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Effect of tempering methods on quality changes of pork loin frozen by cryogenic immersion

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ABSTRACT

The quality characteristics of pork loin frozen by cryogenic immersion were examined, such as the drip loss, cooking loss, water holding capacity, moisture content, protein solubility, lipid and protein oxidation, color, and microstructure, and compared after different tempering methods: radio frequency (27.12 MHz), water immersion, forced-air convection, and microwave tempering. Forced-air tempering was the most time-consuming process, whereas electromagnetic energy methods (radio frequency and microwave) were the shortest. The tempering rate of radio frequency at 400 W was 5 and 94 times greater than that obtained with water immersion and forced-air tempering, respectively. The drip loss, water holding capacity, moisture content, color, and microstructure of pork samples all declined as a result of microwave tempering. By contrast, the least degree of changes in the drip loss, microstructure, and color of the pork loin samples was obtained with radio frequency tempering, suggesting its potential application in providing rapid defrosting without quality deterioration in the frozen meat industry.

1. Introduction

Meats are highly perishable food commodities due to their biological composition (Leygonie, Britz, & Hoffman, 2012). The shelf life of refrigerated meat products is limited owing to high microbial growth and enzymatic activities. Therefore, freezing is an important and widely applied preservation method for ensuring the safety and retaining the quality of meat products for long storage periods (Boonsumrej, Chaiwanichsiri, Tantratian, Suzuki, & Takai, 2007; Cai et al., 2014).

In general, rapid freezing has been recommended to ensure appropriate control of the size and location of ice crystals within raw meats that form during the freezing process (Anese et al., 2012; Zhu, Ramaswamy, & Simpson, 2004). Ice crystals that form during the ice–water phase transition disintegrate tissue membranes, resulting in moisture exudation during defrosting (Anese et al., 2012; Choi, Min, & Hong, 2016). Among the possible quick-freezing methods, ethanol immersion freezing technology has been recently introduced as a new cryogenic liquid freezing method (Liang et al., 2015).

Frozen meats must be defrosted before further processing or consumption (Taher & Farid, 2001). Tempering frozen meat is an important step in the meat processing industry before other applications such as slicing or dicing to reduce the size of meat materials (Jo et al., 2014). For example, frozen pork is used as the main raw material in sausage manufacturing and requires tempering for grinding and casing (Uyar et al., 2015). The quality of frozen meats is closely related to the freezing and defrosting conditions applied. Defrosting generally occurs more slowly than freezing, and longer defrosting times may promote microbial growth on the meat products, reduce protein solubility, and increase energy consumption (Icier, Izzetoglu, Bozkurt, & Ober, 2010; Oliveira, Gubert, Roman, Kempka, & Prestes, 2015; Uyar et al., 2015). Therefore, optimum defrosting procedures should be of concern to food technologists.

Different systems using water, air, vacuum heat, microwave, and infrared light have been applied for defrosting frozen meat, and each method is associated with unique problems (Beauchamp et al., 2010; He, Liu, Nirasawa, Zheng, & Liu, 2013). Although microwave defrosting has been largely adopted in households, its adoption in the industrial production of frozen meats has been limited due to the low penetration depth resulting in localized overheating (Boonsumrej et al., 2007; Brunton et al., 2005). To overcome these problems, it is essential to develop a defrosting method that can maintain the quality and avoid undesirable changes in the frozen meat, while obtaining a fast defrosting rate.

Radio frequency (RF) defrosting is an innovative dielectric technique that generates heat energy within food products due to ionic displacement, leading to direct conversion of electric energy to heat, a phenomenon often referred to as volumetric heating (Rincon & Singh, 2016).

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The dielectric properties, shape, and size of the foods, and the location and distance between RF parallel plate electrodes are important factors contributing to the temperature uniformity in RF-treated foods (Uyar, Erdogdu, & Marra, 2014).

Although several researchers (Choi et al., 2016; Leygonie et al., 2012; Mortensen, Andersen, Engelsen, & Bertram, 2006; Park, Mijan, & Song, 2014) have studied the effects of various freezing technologies on meat qualities, less is known about the quality effect of the combined application of rapid freezing and defrosting meat. In addition, many inconsistencies exist in the literature regarding the combined effect of freezing and defrosting on the color, oxidation susceptibility, and microbiological shelf life of meat products. More research into the combined effects of freezing and tempering is thus essential.

Therefore, this study was performed to examine the effects of six different tempering conditions, including RF (200 W, 300 W, 400 W), forced-air convection, water immersion, and microwave, on the quality characteristics of quick-frozen pork loin.

2. Materials and methods

2.1. Materials

Fresh pork loin (5 carcasses at 24 h post-mortem) were purchased from a local market in Gwangju on the first day of distribution and transported to the laboratory within 20 min. All visible fat and connective tissues were removed prior to the experiment.

For the present investigation, the pork loin (*longissimus thoracis et lumborm*) was selected because it contains large, relatively uniform muscle cells with similar muscle fiber orientation and a relatively uniform chemical composition throughout the tissue. In addition, many commercially prepared, thermally processed, ready-to-eat pork meat products are made with frozen pork loin meat, making this analysis directly relevant for broad industrial application.

2.2. Proximate analysis

The chemical constituents of the fresh pork loin samples were determined according to the official methods of the Association of Official Analytical Chemists (AOAC, 1990). In brief, moisture content was determined by oven-drying a 2 g test sample at 110 °C to a constant weight, ash content was determined by igniting a 5 g test sample in a muffle furnace at 550 °C until light grey ash was observed, crude protein content was measured by the classical macro-Kjeldahl method, and the crude lipid content was measured by petroleum ether extraction using a Soxhlet apparatus.

2.3. Cryogenic immersion freezing

The fresh pork loin muscles were cut into blocks (100 × 100 × 70 mm) using a sterilized knife, and each pork loin sample was separately vacuum-packed using a vacuum-sealing machine (FR-B100WB, CES Co., Siheung, Korea) and polyethylene bags with a thickness of 0.12 mm.

Cryogenic immersion freezing was carried out using an immersion instant freezer (F-500, Top Greentech Co., Seoul, Korea) equipped with a coolant including 95% ethanol and 5% fluoride, and a jet agitation regulator device. The coolant temperature was maintained at −70 ± 2 °C. Vacuum-packed pork meat samples were fully immersed and frozen in the immersion freezer with the coolant at −70 °C for 30 min. The frozen samples were adjusted to the target initial temperature inside a freezer at −20 °C for 48 h prior to the experiment.

2.4. Tempering

The frozen pork samples were tempered using four different techniques: RF, forced-air, water immersion, and microwave. A parallel-plate RF system (FRT-5, Yamamoto Vinita Corp., Ltd., Osaka, Japan) was used for RF tempering, with a 5-kW RF generator and a 50-Ω automatic impedance matching network, and a controller set at a frequency of 27.12 MHz. This system had a metallic enclosure, generator, power amplifier, matching unit, and an RF applicator with a pair of rectangular electrodes (750 mm × 500 mm). A plastic board (800 mm × 600 mm) was placed above the bottom electrode to avoid direct contact between the sample and the bottom electrode. The samples were sandwiched between the top electrode and the bottom electrode and tempered at three different power levels (200 W, 300 W, and 400 W) for 5–30 min, using a 30-mm electrode gap. The RF power (oscillation output) was set automatically by controlling the voltage to the power amplifier from the generator. An unmatched network would trigger an emergency system shutdown to prevent electrical hazards and to protect the electronic components.

Forced-air convection tempering was performed in a thermo-hygrostat system (SH-202 M, Human Corporation, Seoul, Korea) with controlled temperature (15 °C ± 1 °C) and humidity (90 ± 5% relative humidity), which had a measured air velocity of 1.5 m/s determined using an anemometer (LM-8000A, Lutron Electronic Enterprise Co., Taipei, Taiwan). Water immersion tempering was performed by submerging the frozen pork samples in a water bath (VS-1205SW1, Vision Scientific Co., Bucheon, Korea) at 15 °C with forced agitation.

Microwave tempering was carried out in a microwave oven at 2450-MHz (MW231UW, LG Electronics Co., Changwon, Korea) equipped with a turntable and 700-W magnetron. The frozen pork samples were placed on a tray at the center of a turntable.

2.5. Determination of tempering time and tempering rate

The tempering time and tempering rate of frozen pork samples were analyzed according to the method of Mousakhani-Ganjeh, Hamdami, and Soltanizadeh (2015) with some modification. To record the temperature changes during tempering, a button temperature logger (SL52T, Signatrol Ltd., Tewkesbury, UK) wrapped with 0.07-mm copper foil tape with an acrylic polymer adhesive (to shield the electromagnetic waves) was inserted at the geometric center in the *x*, *y*, and *z* directions (used as the tempering endpoint in tempering experiments) of the fresh pork block before cryogenic immersion freezing. The time required to raise the temperature at the center of the frozen pork sample from −20 °C to −2 °C was determined as the tempering time. In the present investigation, the endpoint temperature of tempering was set to approximately −2 °C, because this is the temperature typically used in the meat industry for the handling and manipulation of tempered meat blocks. The tempering rate of the frozen pork samples was then calculated by dividing the sample weight by the thawing time (g/s) as follows:

$$\text{Tempering rate} = \text{weight of frozen pork}/\text{tempering time} \tag{1}$$

2.6. Determination of drip loss and cooking loss

Drip loss was determined by weighing the frozen and tempered pork samples before and after the removal of surface water according to the following equation:

$$\text{Drip loss }(\%) = \mathrm{M_0 - M_T / M_0} \tag{2}$$

where M_0 and M_T are the weights of the frozen pork and the thawed pork, respectively.

For cooking loss, 10 g of the tempered sample was placed in a polyethylene bag and cooked at 75 °C in a water bath for 25 min until the