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Effects of irradiation source and dose level on quality characteristics of processed meat products

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HIGHLIGHTS

- The effect of three irradiation source and dose level on meat products was studied.
- The redness was significantly influenced by irradiation sources and dose levels.
- Lipid oxidation, and microbial properties also affected by irradiation sources.

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ABSTRACT

The effect of irradiation source (gamma-ray, electron-beam, and X-ray) and dose levels on the physicochemical, organoleptic and microbial properties of cooked beef patties and pork sausages was studied, during 10 days of storage at 30 ± 1 °C. The processed meat products were irradiated at 0, 2.5, 5, 7.5, and 10 kGy by three different irradiation sources. The pH of cooked beef patties and pork sausages was unaffected by irradiation sources or their doses. The redness of beef patties linearly decreased with increasing dose level ($P < 0.05$), obviously by e-beam irradiation compared to gamma-ray and X-ray ($P < 0.05$). The redness of pork sausages was increased by gamma-ray irradiation, whereas it decreased by e-beam irradiation depending on absorbed dose level. No significant changes in overall acceptability were observed for pork sausages regardless of irradiation source ($P > 0.05$), while gamma-ray irradiated beef patties showed significantly decreased overall acceptability in a dose-dependent manner ($P < 0.05$). Lipid oxidation of samples was accelerated by irradiation depending on irradiation sources and dose levels during storage at 30 °C. E-beam reduced total aerobic bacteria of beef patties more effectively, while gamma-ray considerably decreased microbes in pork sausages as irradiation dose increased. The results of this study indicate that quality attributes of meat products, in particular color, lipid oxidation, and microbial properties are significantly influenced by the irradiation sources.

1. Introduction

Three irradiation sources, namely gamma-ray, electron-beam (e-beam), and X-ray approved for food irradiation by Codex Alimentarius Commission (2003), have been practically used to ensure microbial safety of meat and meat products even under unrefrigerated storage conditions (Roberts, 2014). With such evident advantage, it has been reported that irradiation could negatively impact color, oxidative stability (particularly lipid oxidation), and sensory palatability, depending on the meat source, packaging methods, and irradiation conditions (Brewer, 2004). Gamma-ray and e-beam have been extensively used in not only commercial food sterilizing process but also scientific research determining quality changes in irradiated meat products (Lacroix and Ouattara, 2000).

However, most consumers are still reluctant to purchase gamma-ray irradiated food due to their negative perceptions on the use of radioisotopes (Eustice and Bruhn, 2013). In terms of e-beam irradiation, the low penetration power of e-beam has been noted with locational variation in the irradiation effects on food

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system. (Miller, 2005).

In this regard, X-ray irradiation has received a great attention as an effective means of food irradiation source with some advantages compared gamma-ray and e-beam. The major benefits of X-ray irradiation could be summarized as follows; 1) convenient operation of mechanical system, 2) higher productivity by reducing processing time, and 3) no generation of radioactive waste. In addition, the penetration power of X-ray irradiation is comparable to gamma-ray irradiation (Cleland and Stichelbaut, 2013). Thus, it has been anticipated that X-ray irradiation could be one of ways to considerably improve the negative perception of consumers on irradiated foods (Mitchell, 1994) and to overcome the technical limitations of e-beam irradiation. For these reasons, recent researches have evaluated the effects of the three irradiation sources on quality characteristics of several foods, for better application of food irradiation technology (Jung et al., 2015; Song et al., 2016).

Although the effects of gamma-ray and e-beam irradiations on quality characteristics of meat products have been compared (López-González et al., 2000; Luchsinger et al., 1997; Park et al., 2010), there has been little information on the effects of the three irradiation sources on the quality characteristics of processed meat products at different absorbed dose levels. Therefore, the objective of this study was to evaluate the effects of irradiation source and dose levels on physicochemical, microbial and sensory properties of cooked beef patties and pork sausages.

2. Materials and methods

2.1. Sample preparation

Cooked beef patties and pork sausages were manufactured according to the methods described by Kim et al. (2014b) and Lee et al. (2015), respectively. Beef patties were composed of 80% ground beef (*M. semitendinosus*), 15% pork back fat and 5% ice water. As additives, 1.2% nitrite picking salt (NaCl: sodium nitrite=99.4:0.6), 0.05% sodium triphosphate, 1% sugar, 1% isolated soy protein, 0.1% pepper, 0.1% garlic powder, 0.1% ginger powder, 0.1% onion powder, 0.1% mixed spice (Nuremberg, Raps GmbH & Co., Kulmbach, Germany), and 0.05% L-ascorbic acid were added, based on total sample weight. Raw beef patties were cooked in a 150 ± 1 °C convention oven until the internal core temperature reached 75 ± 1 °C.

Pork sausages were manufactured with 60% ground pork ham (*M. biceps femoris*, *semitendinosus* and *semimembranosus*), 20% pork back fat and 20% ice. The raw materials were emulsified with 1.2% nitrite picking salt, 0.3% sodium triphosphate, 0.5% sugar, 1% isolated soy protein, and 0.4% mixed spice (Bockwurst, Raps GmbH & Co., Kulmbach, Germany) in a bowl cutter. Meat batter was stuffed into collagen casing (#240, NIPPI Inc., Tokyo, Japan; approximately 25 mm diameter), and the pork sausages were cooked in a 75 ± 1 °C smoke chamber for 40 min until the internal core temperature reached 72 ± 1 °C. After cooling for 1 h, all cooked samples were individually vacuum-packaged with nylon/polyethylene bags (15 × 20 cm; thickness, 0.07 cm; 2 ml $O_2/m^2/24$ h at 0 °C) and stored in a 4 °C refrigerator for one day until irradiation process.

2.2. Irradiation procedure

The vacuum-packaged beef patties (approximately 15 mm thickness) and pork sausages (approximately 25 mm thickness) were irradiated at five absorbed dose levels of 0 (control), 2.5, 5, 7.5 or 10 kGy using three irradiation sources under the ambient temperature of 22 ± 2 °C. Gamma-ray irradiation was conducted in a cobalt-60 irradiator (100 kCi, AECL, IR-79, MDS Nordion Inc., Ottawa, Canada) at the Korea Atomic Energy Research Institute (Jeongeup, Korea) with source strength of approximately 11.1 PBq, at dose rate of 10 kGy/h. E-beam and X-ray irradiation were performed using an ELV-4 electron beam accelerator (10 MeV) and X-ray linear accelerator (7.5 MeV) at the EB-Tech Co. (Daejeon, Korea), respectively. E-beam and X-ray irradiation were performed with a beam current of 1 mA and dose rate of 2.9 kGy/s and 5 kGy/h, respectively. For dosimetry of samples, alanine dosimeters (5 mm diameter; Bruker Instruments, Bremen, Germany) were attached to the top and bottom of the samples, respectively. Subsequent to irradiation, the absorbed dose was measured with an electron paramagnetic resonance analyzer in accordance with international standards (ISO/ASTM 51607, 2004). The dose uniformity ratios (min/max ratios) of all irradiation sources were less than 1.2 and the actual dose was within ±5% of the target dose. After irradiation, the irradiated samples were analyzed for quality characteristics on the day and stored in a 30 ± 1 °C incubator for 10 days, to determine changes in lipid oxidation stability and microbial properties under the accelerated storage condition (Park et al., 2010).

2.3. Analysis of quality characteristics

The pH values of the samples were determined using an electronic pH meter (Model 340; Mettler-Toledo GmbH, Schwerzenbach, Switzerland) (Lee et al., 2015). The CIE a*(redness) of samples was measured using a colorimeter (Chroma Meter CR-210; Konica Minolta, Osaka, Japan) (Lee et al., 2015). The hardness of beef patties and pork sausages were measured using a texture analyzer (TA-XT2i, Stable Micro System Ltd., Godalming, Surrey, UK) in accordance with the method of Choi et al. (2015). The sensory evaluation for overall acceptability (1 = not acceptable and 10 = very acceptable) was conducted by 12 trained panels (Kim et al., 2014a); the sample preparation and evaluation procedure were followed by AMSA research guidelines (2015). Lipid oxidation of samples was determined at 0, 3, 7 and 10 days of storage according to the modified TBARS method of Tarladgis et al. (1960) described by Kim et al. (2014b). Total aerobic bacteria and coliform bacteria were determined at 0, 3, 7 and 10 days of storage, using plate count agar and 3 M-Petrifilm *E. coli*/coliform count plates, respectively (Kim et al., 2014a; AOAC International, 2005). All measurements were conducted in triplicate.

2.4. Statistical analysis

Experimental design was a completely randomized design with three independent batches. Analysis of variance (ANOVA) was performed on all the variables measured using the general linear model (GLM) procedure with SPSS software (SPSS Inc., Chicago, IL, USA, 2008). When significant differences were found, Duncan's multiple-range test was used to compare mean values among treatments at a significance level of 95%. Furthermore, simple linear regression analysis for each ionizing source was conducted to determine the level of relationship between the irradiation dose and analyzed variables.

3. Results and discussion

3.1. Physicochemical and sensory properties

The significances of main effects, irradiation source and absorbed dose level, and their interaction, on physicochemical and sensory properties of cooked beef patties and pork sausages are shown in Table 1. No interactions between those main effects on all measurements of cooked beef patties were found ($P > 0.05$),