Effects of Aging Time and Natural Antioxidants on the Quality of Irradiated Ground Beef

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Summary and Implications

Beef rounds aged for one, two, or three weeks after slaughtering were ground added with 0.05% ascorbic acid + 0.01% α-tocopherol or 0.05% ascorbic acid + 0.01% α-tocopherol + 0.01% sesamol, placed on Styrofoam trays and wrapped with oxygen permeable plastic film, and treated with electron beam irradiation at 0 or 2.5 kGy. The meat samples were displayed under fluorescent light for 7 d at 4° C. Color, lipid oxidation, and volatiles were determined at 0, 3, and 7 d of storage. Irradiation increased lipid oxidation of ground beef regardless of their aging time and storage period. As aging time increased lipid oxidation increased. Adding sesamol increased the effectiveness of ascorbate and tocopherol combination in reducing lipid oxidation especially as aging and storage time increased. The redness of beef were decreased by irradiation and adding ascorbic acid and α-tocopherol before irradiation was effective in maintaining the redness of irradiated ground beef over the storage period. Volatile aldehydes increased only in irradiated control beef. Antioxidant treatments were effective in reducing aldehydes in ground beef during storage.

Introduction

Irradiation is the best and most highly recommended method for pathogen control in ground beef. However, irradiation changes color, produces an off-odor, and accelerates lipid oxidation. These undesirable characteristics negatively impact consumer acceptance because consumer usually uses the appearance of meat, especially meat color, as an indicator of meat freshness. It is estimated that 2% to 20% of all products are discounted, discarded or further processed because of discoloration. Lipid oxidation in food is one of leading causes of quality deterioration. Irradiation of meat has significant impact on lipid oxidation of meat because meat contains 75% or more of water. Aerobically packaged sausages irradiated at higher irradiation dose produced greater amounts of TBARS than those irradiated at lower doses.

Off-odor volatile production is another negative effect of irradiation on meat quality. Many previous researches showed that volatile sulfur compounds as well as non-sulfur volatiles play important role in irradiation off-odor. Because of increased consumer demand for natural products, natural antioxidants have been examined recently as alternative of widely used synthetic antioxidants in food processing. Vitamin E and sesamol are natural phenolic antioxidants that can scavenge free-radicals and stop free-radical chain reactions in meat. Sesamol has a very strong antioxidant effect when used in meat alone or in combination with tocopherol, but shows negative effect on the color of irradiated ground beef. Ascorbic acid is very effective in preventing color changes in irradiated ground beef and pork during storage, especially in aged or stored meat. Addition of ascorbic acid to ground beef prior to irradiation also showed some antioxidant effect, but the antioxidant effect decreased as storage time increased. The objective of this study was to determine the effect of aging time and natural antioxidants on the color, lipid oxidation and volatiles of irradiated ground beef.

Materials and Methods

Twelve beef top rounds were obtained from a local packing plant 24 h after slaughter and aged for 1, 2, or 3 weeks in a 4° C cold room. One round taken from each of 12 different animals, 4 per aging time, was treated as a replication. Each round was trimmed of any visible fat and ground separately through a 6-mm plate at first then through a 3-mm plate. Six different treatments were prepared: (1) nonirradiated control, (2) nonirradiated added with 0.05% (wt/wt) L-ascorbic acid + 0.01% α-tocopherol, (3) nonirradiated added with 0.05% (wt/wt) L-ascorbic acid + 0.01% α-tocopherol + 0.01% sesamol. Treatments 4, 5, and 6 were the same as 1, 2, and 3, respectively, but with irradiation at 2.5 kGy. Ground beef patties were wrapped with clear stretch, oxygen-permeable meat film and irradiated at 0 or 2.5 kGy using a linear accelerator. Color, lipid oxidation, and volatiles were determined at 0, 3, and 7 days of storage.

Lipid oxidation was determined using a TBARS method. The amounts of TBARS were expressed as mg of malondialdehyde (MDA) per kg of meat. The color of meat was measured on the surface of meat samples using a Labscan spectrophotometer that had been calibrated against white and black reference tiles covered with the same film as those used for meat samples. A purge-and-trap apparatus connected to a gas chromatograph/mass spectrometer was used to analyze volatiles produced. The experiment was a complete randomized design with four replications. Data were analyzed by the procedures of generalized linear model of SAS.

Results and Discussion

Lipid oxidation of irradiated ground beef increased as aging period and storage times increased. Adding sesamol to the combination of ascorbic acid + α-tocopherol increased the effect of ascorbic acid + α-tocopherol in controlling lipid oxidation over the storage period. However, sesamol, occasionally, lowered the redness of beef. Aging was not a significant factor influencing the redness of irradiated beef. As aging period increased volatiles such as aldehydes increased at Day 0, but aging had minimal effects on volatiles important for quality changes in irradiated ground beef after storage. Therefore, addition of ascorbic acid + tocopherol is preferred for short-term storage (< 7 days), while ascorbic acid + α-tocopherol + sesamol is recommended if the storage time for the irradiated ground beef is longer than 7 days to minimize color deterioration and prevent lipid oxidation.

Table 1. TBARS values of beef irradiated at different aging time and additives during storage at 4° C.

	1-week aged			2-week aged			3-week aged		
	Non-IR	IR	SEM	Non-IR	IR	SEM	Non-IR	IR	SEM
	----------------------------- (mg MDA/kg meat) -------------------------------								
Day 0									
Control	0.55^{a}	0.69^{a}	0.10	1.06^{a}	1.05^{a}	0.17	1.20^{a}	1.35^{a}	0.10
A+E	0.19^{by}	0.24^{bx}	0.01	0.43^{b}	0.44^{b}	0.04	0.65^{b}	0.79^{b}	0.0.7
A+E+S	0.18^{by}	0.22^{bx}	0.01	0.35^{b}	0.40^{b}	0.03	0.46^{b}	0.52^{c}	0.03
SEM	0.05	0.06		0.11	0.10		0.06	0.08	
Day 3									
Control	0.89^{a}	1.58^{a}	0.31	1.22^{a}	1.37^{a}	0.28	1.36^{a}	1.65^{a}	0.14
A+E	0.20^{by}	0.41^{bx}	0.03	0.47^{b}	0.65^{b}	0.08	0.60^{by}	0.91^{bx}	0.07
A+E+S	0.20^{b}	0.22^{b}	0.01	0.39^{b}	0.39^{b}	0.03	0.46^{b}	0.47^{c}	0.03
SEM	0.13	0.22		0.16	0.18		0.07	0.11	
Day 7									
Control	1.18^{a}	3.14^{a}	0.86	1.41^{a}	2.08^{a}	0.36	1.55^{a}	2.56^{a}	0.35
A+E	0.23^{by}	0.58^{bx}	0.06	0.50^{b}	0.82^{b}	0.15	0.75^{b}	1.23^{b}	0.17
A+E+S	0.21^{by}	0.28^{bx}	0.01	0.40^{b}	0.48^{b}	0.03	0.52^{b}	0.58^{b}	0.02
SEM	0.20	0.67		0.18	0.26		0.10	0.30	

$^{a\text{-}c}$Values with different letters within a column of each storage period are significantly different (P<0.05)
$^{x\text{-}y}$values with different letters within a row of each aging period are significantly different (P<0.05)
Abbreviation: Non-IR: non-irradiated samples, IR: irradiated samples, A: ascorbic acid, E: vitamin E, and S: sesamol, SEM: standard error of the means (n=4).

Table 2. Production of aldehydes from beef irradiated at different aging time and additives during storage at 4° C.

	1 wk aged			2 wk aged			3 wk aged		
Compound	Non-IR	IR	SEM	Non-IR	IR	SEM	Non-IR	IR	SEM
	------------------------------------ (Total ion counts x 10^{4}) ------------------------------------								
After 0-day storage									
Control	394^{x}	410^{x}	78	227	283^{y}	47	938	1175^{x}	225
A+E	345^{ax}	0^{by}	3	282	271^{y}	29	407	409^{y}	103
A+E+S	0^{y}	0^{y}	0	423	687^{x}	95	356	529^{y}	124
SEM	37	51		64	63		155	165	
After 3-day storage									
Control	629^{x}	1365^{x}	424	689	959^{x}	253	289^{y}	487^{x}	165
A+E	326^{ay}	0^{by}	0	495	379^{y}	48	71^{ay}	0^{by}	9
A+E+S	58^{az}	0^{by}	15	392^{a}	0^{by}	75	861^{x}	575^{x}	111
SEM	41	344		156	154		144	76	
After 7-day storage									
Control	175^{bx}	23317^{ax}	538	0^{bz}	6608^{ax}	1208	216^{bx}	1226^{ax}	261
A+E	140^{ax}	0^{by}	24	695^{ax}	0^{by}	87	137^{ax}	0^{by}	28
A+E+S	0^{y}	0^{y}	0	301^{ay}	0^{yy}	54	0^{y}	0^{y}	0
SEM	39	438		84	987		30	212	

$^{a-b}$Values with different superscripts within a row with the same aging time are significantly different (P<0.05).
$^{x-z}$Values with different superscripts within a column of the same storage time are significantly different (P<0.05).
Abbreviation: Non-IR: non-irradiated samples, IR: irradiated samples, A: ascorbic acid, E: vitamin E, S: sesamol, SEM: standard error of the means (n=4).
Aldehydes: acetaldehyde, propanal, 2-methyl-propanal, 3-methyl-butanal, hexanal, heptanal