RADIATION PRESERVED FRANKFURTERS: CURING INGREDIENTS AND PROCESSING EFFECTS ON PHYSICAL, CHEMICAL AND SENSORY TRAITS

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INTRODUCTION

Much of the current food irradiation research is directed towards the wholesomeness of such preserved foods; animal feeding studies to determine toxicity and nutrient alteration have been reported (IAEA, 1978). To date, none of these studies have shown that consumption of irradiated foods produces toxicity or a loss of essential nutrients when compared with conventionally preserved (thermally processed) foods. Radappertization (high dose irradiation using 3-8 megarads) have been reported to adversely affect the physical, chemical and sensory properties of fresh meats; however, these affects were minimized when irradiation was done on frozen fresh meats (Hedin et al., 1961a,b; Merritt et al., 1975; Hall, 1978). Most of these adverse affects are reported to be dose dependent in that the higher dose levels (radappertization $\leq$ 3 M-rads) when compared to lower dose levels (LDI $\leq$ M-rad) produce less desirable irradiated foods (Josephson et al., 1978; Brynjolfsson, 1979a).

A present research challenge is that of minimizing the undesirable palatability of formulated meat products which result from irradiation. For example, in pork rolls and ham slices the addition of sodium tripolyphosphate as well as reduced levels of curing ingredients was reported to enhance the quality of irradiated products (Wierbicki et al., 1975; Shults et al., 1976). Reduction or elimination of curing ingredients is currently being studied as a means of reducing nitrosamine formation in cured bacon (Brynjolfsson, 1979b); other factors may be of equal importance in developing palatable irradiated sausage products. Accordingly, the aim of the present study was to determine the effects of curing ingredient combinations, added moisture levels, seasoning, and cooked product temperatures on the chemical and sensory properties of irradiated frankfurters.

EXPERIMENTAL

The two experiments involved in the present study are described in Table 1. In the first study, frankfurters of 12 treatment combinations were made (in triplicate) as 9.07 kg batches using conventional manufacturing procedures (without vacuum chopping). Treatment combinations were as follows: 0% or 10% added moisture; and either 0, 50 or 100 ppm sodium nitrite; 50 ppm sodium nitrate; 25 ppm sodium nitrate plus 206 ppm DL alpha-tocopherol. Frankfurters from each treatment combination were vacuum packaged (to contain not more than 0.5 ml of residual oxygen) in retortable pouches, frozen at -34.4°C and assigned to one of four irradiation level groups: (1) Check samples not shipped to USNARADCOM (U.S. Army Natick Research and Development Command) for irradiation. (2) 0 megarad (non-irradiated) processing, (3) 0.8 megarad processing, and (4) 3.2 megarad processing. Frankfurters were irradiated by USNARADCOM, at -34°C by use of Cobalt-60.

In the second study, frankfurters of 16 treatment combinations were made (in triplicate) as follows: (1) Curing ingredient combinations of 0 or 50 ppm sodium nitrite; 75 ppm sodium nitrite plus 25 ppm sodium nitrate; or 50 ppm sodium nitrate plus 25 ppm sodium nitrate: (2) Seasoning--natural spice or the equivalent of natural spice as a soluble seasoning: (3) Cooked product temperature, 65.5°C or 76.6°C: (4) Irradiation processing levels of either 0, 0.8 or 3.2 megarads.

Frankfurters were analyzed for moisture, fat, protein and residual nitrite contents acording to AOAC (1975) procedures. Cured color values (Hornsey, 1956) and thiobarbituric acid values (Tarladgis et al., 1964) were obtained. A 7-member panel evaluated the thawed, unheated frankfurters for off-odor intensity by use of an 8-point scale (8=extremely weak to no off-odor; 1=extremely strong off-odor) and evaluated the external and internal color of reheated frankfurters by use of a 7-point scale (7 = excellent cured-pink color; 1=poor cured-pink color). Thawed links were steeped in boiling water (7 min), sectioned, placed in heated aluminum pans and served (warm) to a 9-member trained sensory panel. The following palatability traits were evaluated: moistness (8=extremely moist; 1=extremely dry), off-flavor intensity (8=extremely weak to no off-flavor; 1=extremely strong off-flavor), texture (8=extremely firm exterior and interior; 1=extremely soft exterior and interior), and overall palatability (8=like extremely-would repeat purchase consistently; 1=dislike extremely-would not purchase).

Statistical analyses included analysis of variance (Steel and Torrie, 1960) and the multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Mean values for processing shrinkage, proximate composition and sensory traits are presented in Table 2. In experiment 1, only the chemical properties and off-odor scores were affected ($P<0.05$) affected by shipping treatment. Those frankfurters that were shipped to Natick had lower moisture and higher protein and fat contents and less off-odor than did those frankfurters that were not shipped to Natick. Intransit and handling conditions may have caused loss of moisture in those frankfurters that were shipped to Natick even though both groups of frankfurters were vacuum packaged in flexible-retortable pouches and in spite of the fact that those sent to Natick were packaged in dry ice to maintain them in a frozen state. Shipment effects were not of significance in determining color (external or internal), moistness, off-flavor, texture or overall palatability of control (0-megarad) frankfurters, therefore it was concluded that transportation did not affect sensory properties of the frankfurters sent to USNARADCOM for irradiation and shipped back to TAES for subsequent evaluation. In Experiment 2, frankfurters cooked to an internal temperature of 65.5°C had signifi-

cantly ($P<0.01$) less shrinkage, higher moisture content and lower fat, protein and residual nitrite contents than did those frankfurters cooked to an internal temperature of 76.6°C. Regardless of curing ingredient combinations or levels of irradiation, those frankfurters cooked to 65.5°C had significantly ($P<0.05$) higher scores for internal color, off-odor intensity, off-flavor, moistness, texture and overall palatability than did those frankfurters cooked to 76.6°C. These data suggest that frankfurters which are to be irradiated should be cooked to a lower internal temperature (65.5°C) in order to enhance their palatability.

Mean sensory and chemical values for frankfurters stratified according to curing ingredient combinations are presented in Table 3. In experiment 1, frankfurters made with 100 ppm NO_2 had significantly ($P<0.05$) lower TBA values, higher cured color values and higher external and internal visual color scores than those frankfurters made with either 0 ppm NO_2 or 25 NO_2 plus 25 NO_3. Overall palatability scores were significantly ($P<0.05$) higher for frankfurters made with either 50 NO_2 or 25 NO_2 plus 25 NO_3 than for those made with 0 NO_2 or 25 NO_2 plus 25 NO_3 plus 206 DL alpha tocopherol. Although not significant among all comparisons, frankfurters made with either 0 NO_2 or with 25 NO_2 plus 25 NO_3 plus 206 DL alpha tocopherol had numerically lower scores for texture and off-flavor than did frankfurters made with other curing ingredient combinations. Off-odor scores were not affected by curing ingredient combinations. These data suggest that the most desirable frankfurters (flavor, overall palatability and visual color, and/or cured color and TBA values) contained 50 or 100 NO_2; the least desirable contained 0 NO_2, 25 NO_2 plus 25 NO_3 plus 206 DL alpha tocopherol or 50 NO_3.

In Experiment 2, frankfurters made with 0 NO_2 had significantly ($P<0.05$) lower scores for moistness, off-flavor, overall palatability and external and internal color than did those made with 75 NO_2 plus 25 NO_3 or 50 NO_2 plus 25 NO_3. Off-odor scores were not significantly affectd by curing ingredient combination. In general, sensory evaluations for product in Experiment 2 were numerically lower than those for product in Experiment 1 suggesting that the panel may have become sensitized to the product during the time-course of this study. Nevertheless, consistency of the overall palatability and visual color scores indicates that at least 50 ppm NO_2 was essential for optimizing the overall desirability of frankfurters to be irradiated.

Mean sensory values for frankfurters stratified according to irradiation level are presented in Table 4. In experiment 1, values for off-flavor, off-odor, texture and overall palatability decreased ($P<0.05$) with increasing levels of irradiation while moistness increased. In Experiment 2, values for all traits except moistness decreased ($P<0.05$) with increasing levels of irradiation. Compared to the non-irradiated frankfurters, those products irradiated at 3.2 megarads were definitely not acceptable to members of the sensory panel involved in this study. These data (Table 4) confirm other studies (Terrell et al., 1980a,b) with experienced sensory panelists which suggest that the degree of undesirability associated with irradiated cured meats is dose-dependent. However, extrapolation of these dose-response palatability effects to acceptance by various types of consumers should not be made; rather, separate studies, designed to test consumer market acceptance, should be conducted.

Data from these two experiments suggest that significant improvements in cured color (external and internal) and palatability traits of frankfurters to be irradiated may be achieved by the addition of at least 50 ppm NO_2 and by cooking to a lower internal product temperature (65.5°C vs. 76.6°C). The use of 206 ppm DL-alpha tocopherol, a known antioxident and nitrosamine blocking agent in cured bacon, does not improve palatability traits of irradiated frankfurters.

In data not presented in tabular form there were no effects on palatability traits of frankfurters due to added moisture levels (0% or 10%) or due to type of seasoning (ground spice vs. equivalent soluble seasoning). The use of 0.8 megarads (low dose irradiation) produced fewer palatability defects than did the use of 3.2 megarads (high dose irradiation), thus LDI may be feasible for preserving cured sausages made with reduced levels of NO_2. Nevertheless, product improvement research (i.e., types of meat formula, cured color accelerators, etc.) should be investigated in attempts to minimize differences in palatability and sensory properties between irradiated and non-irradiated frankfurters.

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Table 1--Frankfurter formulations (in kilograms) used in irradiation studies.

Ingredient	Experiment 1[a] Curing and added moisture effects	Experiment 2[b] Curing, spice temperature effects
Pork jowls, skinned	15.9	15.9
Pork, picnic shoulders	11.3	11.3
Beef trim	9.1	9.1
Beef, lean cow	9.1	9.1
Salt	0.9	0.91
Sweetener[c]	1.82	1.82
Seasoning[d]	0.95	0.95 or 1.01[d]
Added moisture	4.54 or 10.4	10.4
Total weight	53.62 59.48	59.46 59.54

[a]To each 9.07 kg meat block, appropriate amounts of nitrite, nitrate and DL-alpha tocopherol were added.
[b]To each 9.07 kg meat block, appropriate amounts of nitrite and nitrate were added before cooking products to an internal temperature of either 65.5°C or 76.6°C.
[c]50% dextrose; 50% corn syrup solids (DE-45).
[d]Contained 550 ppm sodium erythorbate and was formulated as natural ground spice (1.01) or as an equivalent dry soluble seasoning (0.93).

Table 2--Mean processing shrinkage, sensory and chemical values of irradiated frankfurters.

Trait[a]	Experiment 1 Shipping treatment: Not shipped	Shipped	Level of significance[b]	Experiment 2 Product temperature: 65.5C	76.6C	Level of significance[b]
Processing shrinkage	--	--		11.2	12.3	*
Visual color						
External	3.0	3.0	NS	3.5	3.2	NS
Internal	3.3	3.3	NS	4.0	3.6	*
Off-odor	7.5	7.3	*	4.7	4.2	**
Off-flavor	6.5	6.4	NS	4.7	4.0	**
Moistness	6.5	6.4	NS	6.2	5.7	**
Texture	6.7	6.8	NS	5.7	4.8	**
Overall palatability	6.7	6.7	NS	4.3	3.4	**
Moisture	49.8	48.2	*	51.2	50.0	**
Fat	32.4	33.4	*	31.4	32.4	**
Protein	9.8	10.2	*	10.6	10.8	*
Residual nitrite	--	--		2.3	3.4	**

[a]Visual color; 7=excellent cured-pink color, 1=poor cured-pink color. Off-odor; 8=extremely weak to no off-odor, 1=extremely strong off-odor. Off-flavor; 8=extremely weak to no off-flavor, 1=extremely strong off-flavor. Moistness; 8=extremely moist, 1= extremely dry. Texture; 8=extremely firm exterior and interior, 1=extremely soft exterior and interior. Overall palatability; 8=like extremely-would repeat purchase consistently, 1=dislike extremely-would not purchase.
[b]*=($P<0.05$); **=($P<0.01$); NS=nonsignificant ($P>0.05$).

Table 3--Mean sensory and chemical values of irradiated frankfurters stratified according to curing ingredients combinations.

Trait[b]	Experiment 1 Curing ingredients[a]						Experiment 2 Curing ingredients[a]			
	0 NO_2	50 NO_2	100 NO_2	50 NO_3	25 NO_2 25 NO_3	25 NO_2 25 NO_3 206-DLαT	0 NO_2	50 NO_2	72 NO_2 25 NO_3	50 NO_2 25 NO_3
Visual color										
External	1.4[g]	5.1[e]	5.1[e]	1.4[g]	2.3[f]	1.9[f]	1.7[f]	4.1[e]	4.0[e]	3.7[e]
Internal	1.6[h]	5.3[e]	5.4[e]	1.6[h]	2.8[f]	2.3[g]	2.1[f]	4.5[e]	4.4[e]	4.2[e]
Off-odor	5.2[e]	5.2[e]	5.0[e]	5.0[e]	5.2[e]	5.2[e]	4.3[e]	4.5[e]	4.8[e]	4.4[e]
Off-flavor	5.3[fg]	5.9[ef]	5.4[efg]	5.3[fg]	6.1[e]	5.1[g]	4.0[f]	4.4[ef]	4.6[e]	4.5[e]
Moistness	6.3[e]	6.7[ef]	6.5[fg]	6.4[g]	6.7[ef]	6.5[fg]	5.8[f]	5.9[e]	6.1[e]	6.0[e]
Texture	5.9[g]	6.4[e]	6.3[ef]	6.2[ef]	6.1[efg]	6.0[g]	5.4[ef]	5.5[e]	5.0[g]	5.0[eg]
Overall palatability	4.8[f]	5.3[e]	5.0[ef]	4.9[ef]	5.4[e]	4.5[f]	3.4[f]	3.9[e]	4.0[e]	3.9[e]
Cured color (OD)[c]	.023[f]	---	.071[e]	---	.029[f]	---	---	---	---	---
TBA (mg/1000g)[d]	1.16[e]	---	0.99[f]	---	1.04[e]	---	---	---	---	---

[a]Based on ppm added to 9.07 kg raw meat; NO_2 = sodium nitrate; NO_3 = sodium nitrate; DLαT = 206 ppm DL-alpha tocopherol.

[b]Visual color; 7=excellent cured-pink color, 1=poor cured-pink color. Off-odor; 8=extremely weak to no off-odor, 1=extremely strong off-odor. Off-odor; 8=extremely weak to no off-flavor, 1=extremely strong off-flavor. Moistness; 8=extremely moist, 1=extremely dry. Texture; 8=extremely firm exterior and interior, 1=extremely soft exterior and interior. Overall palatability; 8=like extremely-would repeat purchase consistently, 1=dislike extremely-would not purchase.

[c]OD=optical density at 540 mμ.

[d]Mg malonaldehyde/1000g of frankfurter.

[efg]Within experiments, means in the same row followed by a common letter are not different (P>0.05).

Table 4--Mean sensory values of irradiated frankfurters stratified according to irradiation level.

Sensory trait[e]	Experiment 1 Irradiation level (M-rads)			Experiment 2 Irradiation level (M-rads)		
	0	0.8	3.2	0	0.8	3.2
Visual color						
External	3.0[a]	2.9[a]	2.7[a]	4.4[b]	3.1[c]	2.6[d]
Internal	3.3[a]	3.1[a]	3.1[a]	4.8[b]	3.5[c]	3.1[d]
Off-odor	7.3[a]	5.1[b]	3.0[c]	6.8[b]	4.0[c]	2.6[d]
Off-flavor	7.5[a]	5.5[b]	3.6[c]	6.8[b]	3.7[c]	2.6[d]
Moistness	6.4[c]	6.6[b]	6.8[a]	6.0[b]	5.9[b]	6.0[b]
Texture	6.8[a]	6.3[b]	5.4[c]	6.1[b]	5.4[c]	4.2[d]
Overall palatability	6.7[a]	4.9[b]	3.3[c]	6.0[b]	3.3[c]	2.2[d]

[abcd]Within experiments, means in the same row followed by a common letter are not different (P>0.05).

[e]Visual color; 7=excellent cured-pink color. Off-odor; 8=extremely weak to no off-odor, 1=extremely strong off-odor. Off-flavor; 8=extremely weak to no off-flavor, 1=extremely strong off-flavor. Moistness; 8=extremely moist, 1=extremely dry. Texture; 8=extremely firm exterior and interior, 1=extremely soft exterior and interior. Overall palatability; 8=like extremely-would repeat purchase consistently, 1=dislike extremely-would not purchase.