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## EFFECT OF RADIATION PASTEURIZATION ON THE STORAGE LIFE AND ACCEPTABILITY OF SOME NORTH ATLANTIC FISH

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### ABSTRACT

Screening studies were performed on raw and on blanched cod, pollock, whiting, and butterfish and on raw flounder irradiated at pasteurization doses ranging from 116,500 to 1,860,000 rads. Although some samples were acceptable when irradiated at the higher dosage level, those samples that were irradiated at levels of 465,000 rads and lower had greater acceptability.

Storage life studies at 35° F. were performed on raw and on blanched cod fillets and dressed butterfish and on raw pollock that had been irradiated at levels of 232,500 and 465,000 rads. In addition, raw pollock was irradiated at a level of 930,000 rads. The storage life extension of the irradiated fish over that of the unirradiated fish stored at the same temperatures was as follows: butterfish--about three times; cod--about two times; and pollock--no appreciable increase. Blanching did not increase the storage life or improve the acceptability of irradiated butterfish and cod. Deep-fat frying considerably increased the acceptability of raw, irradiated cod and pollock.

### INTRODUCTION

Considerable literature exists on the preservation of meats, fruits, and vegetables by means of ionizing radiation, but relatively little information has been published on the responses of fishery products to this form of preservation. A study of the effect of radiation on the chemistry and acceptability of southern oysters has been reported (Gardner and Watts 1957). No definite conclusions were made on the suitability of this technique as it affects acceptance of the product. Low levels of cathode-ray radiation were applied to haddock fillets on a study (Nickerson, Lockhart, Proctor, and Liciardello 1954) of the effects of this treatment on the chemistry and flavor of the product, but storage periods were of relatively short duration. In another study (Nickerson, Proctor, and Goldblith 1956) cod cakes and halibut steaks were treated with cathode rays to determine the effect on flavor. This also was a relatively short-term study. A report has been made on the acceptability of some irradiated foods, including had-



Fig. 1 - Preparing sample of irradiated fish for testing by the taste panel.

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1/A rad is the quantity of ionizing radiation which results in the absorption of 100 enrgs per gram of irradiated material.

dock, when incorporated into complete menus (McGary, Shipman, and Bernstein 1956). In this case too, holding times were relatively short.

Iced or refrigerated raw fish have a shelf life of 7 to 15 days. Irradiation offers a potential means of considerably extending this period at storage temperatures of 32° to 45° F. when pasteurizing doses are used. Extension of storage life at ambient temperatures may also be realized when the level of radiation applied is sufficient to result in sterilized products.

### OBJECTIVES

The present study was undertaken to determine the effect of pasteurization by irradiation on the useful refrigerated storage life at 35° F. of several commercially-important species of fish caught in North Atlantic waters. The study was divided into two phases.

Phase one consisted of a screening study to determine the organoleptic acceptability of irradiated products after refrigerated storage of not more than a few days.

Phase two consisted of storage-life determinations of samples held at 35° F. after being irradiated at various levels--in one case up to the maximum level as determined in the screening process.

### SCREENING STUDY

**PROCEDURE:** The products examined were raw flounder fillets (*Pseudopleuronectes americanus*), raw and blanched fillets of cod (*Gadus morhua*), pollock (*Pol-lachius virens*), and whiting (*Merluccius bilinearis*), and raw and blanched dressed butterfish (*Poronotus triacanthus*). The fish for the studies were caught 12 to 36 hours before they were received. In the laboratory they were packed in No. 2 C-enamel cans and sealed under a vacuum of 25 inches of water. The fillets that were blanched were heated to an internal temperature of 140° F. and were held at that temperature for 5 minutes and were then canned as described above. All samples were frozen to -20° F. They were then packed with dry ice and were shipped by air to and from the reactor site, where they were irradiated in the frozen state at levels ranging from 116,250 to 1,860,000 rads. On their return to the laboratory the frozen samples were held at 0° F. until they were submitted to the taste panel (fig. 1). This period did not exceed 10 days.

For initial sensory evaluation, the frozen samples were thawed within the cans in cold running water. The raw fish were cooked by being steamed for 20 minutes, and the blanched fish were cooked by being steamed for 15 minutes. Four samples were evaluated at each test. One sample was usually an identified unirradiated fresh control. The taste-panel consisted of 8 to 10 members of the laboratory staff. A hedonic scale ranging from 10 to 90 was used to score the irradiated products, which were evaluated on the bases of flavor, odor, texture, and appearance. A numerical score of 50 or above indicated a commercially-acceptable product.

**RESULTS:** The radiation dosages that resulted in organoleptically acceptable products for the fish tested are shown in table 1. An increase in dosage for any species frequently resulted in increased off-odors and off-flavors. Bleaching of the meat occurred in raw cod, pollock, black-

Species	Maximum Dose Resulting in Acceptable Products		Dose Resulting in Products of Greatest Acceptability	
	Raw Fish	Blanched Fish	Raw Fish	Blanched Fish
	(Rads)			
Cod . . . .	465,000	232,500	116,250	232,500
Pollock . .	232,500	930,000	232,500	232,500
Blackback .	930,000	-	465,000	-
Whiting . .	116,250	232,500	116,250	116,250
Butterfish .	697,500	930,000	232,500	232,500

Note: The irradiated fish were cooked in steam for taste-panel evaluation.

back, and butterfish, even at the lowest dosage employed (116,250 rads). Raw whiting exhibited a slight pink discoloration at the lowest dosage level, and this discoloration became more severe as the dosage level was increased. Blanching changed the discoloration pattern in that the meat of irradiated pollock, whiting, and butterfish became slightly gray.

### STORAGE STUDY

**PROCEDURE:** Storage studies consisted of an examination of raw and blanched cod fillets, raw pollock fillets, and raw and blanched dressed butterfish. The fish were irradiated at levels of 232,500 and 465,000 rads except for one additional lot of pollock fillets that was irradiated at a level of 930,000 rads. Despite the finding that, with some species, irradiation at levels higher than 465,000 rads resulted in acceptable products, the relatively low levels of 232,500 and 465,000 rads were used because irradiation at these levels resulted in products of greater acceptability. Levels lower than 232,500 rads were not used because it was felt that they might not be sufficient to prolong the shelf life significantly.

The samples were prepared and shipped as was previously described in the screening study. After irradiation and return of the samples to the laboratory, they were thawed in air and stored at 35° F. Samples were prepared for evaluation by steaming and, in some cases, by deep-fat frying to determine the effect of cooking methods on acceptability. In all cases, unidentified, unirradiated controls were evaluated with the irradiated samples. These controls were usually stored in the frozen state. Where refrigerated, unfrozen controls were used, it is so noted in the tabulated data. The results of the evaluation studies have been tabulated in two ways in order to (1) reflect the over-all acceptability of the samples as arrived at by finding the mean of the total scores given to each sample for the four attributes examined and (2) to indicate as specifically as possible in which particular attributes there were significant differences between controls and experimental samples as a function of storage time and irradiation dose. For this latter purpose, rank score tables were used (Kramer 1956).

**RESULTS: Butterfish:** The data shown in table 2 indicate that raw butterfish irradiated at 232,500 rads and cooked in steam was acceptable for at least 49 days when stored at 35° F. The maximum commercial storage time in ice for this fish is about 14 days. The unirradiated controls used in these tests had a storage life

Table 2 - Taste-Panel Scores and Degrees of Difference Between Raw Unirradiated and Raw Irradiated Butterfish That Were Stored at 35° F. and Cooked in Steam

Storage Time	Organoleptic Scores <sup>1/</sup>										
	Control	Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads				
		Mean Score	Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor
Days											
8	2/82.5	68.3	4/	4/	5/	6/	68.5	6/	4/	5/	6/
15	2/72.5	72.3	6/	6/	6/	6/	69.5	6/	6/	6/	6/
23	2/73.5	75.3	6/	6/	6/	6/	72.0	6/	6/	6/	6/
30	3/71.1	73.5	6/	6/	6/	6/	75.5	6/	6/	6/	6/
47	3/67.5	66.0	6/	6/	6/	6/	67.5	6/	6/	6/	6/
48	3/62.9	6/	6/	6/	6/	6/	66.0	6/	6/	6/	6/
49	3/74.3	73.0	6/	6/	6/	6/	56.7	6/	4/	4/	6/

<sup>1/</sup> Scores of 49 or less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.

<sup>2/</sup> Refrigerated controls stored at 35° F.

<sup>3/</sup> Frozen controls stored at 0° F.

<sup>4/</sup> Different from the control at the 5-percent level of significance.

<sup>5/</sup> Different from the control at the 1-percent level of significance.

<sup>6/</sup> Not significantly different from the control.

of 23 days. This long storage life was probably due to a very low initial bacterial load of the fish stored under essentially anaerobic conditions at 35° F. With respect to appearance, odor, and flavor, significant differences between the unirradiated controls and the samples irradiated at a level of 232,500 rads occurred only on the 8th day of storage. Samples irradiated at a level of 465,000 rads were significantly

different from the controls with respect to odor and flavor at both the 8th and 49th day of storage. When the data in table 2 are analyzed for the entire 49 days of the study, it is found that, regardless of the dose applied, there are no significant differences between the irradiated samples and the frozen controls except for the appearance of the sample irradiated at a level of 232,500 rads. This difference is at the 5-percent level of significance.

Storage Time	Control	Organoleptic Scores <sup>1/</sup>										
		Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads					
		Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor	Texture	
Days												
9	2/70.0	75.1	4/	4/	4/	4/	70.0	4/	4/	4/	4/	4/
16	2/78.8	70.0	5/	5/	6/	5/	71.5	5/	5/	5/	5/	6/
24	2/71.5	68.8	4/	4/	4/	4/	72.8	4/	4/	4/	4/	4/
31	3/66.8	4/	4/	4/	4/	4/	62.3	6/	4/	4/	4/	4/
38	3/70.9	61.1	5/	5/	5/	5/	62.3	4/	5/	4/	4/	4/

1/ Scores of 49 and less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.  
 2/ Refrigerated controls stored at 35° F.  
 3/ Frozen controls stored at 0° F.  
 4/ Not significantly different from the controls.  
 5/ Different from the control at the 5-percent level of significance.  
 6/ Different from the control at the 1-percent level of significance.

Table 3 indicates that the blanched, irradiated butterfish were acceptable for at least 38 days of storage at 35° F. However, further examination of these data shows that with respect to no attribute did enzyme inactivation by blanching result in an improvement of keeping quality over the period studied. Applying the test for significant difference to the storage period as a whole indicates that, at an irradiation level of 232,500 rads, there were no significant differences between the blanched, unirradiated, frozen controls and the irradiated samples. At the 465,000-rad level, the odor and flavor of the frozen controls were preferred, at the 5-percent level of significance, to the odor and flavor of the irradiated samples.

Cod: Raw, irradiated cod were tested over a period of 94 days, as is shown in table 4. At the end of that time, the samples irradiated at a level of 232,500 rads were still considered acceptable, although barely so. The fillets irradiated at a higher dose became unacceptable after 31 days of storage.

Storage Time	Control	Organoleptic Scores <sup>1/</sup>										
		Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads					
		Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor	Texture	
Days												
3	2/80.0	4/	4/	4/	4/	4/	71.5	4/	5/	4/	5/	5/
6	2/85.3	67.5	4/	6/	6/	6/	65.5	5/	6/	6/	6/	6/
15	3/79.0	62.3	4/	6/	6/	4/	62.3	4/	6/	6/	6/	4/
24	3/79.0	65.3	5/	6/	5/	4/	63.0	4/	5/	5/	6/	6/
31	3/79.3	66.8	5/	5/	5/	5/	60.3	5/	5/	6/	5/	5/
37	3/81.0	50.3	5/	5/	5/	6/	49.3	6/	5/	6/	5/	5/
55	3/78.3	56.7	4/	5/	5/	5/	54.3	5/	5/	5/	5/	5/
94	3/79.0	58.3	6/	6/	6/	6/	49.0	6/	6/	6/	6/	6/

1/ Scores of 49 or less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.  
 2/ Refrigerated controls stored at 35° F.  
 3/ Frozen controls stored at 0° F.  
 4/ Not significantly different from the control.  
 5/ Different from the control at the 5-percent level of significance.  
 6/ Different from the control at the 1-percent level of significance.

A statistical consideration of each attribute over the entire storage period indicates that the frozen controls are uniformly preferred over the samples irradiated at 232,500 and 465,000 rads, at the 5-percent and 1-percent level of significance, respectively.



Blanching of cod fillets prior to irradiation did not significantly affect the acceptability of the product, as is shown in table 5, and an examination of these data does not reveal any marked effect on the scores assigned to the individual attributes as a result of blanching. When the entire storage period is treated as one test, it is found that, regardless of the irradiation dose used, or the attribute under consideration, the frozen control is preferred over the irradiated samples at the 1-percent level of significance.

Table 5 - Taste-Panel Scores and Degrees of Difference Between Blanched Unirradiated and Blanched Irradiated Cod Stored at 35° F. and Cooked in Steam

Storage Time	Control	Organoleptic Scores <sup>1/</sup>									
		Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads				
		Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor	Texture
Days											
3	2/80.0	65.8	4/	5/	6/	6/	-	4/	4/	4/	4/
6	2/80.9	72.0	4/	5/	4/	5/	70.0	5/	4/	5/	5/
16	2/76.8	62.8	5/	6/	6/	6/	46.8	5/	6/	6/	6/
25	3/83.0	54.5	5/	6/	6/	6/	56.5	5/	6/	6/	6/
32	3/80.3	60.9	6/	6/	6/	6/	60.4	6/	5/	6/	5/
39	3/70.8	53.0	4/	5/	5/	4/	53.0	4/	6/	5/	5/

<sup>1/</sup>Scores of 49 or less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.  
<sup>2/</sup>Refrigerated controls stored at 35° F.  
<sup>3/</sup>Frozen controls stored at 0° F.  
<sup>4/</sup>Not significantly different from the control.  
<sup>5/</sup>Different from the control at the 5-percent level of significance.  
<sup>6/</sup>Different from the control at the 1-percent level of significance.

Although experiments with fried cod were few in number, it is clear from an examination of table 6 that deep-fat frying serves to reduce the differences between controls and experimental samples, particularly at the lower level of irradiation.

Table 6 - Taste-Panel Scores and Degrees of Difference Between Raw Unirradiated and Raw Irradiated Cod Stored at 35° F. and Deep-Fat Fried

Storage Time	Control <sup>2/</sup>	Organoleptic Scores <sup>1/</sup>									
		Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads				
		Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor	Texture
Days											
33	80.0	77.1	3/	3/	3/	3/	74.6	3/	3/	5/	3/
58	72.3	66.8	3/	3/	3/	3/	66.8	3/	3/	4/	3/

<sup>1/</sup>Scores of 49 or less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.  
<sup>2/</sup>Frozen controls stored at 0° F.  
<sup>3/</sup>Not significantly different from the control.  
<sup>4/</sup>Different from the control at the 5-percent level of significance.  
<sup>5/</sup>Different from the control at the 1-percent level of significance.

Pollock: Pollock fillets did not respond well to irradiation. Results of the taste panel evaluation of steam-cooked fillets are shown in table 7. Fillets irradiated at the 232,500-rad level had a maximum period of acceptability of 2 to 3 weeks. Fillets irradiated at a level of 465,000 rads were no better than barely acceptable at any

Table 7 - Taste-Panel Scores and Degrees of Difference Between Raw Unirradiated and Raw Irradiated Pollock Fillets Stored at 35° F. and Cooked in Steam

Storage Time	Control <sup>2/</sup>	Organoleptic Scores <sup>1/</sup>									
		Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads				
		Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor	Texture
Days											
7	65.0	66.0	3/	3/	5/	3/	54.3	3/	4/	5/	4/
11	72.5	55.3	4/	5/	4/	5/	52.1	3/	5/	4/	5/
18	70.0	61.7	3/	5/	5/	5/	56.3	3/	5/	5/	3/
21	67.4	52.6	3/	3/	4/	4/	46.0	3/	5/	3/	3/
28	69.8	53.0	4/	5/	5/	4/	39.8	4/	5/	5/	5/
45	69.3	49.3	3/	5/	5/	5/	41.3	3/	5/	5/	5/

<sup>1/</sup>Scores of 49 or less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.  
<sup>2/</sup>Frozen controls stored at 0° F.  
<sup>3/</sup>Not significantly different from the control.  
<sup>4/</sup>Different from the control at the 5-percent level of significance.  
<sup>5/</sup>Different from the control at the 1-percent level of significance.

time during the maximum storage period of 2 weeks. Fillets irradiated at a level of 930,000 rads had a storage life of less than 11 days. This latter sample is not included in the tabulated data.

Statistical treatment of the results of this storage period, considered as one test, shows a preference for the controls over all the irradiated samples for each attribute, except "appearance" of the sample irradiated at 232,500 rads. There was no significant difference between the "appearance" of these samples and that of the frozen controls.

Storage Time	Control <sup>2/</sup> Mean Score	Organoleptic Scores <sup>1/</sup>									
		Samples Irradiated at 232,500 Rads					Samples Irradiated at 465,000 Rads				
Days	Mean Score	Mean Score	Appearance	Odor	Flavor	Texture	Mean Score	Appearance	Odor	Flavor	Texture
12	72.7	78.5	3/	3/	3/	3/	69.0	3/	3/	3/	3/
31	76.8	71.0	3/	3/	3/	3/	64.3	3/	3/	3/	4/

1/Scores of 49 or less indicate poor quality, 50 to 59 borderline, 60 to 69 fair, 70 to 79 good, 80 to 89 very good, and 90 excellent.  
 2/Refrigerated control stored at 35° F.  
 3/Not significantly different from the control.  
 4/Different from the control at the 5-percent level of significance.

Table 8 indicates that deep-fat frying had a marked effect on the acceptability of irradiated pollock fillets. The difference in acceptability of steamed and of fried samples at the lower levels of irradiation is striking; however, when the irradiation level is as high as 930,000 rads, the product remains unacceptable regardless of the cooking method.

### CONCLUSIONS

- (1) At a storage temperature of 35° F. the shelf life of raw butterfish can be extended about three times by treating the butterfish at a level of 232,500 rads. Irradiating at a dosage level of 465,000 rads or blanching before irradiation resulted in slightly decreased acceptability with no increase in storage life.
- (2) Raw cod fillets irradiated at levels of 232,500 or 465,000 rads and stored at 35° F. were less acceptable than were the unirradiated, frozen controls and had a shelf life of approximately 30 days.
- (3) Blanched cod fillets irradiated at either 232,500 or 465,000 rads and stored at 35° F. were less acceptable than the unirradiated, frozen controls and had a maximum storage life of approximately 30 days.
- (4) Deep-fat frying of irradiated cod fillets markedly increased their acceptability over that of fillets cooked in steam.
- (5) Irradiated raw pollock fillets stored at 35° F. and cooked by being steamed exhibited no useful increase in shelf life over that of unirradiated, unfrozen fillets. Deep-fat frying of irradiated pollock fillets markedly increases their acceptability over that of similar fillets cooked in steam.

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