Use of Double Packaging and Antioxidant Combinations to Improve Color, Lipid Oxidation, and Volatiles of Irradiated Raw and Cooked Turkey Breast Patties

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Summary and Implications

Irradiated vacuum-packaged patties had great amounts of sulfur volatiles (dimethyl sulfide and dimethyl disulfide) and increased red color during the refrigerated storage and after cooking compared with the nonirradiated control. Irradiated aerobically packaged meat had accelerated lipid oxidation and aldehyde production at 10 d and after cooking. Gallate+α-tocopherol alone with double packaging was effective in reducing the red color of irradiated meat at 10 d and after cooking. Considerable amounts of off-odor volatiles were reduced by double packaging and antioxidant treatment. Sulfur volatiles were evaporated during the aerobic period of double packaging, and lipid oxidation was prevented by the antioxidants and vacuum condition of double packaging. These beneficial effects of double packaging and antioxidants were more critical in irradiated cooked meat. Therefore, the combined use of antioxidants and double packaging would be a useful method to control the oxidative quality changes of irradiated raw and cooked turkey breast.

Introduction

Antioxidants reduce oxidative quality deterioration of irradiated meat by quenching free radicals. Packaging is also a critical factor influencing the quality of irradiated meat. Under vacuum conditions, almost all sulfur volatiles generated by irradiation were retained in meat, and the intensity of pink color in irradiated meat increased during storage. Under aerobic conditions, almost all sulfur volatiles generated by irradiation disappeared, and pink color intensity decreased after a few days of storage. Lipid oxidation in irradiated meat during storage was accelerated only under aerobic conditions. Therefore, exposing irradiated meat to aerobic conditions for a limited period of time will lower irradiation off-odor odor and decrease pink color intensity, and subsequent storage in vacuum conditions will minimize lipid oxidation.

Materials and Methods

Turkey breast muscles were ground through a 3-mm plate. Six different treatments were prepared using antioxidant, packaging method, and irradiation conditions (Table 1). For double packaging, aerobically packaged patties were repackaged in oxygen-impermeable vacuum bags. The packaged patties were irradiated at 2.5 kGy. The outer vacuum bags of double-packaged meat were removed after 7 d of storage at 4 C to expose the samples under aerobic conditions. Part of the raw meat stored for 10 d was cooked to an internal temperature of 75 C. The colors, lipid oxidation, and volatiles of the raw and cooked meat were determined.

Results and Discussion

Irradiated turkey breast had higher a* values than nonirradiated meat (Table 2). Antioxidants lowered the L* value of vacuum-packaged irradiated meat by about 2 units and a* value by 1 unit. The a* value of aerobically packaged irradiated meat was lower than that of vacuum-packaged meat, but was still higher than nonirradiated control. The increased redness of vacuum-packaged turkey breast by irradiation was stable even after 10 d of refrigerated storage. However, the redness of aerobically or double-packaged meat decreased significantly. This indicated that exposing irradiated meat to aerobic conditions was effective in reducing CO-heme pigment complex formation. Furthermore, the combination of antioxidants with double packaging showed a synergistic effect in reducing the redness of irradiated meat: the presence of oxygen should have accelerated the dissociation of CO-Mb, while antioxidants should have inhibited the radiolytic generation of CO. The redness of meat was still higher in irradiated meat than in nonirradiated meat even after cooking, and the inside of the meat had stronger redness intensity than the surface. Irradiated cooked turkey breast meat from double packaging and antioxidant combinations, however, produced significantly lower a* values than the vacuum-packaged irradiated cooked meat. Gallate plus α-tocopherol was significantly more effective in reducing the redness than sesamol plus α-tocopherol. Therefore, the gallate plus α-tocopherol in combination with double packaging can be effective in controlling off-color in irradiated raw and cooked turkey breast meat.

Both aerobic packaging and irradiation increased the lipid oxidation of turkey breast, but the presence of oxygen was a more critical factor than irradiation on lipid oxidation during storage (Table 2). Vacuum-packaged meat was more resistant to lipid oxidation than aerobically packaged meat, and the TBARS increase was proportional to the exposure time to aerobic conditions. Two antioxidant combinations were very effective in preventing lipid oxidation during storage, and the TBARS of antioxidant-treated meats were lower than even nonirradiated vacuum-packaged meat at 10 d.

The antioxidant effect on lipid oxidation of turkey meat was even more distinct after cooking. The TBARS of irradiated turkey meat increased rapidly after cooking, but those with antioxidants did not. Therefore, the problem of lipid oxidation in aerobically or double-packaged irradiated raw and cooked turkey breast could be solved by the addition of sesamol + α-tocopherol or gallate + α-tocopherol.

Irradiation generated many volatiles not found in vacuum-packaged nonirradiated turkey breast meat. The majority of newly generated volatiles were hydrocarbons and sulfur-containing compounds, and 1-butene, toluene, dimethyl sulfide, and dimethyl disulfide were among the most distinct. S-compounds are regarded as the major volatiles responsible for the characteristic of irradiation off-odor and are different from the rancidity caused by lipid oxidation products. Aerobic packaging was more desirable than vacuum or double packaging in reducing the amounts of hydrocarbons and sulfur compounds. Almost all dimethyl disulfide disappeared under aerobic conditions.

After 10 d of refrigerated storage, volatile profiles of irradiated turkey breast were highly dependent upon antioxidant and packaging conditions (Table 4). Vacuum-packaged irradiated turkey breast had the greatest amounts of total and sulfur volatiles. The amount of dimethyl disulfide increased twofold compared with that at 0 d ($P < 0.01$), and dimethyl trisulfide was newly generated in vacuum-packaged irradiated meat. These sulfur volatiles, however, were not detected in irradiated aerobically or double-packaged meat. Three days of exposure to aerobic conditions was enough for the sulfur volatiles to escape from the meat. However, aerobically packaged irradiated meat without antioxidants produced large amounts of aldehydes (propanal, hexanal) and 2-butanone at 10 d, which coincided with the result of TBARS (Table 2). Therefore, the combination of double packaging with antioxidants in irradiated raw turkey breast was very effective in reducing total and sulfur volatiles responsible for the irradiation off-odor without any problem in lipid oxidation.

The beneficial effects of double packaging and antioxidant combinations on volatiles were more clearly shown in irradiated cooked turkey breast (Table 5). Irradiated cooked turkey breast not only produced considerable amounts of sulfur volatiles, but also aldehydes and ketones. Therefore, irradiated cooked meat had a characteristic irradiation off-odor and lipid oxidation-related volatiles compared with the nonirradiated cooked meat. Cooking of vacuum-packaged irradiated meat produced high amounts of sulfur volatiles, whereas cooking of aerobically packaged irradiated meat produced large amounts of aldehydes. Large amounts of propanal and hexanal were formed in irradiated cooked turkey breast, and the amount of total volatiles was greatest in aerobically packaged irradiated cooked meat. This shows that both lipid oxidation products and irradiation off-odor were problematic when storing irradiated meat under aerobic conditions. Double packaging itself was more effective than vacuum packaging in reducing sulfur volatiles, and lipid oxidation-dependent volatiles compared with aerobic packaging. However, the combination of antioxidant with double packaging was more effective in reducing both sulfur and lipid oxidation volatiles in irradiated cooked meat. Production of most aldehydes in irradiated cooked turkey breast was prevented by antioxidants and double packaging. In conclusion, the combination of double packaging and antioxidants was effective in controlling lipid oxidation and irradiation off-odor of irradiated raw and cooked turkey breast patties

Table 1. Packaging, irradiation, and antioxidant treatments used in this study.

Treatment	Irradiation (kGy)	Antioxidant (100 ppm each)	Packaging method
Nonir/vacuum pkg[1]	0	Not added	Vacuum for 10 d
Ir/vacuum pkg	3	Not added	Vacuum for 10 d
Ir/aerobic pkg	3	Not added	Aerobic for 10 d
Ir/double pkg	3	Not added	Vacuum for 7 d then aerobic for 3 d
Ir/double pkg/S+E[2]	3	Sesamol, tocop.	Vacuum for 7 d then aerobic for 3 d
Ir/double pkg/G+E[3]	3	Gallate, tocop	Vacuum for 7 d then aerobic for 3 d

[1]Packaged. [2]Sesamol (100 ppm) and α-tocopherol (100 ppm). [3]Gallic acid (100 ppm) and α-tocopherol (100 ppm).

Table 2. CIE color L- and a-values, and TBARS of irradiated turkey breast patties treated by different packaging and antioxidants during the 10 d of storage and after cooking.

	Nonirradiated	Irradiated					
	Vacuum	Vacuum	Aerobic	Double packaging[1]			
Storage	packaging	packaging	packaging	None	S+E[2]	G+E[3]	SEM
L* value							
0 d	54.29^{abz}	55.36^{az}	55.39^{ay}	55.20^{ay}	53.57^{bz}	53.59^{by}	0.29
10 d	54.44^{bz}	56.88^{ay}	56.71^{ay}	56.14^{ay}	54.03^{bz}	53.44^{by}	0.37
Cooked[4] (surface)	84.38^{ax}	84.73^{ax}	83.65^{ax}	84.41^{ax}	84.71^{ax}	81.70^{bx}	0.31
Cooked (inside)	82.05^{y}	84.30^{x}	82.65^{x}	83.73^{x}	82.39^{y}	81.98^{x}	0.81
a* value							
0 d	4.42^{cz}	7.95^{ay}	7.15^{bx}	7.74^{axy}	6.95^{by}	6.74^{bx}	0.13
10 d	4.67^{dz}	7.89^{ay}	5.66^{cy}	6.98^{by}	4.68^{dz}	5.63^{cy}	0.11
Cooked[4] (surface)	5.96^{by}	7.53^{ay}	3.99^{cz}	6.20^{bz}	5.55^{bz}	4.51^{cz}	0.21
Cooked (inside)	7.50^{cx}	10.04^{ax}	5.58^{dy}	8.62^{bx}	7.51^{cx}	5.75^{dy}	0.23
TBARS value	------------------------------------- (mg MDA/kg meat) -------------------------------------						
0 d	0.66^{by}	0.84^{ay}	0.91^{ay}	0.83^{ay}	0.42^{dy}	0.55^{c}	0.03
10 d	0.72^{cy}	0.84^{cy}	2.18^{ax}	1.61^{by}	0.53^{cx}	0.53^{c}	0.09
Cooked[4]	1.12^{dx}	1.67^{cx}	2.37^{ax}	2.09^{bx}	0.54^{ex}	0.64^{e}	0.07

[1]Vacuum packaged for 7 d then aerobically packaged for 3 d [2]Sesamol (100 ppm) and α-tocopherol (100 ppm) added. [3]Gallic acid (100 ppm) and α-tocopherol (100 ppm) added. [4]Cooked to 75 C after 10 d of storage.

Table 4. Volatile profiles of irradiated raw turkey breast patties treated by different packaging and antioxidant after 10 d of refrigerated storage.

	Nonirradiated	Irradiated					
	Vacuum	Vacuum	Aerobic	Double packaging[1]			
Storage	packaging	packaging	packaging	None	S+E[2]	G+E[3]	SEM
	------------------------------ (Total ion counts $\times 10^4$) ------------------------------						
Sulfurs							
Dimethyl sulfide	$1,304^{b}$	$1,990^{a}$	140^{d}	831^{c}	676^{c}	546^{c}	85
Carbon disulfide	258^{b}	306^{a}	0^{c}	0^{c}	0^{c}	0^{c}	14
Dimethyl disulfide	0^{b}	$22,702^{a}$	0^{b}	32^{b}	0^{b}	43^{b}	739
Dimethyl trisulfide	0^{b}	554^{a}	0^{b}	0^{b}	0^{b}	0^{b}	16
Aldehydes and Ketones							
Propanal	0^{b}	0^{b}	$1,966^{a}$	600^{b}	0^{b}	0^{b}	14
Hexanal	0	0	755	0	0	0	308
2-Propanone	$1,739^{b}$	$2,116^{ab}$	$2,465^{a}$	$2,147^{ab}$	$1,962^{ab}$	$1,992^{ab}$	140
2-Butanone	0^{b}	0^{b}	107^{a}	0^{b}	0^{b}	0^{b}	5
Total	$5,172^{b}$	$34,120^{a}$	$9,102^{b}$	$7,132^{b}$	$4,785^{b}$	$5,183^{b}$	1,152

[1]Vacuum packaged for 7 d then aerobically packaged for 3 d.
[2]Sesamol (100 ppm) and α-tocopherol (100 ppm) added.
[3]Gallic acid (100 ppm) and α-tocopherol (100 ppm) added.

Table 5. Volatile profiles of irradiated, cooked turkey breast patties with different packaging and antioxidants.

	Nonirradiated	Irradiated					
	Vacuum	Vacuum	Aerobic	Double packaging[1]			
Storage	packaging	packaging	packaging	None	S+E[2]	G+E[3]	SEM
	(Total ion counts × 10^4)						
Sulfurs							
Dimethyl sulfide	1,008[b]	2,032[a]	451[d]	1,005[b]	689[c]	588[cd]	48
Carbon disulfide	419[a]	339[ab]	210[b]	271[ab]	278[ab]	374[a]	35
Dimethyl disulfide	0[b]	17,861[a]	342[b]	940[b]	412[b]	210[b]	601
Dimethyl trisulfide	0[b]	1,007[a]	0[b]	118[b]	0[b]	0[b]	49
Aldehydes and Ketones							
Propanal	233[d]	2272[c]	8,637[a]	5,962[b]	38[d]	427[d]	377
Butanal	0[e]	127[d]	592[a]	195[c]	302[b]	226[c]	22
Pentanal	62[c]	875[c]	3,014[a]	1,667[b]	0[c]	31[c]	223
Hexanal	0[b]	3,734[b]	37,617[a]	9,686[b]	0[b]	0[b]	2,626
2-Propanone	1,770[d]	2,828[bc]	3,744[a]	33,84[ab]	2,863[bc]	2,637[c]	167
2-Butanone	0[c]	116[b]	0[c]	231[a]	223[a]	142[b]	10
3-Methyl butanal	0[c]	100[b]	223[a]	204[a]	131[b]	142[b]	12
Total	6,706[c]	47,171[b]	101,773[a]	58,251[b]	13,046[c]	13,691[c]	4,889

[a-e]Different letters within a row are significantly different ($P < 0.05$); $n = 4$.
[1]Vacuum packaged for 7 d then aerobically packaged for 3 d.
[2]Sesamol (100 ppm) and α-tocopherol (100 ppm) added.
[3]Gallic acid (100 ppm) and α-tocopherol (100 ppm) added.