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Washington, D.C.

August 9-14, 1970

HIGH DOSE RADIATION PROCESSING OF MEAT, POULTRY AND SEAFOOD PRODUCTS

by

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It is estimated that in the year 2000 the world population will be over 6 billion and to satisfy the food requirements, the world food supply has to be increased three times the present world production. Therefore, food preservation and storage, particularly of highly perishable foods such as meats, is of particular importance. High dose radiation processing of meats, poultry and seafood offers an opportunity to relieve food shortages, particularly in animal protein, because there is no way currently to keep these foods in highly acceptable and wholesome conditions for long periods of time without refrigeration. For this reason, food irradiation has been part of the "Atoms for Peace" program since its inception in 1953. The scientific feasibility of using ionizing radiations to preserve prepackaged meats, poultry and seafood, for long periods of time under non-refrigerated conditions has been proven under the U. S. Army Radiation Preservation of Foods Program.

1. PRODUCT TECHNOLOGY

a. First products.

SLIDE NO. 1

Technology is well advanced for radappertization of nine foods. These are listed in this slide showing the temperature range of the food during irradiation and the minimum required radiation sterilizing dose in megarads (MRD).

Except for determination of the MRD, technology is nearly completed for highly acceptable ground beef (hamburger), beef with gravy, lamb, and barbecued beef, pork, and chicken radappertized at -30 ± 10°C. Research on radappertized frankfurters is underway.

b. Microbiological safety.

The minimum radiation doses given in this slide were obtained in accordance with the 12D concept of microbiological safety, using the method by Schmidt and Nank, published in Food Research in 1960. The MRD data indicate the radiation dose in megarads needed to reduce the numbers of viable spores by a factor of 1×10^{12}, based upon the recovery data of the most radiation resistant strains of Clostridium botulinum used in inoculated pack studies with the individual foods in sealed cans as the substrate. As the data indicate, the MRD values depend on the food and its temperature during irradiation; the foods containing added curing agents and/or spices have lower MRD's (ham, pork sausage, bacon) than foods without these ingredients.

c. Enzyme Inactivation.

SLIDE NO. 2

To make the irradiated meats shelf-stable, in addition to the destruction of food spoilage microorganisms, the naturally occurring enzymes, particularly proteases, such as cathepsins, must be inactivated. The most reliable method employed so far is a mild heat treatment, or blanching, prior to irradiation.

A fast and sensitive method for the assay of proteolytic enzyme activity, if any, in irradiated meats within a few hours, instead of after many months of storage, is now available to study the shelf stability of radappertized blanched meats. This method is based on incubating meat samples (enzyme source) with C^{14} labelled, cysteine-treated, hemoglobin substrate and determining the radioactivity in the acid-soluble filtrate.

As the data in this slide indicate, about 30 to 40 minutes are required to inactivate proteolytic enzymes in beef at 65°C; by using this method it was shown that over 180 minutes are required at 60°C, whereas only 5 to 10 minutes are required at 70°C.

d. Packaging

Two program goals have guided progress in the field: (a) determining reliability of commercially available metal containers for low temperature radiation sterilization of prepackaged foods, and (b) developing flexible lightweight containers capable of withstanding rough handling and storage, retaining protective qualities during storage without any adverse effects on the food contained therein.

There is no problem in irradiation of tinplate containers at doses up to 7.5 megarads at temperatures as low as -90°C, provided the can enamels used are of the epoxy-phenolic or phenolic types and the end-sealing compounds are of the butadiene-styrene or neoprene types.

SLIDE NO. 3

This slide shows five materials approved by FDA as food contactants for high dose (up to 6 megarads) cobalt-60 or cesium-137 irradiated foods.

The approval was based on the small and insignificant amounts of the extractives formed, and the freedom from induced radioactivity as a result of irradiation. The four food contacting plastic films, including Nylon 11 (not cleared as yet), are being used as components of flexible packaging, in the form of pouch laminates with aluminum foil as the gas, water-vapor and light barrier.

SLIDE NO. 4

This slide shows specimens of such flexible packaging. In a two year pack test of bacon, ham, pork, beef, and chicken, such multilayered flexible packages provided the needed protective characteristics and radiation stability for packaging of electron and gamma irradiation sterilized meats, even when irradiated at -30 $\pm$ 10°C.

e. Irradiation Temperature

SLIDE NO. 5

Continued investigation of irradiation of food in the frozen state has shown that lowering the temperature to -30°C and below results in drastic improvement in acceptance over ambient temperature for most products. As shown in this slide, improvements are significant in nearly all factors including reduction in off-color, off-texture and irradiation flavor intensity. However, as temperatures are lowered below 0°C., higher irradiation doses are required to achieve the same degree of biocidal effect under the 12D concept. Cost increases as temperature is lowered, particularly below the limit of mechanical refrigeration which is at about -30°C. The most favorable balance of quality, cost, and required irradiation dose appears to be at about -30 $\pm$ 10°C.

Irradiation of meats in the frozen state minimizes destruction of vitamins, particularly thiamine.

SLIDE NO. 6

In this study ground ham was irradiated at three levels (3.0, 4.5, 6.0 Mrads) at five different temperatures (+5°, -20°, -40°, -60°, -80°C). The results indicate that as the irradiation temperature is decreased, the retention of thiamine in the product is increased.

SLIDE NO. 7

In another study, changes in the thiamine, riboflavin, niacin and pyridoxine contents of smoked ham and pork loin were compared after irradiation or conventional thermal sterilization processing, followed by storage and preparation for serving. The results showed that of the vitamins studied, thiamine was affected most, and riboflavin the least. This slide shows the retention of the vitamins in smoked, irradiated ham and in a commercial thermally sterilized ham. As the data indicate, the vitamin retention was as good or better after irradiation to 4.5-5.6 megarads at -80°C as it was after the thermal processing. Vitamin losses during preparation for eating were negligible regardless of prior treatment. Riboflavin and niacin were stable during storage at 21°C for twelve months; however, the losses of thiamine and pyridoxine during the storage accounted for 54 and 16%, respectively.

f. Additives

(1) Cured Meats

SLIDE NO. 8

It has been established that in order to stabilize the color in radappertized ham, it is necessary that the curing solutions contain both

sodium nitrate and ascorbate in addition to sodium nitrite. However, as shown in this slide, only about 25 parts per million (ppm) nitrites are needed, instead of the 200 ppm allowed by USDA, to get the desired cured meat color of the product.

SLIDE NO. 9

As far as the addition of sugar (sucrose, glucose or corn syrup) is concerned, this additive is not needed to get good quality irradiated cured meats. This slide shows data to support this conclusion in the case of cured, smoked ham.

(2) Binding Agents

SLIDE NO. 10

Mixtures of about 1 percent sodium chloride and 0.25 to 0.5 percent food grade phosphates, such as sodium tripolyphosphate, have been found to be excellent binding agents both for radappertized hamburgers and for formed rolls of several meats including beef, chicken, pork and lamb, as shown in this slide. Weight loss during cooking was reduced from the normal 30-35 percent loss with no additives to 10-15 percent with these additives. All products retained their shape through extended room temperature storage and during kitchen preparation. The meat rolls may be readily sliced after reheating. Consumer acceptance approaches that of counterparts prepared from fresh or frozen meats.

g. Quality

SLIDE NO. 11

For the quality evaluation of irradiated foods the 9-point hedonic scale for preference or acceptance is used. In the case of meat and poultry, the score of 5 ("neither like nor dislike") is considered to be

the threshold of acceptability. A rating of 7 or above indicates a highly acceptable product. This slide shows average acceptance scores for ham irradiated in the frozen state (-80 and -30 $\pm$ 10°C) when served as a component of regular meals. These data show the high acceptance of irradiation sterilized ham. Similar data were obtained on other foods radappertized in the frozen state.

2. WHOLESOMENESS OF IRRADIATED FOODS

The wholesomeness or safety for consumption of irradiated foods has been studied in considerable depth since the early 1950's. A major portion of these studies was conducted under the direction of the Surgeon General of the U. S. Army.

Based on the wholesomeness studies on twenty-one different foods which were selected as representative of food consumed by the United States populace, the Army Surgeon General concluded in 1965 "that foods irradiated up to absorbed doses of 5.6 megarads with a cobalt 60 source of gamma radiation or with electrons with energies up to 10 million electron volts have been found to be wholesome, i.e., safe and nutritionally adequate" (Congress of the United States, JCAE Hearings, June 9 and 10, 1965.)

In August 1968, the Army withdrew its petition to FDA which requested approval of irradiation sterilized canned ham after the FDA stated that the data submitted were insufficient to prove wholesomeness. Since the petition for ham was based upon wholesomeness data for previously approved bacon-ham not being one of the 21 foods subjected to long term wholesomeness studies - FDA subsequently revoked its previous approval for radappertized bacon.

The Army Medical Department has reiterated that radappertized foods are wholesome. However, additional studies in much greater depth are planned to satisfy current requirements of the FDA for proof of wholesomeness.

The Army has prepared protocols for animal feeding studies to determine the wholesomeness of radappertized beef and ham. The protocols are being reviewed by the National Academy of Sciences - National Research Council, the USDA and the FDA. It is anticipated that animal feeding studies with beef* or ham will commence before the end of the current calendar year.

3. CONCLUSIONS

a. Radappertization of meat, poultry and seafood has been shown to be feasible on a laboratory scale. Fifteen foods preserved this way are well accepted organoleptically.

b. The major remaining research problem is to obtain data sufficiently convincing to FDA that radappertized foods are safe to eat so that FDA will grant the approvals required by law.

c. After FDA approvals are obtained, radappertization will be able to play its role of providing high quality and more abundant food to the protein deficient and hungry people throughout the world.

* Animal feeding studies with radappertized beef started 28 April 1971. (EG 25 July 1972).

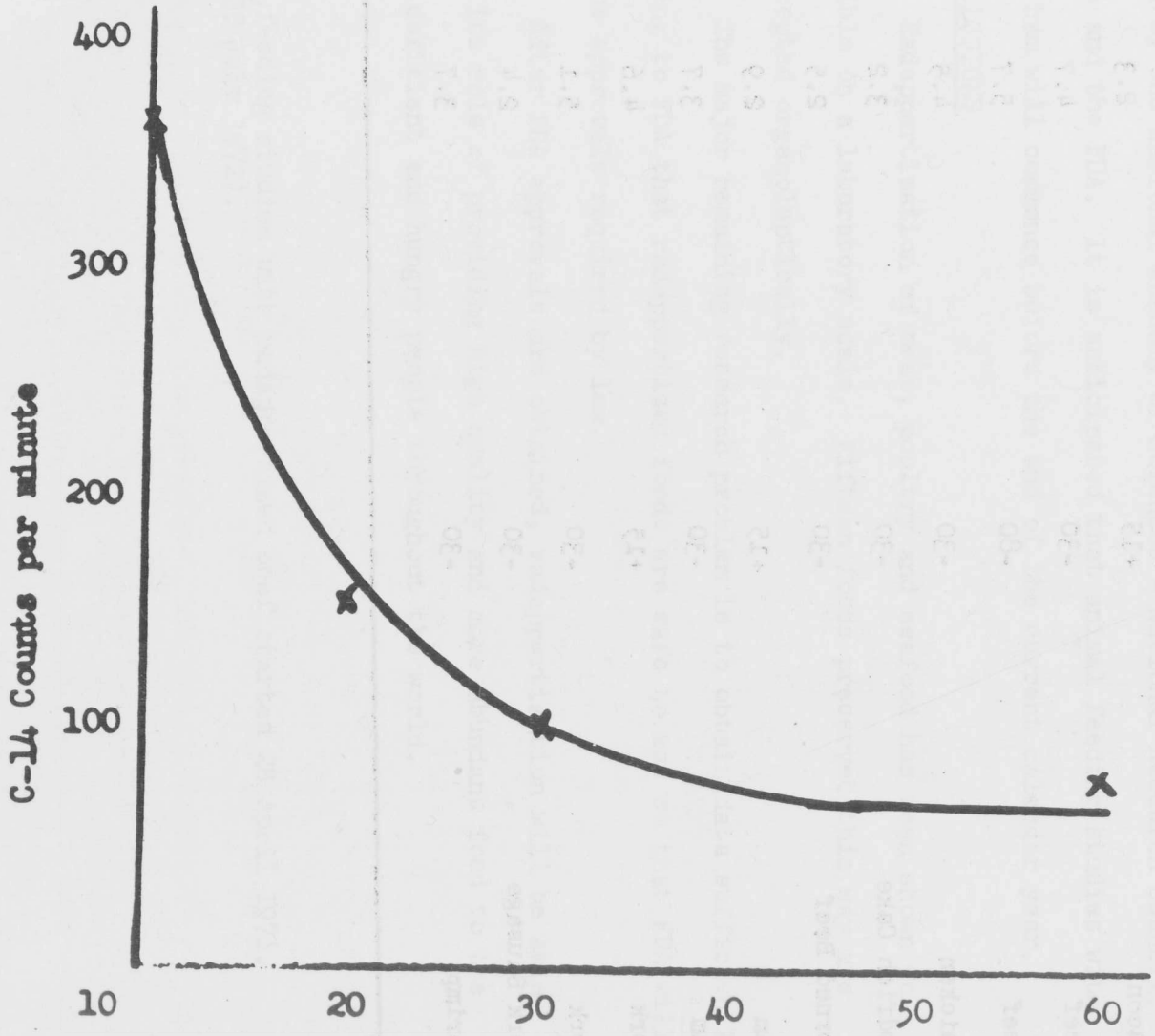
SLIDE NO. 1

Minimum Radiation Dose (MRD) for Radappertized Foods Based upon 12 Logarithm Reduction of *Clostridium botulinum* Spores (12D).

Food	Irrad. Temp. $^{o}C \pm 10^{o}C$	MRD (Mrad)
Bacon	+15	2.3
Beef	-30	4.7
Beef	-80	5.7
Chicken	-30	4.5
Codfish Cake	-30	3.2
Corned Beef	-30	2.5
Ham	+15	2.9
Ham	-30	3.7
Pork	+15	4.6
Pork	-30	5.1
Pork Sausage	-30	2.4
Shrimp	-30	3.7

SLIDE NO. 2

Effect of Blanching Time at 65°C on Proteolytic Activity in Beef



SLIDE NO. 3

Packaging Materials Approved by the U.S. Food and Drug Administration as Contactants for Foods at Gamma Irradiation Doses up to 6 Mrads.

Polyethylene

Polyethylene Terephthalate

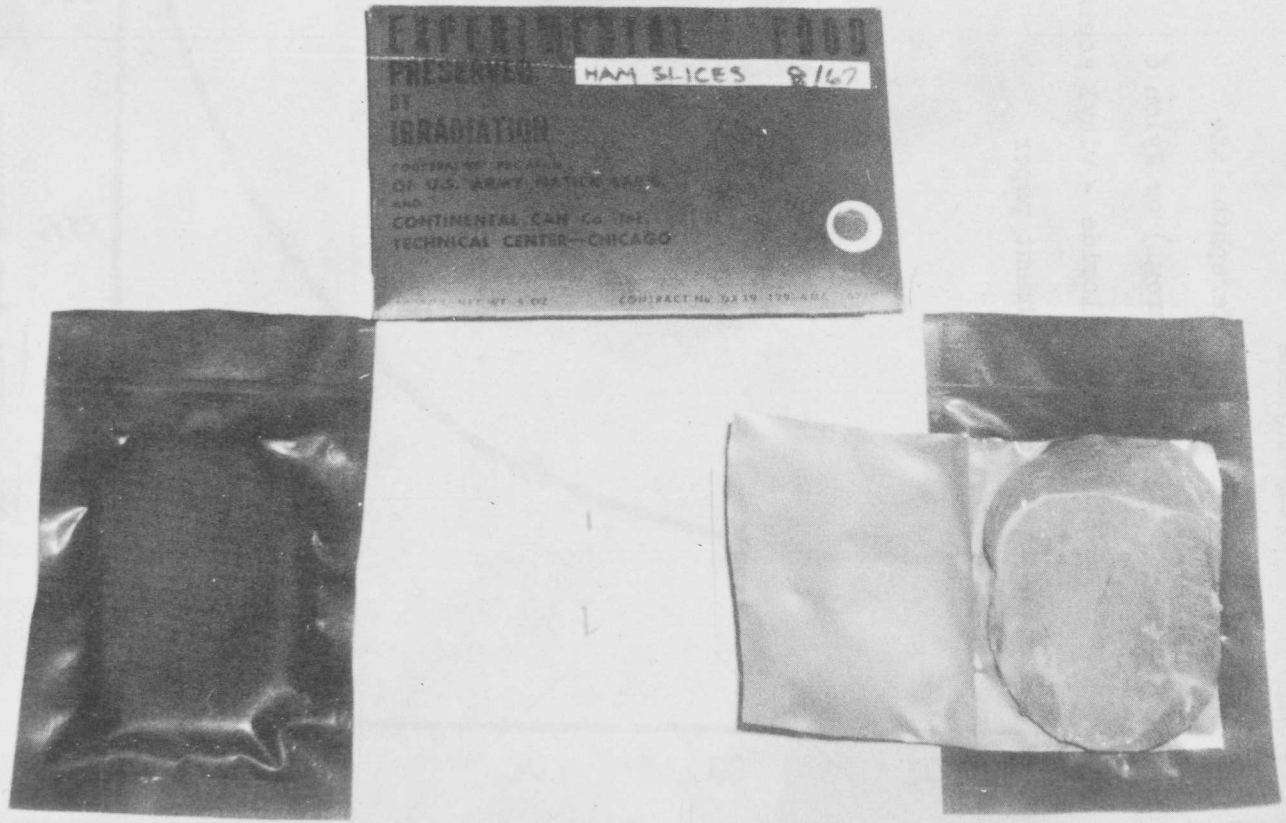
Poly (iminocaproyl) or Nylon 6

Poly (vinyl chloride - vinyl acetate)

Vegetable parchment paper

SLIDE NO.4

FLEXIBLE PACKAGING FOR RADAPPERTIZED FOODS



SLIDE NO. 5

Effect of Irradiation Temperature on the Sensory Characteristics of Beef.
(U.S. Choice Top Round, 4.5 - 5.6 Mrad Cobalt-60 Irradiation)

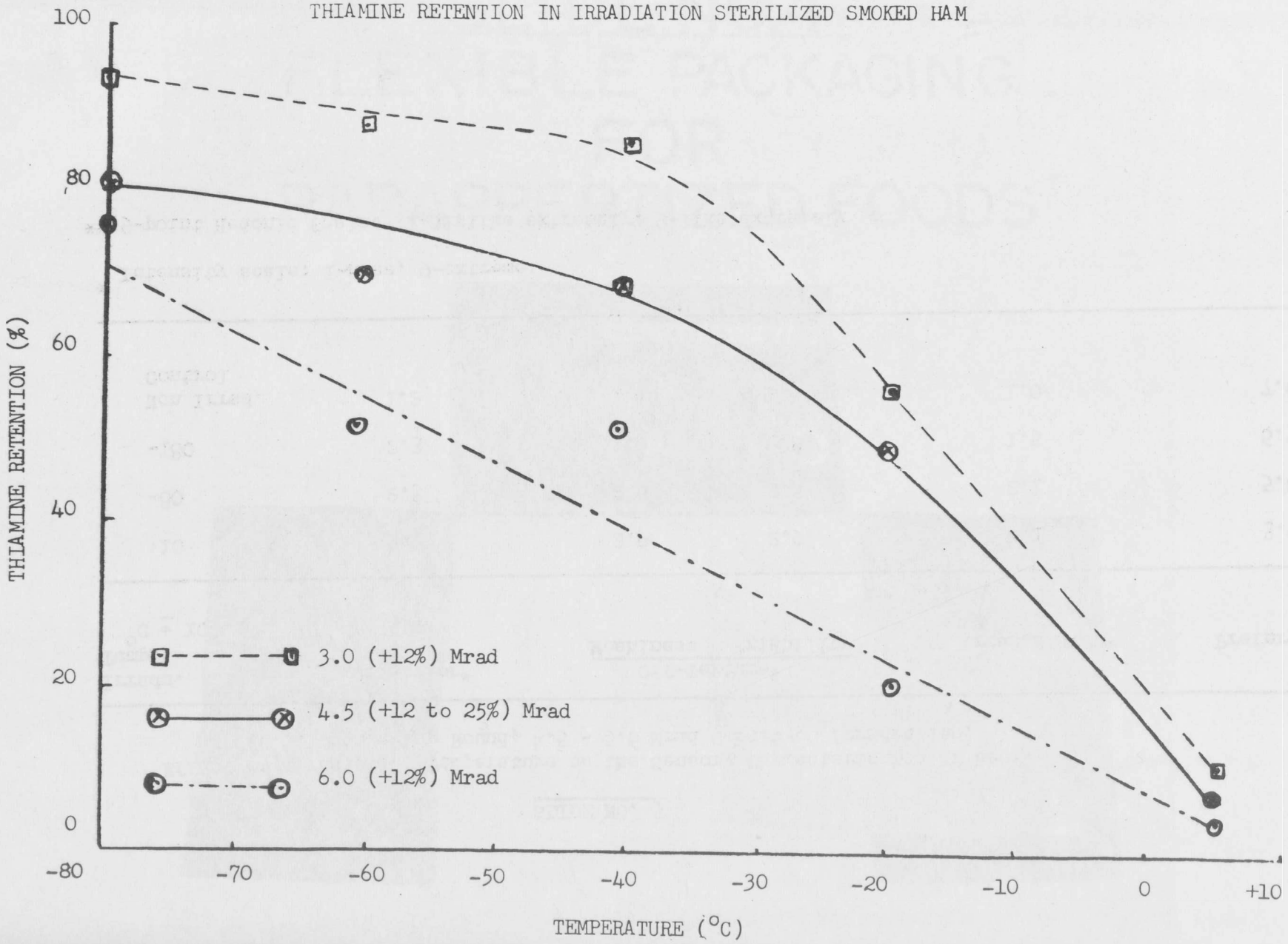
Irradn. Temp. °C ± 10°C	Off-color*	Off-Texture*		Irrad Flavor*	Preference**
		Mushiness	Friability		
+10	3.9	2.9	2.9	4.1	3.9
-80	2.3	2.0	2.5	2.1	5.8
-180	2.3	1.6	1.8	1.5	6.5
Non Irrad. Control	1.2	1.4	1.4	1.0	7.6

* Intensity scale: 1-none, 9-extreme;

** 9-point Hedonic Scale: 1-dislike extremely, 9-like extremely

SLIDE NO. 6

THIAMINE RETENTION IN IRRADIATION STERILIZED SMOKED HAM



SLIDE NO. 7

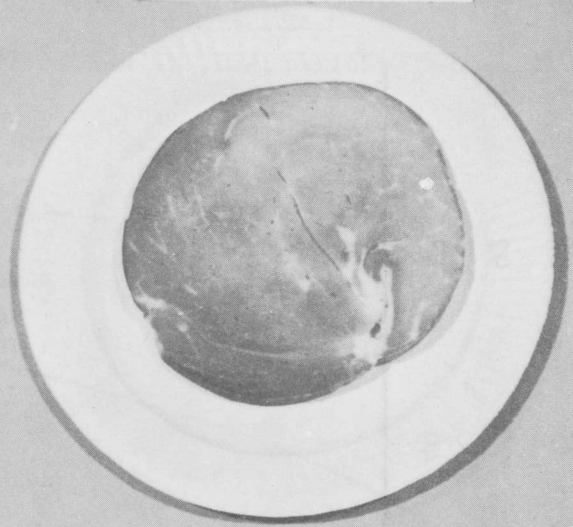
Effect of Processing on Vitamin Retention in Ham.

Processing Treatment:		Vitamin Retention, Percent:			
Dose[1/]	Irrad. Temp.	Thiamine	Riboflavin	Niacin	Pyridoxine
3.5-4.4	-80 ± 5°C	69	110	65	87
3.5-4.4	5 ± 5°C	6	93	86	87
3.5-4.4	Ambient	4	98	85	55
4.5-5.6	-80 ± 5°C	88	122	76	92
Thermally Sterilized[2/]		33	108	46	53

1/ Megarads.

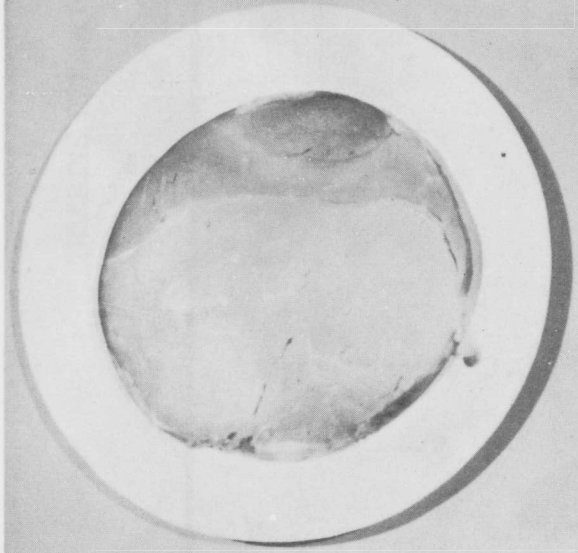
2/ Commercial canned 1-1/2 lb. ham.

SLIDE NO. 8



25

$NaNO_2$, ppm



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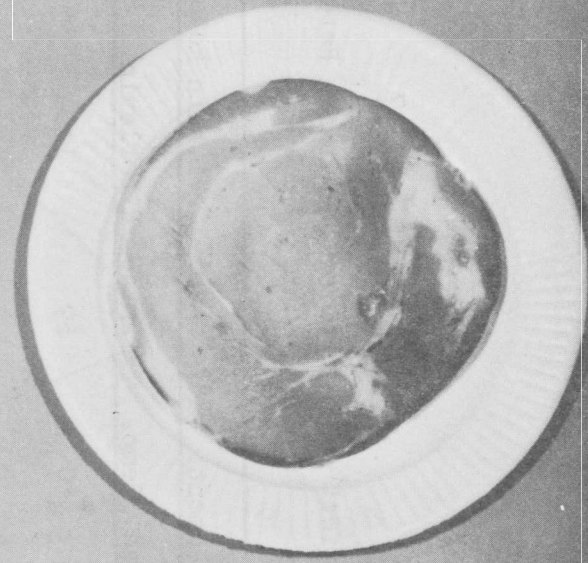


200

Effect of Nitrite on the Cured Meat Color in Ham

SLIDE NO. 9

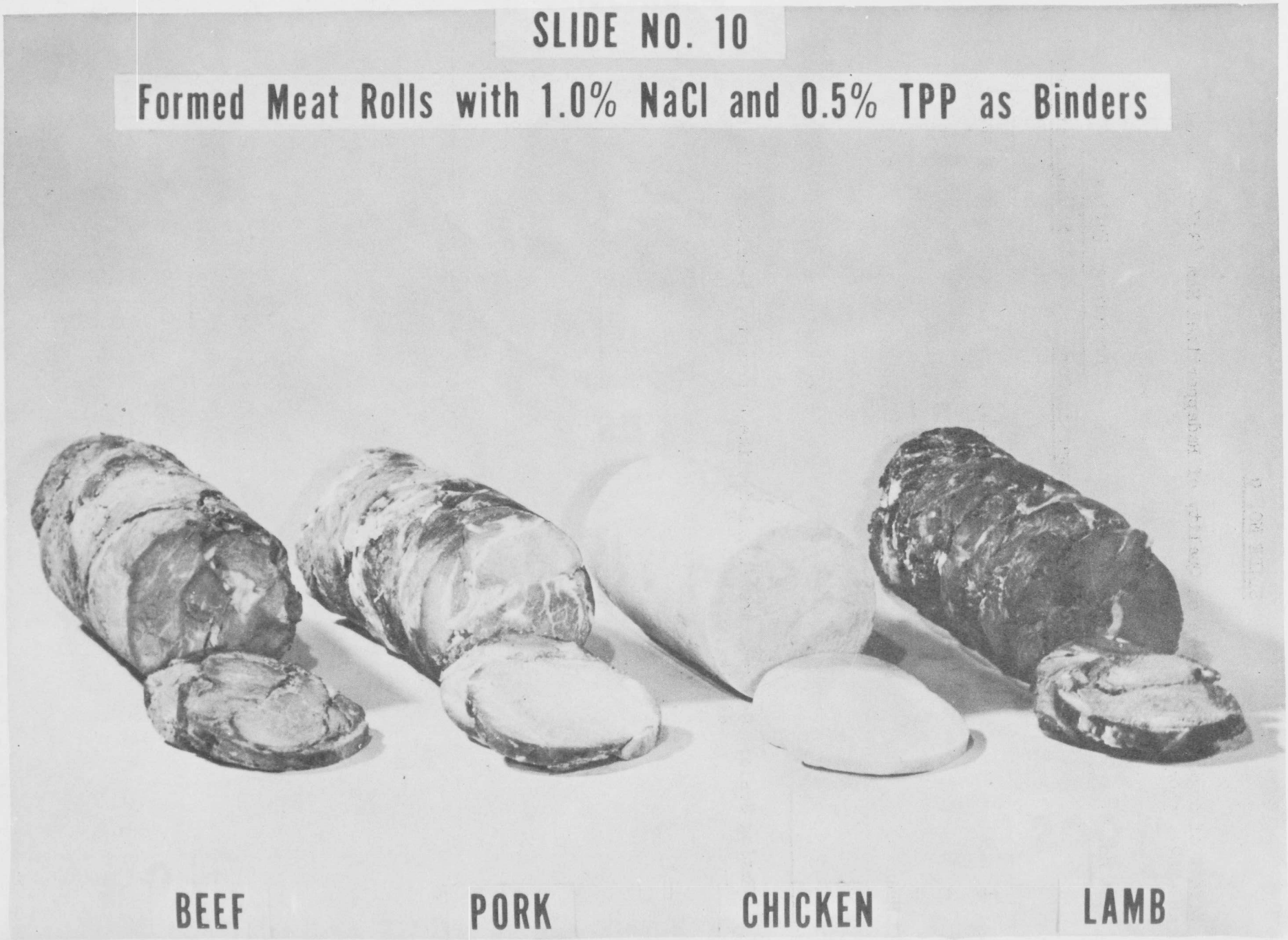
Effect of Sugar in the Cure on Quality of Radappertized Ham (3.7-4.7 Mrad at -30° ± 10°C).

Test No.	No. of Raters	Preference Ratings[1]	
		Sugar in Cure	No Sugar in Cure
1	40	5.45	6.37
2	40	6.15	6.25
Mean	80	5.80	6.31

[1] Rating Scale: 9-like extremely, 1-dislike extremely, 5-neither like nor dislike.

SLIDE NO. 10

Formed Meat Rolls with 1.0% NaCl and 0.5% TPP as Binders



SLIDE NO. 11

ACCEPTANCE OF IRRADIATED HAM

WHEN SERVED AS COMPONENT OF REGULAR MEALS

(Irrad. hams stored at room temp. for 1 to 12 months prior to serving.)

Dose Mrad (+12% to +25%)	Irradn. Temp. °C (± 10°C)	RECIPES	No. of Raters	Average Accept. Rating (*)
4.5	-30	Baked Ham w/Pineapple Glaze	102	6.97
4.5	-80	Baked Ham w/Pineapple Sauce	18	8.11
4.5	-30	Baked Ham w/Raisin Sauce	15	7.20
4.5	-30	Baked Ham w/Mustard Glaze	64	7.31
4.5	-30	Fried Ham Steaks	18	7.38
4.5	-30	Grilled Ham Steaks	15	8.26
3.7	-30	Baked Ham	93	7.33
3.7	-30	Baked Ham w/Pineapple Sauce	60	7.10

(*) 9-point hedonic scale: "9" = like extremely; "1" = dislike extremely; "5" = neither like nor dislike.

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