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Effects of soy sauce and packaging method on volatile compounds and lipid oxidation of cooked irradiated beef patties

Hyun-Wook Kim [a], Soo-Yeon Lee [a], Ko-Eun Hwang [a], Dong-Heon Song [a], Yong-Jae Kim [a], Yun-Kyung Ham [a], Choong-Hee Lee [a], Yun-Sang Choi [a], Ju-Woon Lee [b], Cheon-Jei Kim [a,*]

[a] Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Republic of Korea
[b] Team for Radiation Food Science and Biotechnology, Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute, Jeongeup 580-185, Republic of Korea

HIGHLIGHTS

- Soy sauce (SS) could inhibit volatiles cooked irradiated beef patties.
- Vacuum packaging and SS treatment is effective to prevent lipid oxidation.
- Hexanal content was highly correlated with TBA value of the irradiated beef patties.

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ABSTRACT

The objective of this study is to determine the effect of soy sauce on volatile compounds and lipid oxidation of cooked irradiated beef patties. Sulfur-containing volatile components, which are produced by irradiation, were not found in all treatments. Volatile components derived from soy sauce, such as 3-hydroxy-2-butanone, acetic acid, 3-methyl-1-butanol and 2-methyl-1-butanol, were detected in beef patties containing soy sauce regardless of irradiation and packaging method. Volatile aldehydes, including hexanal, significantly decreased the irradiated beef patty prepared with soy sauce compared to those of irradiated beef patty made with NaCl at 1 day and 5 days after irradiation. In addition, combined use of vacuum packaging and soy sauce treatments could inhibit the formation of volatile compounds and 2-thiobarbituric acid reactive substances during chilled storage. Therefore, the use of soy sauce in cooked and irradiated beef could reduce the production of volatile components associated with the irradiation-induced off-flavor and lipid oxidation.

1. Introduction

Irradiation has been recognized as an effective technology for improving the microbial safety of meat and meat products. In previous studies, it has been reported that the food irradiation causes the production of off-flavor and odor induced by irradiation, discoloration, and acceleration of lipid oxidation in meat and meat products. Thus, the improvement of these impacts is needed for extending the use of food irradiation technology in the meat industry as well as consumer acceptance. Although there are differences in the degree of off-flavor among animal species and their parts, the formation of sulfur volatile compounds, and hexanal which is related to lipid oxidation during the storage period, is mainly responsible for the radiolytic off-flavor (Nam et al., 2003).

Natural antioxidants which can inhibit and/or reduce the oxidative changes in meat have been commonly examined to improve the problems induced by irradiation. According to Nam and Ahn (2003), in addition, the use of antioxidants could prevent the formation of volatile compounds, particularly sulfur-volatiles, in irradiated pork patties. Nam et al. (2007) suggested that rosemary and onion could prevent the production of hexanal in cooked irradiated pork patties due to its antioxidant activity. Also, Nam et al. (2003) indicated that components within antioxidants affect the formation of volatile compounds in irradiated ground beef. Moreover, Ahn et al. (1998a) indicated that vacuum-packaging prior to irradiation could inhibit the lipid oxidation of raw pork patties, whereas irradiation could cause the production of volatiles regardless of packaging condition. Similarly, Ahn et al. (1998b) suggested that the absence of oxygen is most important condition to inhibit the formation of oxidative products and volatiles of cooked pork patties.

Soy sauce, which is a fermented sauce, is widely used to provide the rich flavor and taste in various traditional meat-based cuisines

* Corresponding author. Tel.: +82 2 450 3684; fax: +82 2 444 6695.
E-mail address: kimcj@konkuk.ac.kr (C.-J. Kim).

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in East Asia (Nam et al., 2010). Recently, Kim et al. (2013a) indicated that the addition of soy sauce could prevent the formation of primary and secondary products of lipid oxidation in raw beef patties. Additionally, Kim et al. (2013b) reported that soy sauce retarded the lipid oxidation of electron beam-irradiated pork patties for 10 days.

The objectives of this study were to evaluate the effects of soy sauce and packaging condition on volatiles formation and lipid oxidation of cooked irradiated beef patties compared to beef patties at 1 day and 5 days after irradiation.

2. Materials and methods

2.1. Sample preparation

2.1.1. Preparation of beef patty

Fresh beef top round and pork back fat were obtained from a commercial supplier. The visible fat and connective tissue of meat was trimmed off. The ground beef and back fat were divided into four portions. Sodium chloride solution was added into each sample as a solution type because of the soy sauce is a liquid. Sodium chloride solution of 10% (w/w) salt concentration was prepared by dissolving sodium chloride in ice water. Commercial soy sauce (fermented soy sauce, Sempio Foods Co., Seoul, Korea) was purchased from a local market. Soy sauce showed pH 4.8 and 16% salt concentration. The soy sauce solution was diluted in ice water to a final salt concentration of 10% (w/w). All samples were composed by 60% ground beef, 20% ground pork back fat, and 20% curing solution. Salt concentration of all treatment was fixed as 2%. Each sample was then finely ground through a 3 mm plate, and the batches were mixed using mixer. The batches were processed into 80 ± 1 g patties with 100 mm in diameter and 1.0 cm below in thickness using patty presses (small ground press, Spikomat Ltd., Nottinghamshire, UK). All beef patties were individually packaged in Nylon/PE film, and stored at -20 °C for 24 h to maintain shape of the beef patties.

2.1.2. Cooking and packaging process

The meat was heated until the core temperatures of beef patties reached 75 °C. The samples were heated using a convective oven (OES 6.06, Convotherm, Germany) at 150 °C for approximately 9 min. Each patty was placed in the center of a shelf in the oven, until the targeted core temperature was reached. The core temperature of beef patty was monitored with a digital thermometer (Tes-1305, Tes Electrical Co., Taiwan) equipped with a data logger (RS-232, Tes Electrical Co., Taiwan) by inserting an iron constantan thermocouple. The cooked patties were cooled down to 4 °C, and then packaged rapidly. In each treatment, the cooked beef patties were divided into two groups (aerobic packaging and vacuum packaging). Vacuum packaging groups were individually vacuum-packaged in a polyethylene/nylon bag (2 ml O_2/m^2/24 h at 0 °C), and all packaged samples were stored in a 4 °C refrigerator for 24 h until gamma-irradiation.

2.1.3. Gamma-irradiation

The aerobic and vacuum-packaged cooked beef patties were irradiated at 2.5 kGy in a cobalt-60 irradiator (point source, AECL, IR-79, Nordion International, Canada) with source strength of 100 kCi in Advanced Radiation Technology Institute of Korea Atomic Energy Research Institute (Korea). Dosimetry was performed using 5 mm diameter alanine dosimeters (Bruker Instruments, Germany), and the actual dose was within $\pm 2\%$ of the target dose. The gamma irradiated beef patties were transferred immediately to a 4 °C refrigerator and analyzed on the next day and after 5 days.

2.2. Analysis of volatiles and lipid oxidation

2.2.1. Volatiles

Volatile compounds of beef patty were determined by solid-phase micro-extraction (SPME) gas chromatograph/mass spectrometry (GC/MS) according to Sohn et al. (2009) and described by Yun et al. (2012). SPME fiber (Supelco, Bellefonte, PA, USA) coated with carboxen/polydimethylsiloxane (CAR/PDMS, 75 μm thickness) was used to adsorb headspace volatiles.

2.2.2. Lipid oxidation

Lipid oxidation was assessed by the TBA method of Tarladgis et al. (1960) with minor modifications. A 10 g sample was blended with 50 ml distilled water for 2 min and then transferred to a distillation tube. The cup used for blending was washed with additional 47.5 ml of distilled water, which was added to the same distillation flask with 2.5 ml 4 N HCl and a few drops of an antifoam agent (KMK-73, Shin-Etsu Silicone Co., Ltd., Korea). The mixture was distilled and a 50 ml distillate was collected. Five ml of 0.02 M 2-thiobarbituric acid in 90% acetic acid (TBA reagent) was added to test tube containing 5 ml of the distillate and mixed well. The tubes were capped and heated in a boiling water bath for 30 min to develop chromogen and cooled to room temperature. The absorbance was measured at 538 nm, against a blank prepared with 5 ml distilled water and 5 ml TBA-reagent, using a UV/vis spectrophotometer (Optizen 2120 UV plus, Mecasys Co. Ltd., Korea). The TBA values were calculated as mg MDA/kg meat. The formula is as follows:

$$\text{TBA (mg MDA/kg meat)} = (\text{optical density of sample} - \text{optical density of blank}) \times 7.8$$

2.3. Statistical analysis

An analysis of variance was performed on all the variables measured using the general linear model (GLM) procedure of the SAS statistical package (2008). Duncan's multiple range test ($p < 0.05$) was used to determine the differences between treatment means.

3. Results and discussion

The effect of soy sauce on volatile compounds of cooked beef patties at 1 day and 5 days after gamma-irradiation is tabulated in Tables 1 and 2, respectively. Generally, it has been recognized that the development of radiolytic off-flavor and odor are greatly associated with the acceleration of lipid oxidation (Champagne and Nawar, 1969) and production of sulfur volatile compounds, such as methyl mercaptan, sulfur dioxide and dimethyl trisulfide (Jo and Ahn, 2000; Patterson and Stevenson, 1995). In this study, sulfur volatile components produced by irradiation were not found in all treatments. Hence, it is assumed that the result might be related to thermal processing prior to irradiation. Similarly, Ahn et al. (1999) noted that a minimum amount of sulfur volatile compounds was detected in cooked irradiated pork sausages (0–4.5 kGy). Further, Kwon et al. (2008) reported that cooking prior to irradiation diminished the production of dimethyl disulfide and dimethyl trisulfide in chicken, beef and pork (0 and 5 kGy). In addition, there is another possibility. Although SPME has been extensively used to determine the flavor of several irradiated meat and meat products, it is reported that SPME method is unsusceptible to detect sulfur components such as dimethyl sulfides and alicyclic sulfides (Madruga et al., 2009). In non-irradiated beef patties at 1 day after gamma-irradiation, the addition of soy sauce affected the formation of volatiles compounds ($p < 0.05$). Cooked