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Effects of Sodium Nitrite, Sodium Acid Pyrophosphate and Meat Formulation on Properties of Irradiated Frankfurters

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ABSTRACT

Frankfurters of twelve treatment combinations were made using a conventional manufacturing procedure. Manufacturing treatments included formulations of either 60% pork/40% beef, 100% mechanically deboned chicken (MDC) or 100% mechanically deboned turkey (MDT); sodium nitrite levels of 0 or 50 ppm; and sodium acid pyrophosphate (SAPP) levels of 0 or 3,750 ppm. Finished frankfurters were either not irradiated or irradiated at temperatures of either -34.4 or -51.1°C and at a dose level of 0.8 or 3.2 Mrad. Addition of SAPP did not significantly affect external or internal color, off-flavor incidence or overall palatability of any of the frankfurters but significantly increased processing shrinkage for pork/beef and chicken franks, decreased frankfurter pH values for pork/beef and chicken franks and improved texture of pork/beef, chicken and turkey franks. Addition of 50 ppm nitrite, as compared to use of no nitrite, significantly decreased processing shrinkage of turkey franks, increased batter and frankfurter pH of pork/beef franks, increased consumer cooking loss of chicken franks but decreased consumer cooking loss of turkey franks, decreased off-flavor of pork/beef, chicken and turkey franks, and improved internal color of pork/beef, chicken and turkey franks. An irradiation temperature of -51.1°C as compared with -34.4°C, decreased off-flavor intensity and increased palatability of pork/beef franks but did not affect other properties of pork/beef franks or any of the properties of chicken or turkey franks. Franks irradiated with 0.8 Mrad differed ($P<0.05$) from those that were not irradiated in only 3 of 18 sensory traits (including overall palatability of pork/beef franks); franks irradiated with 3.2 Mrad differed ($P<0.05$) from those which were not irradiated in 8 of 18 sensory traits (including overall palatability of pork/beef, chicken and turkey franks).

Factors affecting characteristics of irradiated frankfurters have been reported in two previous studies (*9,10*). Sodium nitrite, used alone or in combination with either sodium nitrate or DL alpha-tocopherol, affected processing shrinkage, off-flavor intensity, texture, cured color, visual color and TBA values of pork/beef formulations. Processing to a lower internal cooked product temperature (65.5°C vs 76.6°C) improved all sensory properties of irradiated frankfurters. More detrimental effects, i.e., less desirable visual color, more off-flavor, more off-odor, softer texture and less desirable palatability, resulted when frankfurters were irradiated at 3.2 rather than at 0.8 Mrad or at either level as compared to not irradiating these products. Those data (*9,10*) suggested that improvements in flavor and internal color might result from further modifications in formulations and procedures. Seasonings (ground spice vs soluble spice oils and oleoresins) used in previous studies (*10*) did not affect off-flavor. Irradiation at lower temperatures minimizes detrimental effects in fresh meats (*2*) and addition of a chemical acidulant (disodium dihydrogen diphosphate, SAPP) to frankfurters, decreases pH and accelerates the rate and intensity of cured color development (*6*). One objective of the present study was to investigate the latter two principles for producing more desirable irradiated frankfurters.

Low dose irradiation (LDI) of fresh foods ($\leq$ 1 Mrad) compared to use of sterilizing dose levels ($\geq$ 3 Mrad) decreases the magnitude of detrimental effects (*2,8*). This magnitude may also be associated with species origin of meat (*8*). Although most of the United States literature on irradiation of red meats indicates that such products are not palatable regardless of dose level, LDI beef in South Africa has received 98% acceptance by consumers (*5*). Other commercial meat products irradiated with both LDI and sterilizing dose levels, i.e., pork sausage, frankfurters and beef sausage, have been produced in the United States for export markets (*11*). The second purpose of the present study was to determine effects of irradiation on frankfurters made from different kinds (species/sources) of meat (pork/beef vs mechanically deboned chicken or turkey).

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MATERIALS AND METHODS

General

Frankfurters of twelve treatment combinations were made in triplicate batches (9.07 kg) using a conventional manufacturing procedure. Manufacturing treatment combinations were: (a) formulations of either 60% pork/40% beef, 100% mechanically deboned chicken (MDC) or 100% mechanically deboned turkey (MDT) and (b) ingredient levels of either 0 or 50 ppm sodium nitrite and 0 or 3,750 ppm sodium acid pyrophosphate (SAPP). In addition to these formulations, frankfurters were either not irradiated or were irradiated at temperatures of either -34.4 or -51.1°C and at dose levels of either 0.8 or 3.2 Mrad. Frankfurters were vacuum packaged (flexible retortable pouches), frozen at -34.4°C, placed in appropriate shipping containers and air-transported to the Food Engineering Laboratory (USNARADCOM) for Cobalt^{60} irradiation. After irradiation, frankfurters were air-transported to the Texas Agricultural Experiment Station for subsequent determinations of physical, chemical and sensory properties (completed within 4 wk after irradiation).

Manufacturing

Frankfurters were formulated from commercially available ingredients. Chicken frankfurters received no added moisture due to the high initial moisture content of mechanically deboned chicken, but pork/beef and turkey formulations did receive added moisture (10.1 and 4.2 kg, respectively, based on total batch weights of 59.0 and 53.1 kg, respectively). In general, chicken formulations were more difficult to make into stable batters than were pork/beef or turkey formulations. All formulations were based on achieving moisture, fat and protein contents comparable to those of commercial products. Lean meats, salt, appropriate amounts of nitrite and 1/3 of the total water were added and chopped 1-2 min (3 blade, non-vacuum bowl cutter). Fatter meats, sweeteners, seasonings, appropriate amounts of sodium acid pyrophosphate and the remainder of the water were then added and this composite was chopped for 10-12 min (final batter temperature was 19.2°C). Batters were then stuffed (pneumatic-piston stuffer) into 25 mm diameter clear cellulose casings and formed into links (10.4 cm in length). These links were dipped (30 s) in a solution of liquid smoke (50% water:50% liquid smoke). A conventional cooking cycle (1.75 h) was used to achieve a final cooked product internal temperature of 65.5°C. Links were then chilled (14-16 h at 3°C) before peeling and subsequent vacuum packaging in flexible retortable pouches (5 links/pouch).

Analytical

A seven-member experienced sensory panel evaluated thawed unheated frankfurters for external and internal visual color (7=excellent cured-pink color, 1=no cured-pink color). Frankfurters from different treatments were grouped according to formulation (pork/beef, chicken, turkey) and links from each formulation were randomly assigned to separate sensory panel sessions. Thawed links (0°C) were steeped in boiling water (7 min), sectioned, placed in aluminum pans and served warm to the panel under red lighting. Palatability traits were evaluated by use of the following scales: moistness, 8=extremely moist, 1=extremely dry; off-flavor, 8=extremely weak 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. Moisture, fat and protein were determined (*1*). The pH of frankfurter batters was determined by directly inserting the electrode into batters; pH of cooked frankfurters was determined by making a 1:10 dilution of sample with deionized, distilled water and reading pH values of this slurry with a Corning Model 7 pH meter.

Statistical analyses using analysis of variance (*7*) and multiple range tests (*3*) were completed on the data. Analysis of variance was conducted within a formulation (i.e., pork/beef) rather than between formulations (i.e., pork/beef vs chicken vs turkey).

RESULTS AND DISCUSSION

Mean values for physical and sensory properties according to formulation and SAPP levels are shown in Table 1. Processing shrinkage values were increased ($P<0.05$) when SAPP was used for pork/beef and chicken frankfurters but not for turkey franks. Batter pH values were not different when SAPP was added, but finished frankfurter pH values were lower (pork/beef and chicken frankfurters) when SAPP was added. Percentages of consumer cooking loss were lower ($P<0.05$) when SAPP was used for chicken and turkey frankfurters but not for pork/beef franks. Pork/beef and chicken frankfurters made with SAPP were less moist and firmer ($P<0.05$) than those same formulations made without SAPP. Turkey frankfurters were firmer ($P<0.05$) when made with SAPP but were not different in moistness. Regardless of meat formulation, other traits, including visual color (external and internal), were not affected by addition of SAPP.

SAPP is approved for use in frankfurters to accelerate the rate of cured color development through a reduction of pH (*6*). SAPP is a non-shorting (does not break-down sausage batter) acid phosphate which usually lowers pH of the cooked product. This reduction of pH increases the rate and intensity of cured color development and reduces residual nitrite levels (*6*). In the present study, SAPP reduced moistness (2 of 3 formulations) and increased firmness (3 of 3 formulations) of frankfurters which may be associated with slightly greater processing shrinkages (Table 1) when used. Since previous studies with irradiated frankfurters (*9,10*) suggested that higher doses of irradiation substantially reduced visual color, we thought that SAPP might correct this color problem. However, this hypothesis is not supported by data presented in Table 1.

Mean values for physical and sensory properties of frankfurters according to formulation and nitrite level are shown in Table 2. Addition of 50 ppm nitrite as compared with no nitrite increased batter pH, frankfurter pH, overall palatability, external color and internal color values and decreased off-flavor of pork/beef formulations; increased consumer cooking loss and internal color values but decreased off-flavor for chicken frankfurters; and reduced processing shrinkage, consumer cooking loss and off-flavor scores but increased moistness, texture, overall palatability and internal color of turkey frankfurters.

In previous studies (*9,10*) it was suggested that irradiation might preserve frankfurters made without the use of nitrite. If no nitrite was used it might be possible to avoid formation of nitrosamines. However, in those studies (*9,10*) addition of some nitrite was required to produce a palatable product. Data from the present study (Table 2) support the conclusion that nitrite is required for improved palatability of frankfurters made with pork/beef, mechanically deboned chicken or

TABLE 1. *Mean values for physical and sensory properties of frankfurters according to formulation and sodium acid pyrophosphate level.*

Property	Formulation and sodium acid pyrophosphate level (ppm)					
	Pork/beef		Chicken		Turkey	
	0	3,750	0	3,750	0	3,750
Physical						
Processing shrinkage[a] (%)	16.67d	18.28c	15.01d	18.86c	15.58	16.34
Batter pH	5.37	5.37	5.46	5.40	5.68	5.60
Frankfurter pH	5.42c	5.31d	5.61c	5.40d	5.77	5.72
Consumer cooking loss[a] (%)	1.32	0.91	2.78c	1.06d	7.45c	2.30d
Sensory[b]						
Moistness	5.1c	4.4d	5.9c	5.3d	5.6	5.8
Off-flavor	5.0	4.8	4.7	4.6	5.1	4.9
Texture	5.7d	6.5c	4.3d	5.3c	3.2d	4.6c
Overall palatability	4.6	4.4	4.2	4.1	3.7	4.2
External color	5.8	5.6	5.2	5.4	5.1	5.4
Internal color	4.2	3.8	3.8	3.7	3.8	3.8

[a]Processing shrinkage includes weight loss from heat processing and 14-16 h cooler shrinkage. Consumer cooking loss = weight loss upon reheating in water.

[b]Moistness, 8 = extremely moist, 1 = extremely dry; off-flavor, 8 = extremely weak off-flavor, 1 = extremely strong off-flavor; texture, 8 = extremely firm exterior and interior, 1 = extremely soft exterior and interior; overall palatability, 8 = like extremely - would repeat purchase; 1 = dislike extremely - would not purchase; external and internal color, 7 = excellent pink-cured color, 1 = poor pink-cured color.

[cd]Means in the same row within a formulation followed by different letters, are different ($P<0.05$). Means in the same row within a formulation without letters are not different ($P>0.05$).

TABLE 2. *Mean values for physical and sensory properties of frankfurters according to formulation and nitrite level.*

Property	Formulation and nitrite level (ppm)					
	Pork/beef		Chicken		Turkey	
	0	50	0	50	0	50
Physical						
Processing shrinkage[a] (%)	17.98	16.98	17.22	16.58	16.74c	15.23d
Batter pH	5.26d	5.48c	5.44	5.41	5.66	5.62
Frankfurter pH	5.32d	5.41c	5.50	5.51	5.73	5.76
Consumer cooking loss[a] (%)	1.30	0.93	1.54d	2.33c	7.04c	2.64d
Sensory[b]						
Moistness	4.6	4.9	5.4	5.8	5.4d	5.9c
Off-flavor	4.7d	5.1c	4.4d	4.9c	4.8d	5.2c
Texture	6.1	6.0	4.9	4.7	3.7d	4.2c
Overall palatability	4.2d	4.8c	4.0	4.4	3.4d	4.5c
External color	5.7d	5.8c	5.8	5.6	5.1	5.4
Internal color	2.6d	5.4c	3.3d	4.3c	1.9d	5.3c

[a]Processing shrinkage includes weight loss from heat processing and 14-16 h cooler shrinkage. Consumer cooking loss = weight loss upon reheating in water.

[b]Moistness, 8 = extremely moist, 1 = extremely dry; off-flavor, 8 = extremely weak off-flavor, 1 = extremely strong off-flavor; texture, 8 = extremely firm exterior and interior, 1 = extremely soft exterior and interior; overall palatability, 8 = like extremely - would repeat purchase, 1 = dislike extremely - would not purchase; external and internal color, 7 = excellent pink-cured color, 1 = poor pink-cured color.

[cd]Means in the same row within a formulation followed by different letters are different ($P<0.05$). Means in the same row within a formulation without letters are not different ($P>0.05$).

TABLE 3. *Mean values for physical, sensory and chemical properties of frankfurters according to sodium acid pyrophosphate and nitrite levels and formulation.*

Formulation and property	Sodium acid pyrophosphate and nitrite level (ppm)			
	0		3,750	
	0	50	0	50
Pork/beef				
Processing shrinkage[a] (%)	16.6c	16.9c	19.5b	17.1c
Frankfurter pH	5.35c	5.50b	5.29d	5.32cd
Consumer cooking loss[a] (%)	1.82c	0.82b	0.80b	1.03b
External color[a]	5.6	6.0	5.8	5.5
Moisture (%)	56.9b	56.8b	55.7c	57.7b
Fat (%)	23.0c	23.0c	24.2b	22.0d
Chicken				
Processing shrinkage[a] (%)	14.4d	15.6d	20.0b	17.7c
Batter pH	5.57b	5.34c	5.32c	5.49b
Frankfurter pH	5.64b	5.58b	5.36d	5.43c
Turkey				
Consumer cooking loss[a] (%)	11.9b	3.0c	2.2c	2.4c
External color[a]	4.6c	5.6b	5.6bc	5.3c
Moisture (%)	59.5b	60.1b	59.6b	56.2c

[a]Processing shrinkage includes weight loss from heat processing and 14-16 h cooler shrinkage. Consumer cooking loss = weight loss upon reheating in water. External color, 7 = excellent pink-cured color, 1 = poor pink-cured color.
[bcd]Means in the same row followed by different letters are different ($P<0.05$). Means in the same row without letters are not different ($P<0.05$).

mechanically deboned turkey and extends our previous conclusions to include franks made with other meats. In addition, the presence or absence of 50 ppm nitrite appears to affect certain processing shrinkage and consumer cooking yields (Table 2); a fact not previously confirmed.

Mean values for those traits for which there was a significant interaction among sodium acid pyrophosphate, formulation and nitrite are shown in Table 3. Addition of nitrite without SAPP (pork/beef frankfurters) increased frankfurter pH values compared to pH values for those same formulations made with SAPP. Data not shown revealed that processing shrinkage was highest and batter pH and frankfurter pH were lowest for pork/beef and chicken formulations in which SAPP alone (3,750 ppm) was added. However, these same traits were not affected when SAPP was added to turkey products. In addition, there were no interaction effects on internal color among all formulations for SAPP and nitrite (data not shown). These data (Table 3) suggest that regardless of formulation, addition of 3,750 ppm SAPP with at least 50 ppm nitrite did not improve external and internal color above those values obtained by using nitrite alone.

Since these products were cooked in a conventional smokehouse for 1.75 h rather than being processed in a continuous smokehouse and with a shorter heating period (40-50 min), internal and external color differences may not be as readily apparent as when continuous cooking systems are used. In rapid heat-processing cycles (continuous systems), use of SAPP decreases the incidence of under-cured frankfurters (gray cores) and improves peelability (*6*).

Previous studies (*2,8*) have reported that freezing of meat and irradiating at frozen temperatures results in fewer detrimental effects on sensory properties. Mean values for sensory properties of frankfurters according to formulation and temperature of irradiation (-34.4 or -51.1°C) are shown in Table 4. Irradiation at -51.1 C as compared to -34.4°C decreased ($P<0.05$) off-flavor and internal color and increased ($P<0.05$) overall palatability for pork/beef frankfurters but had no effect ($P>0.05$) on any of the properties of chicken or turkey frankfurters. Improvements in sensory properties of frankfurters irradiated at a lower temperature (-51.1°C vs -34.4°C) may depend on type of formulation; it appears that pork/beef frankfurters are more sensitive to irradiation temperature than are those products made with mechanically deboned chicken or mechanically deboned turkey. In data not shown in tabular form, moisture, fat and protein differed among formulations. Frankfurters made with pork/beef had higher fat and protein and lower moisture contents than did chicken or turkey products. Mean values for proximate composition were: pork/beef franks--56.8% moisture, 23.0% fat, 13.9% protein; chicken franks--58.8% moisture, 21.6% fat, 12.7% protein; and turkey franks--57.2% moisture, 21.4% fat, 12.8% protein. The type of fat (species origin) rather than the quantity of fat may be associated with temperature effects on off-flavor and overall palatability (*4*).

Dose levels of irradiation are known to affect sensory

TABLE 4. *Mean values for sensory traits of frankfurters according to formulation and irradiation processing temperature.*

Sensory trait[a]	Formulation and irradiation temperature (°C)					
	Pork/beef		Chicken		Turkey	
	-34.4°	-51.1°	-34.4°	-51.1°	-34.4°	-51.1°
Moistness	4.8	4.6	5.6	5.6	5.8	5.6
Off-flavor	4.6c	5.1b	4.6	4.7	5.0	4.9
Texture	6.0	6.2	5.0	4.6	4.0	3.9
Overall palatability	4.3c	4.7b	4.2	4.2	4.1	3.9
External color	5.8	5.7	5.4	5.2	5.2	5.3
Internal color	4.2b	3.8c	3.8	3.8	3.9	3.6

[a]Moistness, 8 = extremely moist, 1 = extremely dry; off-flavor, 8 = extremely weak off-flavor, 1 = extremely strong off-flavor; texture, 8 = extremely firm exterior and interior, 1 = extremely soft exterior and interior; overall palatability, 8 = like extremely - would repeat purchase, 1 = dislike extremely - would not purchase; external and internal color, 7 = excellent pink-cured color, 1 = poor pink-cured color.

[bc]Means in the same row within a formulation followed by different letters are different ($P<0.05$). Means in the same row within a formulation without letters are not different ($P>0.05$).

TABLE 5. *Mean values for sensory traits of frankfurters according to formulation and level of irradiation.*

Sensory trait[a]	Formulation and irradiation level (Mrad)								
	Pork/beef			Chicken			Turkey		
	0	0.8	3.2	0	0.8	3.2	0	0.8	3.2
Moistness	4.7	4.7	4.8	5.6	5.4	5.8	5.7	6.0	5.4
Off-flavor	5.8b	5.2c	3.7d	5.0b	4.9b	4.1c	5.4b	5.1b	4.4c
Texture	6.2b	6.2b	5.8c	4.8bc	5.4b	4.2c	4.4	3.7	3.8
Overall palatability	5.3b	4.7c	3.4d	4.6b	4.3b	3.6c	4.6b	4.3bc	3.4c
External color	6.0	5.6	5.6	5.7b	5.3bc	5.0c	5.5	5.1	5.1
Internal color	4.0bc	3.8c	4.3b	3.6	3.7	4.1	4.0b	3.5c	3.7bc

[a]Moistness, 8 = extremely moist, 1 = extremely dry; off-flavor, 8 = extremely weak off-flavor, 1 = extremely strong off-flavor; texture, 8 = extremely firm exterior and interior, 1 = extremely soft exterior and interior; overall palatability, 8 = like extremely - would repeat purchase, 1 = dislike extremely - would not purchase; external and internal color, 7 = excellent pink-cured color, 1 = poor pink-cured color.

[bcd]Means in the same row within a formulation followed by different letters are different ($P<0.05$). Means in the same row within a formulation without letters are not different ($P>0.05$).

properties of frankfurters made from pork and beef (*9,10*). However, these same effects have not previously been reported for frankfurters made from chicken or turkey. Mean values for sensory traits of frankfurters according to formulation and level of irradiation (Mrad) are shown in Table 5. In pork/beef formulations, values for internal color increased and values for off-flavor, texture and overall palatability decreased (not significant among all comparisons) with increasing levels of irradiation (0, 0.8 and 3.2 Mrad). With the exception of texture and internal color, these traits were affected in a similar manner for chicken and turkey frankfurters. Regardless of formulation, significant differences between no irradiation and 3.2 Mrad levels were apparent for off-flavor and overall palatability; frankfurters irradiated at 3.2 Mrad compared to those which were not irradiated had more off-flavor ($P<0.05$) and were less palatable ($P<0.05$). These data (Table 5) are consistent with previous reports on pork/beef frankfurters (*9,10*) and suggest that similar losses in palatability occur with increasing levels of irradiation for chicken or turkey frankfurters as well. Although differences in all sensory traits were generally not as great between no irradiation and 0.8 Mrad levels, a higher dose level (3.2 Mrad) resulted in less desirable products regardless of species origin (formulation) of meats.

CONCLUSIONS

It is apparent from this study and from two previous reports (*9,10*) regarding production of irradiated frankfurters that: (a) nitrite is essential for enhancing sensory traits (less off-flavor, more desirable internal color, more palatable); (b) an irradiation dose level of 0.8 Mrad results in fewer detrimental effects to sensory traits than a level of 3.2 Mrad; (c) freezing to -51.1°C may be beneficial as compared with freezing to -34.4°C before irradiation, but this is dependent upon formulation used; and (d) sodium acid pyrophosphate reduces frankfurter pH values (which may be of importance for reasons not associated with its usefulness in irradiation) but this additive did not enhance internal cured color or overall palatability of irradiated frankfurters.

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