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Effects of gamma irradiation on physicochemical properties of heat-induced gel prepared with chicken salt-soluble proteins

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HIGHLIGHTS

- The effect of gamma irradiation on salt-soluble meat proteins was investigated.
- Gelling properties of salt-soluble protein affected by gamma irradiation.
- Gamma irradiation of meat products provides a basic resource processing technology.

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ABSTRACT

The technological effects of gamma irradiation (0, 3, 7, and 10 kGy) on chicken salt-soluble meat proteins in a model system were investigated. There were no significant differences in protein, fat, and ash content, and sarcoplasmic protein solubility among all samples. The samples with increasing gamma irradiation levels had higher pH, lightness, yellowness, and apparent viscosity, whereas moisture content, water holding capacity, redness, myofibrillar protein solubility, total protein solubility, hardness, springiness, cohesiveness, gumminess, and chewiness were the highest in the unirradiated control. The result from meat products using gamma irradiation was intended to provide a basic resource processing technology.

1. Introduction

In general gamma irradiation, unlike heat treatment, has been widely applied in medicine and biology in terms of its biological effects induced by the counter-intuitive switchover from low-dose stimulation to high-dose inhibition (Chung et al., 2006). Food irradiation technology has been confirmed as an effective method for the prevention of food spoilage as well as for the control of food pathogens, because the food technology is applied abundantly (Kim et al., 2014). Irradiation for meat and meat products is expected to prolong shelf life during storage. The World Health Organization (WHO) (1999) reported that irradiation up to 10 kGy is generally known to result in no change in the nutritional properties of food or in its safety. According to Jo et al. (1999), in irradiated meat and meat products, irradiation can have an effect on the acceleration of lipid oxidation, discoloration and the decline of sensory characteristics, which can generate negative consumer responses.

The gel formation of muscle proteins is the most important functional property of processed meat products (Wang et al., 1990). The muscle proteins, such as myofibrillar protein (salt-soluble), sarcoplasmic protein (water-soluble) and stroma protein (insoluble), undergo partial denaturation followed by an irreversible aggregation, which results in a three-dimensional network (Lanier et al., 2004). Total muscle protein is composed of approximately 30% myofibrillar proteins, in which the myofibrillar protein commonly results in gel formation due to the heat denaturation of the protein (Wang et al., 1990; Vega-Warner et al., 1999). The gel forms a stable tertiary structure due to a polymerization reaction between the protein molecules, depending on the moisture, salt, protein, pH, actomyosin solubility, and cooking methods (Yasui et al., 1982). Lee et al. (2000) reported the conformational changes of myosin by gamma irradiation. However, the effects of the heat-induced gelation properties of gamma-irradiated chicken salt-soluble protein are not known. Moreover, it is not understood whether the irradiated meat protein interacts with the salt-soluble meat proteins during gel network formation.

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The objective of this study was to investigate the effect of gamma irradiation (0, 3, 7, and 10 kGy) on the proximate composition, water holding capacity, pH, color, protein solubility, apparent viscosity, and textural properties of heated-induced gel prepared with chicken salt-soluble protein in the model systems.

2. Materials and methods

2.1. Protein extraction

Fresh chicken breast meat (broiler, *Muscularis pectoralis major*, 2 wk of age, approximately 1.5–2.0 kg live weight, moisture 74.95%, protein 22.58%, fat 1.09%, ash 1.31%) was purchased from a local processor. The reason for using chicken breast meat was due to its relatively low cost of production, low fat content, and high nutritional value. In addition, chicken meats are very popular among consumers and provide an excellent source of animal protein. The chicken meat was ground initially through an 8-mm plate, and then again ground through a 3-mm plate. The ground tissue was then placed in polyethylene bags, vacuum-packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Seoul, Korea) and stored at 0 °C until required for salt-soluble protein manufacture. The samples were allowed to equilibrate at 2 °C and the meat pH was determined with a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland) after mixing 10 g of ground muscle with 100 ml deionized–distilled water for 1 min. One part meat and two parts 0.58 M saline (0.49 M NaCl, 17.8 mM $Na_5P_3O_{10}$, and 1 mM NaN_3, pH 8.3, 2 °C) solution of the same ionic strength and pH were blended for 30 s in a blender. The slurry was kept at 2 °C for 1 h and then centrifuged (12,000*g*, 2 °C) for 1 h (Supra 25 K high speed refrigerated centrifuge, Hanil Science Industrial, Seoul, Korea). The protein extract was strained through three layers of cheesecloth (Camou et al., 1989). Protein concentrations of the meat solids and supernatant were determined by a nitrogen analyzer (Kjeltec® 2300Analyzer Unit, Foss Tecator AB, Höganas, Sweden). Nitrogen was converted to protein by multiplying by 6.25. Moisture and fat determinations were performed by AOAC (1995) methods.

2.2. Gamma irradiation

The vacuum-packaged ground chicken breast was irradiated at 0, 3, 7, and 10 kGy in a cobalt-60 irradiator (point source, AECL, IR-79, Nordion International, Canada) with source strength of 3.7×10^{12} kBq (100 kCi) in Advanced Radiation Technology Institute of Korea Atomic Energy Research Institute (Republic of Korea). The size of each packaged sample was 8×10 cm^2, and the thickness was below 1 cm. Dosimetry was performed using 5 mm diameter alanine dosimeters (Bruker Instruments, Germany), and the actual dose was within $\pm 2.0\%$ of the target dose. The gamma-irradiated chicken breast (IP) was transferred immediately to a 4 °C refrigerator and stored until gel preparation (for 1 day).

2.3. Gel preparation

Salt-soluble chicken meat protein solutions were diluted to 5% protein with a saline solution of the same pH (6.0) as that of the protein extract, and transferred to glass gelling tubes (dimension=20 mm). The sealed tubes were centrifuged at 800*g* for 15 min at 4 °C to remove air bubbles. The samples were equilibrated at 20 °C for 10 min in a water bath, heated to 90 °C at 1.75 °C/min and held at 90 °C for 20 min. After heating, the tubes were immersed in water overnight at 4 °C (McCord et al., 1998).

2.4. Water holding capacity (WHC)

Water holding capacity (WHC) was measured gravimetrically as described by Kocher and Foegeding (1993) using chicken meat heat-induced gels prepared from four formulations (0, 3, 7, and 10 kGy). Before thermal processing, the sealed tubes were centrifuged at 1000*g* for 15 min at 4 °C to remove air bubbles. Samples were equilibrated at 20 °C for 10 min in a water bath, heated to 90 °C at 1.75 °C/min and held at 90 °C for 20 min after which the resulting supernatant was decanted and weighed. The samples were then stored at 4 °C for 24 h. Gels were centrifuged (Supra 25 K high speed refrigerated centrifuge, Hanil Science Industrial, Seoul, Korea) at 1000g for 15 min at 4 °C. Weights of the centrifuge tubes and the moisture captured within, as well as the filters with the cooked gel, were measured for calculation of the moisture loss and the cooked gel weight. Water holding capacity (%) was expressed using the following formula:

$$\text{WHC } (\%) = [1-(\text{ML}/\text{CG})] \times 100$$

ML is the weight of the moisture loss from the gel after centrifugation and CG is the weight of the cooked gel. Data reported represent mean values from three replicates. Each replicate consisted of three observations per treatment.

2.5. Proximate composition

Compositional properties of the samples were determined using AOAC procedures (1995). Moisture content (950.46B, oven air-drying method) was determined by weight loss after 12 h of drying at 105 °C in a drying oven (SW-90D, Sang Woo Scientific Co., Bucheon, Korea). Fat content (960.69, ether extractable component) was determined by the Soxhlet method with a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Höganas, Sweden), and protein content (981.10) was determined by the Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300Analyzer Unit, Foss Tecator AB, Höganas, Sweden). Ash content was determined according to AOAC method 920.153 (muffle furnace).

2.6. pH determination

The pH values of each sample were measured in a homogenate prepared with 5 g of sample and distilled water (20 ml) using a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). All determinations were performed in triplicate.

2.7. Color evaluation

The color of each gel was determined using a colorimeter (Minolta Chroma meter CR-210, Minolta Co., Osaka, Japan; illuminate C, calibrated with a white plate, $L^*=+97.83$, $a^*=-0.43$, $b^*=+1.98$). Six measurements for each of five replicates were taken. Lightness (CIE L^*), redness (CIE a^*), and yellowness (CIE b^*) values were recorded.

2.8. Protein solubility

Protein solubility was utilized as an indicator of protein denaturation (Joo et al., 1999). Sarcoplasmic protein solubility was determined by dissolving 2 g of muscle powder in 20 ml of ice-cold 25 mM potassium phosphate buffer (pH 7.2). The heat-induced gel samples and buffer were homogenized on ice with a homogenizer (Model AM-7, Nihonseiki Kaisha Ltd., Tokyo, Japan) set at 1500 rpm, and were left to stand on a shaker at 4 °C overnight. The mixtures were centrifuged at 1500*g* for 20 min and the protein concentrations of the supernatants were determined using the biuret method (Gornall