Effect of Garlic, Onion, and their Combination on the Quality and Sensory Characteristics of Irradiated Raw Ground Beef

A.S. Leaflet R2765

Han Sul Yang, Visiting Scholar; Eun Joo Lee, Assistant Scientist; Sunhee Moon, Visiting Scholar; Hyun Dong Paik, Visiting Scholar; Dong Ahn, Professor, Department of Animal Science

Summary and Implications

Irradiated raw ground beef had lower a*- and b*-values than nonirradiated ones regardless of garlic or onion treatment at 0 d. Irradiation increased TBARS values of control ground beef, but addition of 0.5% onion or 0.1% garlic + 0.5% onion reduced oxidative changes during storage. Addition of garlic or onion greatly increased the amounts of sulfur compounds, but the increase was greater with garlic. With irradiation, the profiles and amounts of S-volatiles in raw ground beef changed significantly. However, the intensity of irradiation aroma in irradiated raw ground beef with garlic or onion was similar to that of the nonirradiated control. This indicated that some of the sulfur compounds unique to garlic or onion interacted with common sulfur compounds detected in irradiated meat and masked or changed the odor characteristics of irradiated raw ground beef. It was concluded that > 0.5% onion or < 0.01% garlic would be needed to mask or prevent irradiation aroma in irradiated raw ground beef.

Introduction

Ground beef products comprise about 42% of beef consumption and are also the major cause of foodborne illness in the U.S. Ground beef is highly susceptible to microbial contamination because of its nature and method of preparation, and the elimination of contaminated pathogens such as *E. coli* O157:H7 and *Salmonella* in raw ground beef is a challenge. Irradiation is recognized as the most effective method for controlling pathogenic microorganisms in ground beef; yet only a small fraction of ground beef (0.15%) is irradiated. Consumer surveys and research indicated that decreased meat quality has the greatest impact on consumer rejection of irradiated meat. Therefore, developing methods to minimize quality changes are critical to increase consumer acceptance of irradiated ground beef.

The most important quality changes in raw ground beef by irradiation include color change, off-odor production, and accelerated lipid oxidation. The color changes in irradiated meat vary depending on irradiation dose, animal species, muscle type, and packaging conditions. In general, light meat such as pork loin and poultry breast meat produced pink color, while dark meat such as beef became brown or gray after irradiation under aerobic conditions. All irradiated meat produced characteristic irradiation odor regardless of degree of lipid oxidation. Several off-odor volatile compounds were newly generated or increased in meat after irradiation. Dimethyl sulfide, dimethyl disulfide and dimethyl trisulfide were among the most prominent sulfur compounds produced by irradiation and were responsible for irradiation off-odor in meat.

Antioxidants are used in fresh and further processed meat to prevent oxidative rancidity and improve color stability, but the use of antioxidant in meat products is highly regulated by the Food Safety Inspection Agency (FSIS). Consumers prefer the use of plant-derived natural antioxidants to conventional synthetic antioxidants. Research results showed that many natural antioxidants such as ascorbic acid, α-tocopherol, sesamol, gallic acid, and quercetin had high potential in preventing oxidative changes, minimizing off-odor production and preventing color change in irradiated meat. Garlic and onion are two major spices widely used in cookery to complement and enhance the flavor of meat products. Both garlic and onion possess strong antioxidant and flavor properties because of their high phenolic and sulfur compounds, respectively. The organosulfur compounds and their precursors in garlic such as allicin, diallyl sulfide and diallyl trisulfide are the key compounds that are involved in garlic odor and flavor. Therefore, addition of garlic or onion may change, mask, or improve the odor/flavor characteristics of irradiated raw ground beef. Currently, only non-fluid seasonings and dried spices and herbs can be added to fresh or frozen red meat and irradiated. However, dried garlic and onion lose most of their sulfur compounds during the drying processing process, and will be much less effective than using fresh ones.

The objective of this study was to determine the effectiveness of fresh ground garlic, onion, and their combination in preventing lipid oxidation and color changes, and masking irradiation aroma in raw ground beef after irradiation while not producing excessive onion or garlic odor.

Materials and Methods

Eight beef top rounds from different steers were obtained from a local packing plant 6d post-slaughter. Each round was trimmed of any visible fat and connective tissues. Beef was ground through a 3-mm plate twice and eight 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, 6) irradiated added with 0.5% onion, 7) non-irradiated added with 0.1% garlic + 0.5% onion and 8) irradiated added with 0.1% garlic + 0.5%

onion. Skinned fresh garlic and onion were ground until they became semi-liquid form immediately before use and then mixed for 1 min in a bowl mixer. Ground beef patties were made by hand, packaged individually in oxygen-permeable bags (polyethylene, 10 × 15 cm, 2 mil, 2,300 mL/m^2/24 h at 22.7 ^{o}C), stored at 4 °C overnight, and irradiated at 0 or 2.5 kGy using a linear accelerator facility the next day morning. TBARS, volatiles, and sensory characteristics were determined.

Statistical Analysis

Data were analyzed by the procedures of generalized linear model (GLM) of SAS (2000). SNK (Student-Newman-Keuls) multiple-range test was used to compare the mean values of treatments. Mean values and standard error of the means (SEM) were reported. Differences in sensory values were compared using the Tukey's significant differences. For sensory data, mean values and standard deviations were reported. Statistical significance for all comparisons was made at $P < 0.05$.

Results and Discussion

The TBARS values of irradiated samples were higher than those of non-irradiated ones ($P < 0.05$) throughout storage except for 0.5% onion and 0.1% garlic + 0.5% onion treatments at 3 d storage (Table 1). TBARS values of ground beef showed an increasing trend as the storage time increased. Additives, especially onion and garlic + onion treatments started to show antioxidant effects in irradiated raw ground beef after 3 d storage. After 7 d storage, 0.5% onion and 0.1% garlic+0.5% onion treatments showed significant antioxidant effects in both irradiated and nonirradiated raw ground beef. The differences in TBARS values between control and 0.5% onion and 0.1% garlic+0.5% onion treatments are small, but maintaining the TBARS values of ground beef as low as possible is important because some sensitive consumers start to recognize oxidation odor when the TBARS value is greater than 1.0.

In nonirradiated ground beef, the production of sulfur compounds (S-volatiles) greatly increased by the addition of 0.1% garlic, 0.5% onion, or 0.1% garlic + 0.5% onion at Day 0: the sulfur compounds produced from the nonirradiated ground beef with garlic include methanethiol, 2-propene-1-thiol, dimethyl disulfide, 3,3-thiobis-1-propene, methyl 2-propenyl disulfide, and di-2-propenyl disulfide. Garlic produces greater number sulfur compounds than those listed here, but the amounts of minor sulfur compounds were below the limit used here. 2-Propen-1-thiol was the major sulfur compounds of raw ground beef added with garlic, but very large amounts of dimethyl disulfide, 3,3-thiobis-1-propene, and di-2-propenyl disulfide were also produced. With 0.5% onion treatment alone, only 2-propene-1-thiol, dimethyl disulfide, 3,3-thiobis-1-propene and methyl 2-propenyl disulfide were newly produced. 2-Propen-1-thiol was the major sulfur compounds of raw ground beef added with onion, but the amount was much smaller than those with garlic. Carbon disulfide was produced from all ground beef including control, but the amount was small compared with other sulfur compounds. Total amount of sulfur compounds produced from the ground beef containing garlic (0.1% garlic and 0.1% garlic + 0.5% onion treatments) was over 20 times greater than that with onion alone, indicating that the amount of sulfur compounds produced from 0.1% garlic was much greater than that from 0.5% onion. During storage under aerobic packaging conditions, the amounts of all sulfur compounds in ground beef decreased rapidly, and 2-propene-1-thiol and dimethyl disulfide were not detected from the nonirradiated ground beef with 0.5% onion treatment after 7 d storage (Table 2).

With irradiation, the profiles and amounts of S-volatiles in raw ground beef were significantly different from those of nonirradiated ground beef: in control beef, carbon disulfide was not detected, but methanethiol, dimethyl disulfide and dimethyl trisulfide were newly produced after irradiation (Table 2). The perception of odor from samples containing sulfur volatiles, however, can be changed depending on the composition and amounts of sulfur compounds as well as those of other volatiles in the sample because aroma is not a simple result of sulfur volatile content but the interactions among sulfur compounds as well as sulfur compounds with other volatile compounds. Therefore, the aroma of onion and garlic are different from irradiation odor, and high levels of sulfur compounds such as mercaptomethane, dimethyl sulfide and dimethyl disulfide found in irradiated meat do not necessary mean strong irradiation aroma.

The amount of total sulfur compounds in raw ground beef with garlic, onion, and garlic + onion treatments decreased dramatically after irradiation (Table 2). As in irradiated control, carbon disulfide was not detected in irradiated garlic and/or onion-added ground beef. In garlic-added raw ground beef, the amounts of 2-propene-1-thiol and di-2-propenyl disulfide decreased more than 80% after irradiation, but changes of other sulfur compounds were not comparatively small. In onion-added ground beef, the amount of 2-propene-1-thiol decreased by 90%, but methanethiol was newly produced. The amounts of sulfur volatiles in irradiated ground beef decreased dramatically as in nonirradiated ground beef during storage: only 2-propene-1-thiol, dimethyl disulfide, methyl 2-propenyl disulfide, and dimethyl trisulfide were detected in 0.5% onion-added ground beef after 3 d and no sulfur compounds were found in both onion alone and control ground beef after 7 d storage. In garlic added ground beef, however, significant amounts of sulfur compounds, which include 2-propene-1-thiol, dimethyl disulfide, 3,3-thiobis-1-propene, methyl 2-propenyl disulfide, dimethyl trisulfide and di-2-

propenyl disulfide were produced even after 7 d storage (Table 2).

Sensory results indicated that the intensity of irradiation aroma was significantly ($P < 0.05$) higher in irradiated control than non-irradiated control beef. Addition of 0.5% onion treatment had no effect on the intensity of "irradiation aroma" in irradiated raw ground beef (Table 3). It seems that the amounts and odor intensity of sulfur compounds from onion, which include 2-propene-1-thiol, 3,3-thiobis-1-propene, methyl 2-propenyl disulfide, were not large and strong enough to overcome the odor produced by methanethiol, dimethyl disulfide, and dimethyl trisulfide (Table 2). Addition of 0.1% garlic or 0.1% garlic + 0.5% onion significantly reduced, and the intensity of sulfury aroma in irradiated raw ground beef with garlic and garlic + onion was similar to that of the nonirradiated control (Table 3), indicating that adding garlic or garlic + onion can mask or totally change the odor/flavor characteristics of irradiated ground beef. Ground beef with 0.1% garlic and 0.1% garlic + 0.5% onion produced very large amounts of sulfur compounds including mercaptomethane, 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. Irradiated raw ground beef produced significantly lower "ground beef aroma" than non-irradiated ones regardless garlic, onion or garlic + onion treatment and addition of garlic or onion had no effect on the intensity of "ground beef aroma" in irradiated ground beef. This suggested that some of the sulfur compounds unique to garlic or onion (2-propen-1-thiol, 3,3-thiobis-1-propene and di-2-propenyl disulfide) interacted with common sulfur compounds detected in irradiated meat (methanethiol, dimethyl disulfide and dimethyl trisulfide) and masked or changed the odor characteristics of irradiated raw ground beef. The color of irradiated ground beef was lighter than nonirradiated beef and addition of garlic or onion had little effect on the color of irradiated ground beef (Table 3).

Garlic and onion both produce sulfury odor, but their odor in foods is not considered as off-odor. The amounts of sulfur compounds produced in irradiated ground beef by 0.5% onion were similar to those by irradiation, and the intensity of onion aroma in meat was relatively low and was not enough to mask or reduce irradiation aroma. Addition of 0.1% garlic or 0.1% garlic + 0.5% onion produced 10 times greater amounts of sulfur compounds than those produced by 2.5 kGy irradiation, but produced significant "onion/garlic aroma". Therefore, we suggest use of > 0.5% onion, < 0.1% garlic, or their combination to mask or prevent irradiation aroma in irradiated raw ground beef. Both dried or freshly ground onion and garlic are permitted to use in irradiated ground beef, and use of dried onion and garlic would be more convenient than freshly ground ones. However, we suggest use of freshly ground onion and garlic because they contain greater amounts of sulfur compounds than dried ones and are more efficient in masking irradiation aroma.

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

(Unit: mg MDA/kg meat)

	Control	G0.1%	O0.5%	G0.1+O0.5%	SEM
O day					
Non-IR	0.15^{y}	0.15^{y}	0.13^{y}	0.15^{y}	0.01
IR	0.23^{x}	0.24^{x}	0.20^{x}	0.24^{x}	0.02
3 days					
Non-IR	0.34^{y}	0.38^{y}	0.33	0.37	0.04
IR	0.59^{abx}	0.63^{ax}	0.46^{b}	0.49^{b}	0.04
7 days					
Non-IR	0.69^{ay}	0.43^{by}	0.37^{by}	0.41^{by}	0.09
IR	0.97^{ax}	0.91^{ax}	0.60^{bx}	0.64^{bx}	0.07

Table 2. Sulfur compounds of irradiated and nonirradiated raw ground beef with different additives during aerobic storage at 4 °C.

	Non-IR				IR			
	Control	G0.1%	O0.5%	G0.1+O0.5%	Control	G0.1%	O0.5%	G0.1+O0.5%
0 day								
Methanethiol	0^{b}	554^{a}	0^{b}	649^{a}	180^{ab}	329^{a}	22^{b}	198^{ab}
Carbon disulfide	73	71	98	81	0	0	0	0
2-Propen-1-thiol	0^{b}	14864^{a}	647^{b}	18880^{a}	0^{b}	2631^{a}	56^{b}	1109^{ab}
Dimethyl disulfide	0^{b}	1334^{a}	209^{b}	1474^{a}	357^{b}	1126^{a}	446^{b}	930^{a}
3,3-Thiobis-1-propene	0^{b}	1553^{a}	60^{b}	543^{b}	0^{b}	642^{a}	119^{b}	322^{ab}
Methyl 2-propenyl disulfide	0^{c}	500^{a}	0^{c}	380^{b}	0	218^{a}	19^{b}	202^{a}
Dimethyl trisulfide	0	0	0	0	38^{b}	200^{a}	10^{b}	200^{a}
Di-2-propenyl disulfide	0^{c}	3195^{a}	0^{c}	1969^{b}	0	412	0^{b}	174^{a}
3 days								
Methanethiol	0^{b}	212^{a}	0^{b}	298^{a}	0^{b}	100^{a}	0^{b}	90^{a}
Carbon disulfide	18	21	36	29	0	0	0	0
2-Propen-1-thiol	0^{b}	10222^{a}	982	9896^{a}	0^{c}	630^{a}	97^{c}	330^{b}
Dimethyl disulfide	0^{b}	692^{a}	67^{b}	804^{a}	0^{c}	529^{a}	50^{b}	288^{b}
3,3-Thiobis-1-propene	0^{b}	920^{a}	25^{b}	865^{a}	0^{c}	398^{a}	0^{c}	302^{b}
Methyl 2-propenyl disulfide	0^{b}	200^{a}	18^{b}	200^{a}	0^{b}	167^{a}	20^{b}	151^{a}
Dimethyl trisulfide	0^{b}	194^{a}	2^{b}	139^{a}	0^{b}	60^{a}	8^{b}	50^{a}
Di-2-propenyl disulfide	0^{b}	1124^{a}	0^{b}	1122^{a}	0^{b}	142^{a}	0^{b}	139^{a}
7 days								
Methanethiol	0	118	0	52	0^{b}	50^{a}	0^{b}	0^{b}
Carbon disulfide	0	0	11	0	0	0	0	0
2-Propen-1-thiol	0^{c}	3434^{a}	0^{c}	1501^{b}	0^{c}	127^{b}	0^{c}	478^{a}
Dimethyl disulfide	0^{b}	181^{a}	0^{b}	111^{a}	0^{c}	229^{b}	0^{c}	400^{a}
3,3-Thiobis-1-propene	0^{c}	533^{a}	23^{c}	298^{b}	0^{c}	369^{a}	0^{c}	236^{b}
Methyl 2-propenyl disulfide	0^{b}	150^{a}	25^{b}	70^{b}	0^{c}	106^{a}	0^{c}	58^{b}
Dimethyl trisulfide	0^{b}	80^{a}	10^{b}	20^{b}	0^{c}	20^{a}	0^{c}	20^{b}
Di-2-propenyl disulfide	0^{c}	340^{a}	0^{c}	69^{b}	0^{c}	92^{a}	0^{c}	60^{b}

^{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, G0.1+O0.5%: 0.1% garlic + 0.5% onion, Non-IR: non-irradiated, IR: 2.5 kGy irradiation.
SEM: standard error of the means.

Table 3. Sensory evaluation of irradiated and nonirradiated raw ground beef with different additives during aerobic storage at 4 °C (Tukey's HSD 5%).

	Nonirradiated	Irradiated (2.5 kGy)			
	Control	Control	G0.1%	O0.5%	G0.1+O0.5%
Irradiation aroma	2.57[c]	7.96[a]	4.21[bc]	6.21[ab]	3.13[c]
Ground beef aroma	7.75[a]	4.19[b]	3.63[b]	4.07[b]	3.69[b]
Onion/garlic aroma	0.60[c]	0.83[c]	7.24[a]	3.25[b]	7.99[a]
Ground beef color	12.22[a]	7.44[bc]	6.19[c]	8.34[b]	6.50[bc]

[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), and ground beef color (0: light and 15: dark). Control: without garlic and onion, G0.1%: 0.1% garlic, O0.5%: 0.5% onion, G0.1+O0.5%: 0.1% garlic + 0.5% onion