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Addition of Garlic or Onion before Irradiation on Lipid Oxidation, Volatiles and Sensory Characteristics of Cooked Ground Beef

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Summary and Implications

Addition of 0.5% onion was effective in reducing lipid oxidation in irradiated cooked ground beef after 7 d storage. Addition of garlic or onion greatly increased the amounts of sulfur volatiles from cooked ground beef. Irradiation and storage both changed the amounts and compositions of sulfur compounds in both garlic- and onion-added cooked ground beef significantly. Although, addition of garlic and onion produced large amounts of sulfur compounds, the intensity of irradiation odor and irradiation flavor in irradiated cooked ground beef was similar to that of the nonirradiated control. Addition of garlic (0.1%) or onion (0.5%) to ground beef produced garlic/onion aroma and flavor after cooking, and the intensity was stronger with 0.1% garlic than 0.5% onion treatment. Considering the sensory results and the amounts of sulfur compounds produced in cooked ground beef with added garlic or onion, 0.5% of onion or less than 0.1% of garlic is recommended to mask or change irradiation off-odor and off-flavor.

Introduction

Irradiation has been approved for use in beef since 2000 and is the best known method in controlling pathogens in raw ground beef. However, the amount of irradiated beef sold in the U.S. is less than 1% of total beef consumption because irradiation of meat changes quality, which negatively influences consumer acceptance. The primary changes in irradiated meat are mainly related to the generation of off-odor, color change, and lipid oxidation. Color and odor of meat at the time of opening packaging bag, and subsequent cooking and eating determine whether consumers will purchase the meat again next time.

Irradiated meat, regardless of packaging methods, produced more volatiles than non-irradiated ones and developed a characteristics aroma. Sulfur compounds produced by irradiation are responsible for irradiation off-odor. Volatile sulfur compounds can be produced in two different ways: one is a direct radiolytic cleavage of the side chains of sulfur containing amino acids such as methionine and cysteine, and the other is by secondary reactions of primary sulfur compounds with surrounding compounds. Significant amino acid-lipid interactions are also involved. Among the sulfur compounds, dimethyl sulfide, dimethyl disulfide and dimethyl trisulfide were the most prominent sulfur compounds produced by irradiation and are responsible for irradiation off-odor in meat. The perception of odor from samples containing sulfur volatiles is changed somewhat depending on the composition of other volatiles in the sample, but the roles of nonsulfur compounds to the overall odor characteristics of irradiated liposomes prepared with phosphatidyl choline, phosphatidic acid, amino acid homopolymers were minor.

Irradiation is expected to accelerate oxidative changes in meat significantly, but increases TBARS only in aerobically packaged raw meat. Exposure to oxygen after cooking was the most important factor in oxidative changes of cooked pork, and hexanal concentrations represented the lipid oxidation status of cooked meat better than any other volatile components. The addition of tocopherol+gallate and tocopherol+sesamol is highly effective in reducing lipid oxidation and off-odor volatiles in irradiated cooked turkey and pork patties, but has only minor effects on the production of sulfur compounds and off-odor intensity.

Sensory panels characterized irradiation odor as “barbecued-corn-like” odor. Sulfury odor in ready-to-eat (RTE) turkey hams increases as irradiation dose increases, and the contents of sulfur compounds in irradiated hams are higher than those in nonirradiated samples. Irradiation increases the production of acetaldehyde, which could be related to a “metal-like” flavor in irradiated hams. Masking or preventing off-odor/off-flavor production in irradiated meat is among the most critical factors for consumer acceptance of irradiated ground beef. Garlic (*Allium sativum L.*) and onion (*Allium cepa L.*) are two major food ingredients widely used in cookery to complement and enhance the flavor of meat products. Garlic and onion both produces many sulfur compounds, which provides their unique flavor and odor. Therefore, addition of garlic or onion may change, mask, or improve the odor/flavor characteristics of irradiated cooked meat. Nonfluid seasonings such as garlic and onion are permitted for use in irradiated ground meat and meat byproducts.

The objective of this study was to determine the effect of garlic and onion on lipid oxidation volatile profiles, and masking or preventing off-odor/off-flavor in irradiated cooked ground beef.

Materials and Methods

Eight beef top rounds from different steers were obtained from a local packing plant. All the muscles from the two rounds were pooled and ground together to make a replication. Six different treatments were prepared: 1) non-irradiated control, 2) irradiated control, 3) non-irradiated added with 0.1% garlic (wt/wt), 4) irradiated added with 0.1% garlic, 5) non-irradiated added with 0.5% onion, and 6) irradiated added with 0.5% onion. Each additive was added to the ground meat and then mixed for 1 min, beef patties were prepared, packaged individually in oxygen-impermeable bags (O_2 permeability, 9.3 mL $O_2/m^2/24$ h at 0 °C), stored at 4 °C overnight, and irradiated the next day morning.

The packaged ground beef patties were irradiated at 0 or 2.5 kGy using a linear accelerator facility. Patties were cooked in a 90 °C water bath, stored in oxygen-permeable bags (polyethylene, 10 x 15 cm, 2 mil) for 7 days at 4 °C, and used for TBARS volatile analyses and sensory analyses.

Lipid oxidation was determined using a TBARS method. A purge-and-trap apparatus connected to a gas chromatograph/mass spectrometer was used to analyze volatiles produced. Ten panelists were recruited and trained in 3 training sessions. Ten trained panelists were used for the sensory analysis. Panelists evaluated irradiation aroma/flavor, ground beef aroma/flavor and garlic/onion aroma/flavor using a 15-point hedonic scale, where one 1 was “no aroma/flavor” and fifteen 15 was “strong aroma/flavor.”

Results and Discussion

Irradiation had no effect on the TBARS of cooked ground beef at Day 0 regardless of the additive treatments, but irradiated control and 0.1% garlic-added beef had higher TBARS values than those of non-irradiated ones at 3 day storage ($P < 0.05$) (Table 1). At Day 7, additive treatments had no effect on the oxidation of nonirradiated cooked ground beef, but 0.5% onion-treatment showed a significant antioxidant effect in irradiated samples (Table 1). Over the 7 d storage period, the TBARS of cooked ground beef increased by about 3 times from 0 d values in all treatments. Irradiation is reported to accelerate lipid oxidation of meat under aerobic conditions and oxygen availability during storage was important than irradiation on the lipid oxidation of raw and cooked meat, but little differences in TBARS values were found between irradiated and nonirradiated cooked ground beef after 7 d storage under aerobic conditions.

Among the volatiles, only the amounts of aldehydes showed difference by additive treatments in non-irradiated cooked ground beef (Table 2**)**. Irradiation had minor effects on the production of alcohols at Day 0, but irradiated cooked ground beef with garlic or onion produced less amounts of alcohols after 3 d storage. The amounts of aldehydes in cooked ground beef increased during storage, but irradiation had little effect except for nonirradiated cooked ground beef at Day 0 when 0.1% garlic- or 0.5% onion-added ground beef produced more aldehydes than control. The increase of aldehydes in both irradiated and non-irradiated cooked meat should be caused by lipid oxidation under aerobic conditions during storage, but additive treatments had no effect on the amounts of aldehydes at 3 d and 7 d storage. Hexanal, butanal, heptanal, propanal and pentanal were detected in the cooked ground beef, but hexanal was the major volatile aldehydes and the production of aldehydes agreed well with TBARS data (Table 2).

Addition of garlic or onion greatly increased the amount of sulfur volatiles from irradiated and nonirradiated cooked ground beef (Table 3). Non-irradiated cooked ground beef produced only carbon sulfide, which disappeared after 7 d storage (Table 3). The amount of S-volatiles produced in non-irradiated cooked ground beef with 0.1% garlic or 0.5% onion treatment was much greater than those of the control ($P < 0.05$). The amount of total sulfur volatiles produced from both irradiated and non-irradiated 0.1% garlic-added cooked ground beef was more than 10-fold of the 0.5% onion-added samples. Most of the sulfur compounds in non-irradiated 0.1% garlic-added ground beef was remained in the meat, but only a small portion of 3,3-thiobis-1-propene was detected in onion-added cooked ground beef after 7 d storage. The organosulfur compounds and their precursors in garlic such as allicin, diallyl sulfide and diallyl trisulfide are reported to be involved in garlic odor and flavor. None of them were detected in this study probably due to their high reactivity and low stability.

Irradiation produced significant amounts of methanethiol, dimethyl disulfide and dimethyl trisulfide, which are the main sulfur compounds involved in irradiation off-odor in meat (Table 3). Irradiation changed the compositions and amounts of sulfur compounds in both garlic- and onion-added cooked ground beef. In 0.1% garlic added meat, the amounts of 2-propene-1-thiol and di-2-propenyl disulfide decreased by 80% and 70%, respectively. In onion added meat, the amount of methanethiol increased by 2-fold, but 3,3-thiobis-1-propene disappeared after irradiation. The amounts and compositions of sulfur compounds in garlic- and onion-added cooked ground beef changed dramatically during storage, especially in 0.5% onion added-meat, and no sulfur compounds were detected in onion-added irradiated beef after 7 days of storage. No sulfur compounds were detected in irradiated control meat after 3 d storage under aerobic conditions. Most of sulfur compounds produced in irradiated ground beef with 0.5% onion disappeared after 3 d storage and completely disappeared after 7 days (Table 3). After 7 d storage, therefore, the cooked ground beef with onion may not have irradiation odor/flavor nor onion odor/flavor because no sulfur compounds were detected. With 0.1% garlic, most of the sulfur compounds still remained and the composition not changed much even after 7 d storage. Therefore, using 0.1% garlic would be more efficient than 0.5% onion to produce sulfur compounds to mask or modify irradiation off-odor.

No differences in the intensities of irradiation aroma and irradiation flavor between irradiated and nonirradiated cooked ground beef were found (Table 4). The intensity of ground beef aroma, however, was the strongest in nonirradiated cooked ground beef and the lowest in 0.1% garlic treatment, and the differences were insignificant. Ground beef flavor also showed similar trends to ground beef aroma, but the intensity was significantly lower with the addition of garlic.

Ground beef with garlic produced very large amounts of sulfur compounds including methanethiol, dimethyl sulfide, and dimethyl disulfide, which are the main sulfur compounds produced in meat by irradiation. In addition, garlic produced even larger amounts of other sulfur compounds that are responsible for their characteristic odor/flavor than onion. Although the intensity of irradiated cooked control had higher irradiation aroma than other treatments, it was not significantly different from other treatments. The composition and amounts of sulfur compounds found in irradiated cooked ground beef with 0.5% onion were similar to those of non-irradiated ones at Day 0 and produced only methanethiol and dimethyl disulfide after 3 d storage in aerobic packaging conditions (Table 3). So, the odor/flavor of onion-added irradiated cooked ground beef were expected to be similar to that of the irradiated cooked control. Also, the intensities of irradiation aroma and irradiation flavor between 0.1% garlic-added and 0.5% onion-added irradiated cooked meat were expected to be different because the composition and amounts of sulfur compounds between the two treatments were differ significantly. However, the intensity of irradiation flavor of irradiated cooked ground beef with garlic or onion was weak and was not different from that of non-irradiated or irradiated control (Table 4), indicating that cooking changed or eliminated the irradiation aroma and irradiation flavor. The perception of odor from samples containing sulfur volatiles can be changed greatly depending upon their composition and amounts present in the sample. Another reason could be large variations among sensory panelists as shown in Table 4.

The intensities of "onion/garlic aroma" and "onion/garlic flavor" in ground beef remained strong even after cooking, but ground beef with onion alone had significantly lower scores than garlic treatment. Garlic and onion produce sulfury odor and flavor, but they are not considered as off-odor or off-flavors. However, too strong garlic or onion odor and flavor can be objectionable to some consumers. Considering the sensory results and the amounts of sulfur compounds produced in cooked ground beef with added garlic or onion, 0.5% of onion would be good enough to mask or change odor of irradiated ground beef, but < 0.1% of garlic is recommended to reduce the intensity of garlic aroma and garlic flavor.

Table 1. TBARS values of irradiated and nonirradiated cooked ground beef with different additives during aerobic storage at 4°C.

(Unit: mg MDA/kg meat)

	Control[1]	G0.1%	O0.5 %	SEM
O day				
Non-IR	0.34	0.33	0.29	0.02
IR	0.31	0.30	0.30	0.02
3 days				
Non-IR	0.71[y]	0.74[y]	0.65[y]	0.03
IR	0.91[x]	0.89[x]	0.77[x]	0.05
7 days				
Non-IR	1.09	0.99	0.88	0.06
IR	1.04[a]	0.99[a]	0.78[b]	0.05

[a-b]Values with different superscripts within a row are significantly different (*P* < 0.05). n = 4.
[x-y]Values with different superscripts within a column of the same storage time are significantly different (*P* < 0.05).
[1]Control: without garlic and onion, G0.1%: 0.1% garlic, O0.5%: 0.5% onion, Non-IR: non-irradiated, IR: 2.5 kGy irradiation. SEM: standard error of the mean.

Table 2. Alcohols, aldehydes, hydrocarbons and ketones compounds of irradiated and nonirradiated cooked ground beef with different additives during aerobic storage at 4 °C.

(**Unit:** Total ion counts × 10^6)

		Non-IR				IR			
		Control	G0.1%	O0.5%	SEM	Control	G0.1%	O0.5%	SEM
0 day									
	Alcohols	257	584	112	102	136	123	81	17
	Aldehydes	427[b]	786[a]	918[a]	89	816	733	1029	92
	Hydrocarbons	558	825	512	144	945	511	849	119
	Ketones	416	344	356	61	452	605	350	66
3 days									
	Alcohols	250	105	111	74	388[a]	63[b]	181[b]	54
	Aldehydes	1743	1806	1950	209	1458	1786	1564	148
	Hydrocarbons	200[b]	1008[a]	498[b]	122	695	580	1060	140
	Ketones	314	273	293	99	374	96	372	95
7 days									
	Alcohols	95	145	96	51	241	116	197	86
	Aldehydes	1481	1425	1402	222	1130[b]	1878[a]	1131[b]	65
	Hydrocarbons	175	816	326	163	285	252	287	45
	Ketones	280	271	220	89	445	113	368	110

[a-b]Values with different superscripts within a row of the same irradiation treatment are significantly different ($P < 0.05$). Control: without garlic and onion, G0.1%: 0.1% garlic, O0.5%: 0.5% onion, Non-IR: non-irradiated, IR: 2.5 kGy irradiation. SEM: standard error of the means. *Alcohols* (ethanol, 1,2-propanol and 1-butanol), *Aldehydes* (hexanal, butanal, heptanal, propanal and pentanal), *Hydrocarbons* (1-pentane, pentane, 1-hexane, hexane, heptane and octane) and *Ketones* (2-propanone, 2,3-butanedione, 2-butanone and 2-heptanone).

Table 3. Sulfur compounds of irradiated and nonirradiated cooked ground beef with different additives during aerobic storage at 4 °C.

(**Unit:** Total ion counts × 10^5)

	Non-IR				IR			
	Control	G0.1%	O0.5%	SEM	Control	G0.1%	O0.5%	SEM
0 day								
Methanethiol	0^{b}	221^{a}	91^{ab}	43	203	468	222	115
Carbon disulfide	26	111	75	55	0	10	18	10
2-Propen-1-thiol	0^{b}	2504^{a}	0^{b}	54	0^{b}	524^{a}	0^{b}	78
Dimethyl disulfide	0^{b}	152^{a}	133^{a}	22	135	233	127	38
3,3-Thiobis-1-propene	0^{b}	598^{a}	12^{b}	53	0^{b}	444^{a}	0^{b}	45
Methyl 2-propenyl disulfide	0^{b}	185^{a}	39^{b}	14	0^{b}	220^{a}	24^{b}	25
Dimethyl trisulfide	0^{c}	82^{a}	34^{b}	7	40	129	57	27
Di-2-propenyl disulfide	0^{b}	663^{a}	0^{b}	49	0^{b}	186^{a}	0^{b}	27
3 days								
Methanethiol	0	8	47	22	0^{b}	296^{a}	8^{b}	71
Carbon disulfide	0	5	6	20	0	16	0	9
2-Propen-1-thiol	0^{b}	1151^{a}	0^{b}	41	0^{b}	1138^{a}	0^{b}	43
Dimethyl disulfide	0^{b}	64^{a}	51^{a}	16	0^{b}	147^{a}	18^{b}	45
3,3-Thiobis-1-propene	0	470	144	34	0^{b}	423^{a}	0^{b}	15
Methyl 2-propenyl disulfide	0	104	49	31	0^{b}	134^{a}	0^{b}	4
Dimethyl trisulfide	0	0	0	0	0^{b}	73^{a}	0^{b}	4
Di-2-propenyl disulfide	0^{c}	122^{b}	175^{a}	5	0^{b}	20^{a}	0^{b}	11
7 days								
Methanethiol	0^{b}	31^{a}	0^{b}	8	0^{b}	158^{a}	0^{b}	9
Carbon disulfide	0	0	0	0	0	20	0	11
2-Propen-1-thiol	0^{b}	2756^{a}	0^{b}	79	0^{b}	1369^{a}	0^{b}	52
Dimethyl disulfide	0^{b}	64^{a}	0^{b}	9	0^{b}	240^{a}	0^{b}	16
3,3-Thiobis-1-propene	0^{b}	483^{a}	10^{b}	22	0^{b}	320^{a}	0^{b}	18
Methyl 2-propenyl disulfide	0^{b}	109^{a}	0^{b}	12	0^{b}	107^{a}	0^{b}	9
Dimethyl trisulfide	0	0	0	0	0	57	0	32
Di-2-propenyl disulfide	0^{b}	213^{a}	0^{b}	21	0^{b}	89^{a}	0	11

[a-b]Values with different superscripts within a row of the same irradiation treatment are significantly different ($P < 0.05$). n = 4.

Control: without garlic and onion, G0.1%: 0.1% garlic, O0.5%: 0.5% onion, Non-IR: non-irradiated, IR: 2.5 kGy irradiation. SEM: standard error of the means.

Table 4. Sensory evaluation of irradiated and nonirradiated cooked ground beef with different additives during aerobic storage at 4 °C.

	Non-irradiated	Irradiated		
	Control	Control	G0.1%	O0.5%
Irradiation aroma	3.18±2.22	5.22±4.74	3.06±2.97	4.07±3.88
Ground beef aroma	8.16±3.06	6.25±3.53	5.71±4.24	6.39±3.39
Onion/garlic aroma	0.14±0.09[c]	0.73±0.62[c]	6.52±4.00[a]	3.69±3.19[b]
Irradiation flavor	3.16±3.09	2.94±2.45	2.61±2.71	3.46±3.16
Ground beef flavor	8.36±3.36[a]	7.31±3.45[ab]	5.58±3.71[b]	6.33±3.02[ab]
Onion/garlic flavor	0.00±0.00[c]	0.48±0.39[c]	5.64±3.34[a]	3.15±3.05[b]

[a-c]Values with different superscripts within a row are significantly different ($P < 0.05$). n = 10.
Irradiation aroma (0: weak and 15: strong intense), ground beef aroma (0: weak and 15: strong intense), onion/garlic aroma (0: weak and 15: strong intense), irradiation flavor (0: weak and 15: strong intense), ground beef flavor (0: weak and 15: strong intense), and onion/garlic flavor (0: weak and 15: strong intense). Control: without garlic and onion, G0.1%: 0.1% garlic, O0.5%: 0.5% onion.