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Effects of Sodium Nitrite, Sodium Nitrate and DL, Alpha-Tocopherol on Properties of Irradiated Frankfurters

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ABSTRACT

Frankfurters were manufactured to contain certain combinations of curing ingredients (sodium nitrite, sodium nitrate and DL, alpha-tocopherol). Some frankfurters were made to contain in the finished product 0% added moisture, others were made to contain 10% added moisture, some frankfurters were not irradiated (0-megarad), others were irradiated with either 0.8 or 3.2 megarads (Cobalt-60 radiation source). Use of DL, alpha-tocopherol (at a level of 206 ppm) was associated with greater processing shrinkage, more off-flavor and less overall palatability ($P<0.05$). The most desirable external and internal cured color and firmest texture was in frankfurters made with 50 ppm of NO_2 or with 100 ppm of NO_2, irrespective of irradiation level. Use of irradiation (0.8 or 3.2 megarads) on frankfurters made without nitrite or nitrate did not improve visually determined cured color but did improve this color when determined spectrophotometrically; nevertheless, cured color of irradiated frankfurters made without use of nitrite or nitrate was not comparable to that of non-irradiated or irradiated frankfurters made with 100 ppm NO_2. Irrespective of added moisture or curing ingredient combinations, significant differences ($P<0.05$) in palatability traits were associated with increasing irradiation levels (0, 0.8 or 3.2 megarads). Off-flavor increased, texture was less firm and overall palatability was less desirable as irradiation level increased. Low-dose irradiation (≤1 megarad) may be feasible for enhancing the palatability traits of frankfurters containing lower levels of nitrite (lower than 156 ppm) but it appears that the correct irradiation level would be lower than the 0.8 megarad used in this study.

Radiation preservation studies involving raw agricultural commodities are currently underway in 50 or more countries (*4, 18*). Commercial applications of low-dose (≤ 1 megarad) irradiation (LDI) to prevent sprouting in stored potatoes, onions and garlic and to reduce microbial loads in certain spices are currently used (*4*).

Early studies of irradiation with fresh meats were conducted by use of high-dose irradiation (3-8 megarads); dosages of this magnitude (radappertization) effectively sterilize the product. Unfortunately, radappertization adversely affected the physical, chemical and sensory properties of fresh chilled meats; however, these effects were minimized when irradiation was done on frozen fresh meats (*7, 8, 9, 15*). More recently, LDI has been used to preserve cured meat products like sectioned and formed ham, sliced bacon and sliced corned beef (*6, 25*).

Unlike ham, bacon and corned beef, frankfurters are preformulated, cured, batter-type products which are fully cooked (70-72 C) within a relatively short time (1.5 h). Cured sausage products are less perishable than are fresh meats; however, both cured and fresh meats require an energy-intensive refrigerated manufacturing, transportation and distribution system. Enhancement of shelf-life properties via low-dose irradiation could possibly be used to reduce the amount of energy required for transportation and distribution of these products.

LDI could also be used, in combination with lower levels of nitrate (NO_3) and/or nitrite (NO_2), to assure that color and palatability traits are satisfactory and that consumers are protected against the threat of botulism. Use of lower nitrite levels (less than 120 ppm) in vacuum-packaged bacon maintained acceptable color scores and eliminated nitrosamine formation in irradiated, fried bacon slices (*14, 24*).

The present study was conducted to determine the effects of differing levels and combinations of sodium nitrite (NO_2), sodium nitrate (NO_3) and DL-alpha tocopherol on chemical, sensory and physical properties of frankfurters irradiated at levels of 0, 0.8 or 3.2 megarads.

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MATERIALS AND METHODS

General

Frankfurters of 12 treatment combinations were prepared (in triplicate) as 9.07-kg batches using conventional manufacturing procedures (without vacuum chopping). Treatment combinations were as follows: estimated 0% or 10% added moisture in final cooked product; sodium nitrite alone at 0, 50 or 100 ppm; sodium nitrate alone at 50 ppm; combinations of nitrite and nitrate of 25 ppm of nitrite-25 ppm of nitrate or 25 ppm of nitrite-25 ppm of nitrate plus 206 ppm of DL, alpha-tocopherol. Frankfurters from each treatment combination were vacuum-packaged in retortable pouches (American Can Co.), frozen at -34.4 C and assigned to one of three irradiation treatments: (a) 0-megarad (non-irradiated), (b) 0.8-megarad and (c) 3.2-megarad processing.

Manufacturing

Batches were formulated from commercially available ingredients (Table 1). Raw meat ingredients were 60% pork and 40% beef, formulated to contain 30% fat in the finished, cooked frankfurters. Lean meats, salt, the appropriate nitrite and/or nitrate mixture and 1/3 of the total water were chopped for 1-2 min. Then fatter meats, sweeteners, seasoning and the remainder of the water were added and the composite was chopped for 9-10 min (final batter temperature was 19-20 C). Batters were then stuffed, using a pneumatic piston stuffer, into 25-mm cellulose casings and linked (10.4 cm in length). A conventional cooking and smoking cycle, (2.75 h) designed to accomplish a product internal temperature of 70-71 C, and subsequent cold shower period (5 min) was completed by use of an Alkar-DEC commercial food process oven. Cooked frankfurters were chilled for approximately 14-16 h in a 3-C cooler before peeling and subsequent vacuum-packaging in flexible retortable pouches (5 links/pouch). The packaged frankfurters were blast frozen at -34 C, packed in dry ice, and those samples to be irradiated were air-freighted to USNARADCOM (Natick, MA) for Cobalt-60 irradiation at -34.4 ± 5 C. Irradiated frankfurters were air-transported back to TAES for subsequent study of physical, chemical and sensory properties. Time-lag between manufacturing, irradiation and return to our laboratory was about 3 weeks. Upon return to our laboratory samples were maintained at -34 C until chemical, sensory and physical determinations were completed (about 3 weeks).

Analytical

Frankfurters were analyzed for moisture, fat, protein and salt contents according to AOAC procedures (*1*). Cured color values and thiobarbituric acid values (TBA) were determined (*11, 20*). Instron textural values (using a L.E.E.-Kramer cell attached to the Instron Universal Testing Machine) were obtained from force deformation curves (*2,23*). A 5-member panel evaluated the thawed, non-reheated frankfurters for off-odor intensity by use of an 8-point scale (8= extremely weak off-odor or no off-odor; 1=extremely strong off-odor). External and internal color of reheated frankfurters was evaluated by the same 5-member panel using the following scale: 7=excellent cured-pink color, 1=poor cured-pink color. A table of random numbers was used to assign frankfurters of different treatment combinations to specific taste panel sessions (7 samples per session; 2 sessions per day for 18 days). Thawed samples were steeped in boiling water for 7 min to reheat them, whereupon they were sectioned, placed in heated aluminum pans, and served while warm to an 8-member trained domestic sensory panel (5 males, 3 females; age range 22-28 yrs). The following palatability traits were evaluated: moistness (8=extremely moist; 1=extremely dry), off-flavor intensity (8=extremely weak off-flavor or 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 (*19*) and multiple range tests (*5*).

RESULTS AND DISCUSSION

Mean chemical and panel texture values for frankfurters according to estimated added moisture levels and irradiation levels are presented in Table 2. Volume dilutions of fat, protein and salt contents of 10% vs. 0% added moisture in formulations are readily apparent; frankfurters made to contain 10% added moisture had a higher ($P<0.05$) percentage of moisture and lower percentages of fat, protein and salt than frankfurters made to contain 0% added moisture. Processing shrinkage values (not shown in tabular form) were not affected by level of added moisture. Texture scores were ($P<0.05$) higher (firmer) for frankfurters made to contain 0% added moisture than for those made to contain 10% added moisture. Thiobarbituric acid values (measure of rancidity) increased ($P<0.05$) with increasing levels of

TABLE 1. *Frankfurter formulations.*[a]

Ingredient	Weight (kg)	Composition (%) Added moisture level[b] 0%	10%
Pork jowls, skinned, 63% fat	15.9	29.66	26.74
Pork picnics, 27% fat	11.3	21.08	19.00
Beef trim, 37% fat	9.1	16.97	15.30
Beef, lean cow, 9% fat	9.1	16.97	15.30
Salt	0.9	1.70	1.51
Sweetener[c]	1.82	3.39	3.06
Seasoning[d]	0.95	1.77	1.60
Added moisture	4.54 or 10.4	8.46	17.49
TOTAL	53.61 59.47	100.00	100.00

[a]Appropriate amounts of nitrite, nitrate and/or DL, α-tocopherol (ppm) were added. Batches were made based on raw meat wt. of 9.07 kg.

[b]Added moisture level based on 4 times meat protein percentage + 10% (in the finished product).

[c]50% dextrose; 50% corn syrup solids (DE-45).

[d]Seasoning ingredients: 43.86% salt, 49.38% heat-treated mustard flour; 0.88% extractives of spice, 4.52% extractives of paprika, 1.36% tricalcium phosphate - anticaking agent. 185 g of seasoning was added to each 9.07 kg of meat batch. In addition to the seasoning, 550 ppm of sodium erythrobate was added to each formulation.

irradiation. Although not significantly different among all levels of irradiation, cured color values and protein content decreased and moisture contents increased between the 0-, 0.8- and 3.2-megarad processing levels. These cured color values (Table 2) confirm earlier research in ham and corned beef (*12, 17*), that decreasing amounts of cured color result from increasing levels of irradiation.

Effects of curing ingredient combinations on processing shrinkage, sensory and chemical values are shown in Table 3. Addition of 206 ppm of DL, alpha-tocopherol increased ($P<0.05$) processing shrinkage above that sustained by frankfurters in other treatments. Alpha-tocopherol, a known antioxidant and a recently identified blocking-agent against formation of nitrosamines in bacon (*14*) has not previously been reported to increase processing shrinkage of frankfurters. It is possible that the oil emulsifier (5-8 carbon chain triglyceride) used to solubulize DL, alpha-tocopherol contributed to increase shrinkage. Frankfurters made with DL, alpha-tocopherol also had ($P<0.05$) more off-flavor than those made with either 25 NO_2/25 NO_3 or 50-NO_2. Although not different ($P>0.05$), frankfurters made with 0-NO_2 or with 50-NO_3 had slightly more off-flavor (lower scores) than did frankfurters made with 50-NO_2. Rancidity values (TBA) were lower ($P<0.05$) for frankfurters made with 100-NO_2 than for frankfurters made with either 0-NO_2 or 25 NO_2/25 NO_3. The role of NO_2 in development of cured flavor and cured color is well-documented (*3*). The effect of NO_2 on cured meat flavor has been described as the absence of a "porky" "rancid" taste. Cured color values (OD) were significantly greater in frankfurters made with 100-NO_2 compared to those made with 0-NO_2 or 25 NO_2/25 NO_3.

Texture scores were affected by curing ingredient combinations (Table 3). Frankfurters made with 0-NO_2 or with 25 NO_2/25 NO_3 plus DL, alpha-tocopherol had lower ($P<0.05$) texture scores (less firm) than did those frankfurters made with 50-NO_2, 100-NO_2 or 50-NO_3. Among the many well-known functions of nitrite in cured meats, its contribution to improving texture is not one that has been previously reported. It has been suggested however, that nitrite may contribute to increased texture by forming disulfide linkages, a well-known reaction in many food systems (*18*). Studies concerning formation of disulfide bonds in a model system, using sodium nitrite and cystine have been reported (*13*). In these studies, storage of a solution of s-nitroso cysteine resulted in a lower content of nitrogen and cystine precipitated out of solution, indicating that disulfide bonds were formed. Although the present study was not designed to determine effects of sodium nitrite on textural properties of frankfurters, the disulfide linkage phenomenon could serve as a partial explanation for those texture differences observed in Table 3.

TABLE 2. *Mean chemical and texture values for frankfurters according to added moisture and irradiation level.*

Item	Added moisture level[a]		Irradiation (megarad) level[b]		
	0%	10%	0	0.8	3.2
Moisture (%)	47.0c	51.0d	48.1e	50.0d	51.0c
Fat (%)	34.4c	32.3d			
Protein (%)	9.9c	9.3d	10.23c	9.21d	9.20d
Salt (%)	2.6c	2.4d	2.6c	2.4d	2.5cd
Cured color (OD)[b]			.059c	.036d	.031d
TBA (mg/1000 gm)			.810e	.936d	1.419c
Texture	6.4c	6.0d			

[a]Added moisture across all levels of irradiation. Means in the same row contrasting added moisture levels followed by a common letter are not different (P>.05).

[b]Means in the same row contrasting irradiation levels followed by a common letter are not different (P>.05). OD=optical density at 540 mμ.

TABLE 3. *Mean process shrinkage, sensory and chemical values for frankfurters according to curing-ingredient combination.*

Curing-ingredient combination[a]	Processing shrinkage[b] (%)	Sensory[b]		Chemical[b]	
		Off-flavor	Texture	TBA (mg/1000g)[c]	Cured color (OD)[d]
0 NO_2	9.6[e]	5.3[fg]	5.9[g]	1.16[e]	.023[f]
50 NO_2	9.5[e]	5.9[ef]	6.4[e]		
100 NO_2	9.6[e]	5.4[fg]	6.3[ef]	0.99[f]	.071[e]
50 NO_3	9.5[e]	5.3[fg]	6.2[ef]		
25 NO_2/25 NO_3	8.7[e]	6.1[e]	6.1[efg]	1.04[e]	.029[f]
25 NO_2/25 NO_3/206α-T	10.4[f]	5.1[g]	6.0[g]		

[a]Based on amounts (ppm) added to 9.07 kg raw meat; NO_2 = nitrite, NO_3 = nitrate, α-T = DL, alpha-tocopherol.

[b]Means in the same column followed by a common letter are not different (P>0.05).

[c]Milligrams of malonaldehyde/1000 grams of frankfurter.

[d]OD = optical density at 540 mμ.

TABLE 4. *Mean visual and cured color values for frankfurters according to curing ingredient combination and irradiation [megarad] level.*

Curing ingredient combination[a]	External color[b] Irradiation (megarad) 0 (A)	0.8 (B)	3.2 (C)	Order of means[d]	Internal color[b] Irradiation (megarad) 0 (A)	0.8 (B)	3.2 (C)	Order of means[d]	Cured color (OD[c])[b] Irradiation (megarad) 0 (A)	0.8 (B)	3.2 (C)	Order of means[d]
0 NO_2	1.3^{g}	1.2^{g}	1.7^{f}	C A B	1.4^{g}	1.5^{g}	1.9^{f}	C B A	$.017^{f}$	$.023^{f}$	$.027^{f}$	C B A
50 NO_2	6.1^{e}	5.1^{e}	4.2^{e}	A B C	6.4^{e}	5.0^{d}	4.5^{e}	A B C				
100 NO_2	6.3^{e}	4.8^{e}	4.2^{e}	A B C	6.5^{e}	5.2^{d}	2.2^{e}	A B C	$.122^{e}$	$.047^{e}$	$.044^{e}$	A B C
50 NO_3	1.0^{g}	1.4^{g}	1.7^{f}	C B A	1.2^{g}	1.5^{g}	2.1^{f}	C B A				
$25NO_2/25NO_3$	1.9^{f}	2.7^{f}	2.3^{f}	B C A	2.4^{f}	3.1^{e}	3.0^{f}	B C A	$.030^{f}$	$.037^{e}$	$.021^{f}$	B A C
$25NO_2/25NO_3/206$ α-T	1.6^{fg}	2.1^{fg}	2.2^{f}	C B A	1.8^{fg}	2.6^{f}	2.5^{f}	B C A				

[a]Based on amount (ppm) added to 9.07 kg of raw meat; NO_2 = nitrite, NO_3 = nitrate, α-T = alpha-tocopherol.
[b]Means in the same column followed by a common letter are not different ($P>0.05$).
[c]OD = optical density at 540 mμ.
[d]Means underscored by a common line are not different ($P>0.05$).

Frankfurters, as affected by curing-ingredient combinations and irradiation levels, are shown in Table 4. External and internal visual color scores were higher ($P<0.05$) (all irradiation levels) for frankfurters made with 50-NO_2 or with 100-NO_2 than for frankfurters from other treatments. These visual color scores (Table 4) (frankfurters made with 100-NO_2 compared to frankfurters made with 0-NO_2 or with 25 NO_2/25 NO_3) are confirmed by cured color values presented in Table 3.

Mean palatability and Instron values for frankfurters according to irradiation levels are shown in Table 5. Increasing levels of irradiation produced more off-flavor, a softer texture and a less palatable frankfurter ($P<0.05$). Although not significantly different, moistness values were higher in frankfurters irradiated at 3.2 megarads compared to other levels of irradiation. High-dose irradiation (3.2 megarads) may soften (increase amounts of free water) the structural lattice of sausage batters, which in turn contributes to a slightly more moist but softer frankfurter. Force of rupture (force in Newtons required to completely shear through frankfurters) was significantly lower ($P<0.05$) for the 0.8- and 3.2- megarad levels than for the non-irradiated (0-megarad) controls. The work of rupture (work in N-cm/cm^2, required to completely shear through frankfurters) was not significantly affected by irradiation levels. Although not statistically significant, values for skin strength (strength in N/cm^2 required to shear the outer skin) and force of rupture were higher at 0.8 megarad than at 3.2 megarads. These observations suggest that both low-dose and high-dose irradiation decrease the strength of the structural (protein-salt-water) lattice in cured, cooked sausages which, in turn, results in softer and less palatable frankfurters when compared with non-irradiated controls. However, plasma protein added at low levels to all-meat frankfurters and to frankfurters made with cottonseed protein increased skin strength (*22,23*). Thus this protein additive might be useful in counteracting the undesirable texture of irradiated frankfurters reported in the present study and by others (*21*).

TABLE 5. *Mean palatability and Instron values for frankfurters according to irradiation levels.*

Trait[a]	Irradiation (megarad) level 0	0.8	3.2
Off-odor	7.3b	5.1c	3.0d
Moistness	6.4b	6.6b	6.8b
Texture	6.8b	6.3c	5.4d
Off-flavor	7.5b	5.5c	3.6d
Overall palatability	6.7b	4.9c	3.3d
Skin strength (N/cm^2)	465.0b	443.3bc	411.1c
Force of rupture(N)	866.9b	751.0c	683.5c
Work of rupture (N-cm/cm^2)	404.0b	562.6b	499.2b

[a]Off-odor, 8=extremely weak or no off-odor; 1=extremely strong off-odor; moistness, 8=extremely moist, 1=extremely dry; texture, 8=extremely firm exterior and interior, 1=extremely soft exterior and interior; off-flavor, 8=extremely weak or no off-flavor, 1=extremely strong off-flavor; overall palatability; 8=like extremely - would repeat purchase, 1=dislike extremely - would not purchase. Instron values (skin strength, force of rupture and work of rupture) determined from force - deformation curves.
[bcd]Means in the same row followed by a common letter are not different ($P<0.05$).

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