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TECHNICAL REPORT

76-19-FEL

**THE EFFECTS OF IRRADIATION DOSE AND
TEMPERATURE ON CURED HAM**

Irradiated Food Products Group
Radiation Preservation of Food Division

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) → This investigation was conducted to determine the irradiation dose and temperature effects on the radiation induced sensory characteristics (discoloration, off-odor, irradiation flavor, off-flavor, mushiness, and friability) and preference ratings of cured ham. Cured hams were irradiated at doses of 0, 1.5, 3.0, 4.5 and 6.0 megarads and at temperatures of +5°, -30°, -80°, and -130°C. Smoked, cured hams were irradiated at doses of 0, 1.5, 3.0, 4.5, and 6 megarads and at irradiation temperatures of +5°, -30°, -80°, and -130°C using a Cobalt		

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source. Data obtained from sensory evaluations on these samples showed that as the dose increased, intensity ratings for all the sensory characteristics increased and the preference ratings decreased. As the temperature of irradiation was lowered, the intensity ratings decreased and preference ratings increased. These results demonstrated the effect dose and temperature of irradiation has on product quality. ←

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PREFACE

This investigation was conducted to determine the irradiation dose and temperature effects on the radiation induced sensory characteristics (discoloration, off-odor, irradiation flavor, off-flavor, mushiness, and friability) and preference ratings of cured ham. Cured hams were irradiated at doses of 0, 1.5, 3.0, 4.5 and 6.0 megarads and at temperatures of +5°, -30°, -80°, and -130°C.

The results from this experiment have shown that, as the dose increases, the intensity ratings for all the sensory characteristics increase and the preference ratings decrease. This indicates a lowering of product quality. As the temperature during irradiation is lowered, the intensity ratings are decreased indicating an improvement in the product quality.

This study was undertaken as a research project of the Irradiated Food Products Group, Food Engineering Laboratory under Project IT762724AH99, Radiation Preservation of Foods.

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THE EFFECTS OF IRRADIATION DOSE AND TEMPERATURE ON CURED HAM

INTRODUCTION

The process of irradiation at subzero temperatures has been beneficial in reducing the radiation-induced changes in the sensory characteristics and production of chemical, radiation-induced constituents of meats. The improvements in the sensory characteristics have been demonstrated in beef, pork, chicken and shrimp (Snyder¹(1960)¹, Coleby, et al. (1961)², Wadsworth and Shults (1966)³, and Shults and Wierbicki (1974)⁴. Harlan, et al. (1967)⁵ and Kauffman, et al. (1964)⁶ observed a linear decrease in the intensity of irradiation off-flavor of beef steak as the temperatures during irradiation were decreased from +20°C to -196°C. Wadsworth and Shults (1966)³ were reported improvements in color, odor, and flavor as the temperature of irradiation was decreased from 0°C to -196°C, but this decrease was not linear. Shults and Wierbicki (1974)⁴ found beef irradiated at -196°C statistically preferred to beef irradiated at 0°C, however, no significant differences were noted between samples irradiated at -80°C and -196°C.

¹ Snyder, O. P., 1960. Low temperature irradiation of foods. Internal Study. Food and Container Institute to the Armed Forces Project No. 7-84-01-002 1 Apr to 1 June.

² Coleby, B. et al, 1961. Treatment of meats with ionizing radiation. VII. Effects of low temperatures during irradiation. J. Sci. Fd. Agr. 6: 483.

³ Wadsworth, C. K. and G. W. Shults, 1966. Low temperature irradiation of meats. Activities REport, Vol. 18 (1): 13-17.

⁴ Shults, G. W. and E. Wierbicki 1974. Development of irradiated beef. I. Acceptance of beef loin irradiated at cryogenic temperatures. Technical Report 74-57-FL, July 1974.

⁵ Harlan, J. W., F. L. Kauffman and F. Hubymar 1967. Effects of irradiation temperature and processing conditions on organoleptic properties of beef. Rad. Preservation of Foods Adv in Chem. Series 65, Am. Chem. Soc., Washington, D. C., pp 35-37.

⁶ Kauffman, F. L., Harlan, J. W., Rasmussen, C. E. and Rothen, H. L., 1964. Influence of product temperature during irradiation on the sensory characteristics of irradiated meat. Final Report Cont. No. DAAG19-129-QM-2000 Swift and Co., 25 June 1962 - 26 June 1964.

Coleby et al. (1961)⁷ found beef and pork samples irradiated with 5 Mrad at -75°C were preferred to samples irradiated with 2 Mrad at +18°C. Shults and Wierbicki (1974)⁸ also reported an increase in the intensity of off-color, odor, and flavor as the dose increases from 3.0 Mrad to 6.0 Mrad.

The literature on the effects of irradiation dose and temperature adequately demonstrates their effects on the sensory characteristics of fresh meat items. Data are not available on the irradiation effects in cured meats, such as ham. This research effort was initiated to determine the effects of irradiating smoked-cured hams over a wide range of doses and temperatures.

MATERIALS AND METHODS

Processing. Deboned, smoked, fully-cooked ham rolls were used for this experiment. The hams were processed using a cure consisting of the following:

Water	25 kg.
Salt (NaCl)	4 kg.
Sodium tripolyphosphate	750 g.
Sodium nitrate	118 g.
Sodium nitrite	29 g.
Sodium ascorbate	54 g.
Sodium erythorbate	54 g.

The fresh hams were pumped to 15% added weight, held overnight and then stuffed into 6-½ fibrous casings. Smoking and cooking were accomplished in an Atmos smokehouse as follows:

65°C, 38% Relative humidity	- 1 hour - no smoke
65°C, 38% Relative humidity	- 2 hours - smoke
77°C, 40% Relative humidity	- 5 hours - smoke
85°C, 25% Relative humidity	- 2 hours - smoke
77°C, dry bulb	- 90 minutes (internal temperature 70° - 75°C).

The hams were processed to 90 percent yield based on green weight.

Packaging. The smoked hams were sliced into 365 ± 5 g. gram pieces and packaged at 16.6 kPa of pressure in 404 x 202 size cans. After closure, the cans were placed in tempering boxes at the desired temperature of irradiation.

⁷ Coleby, B., M. Ingram, and H. J. Shephard 1961. Treatment of meat with ionizing irradiation. VI. Changes in the quality during storage of sterilized raw beef and pork. J. Sci. Fd. Agr. 5: 417.

⁸ Shults, G. W. and E. Wierbicki, 1974. Development of irradiated beef II. Effects of irradiation temperature and dose on the quality of roast beef. Technical Report 74-56-FL, July 1974

Irradiation. The cans of hams were irradiated at the US Army Natick Research and Development Command, Natick, MA with a cobalt-60 source (dose rate: 14 Joules/kg.). The samples received minimum doses of 1.5, 3.0, 4.5 or 6.0 x 10⁴ Joules/kg. and maximum doses + 25 percent of the minimum. Irradiation temperatures were +5°, -30°, -80°, or -130° C with a range of ±10° C of the required temperatures. Temperatures during irradiation were controlled using a liquid nitrogen system.

Evaluation. Technological evaluations, using trained technological panels consisting of 12 panelists were obtained for the sensory characteristics, off-odor, discoloration, mushiness, irradiation flavor, friability and off-flavor using the 9-point intensity scale of 1 (none) to 9 (extreme). Indications of preference were scored on the hedonic scale of 1 (dislike extremely) to 9 (like extremely) (Peryam and Pilgrim, 1957).⁹

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

The samples were served to the panelists in a series of four tests. On the first test, the panelist rated only irradiated flavor intensity. On the second test, the panelists were asked to give an indication of preference. The panelists rated both irradiation flavor and preference in the third test. Ratings for all the sensory characteristics as well as preference were obtained on the fourth test. A non-irradiated, frozen (-20° C) control sample was evaluated on each test and used as the standard. The irradiated samples were stored for 30 days at 21° C prior to testing and the four tests in each series were conducted within a five-day period. Testing the samples in the four-test series was designed to show the effects of irradiation on the flavor and preference ratings.

Results and Conclusion. The effects of the irradiation dose were investigated at two irradiation temperatures, +5° C and -30° C. The samples were irradiated at 0, 1.5, 3.0, 4.5, and 6.0 megarads (Mrad).

Table 1 shows the results of irradiation with the five doses at +5° C irradiation temperature. The average ratings for both irradiation flavor and preference were found to be significant differences (P < 0.01). As the total dose increased, the irradiation flavor intensity scores increased. Within the ratings for irradiation flavor intensity on the four tests, no significant differences were found, indicating that panelists were able to consistently rate the characteristic of irradiation flavor. Preference ratings decreased as the total dose increased. Samples irradiated at 4.5 and 6 Mrad were rated below 5 on the hedonic scale, indicating that the samples were unacceptable. (Ratings of 5.0 or less are considered unacceptable). Panelists did not rate preference as consistently as irradiation flavor. Ratings for three of the five samples (0, 1.5, and 3.0 Mrad) were found significantly different within the four tests.

⁹ Peryam, D. R. and F. J. Pilgrim, 1957. Hedonic scale method for measuring preferences. Food Technol. 11 (9) Supplement: 9-14.

Ratings showing the effects of total dose irradiated at -30°C irradiation temperature are on Table 2. The 12-D sterilizing dose for ham irradiated at -30°C has been determined to be 3.3 Mrad. (Wierbicki et al., 1973).¹⁰ Again, as the dose increased, the irradiation intensity increased; however, the intensity scores were not as great as those for $+5^{\circ}\text{C}$ irradiated samples. Preference ratings showed only the samples irradiated at 6 Mrad unacceptable (5.0 or below). Analysis of the average scores of the samples on the four tests showed that the difference in irradiation flavor and preference ratings were significant. Irradiation at 1.5 or 3.0 Mrad yielded a product that was not rated significantly different from the non-irradiated frozen control.

Table 3 lists the results of the technological evaluation for the sensory characteristics and preference of ham irradiated at $+5^{\circ}\text{C}$ with the 5 doses. No significant differences were found in the ratings for discoloration, odor and off-flavor. Significant differences were found for irradiation flavor, textural characteristics (mushiness and friability) and preference. With the exception of discoloration, ratings for all the sensory characteristics increased as the total dose increased. This follows previous work on other meat products reported by Wadsworth and Shults, 1966³ and Shults et al., 1974.⁴ Preference ratings indicate the samples irradiated at 4.5 and 6.0 Mrad are unacceptable.

The data of the sensory evaluation of ham irradiated at -30° with the five irradiation doses are shown on Table 4. Again, the ratings for the sensory characteristics increased with increasing doses and preference ratings decreased. However, at an irradiation temperature of -30°C , only the 6.0 Mrad sample was judged unacceptable. Ham irradiated at 1.5 Mrad dose was not rated significantly different from the non-irradiated sample for the sensory characteristics and preference. Significance within the ratings for the sensory characteristics and preference was due to the differences between the non-irradiated control and the sample irradiated at 6.0 Mrad.

The analysis of the data obtained for samples irradiated at the five doses shows that irradiation with 6 Mrad total dose at either $+5^{\circ}$ or -30°C results in an unacceptable item. Irradiation with 1.5 Mrads did not significantly affect the ham samples, and the ratings for the sensory characteristics and preference were essentially the same.

The present minimum sterilizing dose for ham is 3.3 Mrad at -30°C . Data obtained on this study show that in a dose range of 3.0 to 4.5 Mrad at -30°C an acceptable ham item can be produced.

¹⁰ Wierbicki, E., and Heilmann, F. Shelf stable cured ham with low nitrate-nitrite additions preserved by radappertization. Proc. Int. Symp. Meat Prod. Zeist, Switzerland.

The effects of temperatures during irradiation were studied. Samples were irradiated at +5°, -30°, -80°, and -130°C with dose range of 4.5 to 5.6 Mrad. (Table 5). Intensity ratings for the sensory characteristics were directly affected by the temperature during irradiation. As the temperature was lowered from +5°C to -130°C, the irradiated flavor intensity ratings decreased. At +5°C, there was a significant difference between the irradiated sample and the non-irradiated control. No significant difference was found between samples irradiated at -130°C and the non-irradiated control.

Preference ratings increased with the lowering of the irradiation temperature. In this series of tests, both the +5°C and -30°C irradiated samples were rated unacceptable. The low ratings for the -30°C irradiated sample may be due to the comparison to higher quality ham samples irradiated at -80° and -130°C. No significant differences were found between the -80° and -130°C irradiated samples and the non-irradiated control. The ratings for irradiation flavor intensity of all irradiated samples on test 4 were significantly lower than the other two tests. No explanation can be offered for these observations.

Evaluation for all the sensory characteristics of the samples irradiated at the four temperatures are listed on Table 6. The trend of the ratings for the characteristics showed a decrease in the intensities with the lowering of the irradiation temperatures. No significant differences were found between the -80° and -130°C and the non-irradiated control samples for any of the sensory characteristics and preference ratings. Again, this data demonstrates a definite dose and temperature of irradiation effect on the quality of ham.

Irradiation at the determined 12-D dose for ham (3.3 Mrad, -30°C) produces a product which is rated highly acceptable by consumer panels (Table 7). These ratings were obtained using the ham as a meal component. The ham was served as a grilled item. Further improvements in the quality of irradiated ham must be obtained by lowering the 12-D sterilizing dose or improving the processing conditions of the raw material.

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Table 1

Effects of irradiation dose on the irradiation flavor intensity and preference ratings of cured ham - +5°C irradiation temperature

Test Number	0 Mrad		1.5 Mrad		5.0 Mrad		4.5 Mrad		6.0 Mrad	
	Irrad. Flavor	Preference	Irrad. Flavor	Preference	Irrad. Flavor	Preference	Irrad. Flavor	Preference	Irrad. Flavor	Preference
1	1.0	-	2.7	-	3.5	-	3.8	-	3.6	-
2	-	7.0	-	6.11	-	5.7	-	5.0	-	3.9
3	1.2	7.0	2.0	6.9	3.3	5.2	3.8	4.8	4.0	5.2
4	1.6	6.0	2.1	5.8	3.0	5.7	4.0	4.6	4.5	3.9

\bar{x}	1.2	6.8	2.2	6.3	3.4	5.4	3.9	4.8	4.1	4.3
"F" value	0.04	3.96	0.71	4.04	0.23	5.26	0.27	0.21	0.67	2.47
Significance	NSD	sig. 5%	NSD	sig. 5%	NSD	sig. 1%	NSD	NSD	NSD	NSD

TOTAL - Irradiation Flavor F=8.79
 Sig %
 TOTAL Preference F=19.89
 Sig %

Table 2
 Effects of irradiation dose on the irradiation flavor intensity and preference ratings of cured ham, -30°C irradiation temperature

Test Number	0 Mrad		1.5 Mrad		3.0 Mrad		4.5 Mrad		6.0 Mrad	
	Irrad. Flavor	Preference	Irrad. Flavor	Preference	Irrad. Flavor	Preference	Irrad. Flavor	Preference	Irrad. Flavor	Preference
1	1.4	-	1.6	-	3.2	-	3.1	-	2.9	-
2	-	7.7	-	5.8	-	6.0	-	5.7	-	5.3
3	1.2	6.6	1.7	6.3	2.0	6.3	2.4	5.7	3.3	4.9
4	1.4	6.6	2.1	6.1	2.7	5.6	3.3	5.0	4.5	3.7
X	1.4	6.9	1.7	6.2	2.6	6.0	3.1	5.5	3.6	4.7
"p" Value	0.16	2.72	0.21	1.09	2.54	1.23	3.72	1.67	3.05	3.13
Significance	NSD	NSD	NSD	NSD	NSD	NSD	Sig 5%	NSD	NSD	Sig 5%

Total Irradiation Flavor F=14.13 Sig 1%
 Total - Preference F=3.39 Sig 5%

Table 3

Effects of irradiation dose on the sensory characteristics and preference ratings of cured ham - +5° irradiation temperature

Samples Irradiation dose-Mrad	Sensory Characteristics*						Preference **
	Discolor ation	Off odor	Irrad. Flavor	Off Flavor	Mushi ness	Friab- ility	
1.5	2.9	2.4	2.1	1.7	1.7	1.6	5.8
3.0	2.9	2.7	3.4	1.9	2.2	3.0	5.2
4.5	2.6	3.1	4.0	2.0	3.0	3.4	4.6
6.0	3.5	3.5	4.5	2.7	3.0	3.6	3.9
0	2.2	1.9	1.6	1.7	1.4	1.5	6.0
"P" value	0.84	1.75	10.01	1.27	4.48	6.41	4.41
Significance	NSD	NSD	Sig.	NSD	Sig.	Sig.	Sig.
LSD .05			2.42		1.81	2.01	2.04
LSD .01			3.28		2.45	2.72	2.84

*1 = None, 9 = extreme

**1 = Dislike extremely, 9 = like extremely

Table 4

Effects of irradiation dose on the sensory characteristics and preference ratings of cured ham - -30°C irradiation temperature

Irradiation Dose-Mrad	Sensory Characteristics*						Preference**
	Discolor- ation	Off odor	Irrad. flavor	Off flavor	Mushi- ness	Friab- ility	
1.5	1.4	1.8	2.1	1.5	1.8	1.7	6.6
3.0	1.9	2.4	2.7	2.1	2.9	1.8	5.6
4.5	2.5	2.5	3.3	2.8	1.6	2.7	5.0
6.0	5.1	4.2	4.6	2.3	3.8	3.6	3.7
0	1.5	1.9	1.4	2.2	1.9	1.7	6.6
"p" value	15.64	4.65	8.86	1.69	5.03	4.58	8.73
Significance	Sig.	Sig.	Sig.	NSD	Sig.	Sig.	Sig.
LSD .05	1.88	2.21	2.04		1.89	1.98	2.04
LSD .01	2.55	2.99	2.76		2.55	2.68	2.75

* 1=None, 9=extreme

** 1=Dislike extremely, 9=like extremely

Table 5

Effects of irradiation temperature on the irradiation flavor intensity and preference ratings of cured ham - 4.5 Mrad dose.

Test Number	Control Non-irradiated		+5°C		-30°C		-80°C		-130°C	
	Irrad. flavor	Preference	Irrad. flavor	Preference	Irrad. flavor	Preference	Irrad. flavor	Preference	Irrad. flavor	Preference
1	1.5	-	4.0	-	3.5	-	3.1	-	2.5	-
2	-	6.7	-	4.8	-	4.7	-	5.8	-	6.5
3	1.5	7.0	4.1	4.6	3.5	5.2	3.2	5.5	2.7	5.5
4	1.5	5.4	2.4	4.0	2.5	4.6	1.2	5.7	1.1	6.0
\bar{x}	1.5	6.4	3.5	4.5	3.2	4.8	2.5	5.7	2.1	6.0
"F" Value	0.16	0.72	5.32	2.08	2.70	0.28	4.71	0.35	3.72	2.65
Significance	NSD	NSD	Sig. 1%	NSD	NSD	NSD	Sig. 5%	NSD	Sig. 5%	NSD

Total-Irradiation Flavor - F = 3.13 Sig 1%
 Total-Preference F = 10.70 Sig 1%

Table 6

Effects of irradiation temperatures on the sensory characteristics and preference ratings of cured ham 4.5 Mrad dose

Sample Temp °C	Sensory Characteristics*					Preference **	
	Discoloration	Off odor	Irrad. flavor	Off flavor	Mushiness		Friability
+5°C	3.6	2.2	2.4	2.5	2.5	2.5	4.0
-30°C	3.5	1.8	2.5	2.0	2.25	2.2	4.6
-80°C	1.1	1.7	1.2	1.7	1.8	1.8	5.7
-130°C	1.7	1.0	1.1	1.3	1.6	1.9	6.0
Frozen control	2.0	1.8	1.5	2.5	1.2	1.2	5.4

"p" value	6.31	0.64	2.09	2.62	2.92	2.01	4.71
Significance	Sig.	NSD	NSD	Sig.	Sig.	NSD	Sig.
ISD .05	1.9			3.1	1.5		2.2
ISD .01	2.6						3.0

* l=none, 9=extreme
 ** l=dislike; extremely, 9=like extremely

Table 7

Acceptance of 12D* radappertized ham

<u>Sample</u>	<u>No. of Panelists</u>	<u>Preference Rating**</u>
<u>Grilled Ham Test</u>		
1	16	8.1
2	16	7.5
3	19	7.3
4	22	7.4
5	17	7.7
6	45	7.1
7	17	7.8
8	25	6.6
9	24	7.1
10	22	7.4

* 3.3-4.3 Mrad at $-30^{\circ}\text{C} \pm 10^{\circ}\text{C}$

** Tested as a meal component