Quality Characteristics of Vacuum-Packaged Pork Patties Irradiated and Stored in Refrigerated or Frozen Conditions

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Summary and Implications

Pork loins were ground twice through a 9-mm plate and patties (approximately 80 g each) were made. Patties were individually vacuum-packaged in oxygen impermeable plastic bags and stored either in a cooler (4°C) or a freezer (-40°C). Refrigerated patties were irradiated 0, 1.5, 3.0, or 4.5 kGy and stored at 4°C for 2 weeks, and frozen ones were irradiated at 0, 2.5, 5.0, or 7.5 kGy and stored at -40°C for 3 months. Samples were analyzed for lipid oxidation, volatile production, and off-odor during refrigerated or frozen storage. The 2-thiobarbituric acid reactive substances (TABRS) values of both refrigerated and frozen patties were not changed during storage. Irradiation dose had no effect on the TBARS of refrigerated patties, but patties irradiated at 7.5 kGy had higher TBARS value than the nonirradiated control. With refrigerated storage, panels could detect irradiation odor at day 0, but could not detect after 1 week of storage at 4°C. With frozen storage, however, irradiation odor was detected even after 3 months of storage. No difference in odor preference was found between irradiated and nonirradiated samples. Vacuum packaging was better than aerobic packaging for irradiation and subsequent storage of meat because it could minimize oxidative changes in patties during storage and produced minimal amount of volatile compounds responsible for irradiation odor.

Introduction

Microbial pathogens in food cause between 6.5 million and 33 million cases of human illness and up to 9,000 deaths in the United States each year, and the estimated annual cost of human illness caused by food-borne pathogens ranges from $5.6 billion to $9.4 billion (4). Irradiation is one of the best methods to control pathogenic microorganisms in meat and meat products. The Food and Drug Administration (FDA) approved irradiation for poultry and red meats to control foodborne pathogens and extend product shelf-life (5). Low-dose (<10 kGy) irradiation can kill at least 99.9% of *salmonella* in poultry and an even higher percentage of *E. coli* O157:H7 (13). However, one of the major concerns with irradiating meat is its effect on meat quality such as lipid oxidation, color, and off-odor production.

The fundamental lipid oxidation mechanisms in irradiated meat are not fully understood, but are likely to be similar to those in nonirradiated meat. Therefore, the susceptibility of irradiated muscle tissues to lipid oxidation is closely related to the nature, proportion, degrees of saturation in fatty acids, and the composition of phospholipids in cell membrane (6). Ang and Lyon (3) reported that hexanal and pentanal had a strong correlation with TBARS and off-odor related to lipid oxidation in meat. However, lipid oxidation alone cannot produce the characteristic irradiation odor because meat irradiated in an oxygen impermeable package, which theoretically stops lipid oxidation, still produces irradiation odor when it is opened.

It was suggested that volatile compounds responsible for off-odor in irradiated meat are produced by radiation impact on protein and lipid molecules and are different from those of lipid oxidation (2). Patterson and Stevenson (14) showed that dimethyltrisulfide is the most potent off-odor compound in irradiated raw chicken meat. Recent study (11) showed that irradiation produced characteristic new volatile compounds from meat model system containing leucine, valine, isoleucine, phenylalanine, methionine, or cysteine by radiolytic degradations. This indicated that both radiolysis of proteins and lipid oxidation were important for off-odor generation in irradiated meat. The objective of this study is to elucidate the effect of different doses of irradiation on lipid oxidation, odor, and volatile compound production in vacuum-packaged pork loin patty during refrigerated or frozen storage.

Materials and Methods

Sample preparation and irradiation. Pork loins were ground twice through a 9-mm plate, and patties (approximately 80 g each) were prepared. Individual patties were vacuum-packaged in oxygen-impermeable nylon/polyethylene bags (9.3 ml $O_2/m_2/24$ h at 0°C) and stored either in a refrigerator (4°C) or a freezer (-40°C). The next day, the refrigerated patties were irradiated at 0, 1.5, 3.0 or 4.5 kGy, and frozen ones at 0, 2.5, 5.0, or 7.5 kGy with a Linear Accelerator (Circe IIIR, Thomson CSF Linac). The refrigerated pork patties were stored at

4°C for 2 weeks, and the frozen ones at –40°C for 3 months. Samples were analyzed for lipid oxidation, volatile production, and off-odor during refrigerated (0, 1, and 2 weeks) or frozen storage (0, 1.5, and 3 months).

Odor intensity and preference. An 11-member trained panel was used to evaluate the irradiation odor intensity and odor preference of both refrigerated or frozen pork patties. Refrigerated patties were tempered about 20 min at room temperature (22°C) and frozen patties were thawed about 2 hr at 22°C before presenting to the panels. Samples (3 g) were presented in a tightly-capped scintillation vial (20 ml), and a 15-cm linear scale was used to rate the samples on each sensory characteristics. Panels were asked three types of questions: irradiation odor intensity (very weak = 0 and very strong = 15), odor preference (highly acceptable = 0 and not acceptable = 15), and odor description. Panels were given a sufficient time (20 min or more) to analyze sample accurately.

Lipid oxidation and volatiles analysis. 2-thiobarbituric reactive substances (TBARS) method (9) was used to indicate the extent of lipid oxidation using a fluorometer (Model 450, Barnstead/Thermolyne Corp., Dubuque, IA) with 520-nm excitation and 550-nm emission. A Precept II and Purge-and-Trap concentrator 3000 (Tekmar-Dohrmann) were used to purge and trap volatile compounds as described by Ahn et al. (2).

Statistical analysis. Two-way Analyses of Variance (15) was used to determine the effect of irradiation dose and storage. Four different sources of pork loin were used as replications and significance level was determined at $p<0.05$. The Student-Newman-Keul's multiple range test was used to compare differences among mean values. Mean values and standard errors of the mean (SEM) were reported.

Results and Discussion

Lipid oxidation. The TBARS of vacuum-packaged patties irradiated at 2.0 and 4.5 kGy and stored at 4°C was not different from that of the nonirradiated control (Table 1). Vacuum packaging changes gaseous environment at meat surface. Respiration of the microorganism at meat surface or meat itself produces CO_2 and eventually, the oxygen concentration within the pack falls below 1% while CO_2 concentration rises to 20% or more. These changes inside of bag can control oxygen-dependent microorganisms or oxidative degradation. The TBARS value of pork patties stored at 4°C for 1 week showed the highest values among storage periods. With frozen storage, the TBARS of pork patties irradiated at 7.5 kGy was higher than that of the non-irradiated control at day 0, but was not different after 1.5 and 3 months of storage (Table 2). Jo and Ahn (10) also reported that the TBARS was higher in irradiated, vacuum-packaged pork sausage at 4.5 kGy dose at first, but the irradiation effect disappeared during storage. Luchsinger et al. (12) previously reported that TBARS values of both chilled and frozen boneless pork chops were stable regardless of display day, dose, and irradiation sources.

Irradiation odor intensity and preference. Sensory test indicated that the panel could detect differences in the intensity of irradiation odor in refrigerated pork patties at day 0, but could not separate differences among irradiation doses (Table 3). After 1 and 2 weeks of refrigerated storage, the panel rated the intensity of irradiation odor in nonirradiated sample high indicating that by-products from lipid oxidation or other chemical reactions can mislead panels. The fact that nonirradiated sample stored for 1 or 2 weeks scored higher irradiation odor than irradiated pork patties at day 0 supported this interpretation (Table 3). Although vacuum packaging minimized oxygen contact with pork patties, the residual oxygen inside of bag and transferred oxygen from outside through the packaging film could be responsible for the development of certain degree of lipid oxidation and odor changes. No irradiation dose effect on odor preference of pork patties was found (Table 3), but patties stored for 1 or 2 week showed lower odor preference than those of day 0.

Irradiation odor intensity increased dose-dependent manner in frozen pork patties (Table 4). Irradiation odor lasted longer in frozen than in refigerated pork patties and some panel could detect irradiation odor after 3 moths of frozen storage. Panels preferred nonirradiated to irradiated patties at day 0, but could not find any difference between irradiated and nonirradiated patties after 1.5 month or longer of frozen storage (Table 4). Panels characterized vacuum-packaged irradiated meat odor as rotten egg, sweet, bloody, cooked meat or barbecued corn, burnt, sulfur, metallic, alcohol or acetic acid. Those words also were found in other studies (7,8). However, the odor description for oxidative degradation such as grassy was not found in vacuum-packaged samples.

Volatile compound analysis. Pork patties irradiated at 4.5 kGy and refrigerated for 1 week produced higher n-hexanal than other treatments (Table 5), but the amount of n-hexanal in patties nonirradiated or irradiated at 1.5 kGy increased with storage time.

Ahn et al. (1) reported that irradiated muscle strips produced a few volatile compounds that were not found in nonirradiated meat. Most of them were sulfur-containing compounds and the amount of 2,3-dimethyldisulfide was the highest. Jo and Ahn (10) reported that 2,3-dimethyldisulfide produced from irradiated oil emulsion containing methionine. The amount of 2,3-dimethylsulfide in refrigerated pork patties rapidly increased with the increase of irradiation doses (Table 5), but nonirradiated sample produced no 2,3-dimethyldisulfide. During the 2-week storage, the amount of 2,3-dimethyldisulfide decreased significantly except for the samples irradiated at 1.5 kGy. Patterson and Stevenson (14) suggested that dimethyltrisulfide was the main contributor to the irradiation off-odor. We also detected small amount of dimethyltrisulfide, but it disappeared quickly during storage

The amounts of hexanal in irradiated samples were not changed during the 1.5-month of frozen storage in vacuum packaging (Table 6). Irradiation increased the production of hexanal in frozen samples. It demonstrated that irradiation can accelerate lipid oxidation in meat to some extent in vacuum-packaged conditions. No significant irradiation dose effect was found in the production of 2,3-dimethyldisulfide from vacuum-packaged, frozen pork patties mainly because of large variation in its content among replications (Table 6). Besides 2,3-dimethyldisulfide, several other irradiation-dependent volatile compounds such as 2-propenal, methanthiol, and 2,3-methyltriulfide, 2-methylbutanal, 3-methylbutanal were also found.

Because vacuum packaging minimizes oxidative changes and the amount of irradiation-related volatile compounds decrease in meat during storage, the use of vacuum packaging would be more beneficial than aerobic packaging for irradiated meat.

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Table 1. TBARS value of vacuum-packaged pork patties irradiated and stored at 4°C.

	Irradiation dose				
Storage (wk)	0 kGy	1.5 kGy	3.0 kGy	4.5 kGy	SEM
	------------------ (mg malondialdehyde/kg meat) ------------------				
0	0.08c	0.08c	0.09b	0.10b	0.007
1	0.22a	0.21a	0.24a	0.32a	0.030
2	0.14b	0.12b	0.15b	0.16b	0.010
SEM	0.018	0.012	0.021	0.022	

a-cDifferent letter within a column is significantly different (P<.05).
SEM, standard errors of the mean.

Table 2. TBARS of vacuum-packaged pork patties irradiated and stored at -40°C.

	Irradiation dose				
Storage (month)	0 kGy	2.5 kGy	5.0 kGy	7.5 kGy	SEM
	------------------ (mg malondialdehyde/kg meat) ------------------				
0	0.15y	0.18xy	0.21xy	0.23ax	0.018
1.5	0.16	0.18	0.18	0.20ab	0.020
3	0.13	0.14	0.15	0.116b	0.015
SEM	0.011	0.014	0.018	0.016	

a,bDifferent letters within a column are significantly different (P<.05).
x,yDifferent letters within a row are significantly different (P<.05).
SEM, standard errors of the mean.

Table 3. Irradiation odor intensity[1] and odor preference[2] of vacuum-packaged pork patties irradiated and stored at 4°C.

	Irradiation dose				
Storage (week)	0 kGy	1.5 kGy	3.0 kGy	4.5 kGy	SEM[3]
Irradiation odor intensity					
0	2.9by	10.3x	10.7x	9.9x	1.00
1	9.5a	9.8	10.3	10.6	1.12
2	8.9a	9.0	9.6	9.8	1.04
SEM	1.27	0.81	1.03	1.04	
Odor preference					
0	7.1b	10.1	9.4	9.3	1.27
1	13.2a	11.1	11.5	9.2	1.18
2	10.5ab	8.1	9.0	8.9	1.16
SEM	1.19	1.07	1.21	1.34	

a,bDifferent letter within a column with the same category is significantly different (P<.05).
x,yDifferent letter within a row is significantly different (P<.05).
[1]0, very weak; 15, very strong;
[2]0, Strongly like;15, not acceptable.
[3]SEM, standard errors of the mean.

Table 4. Irradiation odor intensity[1] and odor preference[2] of vacuum-packaged pork patties irradiated and stored at -40°C.

	Irradiation dose				
Storage (month)	0 kGy	2.5 kGy	5.0 kGy	7.5 kGy	SEM[2]
Irradiation odor intensity					
0	1.5az	4.6yz	7.3xy	10.4x	1.10
1.5	5.1b	5.4	8.6	8.5	1.08
3	2.9aby	6.0xy	7.7x	9.6x	1.27
SEM	0.84	1.25	1.24	1.39	
Odor preference					
0	3.5by	6.8xy	8.2x	9.2x	1.21
1.5	7.3a	7.3	8.6	8.2	0.81
3	6.4a	6.5	7.6	9.3	1.27
SEM	0.92	1.20	1.11	1.42	

a,bDifferent letter within a column with the same category is significantly different (P<.05).
x,yDifferent letter within a row is significantly different (P<.05).
[1]0, very weak; 15, very strong;
[2]0, strongly like; 15, not acceptable.
[3]SEM: standard errors of the mean.

Table 5. n-Hexanal and 2,3-dimethyldisulfide production of vacuum-packaged pork patties irradiated and stored at 4°C.

	Irradiation dose				
Storage (week)	0	1.5 kGy	3.0 kGy	4.5 kGy	SEM
	----------------------- (ion count x 1000) -------------------------				
n-Hexanal					
0	0b	0b	30	21	8.4
1	35ay	43ay	59xy	116x	18.6
2	26ab	29a	134	253	97.6
SEM	8.7	7.4	60.4	97.3	
2,3-Dimethyldisulfide					
0	0z	255z	5338ay	10239ax	297.1
1	0	142	104b	1670b	741.8
2	0y	72y	871by	3946bx	656.7
SEM	-	166.2	562.9	1040.1	

a,bDifferent letters within a column with same compound are significantly different (P<.05).
x,yDifferent letters within a row are significantly different (P<.05).
SEM, standard errors of the mean.

Table 6. n-Hexanal and 2,3-dimethyldisulfide production of vacuum-packaged pork patties irradiated and stored at -40°C.

	Irradiation dose				
Storage (month)	0	2.5 kGy	5.0 kGy	7.5 kGy	SEM
	-------------------- (ion count x 1000) --------------------------				
n-Hexanal					
0	0z	52y	55y	99x	9.8
1.5	0y	52y	92y	270x	43.8
3	0y	110xy	260ax	270x	42.7
SEM	-	22.6	23.5	54.4	
2,3-Dimethyldisulfide					
0	0	0	121	1605	414.3
1.5	0	607	830	150	374.0
3	0	0	0	0	
SEM	-	350.4	250.5	479.4	

x,yDifferent letter within a row is significantly different (P<.05).
SEM, standard errors of the mean.