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Effect of different irradiation dose treatment on the lipid oxidation, instrumental color and volatiles of fresh pork and their changes during storage

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Nonanal (PubChem CID: 31289)
Acetophenone (PubChem CID: 7410)
1-Octen-3-ol (PubChem CID: 18827)
3-Tetradecene, (E)- (PubChem CID: 5352802)
Benzene, 1,3-bis(1,1-dimethylethyl)- (PubChem CID: 136810)
Benzyl methyl sulfide (PubChem CID: 13016)
Trichloroacetic acid (PubChem CID: 6421)
Thiobarbituric acid (PubChem CID: 2723628)
Boron trifluoride (PubChem CID: 6356)
Eicosane (PubChem CID: 8222)

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ABSTRACT

This study mainly investigated the effect of different doses irradiation (0, 3, 5 or 7 kGy) on the quality changes of pork during 4 °C storage by determining the irradiation off-odor intensity, thiobarbituric acid reactive substances (TBARs), fatty acid composition, volatiles and color of the samples during whole storage. The results showed that ≥7 kGy irradiation could make the samples produce obvious irradiation off-odor. However, after 7 days storage irradiation off-odor was reduced. Lipid oxidation was also promoted by irradiation. Benzyl methyl sulfide was produced newly and significantly increased ($P < 0.05$) by irradiation. Fatty acids in pork samples decreased significantly with irradiation dose increase within the range of <7 kGy, but significantly increased ($P < 0.05$) in samples of 7 kGy. Irradiation significantly increased the a* values regardless of storage time but had little effects on b* and L* values, and the increase of a* values was dose-dependent.

1. Introduction

Irradiation has emerged as an efficient technology that increases the microbiological safety (pathogens, parasites) of foods. And up to now, it has been considered to be most thorough non-thermal decontamination methods for foods (Mirmoghtadaie, Aliabadi, & Hosseini, 2016). When the foods are irradiated there will be many free radicals generated, which could cause the changes of food components, such as the lipids and proteins in meat (Ahn & Lee, 2004). So, although irradiation is a very effective cold sterilization technique, its utilization in meat or meat products was restricted. Ahn and Lee (2004) have demonstrated that many chemical changes and quality changes in irradiated meat were associated with free radical reactions, such as lipid and protein oxidation, which consequently caused the odor and color changes of meat. In addition, DNA could also be damaged by irradiation (Şakalar & Mol, 2015).

Lipid oxidation is known to generate aldehydes, ketones, hydrocarbons, esters, furans, and lactones, which can be responsible for rancid flavors and sensory defects during improper meat processing and storage. Jo and Ahn (2000) suggested that the lipolysis and lipid oxidation by the radiation played the key role in off-odor formation of irradiated meat. However, Du, Hur, and Ahn (2002) suggested that lipid oxidation

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immediately after irradiation is not the major contributor to off-odor of irradiated chicken due to the low concentrations of hexanal and pentanal (grassy, pungent), together with low TBARS. Furthermore, Lee and Ahn (2003) reported that volatiles from lipids accounted for only a small part of the irradiation odor. In their study, the amounts of many volatiles from the PUFAs emulsions were decreased by irradiation due to the secondary chemical reactions with direct radiolytic products, which consequently changed volatile profiles of fatty acid emulsions by irradiation. Till now, some researchers have investigated the effect of storage time on the volatiles profile, sensory characteristics, and lipid oxidation as a step toward understanding the mechanisms of off-odor production and changing in irradiated meat. However, less is known about the stability of lipid radiolytic products such as fatty acids over the storage period. Moreover, there were also scanty information about the contribution of potential secondary chemical reactions among volatiles to irradiation odor during storage time.

The color in irradiated meat is also important because they determine the ultimate consumer acceptance of irradiated meat. Many factors, such as the concentration of heme pigments (myoglobin in particular), oxidation status, ligand formation of heme pigments, and physical characteristics (irradiation dose, pH, temperature, storage time) of meat can contribute to variation in irradiated meat color (Brewer, 2004). Generally, irradiation improved the a* (redness) value of chicken thigh meat (Xiao, Zhang, Lee, Ma, & Ahn, 2011). Nam and Ahn (2002) suggested that red color changes induced by irradiation were related to carbon monoxide (CO) production during irradiation. Ramamoorthi, Toshkov, and Brewer (2011) reported that CO-modified atmosphere packaging packaged beef irradiated at <1.0 kGy showed visually redder and had higher a* values than those irradiated at higher doses. However, less information is about the color modification in irradiated meat during storage time.

Irradiation-induced oxidative chemical changes are dose dependent, and the presence of oxygen has a significant effect on the rate of oxidation of lipids and myoglobin in the muscle system (Zhu, Mendonca, Lee, & Ahn, 2004). Kim et al. (2012) reported that no significant changes in the thiobarbituric acid reactive substances values (TBARS) of dry fermented sausages irradiated at 2 and 4 kGy during refrigerated storage were observed. However, Kang, Park, and Ha (2016) showed that the levels of TBARS in irradiated half-dried seafood products increased as the dose was increased (from 3 kGy to 10 kGy). Therefore, the main objective of this study was to investigate the influence of irradiation dose on lipid oxidation, apparent color and volatiles changes of raw chilled pork prepared with vacuum-packaging during storage. The results of this study will provide theoretical guidance for the irradiation technology utilization in raw chilled pork preservation industry.

2. Materials and methods

2.1. Sample preparation

Hindquarter muscle from pig were obtained within 24 h after slaughter from a local supermarket and immediately transported to the lab in chilled condition. Muscle strips (8 per treatment per time point), approximately 50 mm long, 40 mm wide and 15 mm thick, were prepared and loaded into four sterile insulated boxes with labels for each irradiation dose level.

2.2. Irradiation and vacuum-packaging

The loaded samples were irradiated in insulated boxes containing ice in a Food Package Irradiator (HIEC, Hubei, China) with a ^{60}Co source at a dose rate of 3.4 kGy/h. The samples received average doses of 0, 3, 5 and 7 kGy. Having received irradiation, samples were immediately transported back to the laboratory, then vacuum packaged (−1.0 bar) using a vacuum packager (DZ-300, Wuhan Yiteng Machinery Co., Ltd) into the impermeable nylon/polyethylene compound bags (n = 3 replication/bag), and eventually stored up to two weeks at 4 ± 1 °C. Samples were removed from the display refrigerator every 0, 3, 7, 11 and 14 days of storage. Zero-day samples were analyzed 3 h after irradiation.

2.3. Instrumental color

Instrumental color (CIE L*, a*, b* color coordinates, where L* is the relative lightness, a* is the relative redness and b* is the relative yellowness) were determined using MINOLTA Chroma Meter CR-410 (Minolta Co., Ltd., Osaka, Japan) using D-65 lighting, a 2° standard observer angle and an 8-mm aperture in the measuring head. Nine measures of surface color were performed on each group of samples. In addition, hue angle (H*), chroma (C*) and overall color change (ΔE) were calculated based on L*, a* and b* results.

For authentic apparent color observation, a self-made capture image system consisted of a LED device (Fig. 1A) and a Nikon D7100 digital camera (Nikon Corp., Tokyo, Japan). Pork fillets were removed from the vacuum bags and placed in the lighting box, and the digital camera captured a picture of the fillets for each treatment.

2.4. Thiobarbituric acid reactive substances (TBARS) measurement

TBARs values were measured according to the method of Salih, Smith, Price, and Dawson (1987) with tiny modification. One grams of minced pork were weighed into a 50 mL centrifuge tube and homogenized with 20 mL trichloroacetic acid (TCA) and 10 mL of deionized distilled water (DDW) using a Polytron homogenizer for 60 s at high speed.

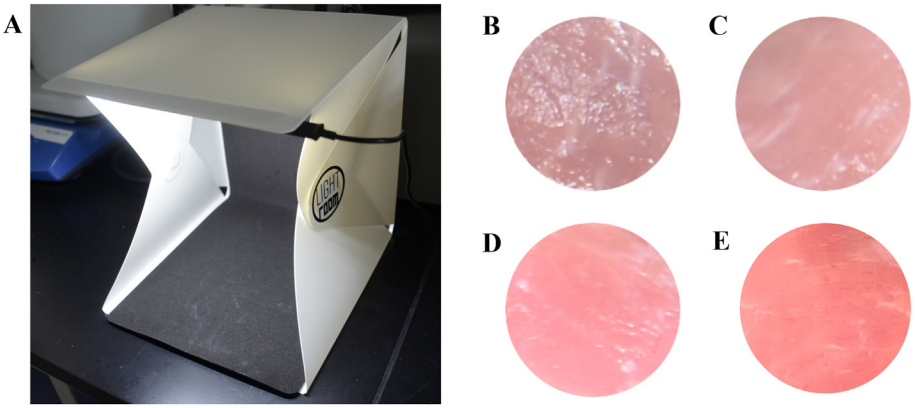

Fig. 1. Pork color image acquisition system with LED device (A). Different apparent color patterns among control (B) and sample irradiated at 3 kGy (C), 5 kGy (D) and 7 kGy (E).