TECHNICAL REPORT
72-32-FL

IRRADIATION STUDIES ON MEAT

by

J. W. Harlan
and
F. L. Kauffman

Swift and Company,
Research Laboratories,
Packers and Exchange Avenues,
Chicago, Illinois 60609

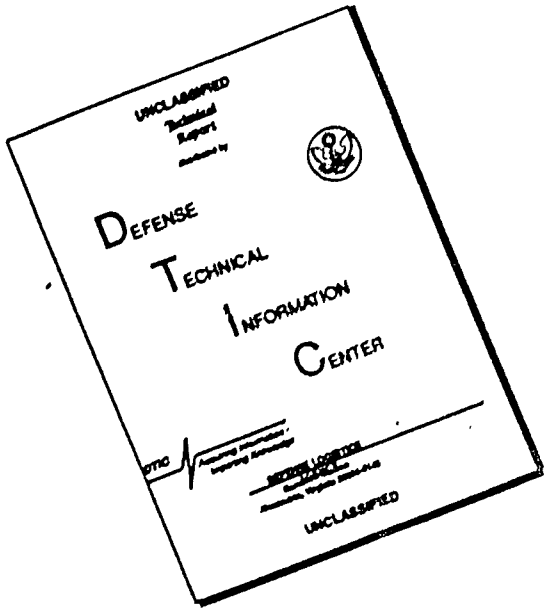
Contract N. NLABS (Natick) No. 172

January 1972

UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Food Laboratory
FL-73

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Swift and Company Research Laboratories Packers and Exchange Avenues Chicago, Illinois 60609	Unclassified 2b. GROUP

3. REPORT TITLE

IRRADIATION STUDIES ON MEAT

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final March 1962 - March 1967

5. AUTHOR(S) (First name, middle initial, last name)

J. W. Harlan and F. L. Kauffman

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1969	15	9

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
NLABS (Natick) No. 172 b. PROJECT NO. 7X84-01-002 c. d.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) 72-32-FL FL-73

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U. S. Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

No differences were noted in degree of irradiation flavor of veal, lamb and beef as regards to age within a species.

Beef, pork, chicken, Brown 'N Serve Sausage, smoked ham and bacon irradiated at -196°C were rated from very little to little irradiation flavor by an expert panel. Consumer panels rated the controls superior to the irradiated samples in most instances.

Ten different items representing five different meats, which had been radiation-sterilized while at a temperature near liquid nitrogen, were evaluated by consumer panels for acceptance, and by a trained expert panel for irradiation flavor intensity. In four of the ten items tested, the consumer panels rated the irradiated samples as good, or better, than the non-irradiated frozen controls.

Acceptance scores and comments were sufficiently favorable to suggest that the consumers did not find any of the irradiated items objectionable. The expert panel rated the irradiated samples on an average midway between "little" and "very little" for irradiation flavor intensity. Expert panel scores were useful in determining to what extent irradiation flavor affected over-all acceptance scores.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

Unclassified
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Irradiation flavor	8		6			
Flavor	8		6		7	
Irradiated meat	9		9		9	
Meat	9		9		9	
Acceptability			7		7	
Radiation sterilization					6	
Military feeding			4		4	

Unclassified
Security Classification

Approved for public release;
distribution unlimited

AD_____

TECHNICAL REPORT
[illegible]

IRRADIATION STUDIES ON MEAT

by

J. W. Harlan P. L. Kauffman

Swift and Company
Research Laboratories
Packers and Exchange Avenues
Chicago, Illinois 60609

Contract No. NLABS (Natick) No. 172

Project reference:
7X84-01-002

Series: FL-73

January 1972

Food Laboratory
U. S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

The availability of shelf-stable, highly acceptable meat items for use in military feeding systems is considered a necessity. The currently available thermally processed items do not fully meet requirements because of their limited utility, stability and acceptability. Radiation processing of "cold" sterilization as it is frequently called, has the potentiality of yielding products that have good military utility, good storage stability, and good acceptability. Therefore, research to develop process criteria that can be used to produce irradiation sterilized meats is underway.

The work covered in this report was performed by Swift and Company Research Laboratories under NLABS (Natick) Agreement No. 172 during the period from March 1962 to March 1967. It represents a series of investigations to determine the effects of the irradiation treatment on sensory characteristics and acceptability of a variety of meat items. Variables studied include such factors as differences in age and diet of the animal prior to slaughter, differences in method of preparation for serving, and product temperature during irradiation. The investigation was performed under Project No. 7X84-01-002, Radiation Preservation of Food.

Dr. F. L. Kauffman was the Project Officer and Official Investigator and Dr. J. W. Harlan the Collaborator in the research work for Swift and Company Research Laboratories. The U. S. Army Natick Laboratories' Project Officer was Dr. F. Heiligman and the Alternate Project Officer was Dr. E. Wierbicki both of the Food Laboratory.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

No differences were noted in degree of irradiation flavor of veal, lamb and beef as regards to age within a species.

Beef, pork, chicken, Brown 'N' Serve Sausage, smoked ham and bacon irradiated at -196°C. were rated from very little to little irradiation flavor by an expert panel. Consumer panels rated the controls superior to the irradiated samples in most instances.

Ten different items representing five different meats, which had been radiation-sterilized while at a temperature near liquid nitrogen, were evaluated by consumer panels for acceptance, and by a trained expert panel for irradiation flavor intensity. In four of the ten items tested, the consumer panels rated the irradiated samples as good, or better, than the non-irradiated frozen controls.

Acceptance scores and comments were sufficiently favorable to suggest that the consumers did not find any of the irradiated items objectionable. The expert panel rated the irradiated samples on an average midway between "little" and "very little" for irradiation flavor intensity. Expert panel scores were useful in determining to what extent irradiation flavor affected over-all acceptance scores.

Approved for public release; distribution unlimited.

Citation of trade names in this report does not constitute an official indorsement or approval of the use of such items.

Destroy this report when no longer needed. Do not return it to the originator.

INTRODUCTION

A number of different types of experiments were conducted as a part of this contract. These included:

(A) A test to determine whether observed degrees of irradiation flavor differed among animals of the same species but of different age;

(B) A study to determine the organoleptic effects of irradiation at low temperature on such items as pork, chicken, sausage, ham, bacon as well as beef;

(C) Expert panel evaluation of frankfurters, salami, turkey rolls, veal and lamb;

(D) A consumer preference experiment on low-temperature irradiated versus non-irradiated samples of bacon, ham, chicken, pork and beef.

EXPERIMENTAL AND RESULTS

(a) Veal, Mutton and Beef of Different Ages:

In order to determine whether observed degrees of irradiation flavor differed among animals of the same species, but of different age, irradiated samples of various types of veal, beef and mutton were prepared for organoleptic evaluation by an expert panel. Four individual animals were included in each of the following groups, with the exception of beef, in which only one animal is represented.

Veal	Milk-fed	100 lb.
	Milk-fed	150-200 lb.
	Native	150-200 lb.
Mutton	Ewe	
	Lamb	
Beef	500 lb.	
	700 lb.	
	Cow, young, soft bone	
	Cow, old, hard bone	

All samples were irradiated at the Radiation Laboratory, U. S. Army Natick Laboratories, using gamma rays emanating from a megacurie cobalt ^{60} source. All test samples were given 4.5 to 5.6 Mrad at ambient temperature. Non-irradiated samples given 3.0-3.7 Mrad were used as open reference

standards at the beginning of each panel session. Samples were evaluated for degree of irradiation flavor on the 1-6 quantitative scale (1-no irradiation flavor 6-very much irradiation flavor) and for tenderness on a 1-9 descriptive (bite and chew very difficult - very easy) scale. Attempts to evaluate texture were abandoned because of consistent, dominant dryness in the veal and crumbliness in the mutton. Samples of each animal were evaluated in duplicate and only one kind of animal (veal, mutton or beef) was sampled in a given panel session. Results are shown in Table I.

TABLE I

IRRADIATION FLAVOR AND TENDERNESS SCORES FOR VARIOUS ANIMAL TYPES

(Mean values and 95% confidence limits)

		Irradiation Flavor (1-6)	Tenderness (1-9)
Veal			
Milk-fed	100 lb.	5.20 ± .56	6.06 ± .42
Milk-fed	150-200 lb.	4.52 ± .56	5.68 ± .42
Native	150-200 lb.	5.01 ± .56	5.63 ± .42
Mutton			
Lamb		3.67 ± .34	7.56 ± .36
Ewe		3.68 ± .18	5.11 ± .10
Beef			
500 lb.		4.00 ± .54	6.79 ± .42
700 lb.		4.21 ± .54	5.79 ± .42
Young cow		4.50 ± .54	4.86 ± .42
Old cow		3.71 ± .54	5.87 ± .42

Examination and statistical analysis of the data indicates no differences in degree of observed irradiation flavor among the types

[illegible] the largest variation was among the four individual animals [illegible] within each type. Tenderness scores indicated, as might be expected, the cow to be less tender than the lamb and the cow meat less tender than the beef.

The relatively intense degree of irradiation flavor observed in the veal is not readily explained. It might be postulated that the inherent mild flavor of veal enabled the irradiation flavor to be detected more easily than when masked by natural meat flavor. It was noted by several experienced panel members that the observed irradiation flavor in both veal and lamb was unlike the typical sensation experienced with irradiated beef heretofore. Several of the ewe samples were strongly "mutton" in flavor, and this also tended to confuse judges.

(B) Low Temperature Irradiation of Pork, Chicken, Sausage, Ham, Bacon and Beef:

Beef steaks from choice animals were obtained, cut into 1" thick pieces, frozen, seared on both sides in an infrared oven, and then enzyme inactivated at 65°C for approximately 10 minutes at 50% relative humidity in a smokehouse. Chicken and pork chops were prepared fresh and then enzyme inactivated in a manner similar to the beef without searing. Brown 'N Serve Sausage was taken from a Swift Premium plant batch and placed frozen in cans. Swift's Premium boneless Hostess Smoked Ham and Swift's Premium Bacon were taken directly from commerical packages, trimmed and placed in cans without further treatment. Samples were then sent to the

Natick Laboratories for irradiation at liquid nitrogen temperature (-180 to -190°C) and returned to Swift's Laboratories. Non-irradiated controls prepared at the same time were held in a freezer until evaluation.

For consumer evaluations a non-trained laboratory personnel panel gave over-all acceptance evaluations of a control and test sample of each meat using a 1-7 facial hedonic scale. A rating of 1 means dislike very much, a rating of 7 means like very much. Samples were presented in reverse order for one-half of the evaluation. Results from the acceptance test are given in Table II.

TABLE II

ACCEPTANCE EVALUATIONS OF IRRADIATED AND CONTROL MEATS

(Mean values and 95% confidence level)

Product	Irradiated Dose In Megarads	No. of Persons Eval.	Mean Score and 95% C.L. Control	Mean Score and 95% C.L. Irradiated	Signif. of Diff. between Cont. & Irrad
Pork	4.5 - 5.6	37	4.38 ± .62	3.89 ± .62	Not Signif.
Ham	3.0 - 3.7				
Warmed		55	5.64 ± .50	4.07 ± .50	99%
Cold		54	5.37 ± .48	3.89 ± .48	99%
Chicken	4.5 - 5.6				
Light		19	4.74 ± 1.02	3.52 ± 1.02	95%
Dark		20	4.75 ± .80	4.40 ± .80	Not Signif.
Sausage	4.5 - 5.6	86	5.14 ± .44	4.14 ± .44	99%
Bacon	3.0 - 3.7	70	5.56 ± .38	4.21 ± .38	99%
Beef	4.5 - 5.6	90	4.40 ± .36	3.36 ± .36	99%

All non-irradiated products with the exception of pork and dark [illegible] meat were significantly better accepted than the irradiated products. The number of evaluations for pork and chicken were small.

These same samples were evaluated for degree of irradiation flavor by a trained panel. The results on a 6 point scale (1 no irradiation flavor - 6 very much irradiation flavor). Results are given in Table III.

TABLE III

IRRADIATION FLAVOR INTENSITY IN VARIOUS IRRADIATED MEATS

(Mean values and 95% confidence limits)

Product	Irradiated Dose In Megarads	Mean Score and 95% C.L. Control	Irradiated
Pork	4.5 - 5.6	1.00	2.13 ± .56
Ham	3.0 - 3.7		
Warmed		1.00	3.33 ± .70
Cold		1.00	3.00 ± .70
Chicken	4.5 - 5.6		
Light		1.13	2.25 ±1.00
Dark		1.38	2.88 ±1.00
Sausage	4.5 - 5.6	1.14	2.86 ± .66
Bacon	3.0 - 3.7	1.14	1.86 ± .66
Beef	4.5 - 5.6	1.14	2.29 ± .46

It appears that the trained panel was unable to distinguish irradiated beef from the non-irradiated and there was considerable disagreement among the tasters concerning the chicken. It should be noted that the panel has been trained only for irradiation flavor in beef and it is not known if a

trained panel in one meat flavor can function as efficiently with other meat flavors even though the irradiation flavor supposedly remains the same.

(C) Frankfurters, Salami, Turkey Rolls, Veal and Lamb:

Beef frankfurters and high fat pork and beef frankfurters were commercial runs of Swift's Premium Franks. These were merely placed in the cans as was the Salami. Turkey rolls were cooked commercially and frozen and slightly defrosted before placing in the cans. No further processing was used. Samples of veal and lamb were enzyme inactivated by placing fresh product in the smokehouse (without smoke) and holding at 65°C for approximately 10 minutes. Samples were sent to the Natick Laboratories for irradiation at ambient temperature (except veal and lamb were irradiated at -80°C (±10°C) in addition to ambient temperature) with 4.5 megarads. These were evaluated by expert panels at Natick Laboratories and at Swift and Company Laboratories.

Table IV shows the results of panel tests of various products irradiated at ambient temperature and at -80°C. These panel tests were conducted at the Natick Laboratores except where indicated.

TABLE IV

PANEL SCORES* IRRADIATED (4.5-5.6 Mrad) AND NON-IRRADIATED CONTROL SAMPLES

	No. of Panelists	Off Odor		Irrad. Flavor		Mushiness		Off Flavor		Discoloration		Preference Score**		Irrad. Flavor Expert Panel Scores*** (Swift Lab.)	
		Irrad.	Cont.	Irrad.	Cont.	Irrad.	Cont.	Irrad.	Cont.	Irrad.	Cont.	Irrad.	Cont.	Irrad	Cont.
All Beef Franks	9	3.44	1.33	3.0	1.11	2.12	1	2.66	1.11	2.9	1.9	5.00	7.00	4.00	1.00
Hi Fat Pork & Beef Franks	9	3.1	1.55	3.3	1.0	3.75	1.75	2.9	1.2	3.7	2.0	5.00	6.55	3.67	1.17
Salami	10	2.5	1.6	2.1	2.2	1.9	1.1	3.1	1.8	1.9	1.3	5.35	-	2.33	1.17
Turkey Roll	8	-	-	3.63	1.12	2.25	1.15	4.0	1.62	3.62	1.0	5.07	6.05	3.83	1.00
Veal (Ambient T)	8	3.37	1.5	4.25	1.75	2.5	1.0	2.12	2.62	1.62	1.5	4.8	6.06	3.33	1.17
Veal (-80°C)	8	2.62	2.0	2.62	1.12	2.62	1.12	2.37	2.87	1.75	1.5	6.2	6.06	3.00	1.17
Lamb (Ambient T)		-	-	-	-	-	-	-	-	-	-	4.6	6.2	4.17	1.00
Lamb (-80°C)	7	1.28	1.14	4.14	1.14	2.14	1.75	2.85	2.4	2.75	1.7	5.35	6.70	3.17	1.00

* 1 - None
2 - Trace
3 - Slight
4 - Below Moderate
5 - Moderate
6 - Above Moderate
7 - Strong
8 - Very Strong
9 - Extreme

** 9 point hedonic scale

*** Based on 6 point scale

1 - None
2 - Very little
3 - Little
4 - Moderate
5 - Much
6 - Very Much

(D) Consumer Evaluations of Some Meat Products Sterilized by Irradiation at Low Temperature:

Many tests have been conducted on the flavor characteristics of meat sterilized by irradiation with beta and gamma rays. Many researchers have noted that irradiation to sterilization conditions imparts and unpleasant flavor to meats. Under the program of research into methods of preparing, irradiating and serving radiation sterilized meats conducted during the past several years by the Natick Laboratories and its contractors, significant improvements have been made in the overall acceptability of irradiated meat products. This progress is reflected in a series of increasingly favorable reports on acceptance of irradiated meats by consumer panels. Included in this series are the reports by Burt (1,2) on irradiation sterilized pork loin, bacon and chicken evaluated by consumer panels at Fort Lee, Virginia; Gernon, Kraus and Drake (4) on evaluation of several meat products by consumer-type panels at the Quartermaster Food and Container Institute in Chicago; the report of Kauffman, Schack and Duxbury (9) on irradiated barbecued beef and beef with gravies and, more recently, the reports of Heiligman (6) on pork and chicken products stored up to 18 months, and of Hembree and Burt (7) on soldier-consumer preference tests wherein pork, beef, chicken and seafood products were evaluated at Fort Lee, Virginia. These reports show that although the non-irradiated control foods were in general slightly preferred over their irradiated counterparts, the acceptance of the irradiated items was sufficiently high for them to be considered satisfactory for incorporation into military

rations. The meat products evaluated in all of the above reports were produced by irradiation at essentially ambient temperatures (about 25°C).

On the basis of expert panel evaluations, Colby, Ingram, Shepherd, Thornely and Wilson (3), Kauffman, Schack and Duxbury (9), and Harlan, Kauffman and Heiligman (5), have presented data showing that the amount of irradiation flavor produced in beef is appreciably lowered by irradiating the product at temperatures down to -196°C. Colby, Ingram, Shepherd, Thornley and Wilson (3) also reported that the same effect was observed in irradiation of pork products.

Kauffman, Harlan, Rasmussen and Roschen (8) reported on limited consumer acceptance evaluation of irradiated beef steaks. They found samples prepared and irradiated under optimum conditions (-196°C followed by slow warming) to be as acceptable as non-irradiated products handled in the same manner. No consumer acceptance data for other meat products irradiated at low temperatures has been reported. The present study was conducted in an effort to determine consumer acceptance of various low temperature irradiation sterilized meats, including beef, pork and poultry products. In order to obtain the reaction of an unbiased civilian population, including both men and women, tests were conducted using untrained panels drawn from a research institute and university population. An overall acceptance paired comparison test was used in which the judges ranked both the irradiated sample and the non-irradiated sample on a 7-point facial hedonic scale. In this type of test, indication of the preferred sample as well as numerical

acceptance scores for both samples were obtained. Irradiation flavor intensity scores were measured on the same samples by an expert panel in order to determine to what extent irradiation flavor intensity ratings could be used as an indication of consumer acceptance.

For those samples prepared at the Swift and Company Research and Development Center: Beef steaks from choice animals were cut into one inch thick pieces, frozen, seared on both sides in an infrared oven and then enzyme inactivated at 65°C for 10 minutes at 50% relative humidity. Chicken and pork chops were obtained fresh and then enzyme-inactivated in a manner similar to beef without the searing, and packed in cans. Boneless smoked ham and premium quality bacon were taken directly from consumer packages, trimmed and placed into cans without further treatment. All cans were closed under a 20 inch vacuum. Samples were sent to the Natick Laboratories for irradiation and returned to Swift's Laboratories. The products were in an environment near the temperature of liquid nitrogen (-180°C to -196°C) during irradiation. Irradiation doses were 4.5 to 5.6 megarads for beef, pork and chicken and 3.0 - 3.7 megarads for ham and bacon. Non-irradiated controls prepared at the same time in the same manner were held in a freezer until evaluation. The samples were held 3 to 4 months before evaluation.

Samples Prepared at the Natick Laboratories

Samples of roast beef, pork loin, and chicken were enzyme inactivated by pressure cooking (10 psig) by the Natick Laboratories. These samples and commercially processed bacon and ham, were packed in cans (20 inch vacuum). They were then irradiated in the same manner as the samples prepared in the Swift and Company Laboratories. These samples along with suitable controls were returned to Swift and Company for further evaluation. The samples were held 3 to 4 months prior to evaluation.

Preference testing was done at Illinois Institute of Technology Research Institute using untrained panelists taken from a regular cafeteria line. Those people willing to participate were taken to one side and furnished a plate with the test sample and non-irradiated control sample both of which were warm. Sample presentation was randomized and sample size was uniform. The samples were coded so that the panelist did not know whether he was tasting the control or test product. No mention was made that the evaluations included irradiated samples. Each panelist indicated on a facial hedonic scale his preference and also was urged to make any comments he desired concerning the samples. After evaluation the preference scores were analyzed using Student's "t" test to establish the statistical significance of indicated preferences.

An expert panel consisting of 8 persons especially trained in detecting irradiation flavor was used to test the same samples of meats that were used in this consumer test.

Mean acceptance scores for each test product are given in Table I along with the number of panelists participating in each evaluation (N). Preferences between irradiated and non-irradiated samples which were found to be real with a probability of 95% or greater are shown in the last column of Table V. The expert panel results are given in Table VI for all products.

TABLE V

CONSUMER PANEL RATINGS FOR PREFERENCE IN VARIOUS MEALS

Product	Source	N	Mean Acceptance Score (a) Irrad.	Non-Irrad.	Indicated Preference (b)
Pork	Natick	61	5.2	4.9	Irradiated
Beef Roast	Natick	69	4.9	4.8	No Difference
Bacon	Swift	105	4.7	5.1	Non-Irradiated
Chicken	Natick	73	4.6	4.9	Non-Irradiated
Bacon	Natick	93	4.5	3.6	Irradiated
Ham	Swift	89	4.2	5.0	Non-Irradiated
Chicken	Swift	40	4.0	5.2	Non-Irradiated
Ham	Natick	72	3.9	4.9	Non-Irradiated
Pork	Swift	50	3.7	4.2	No Difference
Beef Steak	Swift	56	3.7	4.8	Non-Irradiated

(a) 1-7 Facial Hedonic Scale. A rating of 1 means dislike very much; a rating of 4 means neither like nor dislike, and a rating of 7 means like very much.

(b) Statistically significant at 95% probability or greater.

TABLE VI

EXPERT PANEL RATINGS FOR AMOUNT OF IRRADIATION

FLAVOR INTENSITY IN VARIOUS MEATS

Product	Source	Flavor Intensity Scores* Irrad.	Non-Irrad.	Difference
Pork	Natick	2.2	1.3	0.9
Beef Roast	Natick	3.0	1.3	1.7
Bacon	Swift	1.9	1.1	0.8
Chicken	Natick	2.6	1.3	1.3
Bacon	Natick	2.1	1.3	.8
Ham	Swift	2.5	1.2	1.3
Chicken	Swift	2.3	1.7	.6
Ham	Natick	3.6	1.1	2.5
Pork	Swift	2.2	1.3	.9
Beef Steak	Swift	3.2	1.0	2.2

*Based on 6-point scale of irradiation flavor intensity.

1 = none; 6 = very much

The principal deterrent to consumer acceptance of irradiated meat products has in the past been the development of an irradiation flavor objectionable to most consumers. It has been natural, therefore, to evaluate the results of research designed to reduce these flavors in terms of expert panel evaluations of irradiation flavor intensity and to use the more cumbersome and often less definitive consumer acceptance test only when the product has first passed the expert panel screening. In consumer acceptance testing, variables such as texture, odor, color and sample variation all enter into the consumer's appraisal of the

product in addition to the flavor produced by the irradiation. Psychological factors also enter into consumer panel evaluations. Essentially the same test group can give quite different acceptance scores on different days as shown by some of the data on the Fort Lee Army feeding tests.(7) In addition, it is well known that sensitivity to irradiation flavor and the reaction to irradiation flavor varies widely between individuals. Members of an expert flavor panel are pre-screened to determine that they are, first, able to detect small amounts of irradiation flavor and distinguish them from other flavors in the sample and, secondly, are screened to be sure that they can quantitatively measure small differences in irradiation flavor intensity. In addition, expert panel evaluations are conducted under closely controlled environmental conditions and with the use of standard samples of irradiated and non-irradiated product as references. It is not surprising then that the trained expert panels can detect and measure irradiation flavor levels in products where a majority of a consumer panel would not detect any off odor or flavor due to the irradiation processing.

An examination of several sets of data on beef products on which both consumer acceptance and expert panel scores have been obtained in our laboratory have led us to suggest that product scored as having "little" irradiation flavor by our expert panel (2 points above the non-irradiated control on our 6-point scale) would probably be at about the threshold level for detection of an unusual flavor by a consumer acceptance panel.

Product scored less than "little" irradiation flavor by an expert panel would probably not be severely downgraded on the basis of flavor by a consumer panel while product scoring above "little" would probably be penalized by the consumer acceptance panel on the basis of poor flavor. This demarcation point is backed by only a meager amount of data, but it does give us a convenient criterion for deciding whether product is sufficiently good to submit to a consumer panel. Table VII lists the consumer acceptance scores on irradiated products, the loss in acceptability due to irradiation processing and the amount of irradiation flavor produced as measured by the expert panel. If the flavor effect threshold criterion, or 2.0 expert panel points is kept in mind when examinging the data in Table VII it is seen that only for the beef steak prepared at Swift and the ham prepared at Natick would one expect to have a serious loss in acceptability due to poor flavor.

TABLE VII

CONSUMER ACCEPTANCE SCORES, LOSS IN ACCEPTABILITY DUE TO IRRADIATION, AND AMOUNT OF IRRADIATION FLAVOR IN VARIOUS MEATS

Product	Place Prepared	Consumer Acceptance Score of Irrad. Product*	Loss In Acceptability Due to Irradiation**	Irradiation Flavor Produced***
Pork	Natick	5.2	-0.3	0.9
Beef Roast	Natick	4.9	-0.1	1.7
Bacon	Swift	4.7	0.4	0.8
Chicken	Natick	4.6	0.3	1.3
Bacon	Natick	4.5	-0.9	0.8
Ham	Swift	4.2	0.8	1.3
Chicken	Swift	4.0	1.2	0.6
Ham	Natick	3.9	1.0	2.5
Pork	Swift	3.7	0.5	0.8
Beef Steak	Swift	3.7	1.1	2.2

* Taken from Table V.

** Difference between consumer acceptance score of irradiated and non-irradiated samples - taken from Table V.

*** Difference between expert panel score of irradiated and non-irradiated samples - taken from Table VI.

The loss in acceptability for both these products is appreciable. A large number of panelists noted that the irradiated beef steaks had "pork", "scorched" or "foreign" flavors and a number of comments on the ham prepared at Natick were in the nature of a "medicinal" or "re-cooked"

flavor although curiously enough, over ten per cent of the panel members reported the irradiated ham to have a good flavor and texture. Based on the expert panel 2-point difference criteria, the other products in the test should not have experienced a serious loss in acceptability due to flavor. With the exception of chicken irradiated at Swift, which was noted by some panelists to be "almost spoiled", "having an after-taste" and "not good", and which suffered a large loss in acceptability on irradiation processing. this observation seems to be true. Comments on other samples mention "blandness" and "lack of taste" in the cured product particularly but do not suggest the presence of severely objectionable flavor. Instead, other properties of the sample appear to be more important in the overall acceptance scores. The expert panel flavor intensity score on roast beef was close enough to the 2.0 level to raise some question as to whether flavor might be impaired. However, the comments show that irradiation processing produced a tenderizing action which apparently more than compensated for any loss in flavor score. As a result, the consumer acceptance ratings of the irradiated and non-irradiated products were not significantly different. In the case of bacon and pork prepared at Natick, the irradiated samples were actually preferred by the consumer panel over the non-irradiated products. Here the comments clearly indicate that in the case of the pork, the irradiated sample was found to be more tender and moist than the non-irradiated product and in the bacon evaluation of the comments show that the panel objected to the high level of salt in the non-irradiated control, which apparently had

been moderated by the irradiation treatment. The data reported here suggest that sufficient off-flavor to markedly affect the consumer acceptance ratings was found in only three of the ten samples irradiated at liquid nitrogen temperatures. In the case of one of these three samples, the chicken prepared at Swift, the off-flavor apparently was not the "typical" irradiation flavor. In the other seven products, flavor changes were sufficiently small that other properties of the products, such as texture and level of curing agents were at least equally important in the final consumer acceptance rating.

Both the levels of acceptance and, in general, the loss of acceptability due to irradiation processing found in this series of consumer acceptance tests are very similar to those reported for similar products prepared by ambient temperature irradiation by Hembree and Burt (7) in their extensive feeding tests at Fort Lee, Virginia, although it should be noted that in their work they did not find any case in which the irradiated product was preferred to the non-irradiated control.

SUMMARY

No differences were noted in degree of irradiation flavor of veal, lamb and beef as regards to age within a species. Beef, pork, chicken, Brown 'N Serve Sausage, smoked ham and bacon irradiated at -180 - 196°C were rated from very little to little irradiation flavor by an expert panel. Consumer panels rated the controls superior to the irradiated samples in most instances.

Ten different items representing five different meats, which had been radiation-sterilized while at a temperature near liquid nitrogen, were evaluated by consumer panels for acceptance, and by a trained expert panel for irradiation flavor intensity. The consumer panels rated the irradiated samples as good as, or better than, the non-irradiated frozen control in four of the ten items tested. Acceptance scores and comments were sufficiently favorable to suggest that the consumers did not find any of the irradiated items objectionable. The expert panel rated the irradiated samples on an average midway between "little" and "very little" for irradiation flavor intensity. Expert panel scores were useful in determining to what extent irradiation flavor affected overall acceptance scores.

REFERENCES

(1) Burt, T. B., Troop Acceptability Test of Radiation Processed Pork and Bacon, Technical Report T-81, FEA 57029-F, September 1958, Quartermaster Research and Engineering Field Evaluation Agency, Fort Lee, Virginia.

(2) Burt, T. B., Troop Acceptability Tests of Selected Items of Radiated Foods, Technical Report T-104, FEA 58040-F, March 1959, Quartermaster Research and Engineering Field Evaluation Agency, Fort Lee, Virginia.

(3) Coleby, B., Ingram, M., Shepherd, H. J., Thornley, M. J., and Wilson, M., Treatment of Meats with Ionizing Radiation. VII Effects of Low Temperature During Irradiation. J. Sci. Food Agric. 12, 483 (1961).

(4) Gernon, G. D., Jr., Kraus, G. D., and Drake, M. P., Effects of Active Carbon on the Storage Stability of Irradiated Meats. Food Technology 15, 354 (1961).

(5) Harlan, J. W., Kauffman, F. L., and Heiligman, F., Effects of Irradiation Temperature and Processing Conditions on Organoleptic Properties of Beef and Chemical Yields in Model System. Radiation Preservation of Foods, Advances in Chemistry, Series 65. American Chemical Society, Washington, D. C. 1967, pp. 35-37.

(6) Heiligman, F., Storage Stability on Irradiated Meats. Food Technology 19 (7), 114-6 (1965).

(7) Hembree, H. W., and Burt, T. B., Radiation Preservation of Foods, Proceedings of an International Conference, Publication No. 1273, National Academy of Science, 1965, pp. 109-120.

(8) Kauffman, F. L., Harlon, J. W., Rassmussen, C. E., Roschen, H. L., Influence of Product Temperature During Irradiation on the Sensory Characteristics of Irradiated Meats. Final Report Contract No. DA 19-129-QM-2000, Swift and Company, U. S. Army Natick Laboratories, Natick, Massachusetts (1946).

(9) Kauffman, F. L., Schack, W. R., and Duxbury, D. D., Status on the Reduction of Irradiation Flavors in Radiation Sterilized Beef. Presented at First International Congress of Food Science and Technology, London, England (1962).