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Cooked Product Temperature and Curing Ingredients Affect Properties of Irradiated Frankfurters

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ABSTRACT

Frankfurters (9.07-kg batches) were conventionally made in which three replications of the following treatment combinations were used (*a*) curing ingredients: 0 or 50 ppm of sodium nitrite, 75 ppm of sodium nitrite-25 ppm of sodium nitrate, or 50 ppm of sodium nitrite-25 ppm of sodium nitrate, (*b*) seasoning: dry soluble or equivalent ground spice, (*c*) cooked product temperatures of 65.5 or 76.6 C and (*d*) radiation processing levels of either 0, 0.8 or 3.2 megarads. Regardless of curing ingredient combinations or levels of irradiation, lowering internal cooked product temperatures (65.5 vs. 76.6 C) improved internal color, off-odor, off-flavor, moistness and overall desirability scores of frankfurters. Use of a dry soluble seasoning in comparison to an equivalent natural ground spice seasoning had no effect on sensory, chemical or palatability traits of irradiated frankfurters. Although not significant, frankfurters made without nitrite (0-NO_2) compared to those made with 75 NO_2-25 NO_3, had greater process shrinkage values and were significantly less desirable in visual color, off-flavor and overall palatability. External and internal color scores of frankfurters made with NO_2 and NO_3 combinations were less intensely pink, with an increase in irradiation from 0 to 0.8 to 3.2 megarads. Sensory traits (off-flavor, off-odor, texture and overall palatability) were less desirable in those frankfurters irradiated at 3.2 megarads as compared to those irradiated at 0.8 megarads. Both levels of irradiation produced less desirable frankfurters than the non-irradiated controls (0 megarads). Improvements in sensory properties of irradiated frankfurters may be accomplished by use of at least 50 ppm of NO_2 and cooking to a final internal product temperature of 65.5 C.

On a world-wide basis, much current food irradiation research is directed towards the wholesomeness of such preserved foods. Animal feeding studies to determine toxicity and nutrient alteration studies have been reported (*5*). 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 foods (thermally processed). Process improvement research has shown that when free oxygen is removed and the food is properly packaged and irradiated at low temperatures (-34 C), the resultant product has improved palatability and higher nutrient retention values. Most of these values are reported to be dose-dependent in that higher dose levels (radapperization ⩽ 3 M rads), when compared to low dose levels (LDI ⩽ 1 M rad), produce less desirable irradiated foods (*2,8*). Although "wholesomeness" studies are important from a public health-regulatory standpoint, they are of no absolute value in a practical sense when sensory studies report that radappertized products may not be palatable.

Product improvement research on formulated meat prducts which are to be irradiated offers the challenge of minimizing undesirable palatability traits resulting from irradiation (*9*). For example, in pork rolls and ham slices adding sodium tripolyphosphate as well as reducing level of curing ingredients enhanced the quality of irradiated products (*8,10*). Reduction or elimination of curing ingredients is currently being studied as a result of the nitrosamine controversy in cured bacon (*3*). However, factors other than curing ingredients may be of equal importance in developing palatable, preformulated and irradiated sausage products. Accordingly, the aim of this study was to determine the effects of internal cooked product temperature, type of seasoning and combination of curing ingredients on the chemical and sensory properties of irradiated frankfurters.

MATERIALS AND METHODS

General

Frankfurters of 16 treatment combinations were made as 9.07-kg batches, using conventional manufacturing procedures (without vacuum chopping or stuffing). Treatment combinations were as follows (*a*) curing ingredient-combinations: 0 or 50 ppm of sodium nitrite, 75 ppm of sodium nitrite-25 ppm of soidum nitrate, or 50 ppm of sodium nitrite-25 ppm of sodium nitrate, (*b*) seasonings: natural spice or dry soluble, (*c*) cooked product temperatures: 65.5 or 76.6 C, (*d*) radiation processing levels of 0, 0.8 or 3.2 megarads. Frankfurters from each treatment combination (including controls) were vacuum-packaged in flexible retortable pouches, frozen at -34.4 C and air-transported to the Food Engineering Laboratory, USNARADCOM

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for Cobalt-60 irradiation at -34.4 C (± 5° C). After irradiation, frankfurters were air-transported back to TAES for subsequent study of physical, chemical and sensory properties.

Manufacturing

Frankfurters were formulated from commercially available ingredients as follows: pork, 27.20 kg; beef, 18.20 kg; salt, 0.91 kg; sweetener (dextrose and corn syrup solids), 1.82 kg; seasonings, 0.93 or 1.01 kg; and ice water, 10.4 kg. The raw meat ingredients consisted of 60% pork and 40% beef, formulated to contain 30% fat and 10% added moisture in the finished, cooked product. A commercial seasoning made from 100% essential oils or oleoresins of natural spices (DS seasoning 0.93 kg) was compared with a seasoning in which 50% of the oils or oleoresins were converted, on an equivalent basis, to ground natural spices (GS seasoning 1.01 kg). Lean meats, salt and appropriate nitrite and/or nitrate mixtures and 1/3 of the total water (10.4 kg) were chopped 1-2 min. Then fatter meats, sweeteners, seasonings and the remainder of water were added and this composite was chopped for 10-11 min (final batter temperature was 19-20 C). Batters were then stuffed, using a pneumatic piston stuffer, into 25-mm clear cellulose casing and linked (10.4 cm in length). A conventional cooking cycle of 1 3/4 h and various rates of heat input to achieve a cooked product temperature of either 65.5 or 76.6 C was used. The links 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).

Analytical

A 7-member experienced panel evaluated the thawed, unheated frankfurters for off-odor intensity by use of an 8-point scale (8 = extremely weak off-odor to no off-odor; 1 = extremely strong off-odor). External and internal color of reheated frankfurters was evaluated by the same 7-member panel by use of the following scale; 7 = excellent cured-pink color; 1 = poor cured-pink color. Frankfurters of different treatment combinations were assigned to specific taste panel sessions by use of a random numbers table. Thawed links were steeped in boiling water (7 min) whereupon they were sectioned, placed in heated aluminum pans and served (warm) to a 9-member experienced sensory panel (78% males; 22% females; 67% domestic; 33% foreign). The following palatability traits were evaluated: moistness (8 = extremely moist; 1 = extremely dry), off-flavor intensity (8 = extremely weak off-flavor 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). Proximate composition (moisture, fat, protein and residual nitrite) was determined (*1*).

Statistical analyses by use of analysis of variance (*7*) and multiple range test (*4*) were completed on the data.

RESULTS AND DISCUSSION

Mean processing shrinkage, sensory and chemical values of frankfurters according to cooked temperatures are shown in Table 1. Frankfurters cooked internally to 65.5 C had significantly less shrinkage, higher moisture contents and lower fat, protein and residual nitrite contents that 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 higher scores ($P < 0.05$) for internal color, off-odor intensity, off-flavor, moistness, texture and overall satisfaction 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) to enhance the palatability traits of such irradiated sausage products.

Mean processing shrinkage and chemical values are shown in Table 2. Of frankfurters cooked to 65.5 C, those made with 0-NO_2 had greater ($P < 0.05$) processing shrink than those made with 50 NO_2-25 NO_3. No differences in processing shrinkage due to curing ingredients were observed for the 76.6-C treatments. Regardless of cooked temperatures, those frankfurters made without NO_2 had significantly less moisture and more fat than did those frankfurters made with 75 NO_2-25 NO_3. These data suggest that a relationship may exist between use of sodium nitrite vs. no sodium nitrite on processing shrinkage and proximate composition of frankfurters.

TABLE 1. *Mean processing shrinkage, sensory and chemical values of frankfurters according to internal product cooked temperature.*

Trait[a]	Product temperature 65.5 C	Product temperature 76.6 C	Level of significance[b]
Processing shrinkage	11.20	12.29	*
Visual color			
External	3.52	3.25	NS
Internal	4.01	3.59	*
Off-odor	4.74	4.22	* *
Off-flavor	4.72	3.99	* *
Moistness	6.19	5.73	* *
Texture	5.72	4.75	* *
Overall satisfaction	4.25	3.35	* *
Moisture (%)	51.23	49.84	* *
Fat (%)	31.43	32.16	* *
Protein (%)	10.62	10.82	*
Residual nitrite (ppm)	2.26	3.69	* *

[a]Visual color: 7 = excellent pink-cured color, 1 = poor pink-cured color. Off-odor: 8 = extremely weak to no off-odor, 1 = extremely strong off-odor. Moistness: 8 = extremely moist, 1 = extremely dry. Off-flavor: 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. Overall satisfaction: 8 = like extremely-would repeat purchase consistently, 1 = dislike extremely-would not purchase.

[b]* = ($P < 0.05$); * * = ($P < 0.01$); NS = nonsignificant ($P > 0.05$).

Curing ingredient effects on sensory properties are shown in Table 3. Those frankfurters made with 0-NO_2 compared to those made with 75 or 50 NO_2 or 50 NO_2-25 NO_3 combinations had lower scores for moistness, off-flavor, overall palatability and external and internal color. However, differences for these sensory properties were not significant ($P < 0.05$) among frankfurters made with 50-NO_2, 75 NO_2-25 NO_3 or 50 NO_2-25 NO_3. At least some level of sodium nitrite alone or in combination with 25 ppm of sodium nitrate produced irradiated frankfurters with acceptable visual color.

Effects of curing-ingredients and internal cooked product temperatures on visual color scores are shown in Table 4. There were no differences ($P < 0.05$) in external or internal color scores due to cooked temperature or curing ingredients among those frankfurters made with 50-NO_2, 75 NO_2-25 NO_3 or 50 NO_2-25 NO_3. However, frankfurters made without NO_2 (0-NO_2) had more

TABLE 2. *Mean percentage values for processing shrinkage and proximate composition according to curing ingredient combination.*

Curing ingredients[a]	Processing shrinkage (%) Internal cooked temp. 65.5 C	76.6 C	Level of significance[b]	Composition (%) Moisture	Fat	Protein
0-NO_2	11.9[c]	12.3[c]	NS	50.21[d]	32.27[c]	10.61[c]
50-NO_2	11.5[cd]	12.2[c]	NS	50.69[cd]	31.51[d]	10.83[c]
75 NO_2-25 NO_3	10.9[cd]	11.8[c]	NS	50.78[c]	31.55[d]	10.73[c]
50 NO_2-25 NO_3	10.6[d]	12.9[c]	NS	50.50[cd]	31.84[d]	10.70[c]

[a]Parts per million (ppm) added on basis of 45.5 kg of raw meat.
[b]Not significant (P>0.05).
[cd]Means in the same column followed by a common letter are not different (P > 0.05).

TABLE 3. *Mean sensory values of frankfurters according to curing ingredient combinations.*

Curing ingredients[a]	Sensory value[b] Moistness	Off-odor	Off-flavor	Texture	Overall palatability	Visual color External color	Internal color
0-NO_2	5.77[d]	4.29[c]	3.99[d]	5.36[cd]	3.41[d]	1.68[d]	2.07[d]
50-NO_2	5.94[c]	4.51[c]	4.35[cd]	5.45[c]	3.91[c]	4.10[c]	4.47[c]
75-NO_2-25 NO_3	6.08[c]	4.76[c]	4.57[c]	5.05[e]	3.96[c]	4.04[c]	4.41[c]
50-NO_2-25 NO_3	6.03[c]	4.38[c]	4.52[c]	5.10[de]	3.92[c]	3.68[c]	4.21[c]

[a]Parts per million (ppm) added on the basis of 45.4 kg raw meat.
[b]Moistness: 8 = extremely moist, 1 = extremely dry. 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. Texture; 8 = extremely firm exterior and interior, 1 = extremely soft exterior and interior. Overall satisfaction: 8 = like extremely-would repeat purchase consistently, 1 = dislike extremely-would not purchase. Visual color: 7 = excellent pink-cured color, 1 = poor pink-cured color.
[cde]Means in the same column followed by a common letter are not different (P > 0.05).

TABLE 4. *Mean visual color scores of frankfurters stratified according to curing ingredient combination and internal cooked product temperature.*

Curing ingredients[a]	External color[b] Temperature 65.5 C	76.6 C	Level of significance[c]	Internal color[b] Temperature 65.6 C	76.6 C	Level of significance[c]
0-NO_2	2.22[e]	1.10[e]	* *	2.66[e]	1.44[e]	* *
50-NO_2	4.45[d]	3.75[d]	NS	4.83[d]	4.11[d]	NS
75-NO_2-25-NO_3	3.79[d]	4.28[d]	NS	4.36[d]	4.47[d]	NS
50-NO_2-25-NO_3	3.62[d]	3.74[d]	NS	4.21[d]	4.22[d]	NS

[a]Parts per million (ppm) added on basis of 45.4 kg of raw meat.
[b]7 = excellent pink-cured color, 1 = poor pink-cured color.
[c]* =(P <0.05); * * =(P <0.01); NS =non-significant (P >0.05).
[de]Means in the same column followed by a common letter are not different (P > 0.05).

(P < 0.01) intensive external and internal color when cooked to 65.5 C than when cooked to 76.6 C. Although these data suggest that visual color scores of no-nitrite added sausage products may be improved by use of lower cooked product temperatures, the risk of increasing microbial numbers in such products would probably offset visual color advantages gained by lowering cooked product temperatures.

Curing ingredients and irradiation dose level effects on mean external and internal color scores are shown in Table 5. External and internal color scores for those frankfurters made with 75 NO_2-25 NO_3 or 50 NO_2-25 NO_3 became less (P < 0.05) pink with each increasing level of irradiation (from 0 to 0.8 to 3.2 megarads), whereas those frankfurters made with 50-NO_2 did not differ in external and internal color intensity between the 0.8 and 3.2 megarad levels. Although not significant, internal color values increased with increasing levels of irradiation for those frankfurters made without nitrite (0-NO_2). Radiation has been reported to enhance the cured color of processed meats (frankfurters and bacon) to which no nitrite cure (0-NO_2) was added (*9,11*).

Effects of internal cooked product temperature and radiation level on residual nitrite values are shown in Table 6. Cooked product temperatures of 65.5 or 76.6 C did not significantly (P < 0.05) affect residual nitrite values of frankfurters to which no nitrite (0-NO_2) or 50-NO_2 was added. However, those frankfurters to which 25 ppm of nitrate was added had significantly greater

TABLE 5. *Mean visual color scores of frankfurters stratified according to curing ingredient combinations and level of irradiation.*

Curing ingredients	External color[a] Radiation level 0 (A)	0.8 (B)	3.2 (C)	Order of means[c]	Internal color[a] Radiation level 0 (A)	0.8 (B)	3.2 (C)	Order of means[c]
0-NO_2	1.63[e]	1.78[e]	1.61[f]	ABC	1.82[e]	1.93[e]	2.48[e]	ABC
50-NO_2	5.32[d]	3.62[d]	3.36[d]	ABC	5.76[d]	4.05[d]	3.59[d]	ABC
75-NO_2-25-NO_3	5.45[d]	3.74[d]	2.92[de]	ABC	5.87[d]	4.12[d]	3.26[de]	ABC
50-NO_2-25-NO_3	5.07[d]	3.42[d]	2.54[e]	ABC	5.60[d]	3.97[d]	3.07[de]	ABC

[a]7 = excellent pink-cured color, 1 = poor pink-cured color.
[b]Parts per million (ppm) added on basis of 45.4 kg raw meat.
[c]Means underscored by a common line are not different ($P > 0.05$).
[def]Means in the same column followed by a common letter are not different ($P > 0.05$).

TABLE 6. *Mean residual nitrite values of frankfurters stratified according to internal product cooked temperature and irradiation level.*

Curing ingredients[a]	Product temperature 65.5 C	76.6 C	Level of significance	Level of radiation 0 (A)	0.8 (B)	3.2 (C)	order of means[c]
0-NO_2	0.33[f]	0.41[e]	NS	0.29[f]	0.08[e]	0.76[e]	ABC
50-NO_2	3.76[d]	4.48[d]	NS	6.35[e]	3.16[d]	2.64[d]	ABC
75-NO_2-25-NO_3	3.05[de]	5.59[d]	*	7.47[d]	3.27[d]	2.21[d]	ABC
50-NO_2-25-NO_3	1.99[e]	4.13[e]	*	4.85[e]	2.33[d]	1.99[d]	ABC

[a]Parts per million (ppm) added on basis of 45.4 kg of raw meat.
[b]* = ($P < 0.05$); NS = not significant.
[c]Means underscored by a common line are not different ($P > 0.05$).
[def]Means in the same column followed by a common letter are not different ($P > 0.05$).

residual nitrite values at 76.6 C compared to 65.5 C. Although not significant, increasing levels of irradiation (0.8 to 3.2 megrads) decreased residual nitrite values for all curing ingredient combinations with the exception of the 0-NO_2 treatment. In that treatment (0-NO_2), residual nitrite values were numerically higher for the 3.2 megarad than the 0.8 megarad processing level and the non-irradiated (control) sample. Loss of residual nitrite and visual color (Table 5) appears to be increased by irradiation.

Mean sensory panel scores of frankfurters according to radiation levels are presented in Table 7. Less intense cured color (external and internal), more off-flavor and off-odor, a softer texture and poorer palatability resulted from use of irradiation and with increasing radiation levels. However, values for moistness were not affected ($P < 0.05$) by these same increasing levels of irradiation. Compared to the non-irradiated frankfurters, those products irradiated at 3.2 megarads were definitely less acceptable (overall palatability scores), whereas those frankfurters irradiated at 0.8 megarads were more acceptable than those frankfurters irradiated at 3.2 megarads. These data confirm other studies with predominantely domestic sensory panels in that the degree of undesirability in sensory properties of irradiated cured as well as fresh meats may be dose-dependent (sterilizing dose levels produce more undesirable sensory properties than do sub-sterilizing levels). However, extrapolation of these dose-reponse palatability effects to acceptance by various types of consumer markets should not be made; rather, separate research designed to test consumer market acceptance should be conducted.

TABLE 7. *Mean sensory values of frankfurters according to irradiation level.*

Sensory trait[a]	Radiation level (M-rads) 0	0.8	3.2
Visual color			
External	4.37[b]	3.14[c]	2.63[d]
Internal	4.76[b]	3.52[c]	3.11[d]
Off-flavor	6.80[b]	3.67[c]	2.57[d]
Off-odor	6.78[b]	4.00[c]	2.63[d]
Moistness	5.98[b]	5.89[b]	6.00[b]
Texture	6.08[b]	5.42[c]	4.20[d]
Overall palatability	5.96[b]	3.26[c]	2.16[d]

[a]Visual color: 7 = excellent pink-cured color, 1 = poor pink-cured color. Off-flavor: 8 = extremely weak to no off-flavor, 1 = extremely strong off-flavor. Off-odor; 8 = extremely weak to 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. Overall satisfaction: 8 = like extremely-would repeat purchase consistently, 1 = dislike extremely-would not purchase.
[bcd]Means in the same row followed by a common letter are not different ($P > 0.05$).

CONCLUSIONS

Our data suggest that significant improvements in internal cured color and palatability traits of frankfurters to be irradiated may be achieved by initially cooking to a lower internal product temperature (65.5 vs.

76.6 C). Use of a dry soluble seasoning compared to the same seasoning in which 50% of the essential oils and/or oleoresins were converted, on an equivalent basis, to natural ground spice had no effect on palatability traits of irradiated frankfurters. Although not significant, the manufacture of frankfurters without sodium nitrite (0-NO_2) compared to those made with 75 NO_2-25 NO_3 resulted in greater process shrinkage values and more undesirable color, more off-flavor and less overall desirability ($P < 0.05$). Irradiation of frankfurters at 0.8- and 3.2-megarad levels decreased ($P < 0.05$) external and internal color scores of frankfurters made with NO_2 and/or NO_3 combinations. Palatability traits (off-flavor, off-odor, texture and overall palatability) were significantly less desirable in those products irradiated at 3.2 megarads compared to those irradiated at 0.8 megarads. However, both levels of irradiation produced less desirable frankfurters compared to non-irradiated controls (0 megarads). Although radappertization (sterilizing dose levels) has been reported to prevent *Clostridium botulinum* from forming toxin in frankfurters and to prevent nitrosamine formation in bacon, (both products made without sodium nitrite), those frankfurters in this study made without NO_2 were definitely unacceptable to the sensory panel. Thus it appears, from the standpoint of commercialization, that at least some level of nitrite is required for visual and sensory acceptance of irradiated frankfurters. The apparent need for curing ingredients to improve acceptance may become more evident when sensory panel determinations are made in storage stability studies of irradiated frankfurters.

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