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Effects of aging time and natural antioxidants on the color, lipid oxidation and volatiles of irradiated ground beef

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Abstract

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, volatile analysis, oxidation–reduction potential (ORP) and carbon monoxide (CO) production 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. The combination of ascorbic acid + α-tocopherol to ground beef was more effective in reducing ORP than adding sesamol. Irradiation increased CO production from all ground beef regardless of aging time or additives treatments. Volatile sulfur compounds produced by irradiation at Day 0 disappeared over the storage period. Alcohol greatly increased in all nonirradiated beef, but volatiles aldehydes only in irradiated control beef. Antioxidant treatments were effective in reducing aldehydes in ground beef during storage.

Keywords: Ground beef; Aging time; Irradiation; Natural antioxidants; Meat quality

1. 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. In beef, the color changes from the acceptable cherry red to unattractive brown color as a result of oxymyoglobin oxidation and the formation of metmyogobin. Sherbeck et al. (1995) estimated that 2–20% of all products are discounted, discarded or further processed because of discoloration. Carbon monoxide, produced by irradiation, is responsible for the production of pink color in irradiated light meat such as poultry breast and pork (Nam & Ahn, 2002a, 2002b). The mechanism of irradiation-induced greenish or brownish gray color in ground beef reported by many researchers (Kim, Nam, & Ahn, 2002; Nam & Ahn, 2002b; Nanke, Sebranek, & Olson, 1998) is still not clear. However, it has been speculated that free radicals such as hydroxyl or sulfuryl radicals produced by irradiation can react with the binding sites of myglobin and form metmyoglobin and sulfmyoglobin leading to brown and green color, respectively (Giroux et al., 2001).

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. Diehl (1995) reported that irradiation of aqueous systems produced hydroxyl radicals, which can

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initiate oxidative changes in meat. Irradiation-induced oxidative chemical changes in meat are dose-dependent (Ahn et al., 1997) and the presence of oxygen significantly increases oxidative changes in meat (Merritt, Angelini, Wierbicki, & Shuts, 1975). Ahn et al. (1997) reported that lipid oxidation in meat as a result of irradiation a significant problem only under aerobic conditions. Aerobically packaged sausages irradiated at higher irradiation dose produced greater amounts of TBARS than those irradiated at lower doses. The TBARS of aerobic- or vacuum-packaged sausages with higher polyunsaturated fatty acids was higher than those with lower polyunsaturated fatty acids.

Off-odor volatile production is another negative effect of irradiation on meat quality (Ahn & Lee, 2006). Many previous research showed that volatile sulfur compounds such as methyl mercaptan, hydrogen sulfide, bis(methylthio-)methane, sulfur dioxide, mercaptomethane, dimethyl sulfide, methyl thioacetate, dimethyl disulfide and trimethyl sulfide were the major compounds responsible for irradiation off-odor (Batzer & Doty, 1954; Fan, Sommers, Thayer, & Lehotay, 2002; Jo, Lee, & Ahn, 1999; Patterson & Stevenson, 1995). However, other non-sulfur volatiles such as *cis*-3- and *trans*-6-nonenals, 2-methyl butanal, 3-methyl butanal, 1-hexene, 1-heptene, 1-octene, 1-nonene and oct-1-en-3-one were also reported to play important role in irradiation off-odor (Fan et al., 2002; Jo et al., 1999; Nam, Du, Jo, & Ahn, 2002). Volatile sulfur compounds have been shown to be produced by two different ways; direct radiolytic cleavage of the side chains of sulfur containing amino acids, methionine and cysteine, and the other way is by secondary reaction of primary sulfur compounds with surrounding compounds (Ahn & Lee, 2002; Ahn, 2002; Jo & Ahn, 2000).

Because of increased consumer demand for natural products, natural antioxidants have been examined recently as alternative of widely used synthetic antioxidants, such as butylated hydroxyanisol (BHA) and butylated hydroxytoluene (BHT), in food processing. Vitamin E and sesamol are natural phenolic antioxidants that can scavenge free radicals and stop free radical chain reactions in meat (Gray, Gomaa, & Buckley, 1996; Morrissey, Sheehy, Galvin, Kerry, & Buckley, 1998). Nam, Min, Park, Lee, and Ahn (2003) reported that adding phenolic antioxidants to meat is effective in decreasing oxidative reaction by either of those two ways. Lee and Ahn (2003) reported that sesamol had a very strong antioxidant effect when used in meat alone or in combination with tocopherol, but showed negative effect on the color of irradiated ground beef (Nam & Ahn, 2003). Ascorbic acid is very effective in preventing color changes in irradiated ground beef and pork during storage (Giroux et al., 2001; Nam & Ahn, 2002c, 2003), 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 (Ahn & Nam, 2004). 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.

2. Materials and methods

2.1. Sample preparation

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, four 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 (Fisher Scientific, Fair Lawn, NJ, USA) + 0.01% α-tocopherol (Aldrich Chemical Co., Milwaukee, WI, USA), (3) nonirradiated added with 0.05% (wt/wt) L-ascorbic acid + 0.01% α-tocopherol + 0.01% sesamol (3,4-methylenedioxyphenol; Sigma St. Louis, MO, USA). Treatments 4–6 were the same as 1–3, respectively, but with irradiation at 2.5 kGy. The additive treatments were applied as solution form: ascorbic acid and sesamol were dissolved in distilled water, while tocopherol was dissolved first in corn oil, and then oil emulsion was prepared using the aqueous solutions of ascorbic acid and sesamol. The same amounts of water and corn oil were added to all other treatments. Each additive was added to the ground meat and then mixed for 2 min in a bowl mixer (Model KSM 90; Kitchen Aid Inc., St Joseph, MI., USA). Ground beef patties (approximately 30 g) were made by hand, placed individually on Styrofoam trays and wrapped with clear stretch, oxygen-permeable meat film RMF-61 Hy (Borden Division, Borden Packaging and Industrial Products Inc., North Andover, MA, USA), using a single-roll overwrapper, Model 600 A (Heat Sealing Equipment Manufacturing Co., Cleveland, OH, USA). Prepared patties were stored overnight at 4 °C, and irradiated the next morning.

2.2. Ionizing radiation

Wrapped beef patties were irradiated at 0 or 2.5 kGy using a linear accelerator facility (Circe IIIR; Thomson CSF Linac, St. Aubin, France) with 10 MeV of energy and 5.6 KW of power level. The average dose rate was 68.7 KGy/min. Alanine dosimeter were placed on the top and bottom surfaces of a sample and were read using a 104 Electron Paramagnetic Resonance Instrument (Bruker Instruments Inc., Billerica, Mass, USA) to check the absorbed dose. The dose range absorbed at meat samples was 2.45–2.95 KGy (max/min ration 1.20). The nonirradiated control samples were exposed to ambient temperature of linear accelerator facility while others samples were irradiated. After irradiation, the irradiated and non irradiated meat samples were immediately returned to a 4 °C cold room were they displayed under fluorescent light for 7 d.