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Effect of irradiation on the parameters that influence quality characteristics of raw turkey breast meat

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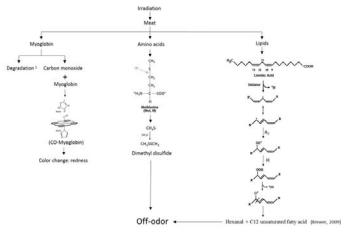
HIGHLIGHTS

- Lipid/protein oxidation was accelerated in raw turkey breast meat by irradiation.
- Redness in raw turkey meat increased after irradiation.
- Volatile profiles of sarcoplasmic proteins were most affected by irradiation.
- Dimethyl disulfide and hexanal are responsible for the irradiation off-odor.

GRAPHICAL ABSTRACT



Mechanisms of color changes and off-odor production in raw turkey breast meat by irradiation

[1]Myoglobin degradation is mainly occurred in raw turkey breast muscle water extracts.

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ABSTRACT

This study was designed to elucidate the mechanisms of quality changes in raw turkey breast meat by irradiation. Raw turkey breast meat was irradiated at 0 kGy, 1.5 kGy, 3.0 kGy and 4.5 kGy, and changes in quality parameters including color, lipid and protein oxidation, and off-odor volatiles were determined. Irradiation accelerated lipid and protein oxidation, and increased redness in raw turkey breast meat. However, irradiation had less effect on the volatile profiles of salt-soluble muscle extract than water-soluble muscle extract because the primary radiolytic product from water (hydroxyl radical) had higher chances to react with the water-soluble molecules nearby. The radiolytic degradation products from sulfur-containing amino acids and aldehydes from lipid oxidation were two major volatile compounds responsible for the off-odor of irradiated raw turkey breast meat. Dimethyl disulfide was found only in irradiated raw turkey breast meat, and the amount of dimethyl disulfide linearly increased as the irradiation dose increased, indicating that this compound can be used as a marker for irradiate meat.

1. Introduction

Irradiation is considered as one of the most effective methods to eliminate potential pathogens and extend the shelf life of meat (Delincée, 1998; Diehl, 2002). However, irradiation breaks water molecules in meat and produces various products including hydroxyl radicals, hydrogen atoms (H^+) and aqueous electrons (e_{aq}-) (Simic, 1983; Thakur and Singh, 1994) and modifies the oxidation-reduction environment within meat (Xiao et al., 2011).

Oxidative deterioration is a major factor that causes quality loss in muscle food products. It also causes economic loss to the processors, nutrient losses to the products, and health risks to the consumers (Jensen et al., 1997). Different meat categories have different resistance to oxidative deteriorations. Fresh muscle tissues have endogenous antioxidants such as antioxidant enzymes (catalase, glutathione peroxidase, and superoxide dismutase) to control the oxidative process *in vivo*, but their antioxidant activities diminish as the time postmortem increases (Xiong, 2000).

Protein (19%) and lipid (2.5%) are the major components of meat and meat products. Muscle protein are generally classified into myofibrillar (salt-soluble), sarcoplasmic (water-soluble), or stromal (insoluble) proteins, while lipids include neutral lipid,

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phospholipids, free fatty acids and fat-soluble substances (Lawrie and Ledward, 2006). All meat products produce characteristic irradiation odor such as "hot fat," "burned oil", "burned feathers", "bloody and sweet", or "barbecued corn-like" odor after irradiation (Hashim et al., 1995; Heath et al., 1990; O'Bryan et al., 2008). Although, sulfur compounds are known as the key volatile compounds to irradiation odor, the perception of irradiation odor changes greatly depending on the composition and amounts of volatile compounds present in the samples. This indicates that the composition of the volatiles generated in the protein and lipid portion of meat or a results of products formed by the interactions between fat and protein during and after irradiation could be important for the characteristics of irradiation odor (Ahn and Lee, 2002). Irradiation also increases redness in light meats by producing carbon monoxide, which binds to myoglobin as a sixth ligand (Nam and Ahn, 2002a). However, the meat components responsible for color changes and off-odor production irradiation odor have not been studied in detail. Moreover, the interactions between lipid and protein oxidation in off-odor production in irradiated meat are still unknown.

The objectives of this study were to 1) evaluate the effect of irradiation on the color and off-odor volatiles of raw turkey breast meat, 2) determine whether water-soluble or salt-soluble muscle fractions are more susceptible to radiolytic degradation and what types of changes are taking place in each of the fractions, 3) determine the effect of irradiation on the production of volatiles from meat lipids using an oil emulsion model system, and 4) elucidate the mechanisms of color changes and off-odor production in raw turkey breast meat by irradiation.

2. Materials and methods

2.1. Sample preparation

2.1.1. Meat samples

Raw turkey breast meat was purchased from a local grocery store and 50-g pieces of meat were individually packaged in vacuum bags (nylon/polyethylene vacuum bags, 9.3 mL O_2/ m^2/24 h at 0 °C; Koch, Kansas City, MO).

2.1.2. Muscle extracts

Raw turkey breast meat was chopped to small pieces and homogenized with 4 volumes of distilled water in a Waring blender for 1 min to extract water-soluble components of meat. The homogenate was centrifuged at 3500x*g* for 30 min and the supernatant was collected. The precipitant was re-extracted with 4 volumes of water and centrifuged as above. The supernatants were pooled and used as a water-soluble fraction (sarcoplasmic proteins) of muscle. The resulting precipitant was homogenized with 4 volumes of 3.5% NaCl solution to extract myofibrillar proteins twice as in water-soluble fraction and the pooled supernatants were used as a salt-soluble fraction of muscle.

2.1.3. Oil emulsion model system:

An oil emulsion was prepared by blending corn oil (1 mL, Sigma) with 100 mL distilled water. Antioxidant (BHA at 0.02% of oil) was added to the oil emulsion to prevent oxidative changes during preparation. All the model system solutions were then transferred to Falcon™ Conical centrifuge tubes, and the headspace was flushed with nitrogen gas for 5 s to minimize oxidation.

2.2. Irradiation

All packages of meat and liquid solutions were irradiated at four target dose levels (0, 1.5, 3.0 and 4.5 kGy) using an electron beam accelerator (Titan Corp., San Diego, CA) with 10 MeV energy and 5.6 kW power level. Alanine dosimeters were placed on the top and bottom surfaces of a package or tubes and read using an Electron Paramagnetic Resonance Instrument to check the absorbed dose. Following irradiation, packaged meat samples and solution were immediately placed in coolers with crushed ice and transported to our Lab and stored at 4 °C. Lipid oxidation, protein oxidation, color and volatiles were determined on the day of irradiation.

2.3. Lipid oxidation and protein oxidation

Lipid oxidation were measured using the thiobarbituric acid reactive substances (TBARS) method of Wang et al. (2012). The amounts of TBARS were calculated as milligrams (mg) of malondialdehyde (MDA) per kilogram (kg^{-1}) of meat. Protein oxidation was determined using the 2,4-dinitrophenylhydrazine (DNPH) derivatization method (Lund et al., 2008). The carbonyl content was calculated and expressed as nmoles per milligram of protein using an absorption coefficient of 22,000 M^{-1} cm^{-1} (Levine et al., 1994).

2.4. Color measurement

The color was measured using a Konica Minolta Color Meter (CR-410, Konica Minolta, Osaka, Japan). The colorimeter was calibrated using an illuminate source C (Average daylight) on a standard white ceramic tile covered with the same film as the ones used for meat samples to negate the color and light reflectance properties of the packaging material. The areas selected for color measurement were free from obvious defects that may affect the uniform color readings. When the color of water-soluble muscle fraction was measured, the colorimeter was calibrated with the ceramic tile, but a plastic container with 15 mL distilled water was located in the center of the tile to negate the color and light reflectance properties of the container materials and blank solution. An aluminum foil was used to cover around the colorimeter and containers to prevent interferences from other light sources. Fifteen milliliter sample solution was transferred to an empty container for each color reading. The color was expressed as CIE L*-(lightness), a*-(redness), and b*-(yellowness) values.

2.5. Volatile compounds

Volatiles of samples were analyzed using a Solatek 72 Multimatrix-Vial Autosampler/Sample Concentrator 3100 (Tekmar-Dohrmann, Cincinnati, OH, USA) connected to a GC/MS (Model 6890/5973; Hewlett-Packard Co., Wilmington, DE, USA) according to the method of Nam et al. (2007). Sample (raw meat: 3 g; solution: 2 mL) was placed in a 40 mL sample vial, flushed with nitrogen gas (40 psi) for 3 s, and then capped airtight with a Teflon*fluorocarbon resin/silicone septum (I-Chem Co., New Castle, DE, USA). The meat sample was purged with He (40 mL/min) for 12 min at 40 °C. Volatiles were trapped using a Tenax/charcoal/silica column (Tekmar-Dohrmann) and desorbed for 2 min at 225 °C, focused in a cryofocusing module (−80 °C), and then thermally desorbed into a column for 2 min at 225 °C. An HP-624 column (7.5 m, 0.25 mm i.d., 1.4 μm nominal), an HP-1 column (52.5 m, 0.25 mm i.d., 0.25 μm nominal), and an HP-Wax column (7.5 m, 0.250 mm i.d., 0.25 μm nominal) were connected using zero dead-volume column connectors (J &W Scientific, Folsom, CA, USA). Ramped oven temperature was used to improve volatiles separation. The initial oven temperature of 25 °C was held for 5 min. After that, the oven temperature was increased to 50 °C at 5 °C per min, increased to 120 °C at 30 °C per min, increased to 160 °C at 15 °C per min and then increased to 200 °C at 5 °C per