Effect of Antioxidants on the Consumer Acceptance of Irradiated Turkey Meat

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Summary and Implications

Antioxidant had no effect on the production of sulfur compounds, color change, and off-odor intensity of irradiated turkey breast meat, but addition of sesamol+tocopherol or gallate+tocopherol was effective in reducing TBARS values and aldehydes, especially under aerobic conditions. Consumers preferred the color of irradiated raw and cooked meat to nonirradiated meat because the pink color of irradiated meat looked fresher than nonirradiated ones. Packaging method was more important than antioxidant treatment in reducing irradiation off-odor because S-compounds produced by irradiation easily volatilized under aerobic packaging conditions. Therefore, the combined use of aerobic packaging and antioxidants is recommended to improve consumer acceptance of irradiated poultry meat.

Introduction

Over 4,000 stores are currently marketing irradiated ground beef products and the consumption of irradiated meat is increasing very rapidly recently. However, consumer and industry response to irradiated poultry meat is lukewarm because of off-odor/off-taste and color changes in irradiated poultry after cooking. Several reports indicated that positive attitudes toward irradiation are increasing and consumer education is very important for the acceptance of food irradiation. Most consumer studies on irradiated foods were carried out only using a questionnaire without presenting real irradiated products, and tests using real products are needed to determine actual consumer response to irradiated meat. The objective of this study was to determine consumer acceptance of irradiated raw and cooked turkey breast meat with antioxidants added.

Materials and Methods

Raw turkey breasts were ground separately through a 3-mm plate, and Nonirradiated and irradiated controls (no antioxidant added) and 2 antioxidant treatments (tocopherol plus gallate, tocopherol plus sesamol, 0.5 mM each, final concentration) were prepared. Patties were prepared after adding an antioxidant treatment to ground meat. Patties were packaged either in oxygen-permeable or vacuum bags. All samples were irradiated at 0 (control) or 3.0 kGy. Consumer acceptance and chemical characteristics of raw meat were determined after 4 days of storage at 4 °C. Patties were cooked in an electric oven to an internal temperature of 78 °C. Volatiles, color, and lipid oxidation of cooked patties were also determined as in raw turkey meat.

Results and Discussion

With aerobic packaging, greater amounts of alcohols and esters were produced in nonirradiated than irradiated meats (Table 1). It seems that the growth of microorganisms during the 4-d storage before chemical analyses affected the increase of these volatiles in nonirradiated meat. Aldehydes, hydrocarbons, and cyclo-compounds increased after irradiation, and antioxidants were effective in reducing these volatiles. Small amounts of sulfur compounds, which are known to cause irradiation off-odor, were detected only in the irradiated control after 4 days of storage under aerobic packaging conditions. With vacuum-packaging, irradiation generated large amounts of sulfur compounds such as dimethyl disulfide and dimethyl trisulfide in turkey breast meat. Antioxidants had no effect in reducing the amounts of sulfur compounds in vacuum-packaged meat, but were effective in reducing the production of lipid-oxidation-dependent volatiles, especially hexanal.

Irradiation increased TBARS values and aerobically packaged control meat had higher TBARS values than vacuum-packaged control meat (Table 2). Antioxidant treatments were effective in controlling lipid oxidation of both aerobically packaged and vacuum-packaged turkey patties. Irradiation increased the redness (a*-value) of turkey breast meat, and the a*-values of vacuum-packaged turkey breast meats were higher than those of aerobically packaged meats. The lightness (L*-value) of irradiated turkey breast in aerobic conditions were also higher than those in vacuum conditions. Consumers easily distinguished odor differences between nonirradiated and irradiated turkey patties (Table 3). For consumer preference of meat odor, nonirradiated turkey meat patties were higher than irradiated meat and aerobically packaged meats were superior to vacuum-packaged meats. This result agrees with the data for volatiles, in which irradiation increased sulfur compounds but the sulfur volatiles disappeared rapidly under aerobic packaging conditions (Table 1). Consumers preferred the color of irradiated control breast patties to nonirradiated control patties. The aerobically packaged, irradiated raw turkey breast meats with added sesamol plus tocopherols showed the lowest consumer preference because the addition of sesamol made the color dull-red. However, consumer liked the color of irradiated turkey breast meat with added sesamol + tocopherol when they were vacuum-packaged. This agrees with the result of the CIE color analysis (Table 2).

Irradiation increased large amounts of aldehydes, but antioxidants were effective in reducing aldehydes in both aerobically packaged and vacuum-packaged, cooked turkey breast meat (Table 4). Under vacuum conditions, large amounts of cyclo-compounds, hydrocarbons, and sulfur compounds were produced by irradiation. Antioxidant treatments reduced the amount of cyclo-compounds and hydrocarbons in vacuum packaged, cooked turkey breast meat. The amounts of sulfur compounds in irradiated, cooked turkey breast meats, which were stored in aerobic conditions before cooking, were much lower than those stored in vacuum conditions. This indicated that packaging conditions were more important than antioxidant treatments in reducing irradiation off-odor. Although large amounts of sulfur compounds were detected in vacuum-packaged cooked turkey meat, the amounts of S-compounds in cooked meat were lower than those in raw meat, indicating that large proportions of S-compounds were volatilized during cooking and subsequent handling. Gallate plus tocopherol treatment was the best in reducing the amount of S-compounds of cooked turkey breast meat under vacuum conditions.

Irradiation increased TBARS values, but all antioxidant treatments were effective in reducing lipid oxidation of cooked turkey breast patties both with aerobic and vacuum packaging (Table 5). This result agrees with that of the effect of antioxidants, which reduced the amounts of aldehydes in cooked turkey meat patties (Table 4). The redness (a*-value) of irradiated meat was still high after cooking. Cooking increased the lightness (L*-value) of meat, and antioxidant treatments were effective in reducing a*-value of irradiated cooked turkey breast meat except for vacuum-packaged meat with sesamol plus tocopherol treatment (Table 5).

Consumers could not distinguish odor differences between nonirradiated and irradiated cooked turkey meat because relatively large amounts of sulfur compounds were volatilized during cooking (Table 5). Consumers liked the interior color of vacuum-packaged cooked turkey breast meat with added sesamol plus tocopherol, which were the most red meat samples among all treatments

Conclusion

The use of free radical scavengers reduced the amounts of aldehydes, but had no effect on sulfur compounds in irradiated turkey meat. Packaging method was more important in reducing irradiation off-odor in raw samples than antioxidant treatment because S-compounds produced by irradiation easily volatilized under aerobic packaging conditions. Antioxidants were effective in controlling oxidative change in irradiated turkey breast meat. The combined use of aerobic packaging and antioxidants was effective in reducing sulfur volatiles and lipid oxidation of raw meat, which improved consumer acceptance of irradiated raw poultry meat. However, the combined effect of packaging and antioxidants on the flavor and color of cooked turkey breast meat was not clear as in raw meat.

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Table 1. **Volatile compounds of raw turkey breast meat patties with different antioxidants added.**

Volatiles	C-nonIR	C-IR	S+Toc-IR	G+Toc-IR	SEM
Aerobic package	------------------------------	ion counts x 10^4	------------------------------		
Cyclo-compounds	270 ^{b}	1148 ^{a}	649 ^{b}	640 ^{b}	123
Hydrocarbons	3544 ^{b}	5466 ^{a}	1730 ^{c}	1523 ^{c}	438
Ketones	21581	25100	22584	20511	1273
Alcohols	273831 ^{a}	27475 ^{b}	18001 ^{b}	16425 ^{b}	5831
Aldehydes	1278 ^{b}	5043 ^{a}	1291 ^{b}	898 ^{b}	730
Sulfur compounds	0 ^{b}	171 ^{a}	0 ^{b}	0 ^{b}	13
Esters	21236 ^{a}	2288 ^{b}	2090 ^{b}	1940 ^{b}	1777
Total volatiles	321739	66691	46344	41938	
Vacuum package					
Cyclo-compounds	604	522	258	428	102
Hydrocarbons	25567	32141	21962	11740	4867
Ketones	13761 ^{b}	15729 ^{ab}	17519 ^{a}	16580 ^{a}	670
Alcohols	135441 ^{a}	15766 ^{b}	13300 ^{b}	13098 ^{b}	670
Aldehydes	741 ^{b}	2288 ^{a}	0 ^{b}	183 ^{b}	278
Sulfur compounds	998 ^{b}	25500 ^{a}	24711 ^{a}	21285 ^{a}	3834
Esters	760	845	631	800	89
Total volatiles	177874	92791	78381	64114	

C-nonIR is nonirradiated control, C-IR is irradiated control, S+Toc-IR is irradiated sesamol and α-tocopherol, G+Toc is irradiated gallate and α-tocopherol.

Cyclo-compounds: cyclooctene, toluene, *Hydrocarbons*: 1-heptane, hexane, octane, pentane, *Ketones*: 2-butanone, 2-heptanone, 2-propanone, *Alcohols*: 1-hexanol, 1-octen-3-ol, 1-penten-3-ol, 1-propanol, 2-butanol, 2-propanol, 3-methyl-1-butanol, ethanol, *Aldehydes*: nonanal, hexanal, 2-heptenal, *Sulfur compounds*: dimethyl disulfide, dimethyl trisulfide, *Esters*: ethyl ester acetic acid, methyl ester formic acid.

Table 2. **TBARS and CIE color values of raw turkey breast meat patties with different antioxidants added.**

	TBARS values			CIE color value					
				L*-value			a*-value		
	Aero.	Vac.	SEM	Aero.	Vac.	SEM	Aero.	Vac	SEM
C-nonIR	0.89 ^{ay}	0.41 ^{by}	0.07	48.79 ^{az}	46.88 ^{by}	0.45	4.39 ^{bz}	4.90 ^{ay}	0.15
C-IR	2.34 ^{ax}	0.63 ^{bx}	0.09	52.53 ^{ax}	46.99 ^{by}	0.40	5.75 ^{bx}	8.73 ^{ax}	0.22
S+Toc-IR	0.38 ^{z}	0.37 ^{y}	0.01	52.26 ^{ax}	49.29 ^{bx}	0.29	4.93 ^{by}	9.13 ^{ax}	0.17
G+Toc-IR	0.35 ^{z}	0.35 ^{y}	0.02	50.73 ^{y}	49.85 ^{x}	0.34	6.60 ^{bw}	9.08 ^{ax}	0.18

C-nonIR is nonirradiated control, C-IR is irradiated control, S+Toc-IR is irradiated sesamol and α-tocopherol, G+Toc is irradiated gallate and α-tocopherol. Aero is aerobic package, vac is vacuum package.

Table 3. Consumer acceptance test of raw turkey breast meat patties with different antioxidants added.

	Aerobic packaging		Vacuum packaging	
Treatment	Exterior color	Odor	Exterior color	Odor
Control (0 kGy)	4.78 ^{b}	6.00 ^{a}	3.94 ^{b}	4.72 ^{a}
Control (3 kGy)	6.64 ^{a}	5.26 ^{b}	5.71 ^{a}	3.68 ^{b}
Sesamol + Tocopherol (3 kGy)	3.83 ^{c}	4.64 ^{c}	5.58 ^{a}	3.30 ^{b}
Gallate + Tocopherol (3 kGy)	5.89 ^{a}	5.00 ^{bc}	6.04 ^{a}	3.40 ^{b}

1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely.

Table 4. Volatile compounds of cooked turkey breast meat patties with different antioxidants added.

	C-nonIR-V	C-IR-A	C-IR-V	S+Toc-IR-A	S+Toc-IR-V	G+Toc-IR-A	G+Toc-IR-V
	ion counts x 10^4						
Cyclo-compounds	1921 ^{d}	4174 ^{bc}	9429 ^{a}	2651 ^{cd}	3212 ^{bcd}	3316 ^{bcd}	4493 ^{b}
Hydrocarbons	42434 ^{b}	59335 ^{b}	148512 ^{a}	28622 ^{b}	41890 ^{b}	33909 ^{b}	59192 ^{b}
Ketones	19211 ^{b}	21253 ^{ab}	24705 ^{a}	16795 ^{b}	19898 ^{ab}	4304 ^{c}	20331 ^{ab}
Alcohols	21393 ^{bc}	32716 ^{a}	26318 ^{b}	20996 ^{bc}	18102 ^{c}	21257 ^{bc}	18124 ^{c}
Aldehydes	22664 ^{b}	77940 ^{a}	76250 ^{a}	9801 ^{b}	6189 ^{b}	6657 ^{b}	11936 ^{b}
Sulfur compounds	927 ^{c}	1555 ^{c}	12359 ^{a}	1374 ^{c}	13308 ^{a}	1075 ^{c}	6968 ^{b}
Total volatiles	108550	196973	297572	80238	102599	70518	121045

C-nonIR-V is nonirradiated control, C-IR is irradiated control, S+Toc-IR is irradiated sesamol and α-tocopherol, G+Toc is irradiated gallate and α-tocopherol. V is vacuum package, A is aerobic package. n = 4.

Cyclo compounds: 4-1,1-dimethylethyl cyclohexanol, cycloheptene, cyclopentane, toluene, *Hydrocarbons*: 1-heptane, 1-heptene, 1-pentene, 2,2,5-trimethyl hexane, 2,2,7,7-tetramethyl octane, 2,4,6-trimethyl octane, 2,5,6-trimethyl octane, 2,6,10-trimethyl dodecane, 2,6,10-trimethyl dodecane, 2,6,7-trimethyl decane, 2,7,10-trimethyl dodecane, 2-methyl butane, 2-methyl decane, 2-methyl undecane, 2-octene, 3,3,7-trimethyl decane, 3,5-dimethyl octane, 3,7-dimethyl nonane, 3-methyl decane, 3-methyl dodecane, 3-methyl nonane, 3-methyl undecane, 4,8-dimethyl undecane, 4-methyl decane, 5,6-dimethyl decane, 5-methyl undecane, butane, decane, dodecane, heptane, hexane, nonane, octacosane, octadecane, octane, pentane, undecane, *Ketones*: 2-butanone, 2-propanone, *Alcohols*: ethanol, 1-octen-3-ol, 1-pentanol, 1-penten-3-ol, 1-propanol, 2-butanol, 2-propanol, *Aldehydes*: 2-methyl butanal, 2-methyl propanal, 3-methyl butanal, acetaldehyde, heptanal, hexanal, nonanal, pentanal, propanal, *Sulfur compounds*: carbon disulfide, dimethyl disulfide, methanethiol.

Table 5. **TBARS, CIE color values and consumer acceptance test of cooked turkey breast meat patties with different antioxidants added.**

	TBARS	CIE color			Consumer acceptance	
		L-value	a-value	b-value	Interior color	Flavor
C-nonIR-V	0.60 ^{c}	82.93 ^{a}	8.35 ^{b}	15.60 ^{ab}	4.94 ^{ab}	5.55
C-IR-A	1.36 ^{a}	81.87 ^{ab}	10.02 ^{a}	16.14 ^{a}	4.55 ^{b}	5.45
C-IR-V	0.96 ^{b}	83.01 ^{a}	10.10 ^{a}	15.34 ^{bc}	4.64 ^{ab}	4.99
S+Toc-IR-A	0.35 ^{d}	81.99 ^{ab}	8.63 ^{b}	15.97 ^{ab}	5.13 ^{ab}	5.04
S+Toc-IR-V	0.35 ^{d}	82.65 ^{ab}	10.25 ^{a}	15.71 ^{ab}	5.54 ^{a}	5.04
G+Toc-IR-A	0.46 ^{cd}	80.16 ^{c}	8.06 ^{b}	15.32 ^{bc}	4.81 ^{ab}	4.71
G+Toc-IR-V	0.41 ^{d}	81.63 ^{b}	8.67 ^{b}	14.88 ^{c}	4.86 ^{bc}	5.00

C-nonIR is nonirradiated control, C-IR is irradiated control, S+Toc-IR is irradiated sesamol and α-tocopherol, G+Toc is irradiated gallate and α-tocopherol. V is vacuum package, A is aerobic package.

S.E.M. is standard error of the means. n = 4. 1= dislike extremely, 5 = neither like nor dislike, 9 = like extremely.