
non-irrad. control 3/	1.8	1.5	1.2	1.2	2.5	1.6	6.4

1/ Significantly different from the non-irradiated control samples.

2/ Irradiated 4.5-5.6 Mrad at -180°C ± 10°C.

3/ Heated for 5 minutes at 71°C.

Significance ($P < .05$)

Table 9

Percent of Non-Protein Nitrogen in Irradiated

Beef Steaks with NaCl Added

		Storage Time (21°C)								
		0 Month			3 Months			6 Months		
Temp °C	Time in min.	N	NPN	%NPN	N	NPN	%NPN	N	NPN	%NPN
* 66	10	3.57	.23	6.4	4.34	.34	7.8	3.56	.38	10.7
	20	3.51	.22	6.3	4.36	.32	7.3	3.56	.32	8.9
	30	3.87	.24	6.2	3.97	.30	7.6	3.63	.33	9.1
	60	4.03	.24	6.0	3.63	.27	7.4	4.13	.34	8.7
* 71	5	3.41	.19	5.5	3.68	.25	6.8	3.86	.33	8.5
	10	3.68	.21	5.7	3.82	.24	6.3	3.54	.27	7.6
	15	3.39	.22	5.7	3.54	.22	6.2	3.15	.25	7.9
77 non-irrad. control 2/	1	4.92	.33	8.3	4.83	.41	8.5	4.55	.35	7.7

1/ Calculated as percent total N.

2/ Stored at -29°C prior to analysis.

* Irradiated 4.5-5.6 Mrad at -180°C ± 10°C.