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TECHNICAL REPORT

74-57-FL

**DEVELOPMENT OF IRRADIATED BEEF**

**I. ACCEPTANCE OF BEEF LOIN  
IRRADIATED AT CRYOGENIC TEMPERATURES**

by

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and

E. Wierbicki

Irradiated Food Products Group  
Radiation Preservation of Food Division

Project: IT762724AH99

July 1974

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Natick, Massachusetts 01760



Food Engineering Laboratory  
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## FOREWORD

These experiments were initiated to determine the effects on the sensory characteristics and preference ratings of beef loin irradiated at various cryogenic temperatures. The objective was to determine the optimal cryogenic temperature for irradiation of beef loin.

Results from these studies showed little need to irradiate beef at temperatures lower than  $-80^{\circ}\text{C}$ . However, irradiation at  $-40^{\circ}\text{C}$  yields an acceptable product after 12 months storage, but not as acceptable as a product irradiated at  $-80^{\circ}\text{C}$ .

These studies were undertaken as a research project of the Irradiated Food Products Group, Food Engineering Laboratory, under Project IT762724AH99, Radiation Preservation of Food.



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## INTRODUCTION

Irradiation at subzero temperatures has been shown to decrease the radiation-induced changes in the sensory characteristics and chemical nature of beef when compared to irradiating in a non-frozen state. Comparatively little data are available on decreases in radiation-induced changes which might be obtained by irradiating beef at extreme low temperatures ( $-80^{\circ}$  to  $-185^{\circ}\text{C}$ ). More information on the advantages of irradiation within this range is needed before the feasibility of producing irradiated beef can be fully established. In response to this need, the temperature range of  $-40^{\circ}\text{C}$  to  $-185^{\circ}\text{C}$  was investigated, the purpose being to find the optimum temperature for the irradiation of beef. To accomplish this purpose, experimental work was carried out to determine differences in the sensory characteristics and preference ratings of beef irradiated at temperatures ranging from  $-40^{\circ}\text{C}$  to  $-185^{\circ}\text{C}$ .

The present investigators were not the first to recognize that the irradiation of meats in a frozen state is a promising method for reducing the deleterious effects of ionizing radiation at high processing doses. Several investigators have reported that the adverse quality changes, such as off-flavor and off-odor formation during irradiation, can be reduced or eliminated by irradiating foods at temperatures in the range of  $-80^{\circ}\text{C}$  to  $-196^{\circ}\text{C}$ . Coleby et al (1961) reported that raw beef and pork irradiated with 5 Mrad at  $-75^{\circ}\text{C}$  were preferred to the meats irradiated with 2 Mrad at  $\pm 18^{\circ}\text{C}$ . The authors reported further that raw beef irradiated at various temperature levels within the range of  $+18^{\circ}\text{C}$  to  $-196^{\circ}\text{C}$  showed a little protection from irradiation damage within the limits of  $0^{\circ}\text{C}$  to  $+18^{\circ}\text{C}$ ; a rapid increase in protection from  $0^{\circ}\text{C}$  to  $-20^{\circ}\text{C}$ ; and smaller increases at temperature levels between  $-20^{\circ}$  and  $-196^{\circ}\text{C}$ .

Snyder (1961) found that off-odor formation in beef steaks was reduced to threshold values when irradiated in liquid nitrogen ( $-196^{\circ}\text{C}$ ). Harlan et al (1967) and Kauffman et al (1969) observed a linear decrease in the intensity of irradiation off-flavors of beef steaks as temperatures of irradiation were successively decreased from  $+20^{\circ}\text{C}$  to  $-196^{\circ}\text{C}$ . Wadsworth and Shults (1966) found beef irradiated at  $-196^{\circ}\text{C}$  was statistically pre-



ferred to beef irradiated at  $-50^{\circ}\text{C}$  by both trained technological panels and consumer-type panels. Harlan (1967) reported that meat items irradiated in liquid nitrogen ( $-196^{\circ}\text{C}$ ) were comparable in their organoleptic characteristics with non-irradiated controls.

#### MATERIALS AND METHOD

##### Materials

Boneless beef loins, the Longissimus muscles of both U. S. Choice and U. S. Commercial grades, were used in an experiment designed to show the effects of irradiation on the sensory characteristics of a high quality and a low quality beef product.

In another experiment, variations found from one loin to another were eliminated by using matched or paired U.S. Choice loins from the same carcass. The product for each testing period and for all variables was from the same set of paired loins - this was done to minimize the variation in the experiments and to assure that the differences (if any) were due directly to the temperature of irradiation.

##### Methods

The products were enzyme inactivated at  $104^{\circ}\text{C}$  in a steam retort; internal temperature obtained within the meat was  $73^{\circ}$  to  $76^{\circ}\text{C}$ . Immediately after the desired internal temperature was reached, products were packed in 404 x 700 or 404 x 200 cans lined with a "C" oleoresinous enamel. Temperature of the product at closing was  $43^{\circ}$  to  $49^{\circ}\text{C}$ . The cans were hermetically sealed under 500 mm vacuum, frozen at  $-40^{\circ}\text{C}$ , and held until irradiation.

All samples, except those designated for controls, were irradiated in a Cobalt-60 source and received a dose in a range of 4.5 to 5.6 megarads. It is noted that based on the experimentally determined preliminary data the 12-D sterilizing doses, using the Schmitt and Nank method, are 4.7 megarads at  $-30^{\circ}\text{C} \pm 10^{\circ}\text{C}$  irradiation temperature and 5.7 megarads at  $-80^{\circ}\text{C}$  irradiation temperature (Wierbicki et al., 1970). This is because the resistance of C. botulinum spores to radiation increases when product temperature during irradiation is lowered from  $+65^{\circ}$  to  $-196^{\circ}\text{C}$  (Grecz et al., 1971). However, for the development of irradiated beef products prior to determining these sterilizing doses, a dose range of 4.5 to 5.6 megarads



was used for all temperatures of irradiation.

The desired temperatures of irradiation were obtained by placing the cans in an insulated container during irradiation and controlling the lower temperatures with liquid nitrogen in a vapor or liquid state. The exact temperatures of the product during irradiation were recorded by thermocouples inserted in the cans. The temperatures were controlled during irradiation to  $\pm 10^{\circ}$  of the desired temperature, except for  $-185^{\circ}\text{C}$  which was controlled within the range of  $-180^{\circ}\text{C}$  to  $-196^{\circ}\text{C}$ .

#### Evaluation:

Samples were evaluated by a panel of trained technologists (6 to 8 panelists per test) for the sensory characteristics: off-odor, irradiation flavor, mushiness, discoloration, and off-flavors other than irradiation flavor. An intensity scale of 1 - 9 (1 denoting "none" and 9 denoting "extreme") was employed in evaluating these sensory characteristics.

Preference ratings were obtained using consumer-type panels of 36 untrained panelists and technological panels of 6 to 8 trained panelists. For this kind of organoleptic evaluation, the hedonic scale of 1 - 9 was used, with 1 denoting "dislike extremely" and 9 "like extremely". The beef was served as a hot roast beef item to all panelists.

The irradiated samples were stored at  $21^{\circ}$  to  $26^{\circ}\text{C}$  for one year. Evaluations were made at 1 week (0-time) and 1, 3, 6, and 12 month intervals except where otherwise stated. Technological panel tests were performed at each withdrawal and consumer-type panel tests were performed at 1 and 3 months storage. Samples for the paired loin experiment were stored at  $21^{\circ}$  to  $26^{\circ}\text{C}$  and evaluated by technological panels at intervals of 1, 3, and 6 months.

#### Statistical Analysis:

The data for the sensory characteristics and preference ratings of each sample were pooled and computer-analyzed. Results of technological and consumer-type panels were analyzed separately. Statistical differences between samples, in respect to the sensory characteristics and preference ratings were computed using an analysis of variance table and Duncan's multiple range test (Duncan, 1955). Significance was determined at the 95% confidence level in all cases.



## RESULTS AND DISCUSSION

Results of sensory evaluation of the irradiated beef loin, U. S. Commercial grade, over a wide range of temperatures are shown on Table #1. It is evident that the intensities of irradiation flavor, mushiness and friability were decreased substantially as the irradiation temperature was lowered. However, little reduction of the intensities in the loins resulted by lowering the temperature below  $-80^{\circ}\text{C}$ . Samples irradiated in the non-frozen state, which had intensities in the moderate range, were judged to be unacceptable for testing after 3 months storage. The degradation of the textural characteristics was the primary factor making these samples unacceptable.

The results shown in Table #2 were obtained from another set of samples of beef loin irradiated in a range of  $0^{\circ}\text{C}$  to  $-185^{\circ}\text{C}$ . The largest differences in the intensity ratings of the sensory characteristics were found in samples irradiated at  $0^{\circ}$  and  $-40^{\circ}\text{C}$ . After both 3 and 10 weeks storage, the intensities for irradiation flavor in the  $0^{\circ}\text{C}$  samples were found statistically different from the other irradiated samples. Ratings for the textural characteristics and technological-panel preference were not statistically significant. The consumer-panel ratings for preference found the  $0^{\circ}\text{C}$  samples significantly different from the other samples.

The data obtained for the U. S. Choice beef loin from 4 withdrawals over one year of storage are tabulated in Table #3. No statistical differences were found between the  $-40^{\circ}$ ,  $-80^{\circ}$ ,  $-120^{\circ}$ , and  $-185^{\circ}\text{C}$  irradiated samples for any of the sensory characteristics; however, statistical differences were obtained for ratings between the irradiated and non-irradiated samples.

Ratings for irradiation flavor and off-odor decreased as the temperature of irradiation was lowered, but the decrease was not statistically significant. The scores for off-odor, irradiation flavor, and off-flavor (other than irradiation flavor) for the irradiated samples stored for 0, 1, and 3 months were high; however, at 12 months storage the intensities of these sensory characteristics were lower (Table #3), indicating an effect of prolonged storage, reported previously by Kauffman *et al.*, (1969).



Preference ratings for the samples were rated in the acceptable range (5.0 or above) (Table #3). After 12-months storage, the  $-80^{\circ}$ ,  $-120^{\circ}$ , and  $-185^{\circ}\text{C}$  irradiated samples were scored higher (6.0) than the  $-40^{\circ}\text{C}$  (5.5), but this difference was not significant.

U. S. Commercial beef loin evaluated over a one-year storage period (Table #4) did not develop the degree of mushiness found in the U. S. Choice beef loin. Ratings for mushiness were statistically different between the control and the  $-40^{\circ}$ ,  $-80^{\circ}$ , and  $-120^{\circ}\text{C}$  irradiated samples, but no statistical differences were found between the mushiness ratings for  $-185^{\circ}\text{C}$  sample and the non-irradiated control after 12-months storage.

The off-odor rating for the  $-40^{\circ}\text{C}$  sample at 0-time storage was significantly higher than the other irradiated samples and the frozen control. No significant differences were obtained in the irradiation flavor scores for the irradiated samples.

Preference ratings for 12-month stored samples showed that the  $-120^{\circ}$  and  $-185^{\circ}\text{C}$  irradiated samples were significantly preferred to the  $-40^{\circ}\text{C}$  sample; however, no significant differences were obtained between the  $-80^{\circ}$ ,  $-120^{\circ}$ , and  $-185^{\circ}\text{C}$  samples. All samples at each storage period received acceptable preference ratings.

Test results of the U. S. Commercial loins (Table #4) obtained by a technological panel at 12 months of storage show an increase in the preference ratings as the irradiation temperature of the samples was lowered. The preference rating of the  $-40^{\circ}\text{C}$  sample was at the border line (5.0 or above) for acceptability and the samples irradiated at the lower temperatures were rated acceptable. The simultaneous evaluation of the beef samples of both grades showed the consumer-panel rating for the  $-40^{\circ}\text{C}$  U. S. Choice loin sample, at 0-storage period was significantly different from the frozen control sample (Table #5).

No significant differences were found in the preference ratings for the U. S. Choice and U. S. Commercial irradiated samples at both the 0 and 3 month storage periods. No significant differences were noted between the U. S. Commercial loin samples, irradiated and non-irradiated, at both storage periods. At the 3-month storage period, the U. S. Choice



frozen control was preferred to the irradiated samples.

Paired beef loins from the same carcass were used in an attempt to minimize variations in the raw material. The experiment was designed to show only the variation in sensory characteristics and preference ratings directly associated with the temperature of irradiation. Technological panel ratings for preference show the control samples preferred to all the irradiated samples and the  $-120^{\circ}\text{C}$  irradiated samples to be statistically preferred to the  $-40^{\circ}\text{C}$  samples (Table #6).

All irradiated samples were rated relatively low for preference on the hedonic scale. Evaluation of the sensory characteristics reveals that the textural characteristics, mushiness, and friability were rated from 3.0 to 4.0 (slight to below moderate) on the intensity scale. These characteristics are believed to be the main factors effecting the preference ratings of the irradiated samples.

#### SUMMARY

U. S. Choice beef loin stored for one year showed no difference in the ratings of samples irradiated at  $-80^{\circ}$ ,  $-120^{\circ}$ ,  $-185^{\circ}\text{C}$  when evaluated for sensory characteristics and preference by a technological (expert) panel. Consumer-type panelists could not detect any differences in the irradiated samples that could be attributed to the temperatures of irradiation within the temperature range from  $-40^{\circ}$  to  $-185^{\circ}\text{C}$ .

Results of technological panel evaluations obtained for the sensory characteristics of U. S. Commercial beef loin stored for one year showed statistical differences between the  $-40^{\circ}$  and  $-80^{\circ}\text{C}$  samples and the non-irradiated controls. No differences were noted in the sensory characteristics and preferences ratings of samples irradiated at  $-120^{\circ}$  and  $-185^{\circ}\text{C}$ . Consumer-type panel ratings do not show any differences between irradiated and non-irradiated samples; however, they preferred the non-irradiated samples to all irradiated samples.

The off-odor and irradiation flavor intensities for the U. S. Choice and U. S. Commercial loins decreased by the lowering of the irradiation temperature. However, the decreases in the intensity scores obtained by lowering the irradiation temperature to below  $-80^{\circ}\text{C}$  were not statistically significant.

After one year's storage, all samples were rated in the acceptable



range of 5.0 or above. Increases in the acceptance ratings of the samples were made by lowering the irradiation temperature to  $-80^{\circ}\text{C}$ . Lowering the temperature below  $-80^{\circ}\text{C}$  did not result in any significant improvements.



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TABLE #1

Effects of irradiation temperatures on flavor and textural characteristics of U. S. Commercial beef loin.

Irradiation Temp °C	Irradiation Flavor	Mushiness	Friability
+ 60°	4.1	5.3	5.0
+ 21°	3.3	3.4	3.0
+ 40°	2.9	2.5	1.9
- 80°	2.1	2.0	1.8
-185°	1.5	2.0	1.9

N = 16

1 - 3 Month Storage

DOSE: 4.5 to 5.6 Megarads



TABLE #2

Effects of irradiation temperature on the sensory and preference ratings of U.S. Commercial beef loin.

3 Weeks at 21° to 25°C						10 Weeks at 21° to 25°C				
Temp. of Irradiation	Irrad. Flavor	Mushi-ness	Friabi-lity	Tech. Pref.	Consumer Pref.	Irrad. Flavor	Mushi-ness	Friabi-lity	Tech. Pref.	Consumer Pref.
0°C	3.9*	2.8	4.2	4.7	4.8*	4.4*	2.4	3.0	5.6	4.8*
- 40°C	2.6	1.8	3.4	5.9	5.7	1.9	1.4	3.0	6.1	5.8
-120°C	2.3	1.8	2.8	6.0	5.7	1.4	1.6	2.3	6.3	6.1
-185°C	2.4	1.4	1.6	5.8	5.9	1.6	1.5	2.8	6.1	5.7

Irradiation dose, 4.5-5.6 Mrad

Technological panels = 8 panelists

Consumer panels = 36 panelists

\*Significantly different from other samples

Significance at the 5% level



TABLE #3

Effects of the temperature of irradiation on the sensory characteristics and preference ratings of U. S. Choice beef loin.

Irradiation Temp.	Storage Time-Mos.	Discoloration	Off Odor	Mushiness	Irrad Flavor	Off Flavor	Preference
- 40°C	0	--	2.06	1.71	1.85	3.00*	6.42
	1	--	2.25	2.25	2.62	2.12	6.00
	3	1.87	2.00	3.00	2.50	2.25	6.00
	12	2.12	1.62	2.62	2.00	1.50	5.50
- 80°C	0	--	1.71	3.00*	1.57	2.42	6.57
	1	--	1.87	1.75	2.12	2.00	6.25
	3	1.62	1.87	2.50	2.25	2.37	6.12
	12	3.42	2.12	2.00	2.75	1.12	6.00
-120°C	0	--	1.57	3.28*	2.28	2.57	6.00*
	1	--	1.62	1.87	2.00	1.75	6.25
	3	2.00	1.73	2.87	2.00	2.75	6.12
	12	1.87	1.75	2.00	1.75	1.50	6.00
-185°C	0	--	1.57	2.28	1.28	2.57	7.00
	1	--	1.37	1.75	1.37	1.25	7.37
	3	1.62	1.62	3.12	1.87	2.75	6.50
	12	2.12	1.87	2.38	2.00	2.38	6.00
Frozen Control Non-Irrad.	0	--	1.14	1.42	1.00	1.14	8.14
	1	--	1.00	1.37*	1.00	1.50	7.75
	3	1.12	1.12	1.75*	1.00	1.62	7.75
	12	1.12	1.25	1.12	1.00	1.62	7.00

N = 8 panelists per test

DOSE: 4.5 - 5.6 Megarads

21°C Storage (irradiated samples); -29°C storage (non-irradiated control)

\* Indicates significant differences (5% level) within the samples for each storage period.



TABLE #4

Effects of irradiation temperature on the sensory characteristics and preference ratings on U. S. Commercial beef loin.

Sensory Characteristics							
Sample	Storage Time-Mos.	Discoloration	Off Odor	Mushiness	Irrad Flavor	Off Flavor	Preference
- 40°C	0	--	3.16*	1.83	3.00	2.16	5.66
	1	1.85	1.57	2.71	2.42	2.42	6.14
	6	2.37	2.37	2.00*	2.12	3.00	5.89*
	12	2.25	2.87	3.87*	2.50	1.75	5.00
- 80°C	0	--	1.83	1.66	2.33	2.16	6.33
	1	1.14	1.71	2.28	2.00	3.14	5.57
	6	2.89	2.12	3.00*	2.62	2.85	5.75*
	12	2.50	2.75	3.25*	2.87	1.62	5.80
-120°C	0	--	2.16	1.66	2.33	1.83	5.66
	1	1.14	1.42	2.00*	1.57	2.57*	6.28
	6	2.62	2.62	3.25*	2.75	3.12*	6.25
	12	1.75	1.75	3.35*	2.00	1.66	6.20
-185°C	0	--	2.00	2.33	2.16	2.33	6.16
	1	1.28	1.42	1.71	1.42	2.28	6.85
	6	1.50	2.00	1.62	2.62	2.50	5.80
	12	1.62	2.25	2.50	2.50	1.12	6.40
Frozen Control	0	--	1.16	1.50	1.00*	1.33*	8.00*
	1	1.00	1.42	2.14	1.42	4.42	6.57
	6	1.12	1.50	1.50	1.50	2.13	7.12
	12	1.87	1.12	1.38	1.12	1.00	7.60

DOSE: 4.5 - 5.6 Mrad

N = 8 panelists

21°C Storage

\* Indicates significance (5% level) within the samples for each storage period.



TABLE #5

Consumer panel ratings for U. S. Choice and U. S. Commercial  
beef loins irradiated at cryogenic temperatures.

Samples	Storage Time-Mos.	Choice	Commercial
- 40°C	0	5.9 <sup>1/</sup>	6.1
	3	5.9	5.7
- 80°C	0	6.1	6.4
	3	5.9	5.8
-120°C	0	6.3	6.5
	3	5.9	5.7
-185°C	0	6.4	6.4
	3	5.8	5.5
Frozen Control	0	6.8 <sup>2/</sup>	6.4
	3	6.9 <sup>2/</sup>	6.2

N = 36 panelists per test

DOSE: 4.5 to 5.6 Mrad

21°C Storage

1/ Significantly different (5% level) from the frozen control sample.

2/ Significantly different (5% level) from the irradiated samples.



TABLE #6

Effects of irradiation temperature on the sensory characteristics of paired  
U. S. Choice beef loin.

Variables	Intensity Scores (n=24)						
	Discoloration	Off-Odor	Mushiness	Friability	Irrad. Flavor	Off- Flavor	Preference Ratings (n=24)
Irrad at:							
- 40°C	2.3 <sup>1/</sup>	1.7	3.3	3.7 <sup>1/</sup>	2.7 <sup>3/</sup>	1.9	5.0 <sup>3/</sup>
- 80°C	2.1 <sup>1/</sup>	2.0	3.3	3.7 <sup>1/</sup>	2.7 <sup>3/</sup>	2.2	5.1
-120°C	1.9	2.3 <sup>1/</sup>	2.6	3.0	2.1	2.3	6.0
-185°C	2.0 <sup>1/</sup>	1.7	3.0	2.6	2.3	2.3	5.5
Non-Irrad Control	1.3	1.4	1.6 <sup>2/</sup>	2.0	1.0 <sup>2/</sup>	1.7	7.3 <sup>2/</sup>

<sup>1/</sup> Significantly different from the control samples

<sup>2/</sup> Significantly different from all the irradiated samples

<sup>3/</sup> Significantly different from the -120°C samples

Significance at 95° confidence level



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) U.S. Choice beef loin stored for one year showed no difference in the ratings of samples irradiated at $-80^{\circ}$ , $-120^{\circ}$ , $-185^{\circ}\text{C}$ when evaluated for sensory characteristics and preference by a technological (expert) panel. Consumer type panelists could not detect any differences in the irradiated samples that could be attributed to the temperatures of irradiation within the temperature range from $-40^{\circ}$ to $-185^{\circ}\text{C}$ . Results of technological panel evaluations obtained for the sensory character- over		



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istics of U.S. Commercial beef loin stored for one year showed statistical differences between the  $-40^{\circ}$  and  $-80^{\circ}$  samples and the non-irradiated controls. No differences were noted in the sensory characteristics and preference ratings of samples irradiated at  $-120^{\circ}$  and  $-185^{\circ}\text{C}$ .

The off-odor and irradiation flavor intensities for the Choice and Commercial loins decreased by the lowering of the irradiation temperatures. However, the decreases in the intensity scores obtained by lowering the irradiation temperature below  $-80^{\circ}\text{C}$  were not statistically significant.

After one year's storage, all samples were rated in the acceptable range of 5.0 or above. Increases in the acceptance ratings of the samples were by lowering the irradiation temperature to  $-80^{\circ}\text{C}$ . Lowering the temperature below  $-80^{\circ}\text{C}$  did not result in any significant improvements.

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