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Effects of pressure-shift freezing conditions on the quality characteristics and histological changes of pork

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ABSTRACT

This study investigated the effect of various pressure-shift freezing (PSF) conditions (0.1–200 MPa) on the quality characteristics of pork. Pork was pressurized and cooled down to corresponding freezing temperature at given pressure level, and thereafter, the pork was finally frozen in a −50 °C freezer for 24 h. The frozen pork was thawed in a 4 °C refrigerator for 24 h, and quality parameters were analyzed. As quality parameters, pH, water-binding properties, shear force, histological change and color were evaluated. The PSF operating at higher pressure than 150 MPa manifested high moisture loss and discoloration, while the PSF at 50 MPa had no advantageous effect on the quality of pork compared to atmospheric freezing (0.1 MPa). The best PSF condition was observed at 100 MPa, where the pork quality did not differ from an unfrozen control after thawing. Consequently, the results reflected that PSF at 100 MPa had a potential application in providing rapid freezing without quality deterioration in the frozen meat industry.

1. Introduction

Freezing has been recognized as the most effective preservative method for meat. Meat quality is closely related to freezing conditions, particularly the freezing rate (Grujić, Petrović, Pikula, & Amidžić, 1993). Ice crystals that form during the ice-water phase transition disintegrate tissue membranes, thereby manifesting moisture exudation (namely, drip loss) during thawing. Therefore, rapid freezing has been recommended. To accelerate the freezing rate, various novel technologies have been introduced, including cryogenic freezing, individual quick freezing, and deep freezing (Boonsumrej, Chaiwanichsiri, Tantratian, Suzuki, & Takai, 2007; Szymońska, Krok, & Tomasik, 2000). In these technologies, the cooling temperature plays a key role in meat freezing. Based on the nature of heat transfer, the heat involved in the meat body is transferred from the inside to the outside of the meat. This phenomenon reflects different freezing rates at the surface, intermediate areas and center of the meat, even if rapid freezing is applied (Sanz et al., 1999).

High-pressure processing has potential applications in the fields of preservation, texturization and freezing (Cheftel & Culioli, 1997). Currently, it has been commercialized as a non-thermal pasteurization or a textural modification technique of meat. From the freezing point of view, high pressure provides three different freezing methods depending on the applied pressure and temperature conditions. According to the definition of Urrutia Benet, Schlüter, and Knorr (2004), high-pressure freezing is classified as pressure-induced freezing, pressure-shift freezing (PSF) or pressure-assisted freezing. Among these methods, PSF has been evaluated as an effective rapid freezing technique (Fernández, Otero, Guignon, & Sanz, 2006). It was reported that the freezing point of water depressed to −20 °C with increasing pressure up to 210 MPa. Upon depression, water undergoes a drastic phase transition that results in instantaneous freezing. Actually, this phenomenon is divided into two processes, i.e., an increase in temperature from a super-cooled state (−20 °C) to the freezing point (~0 °C) due to release of latent heat (primary freezing), followed by an ice-water phase transition and the end of freezing (secondary freezing) (Fernández et al., 2006). Foods subjected to PSF showed less tissue damage compared to commercially frozen food (Chevalier, Sequeira-Munoz, Le Bail, Simpson, & Ghoul, 2000). It was found that the amount and size of ice crystals were closely related to the extent of supercooling and the duration of the phase

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transition, respectively (Fernández et al., 2006). To obtain the greatest supercooling extent, PSF of foods has generally been conducted at 200 MPa as reported in most of the literature (Fernández-Martín, Otero, Solas, & Sanz, 2000; Otero, Martino, Zaritzky, Solas, & Sanz, 2008; Tironi, LeBail, & de Lamballerie, 2007), while little information regarding the effect of the extent of supercooling on meat quality is available.

In the case of meat, high pressure is known to promote discoloration mainly due to denaturation of globin and/or oxidation of meat pigment proteins (Carlez, Veciana-Nogues, & Cheftel, 1995). It was likely that the discoloration was more intensely observed in PSF than in over-zero temperature high-pressure processing because PSF required more holding time to chill the meat body. Alternately, it was identified that moderate pressurization (80–100 MPa) improved meat color and color stability during storage (Cheah & Ledward, 1997; Chun, Min, & Hong, 2014). In over-zero temperature processing, moderate pressurization did not attract any attention because this processing had no effect on texturization and/or preservation of the meat. Conversely, relatively low pressure levels in PSF would have a potential advantage in commercial applications as the primary freezing technique. In particular, the PSF under moderate pressure levels would enable minimization of the quality deterioration, such as meat discoloration. Consequently, this study investigated the effects of PSF at various pressure levels (0.1–200 MPa) on the quality characteristics and histological changes of pork.

2. Materials and methods

2.1. Materials

Pork loins (*M. longissimus thoracis et lumborum*) from six domestic half-carcasses (crossbreed of Landrace × Yorkshire × Duroc, 6-month-old hogs) with pH 5.6–5.8 were selected at 24 h postmortem from a local meat market. All visible fat and connective tissues were trimmed off, and six strips (6 × 6 × 15 cm) with fiber parallel to the muscle were taken from each loin and weighed. The meat strips were separately vacuum-packaged with poly nylon pouches (Nylon/Poly ethylene coextrusion, thickness of 30–300 μm) and stored in a 4 °C refrigerator prior to treatment for less than 2 h. The whole sampling procedure was repeated on three different days (n = 3). All chemicals used for analyses were of analytical grade.

2.2. Treatment

One sample strip from each loin was allocated to each treatment. Total 6 strips were used for each treatment, and one group was kept in a 4 °C refrigerator for 48 h (untreated fresh control). The other five groups were frozen under PSF conditions of 0.1 (atmospheric freezing), 50, 100, 150 and 200 MPa (Fig. 1). The PSF was applied using a lab-assembled high-pressure system as described in our previous study (Hong, Ko, Choi, & Min, 2008), with ethanol as a pressure-transmitting medium. The compression and depression rates were 2.7 and 20 MPa/s, respectively. Each group was placed in a pressure vessel (working volume of 1 L), and the vessel was cooled down to the corresponding freezing point of pork using circulating −50 °C ethanol. Based on our previous study (Hong, Ko, Choi, & Min, 2006), the freezing point of pork was estimated to be −1.4 °C (0.1 MPa), −4.2 °C (50 MPa), −8.9 °C (100 MPa), −14.1 °C (150 MPa), and −21.2 °C (200 MPa). When the inner vessel temperature reached the corresponding freezing point of meat, the pressure was removed (primary freezing). The total pressure holding time was expressed as the duration prior to depression and was estimated to be 17.3 min (0.1 MPa, cooling time only) 39.9 min (50 MPa), 48.2 min (100 MPa), 72.4 min (150 MPa), and 114.4 min (200 MPa). Immediately after depression, the samples were transferred to a −50 °C deep freezer (secondary freezing) and stored for 24 h. For analysis, all frozen samples were thawed in a 4 °C refrigerator for 24 h.

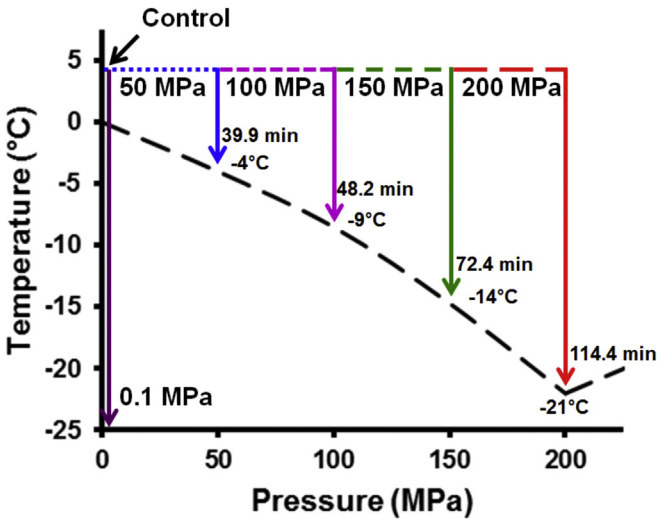

Fig. 1. Experimental design and pressure-shift freezing conditions. The dashed line indicates freezing point of pork meat.

2.3. Sampling

From the six strips of each treatment, three strips were randomly selected, and a 1-g portion of each strip was aseptically sampled to determine the total plate count (TPC). A small piece of meat was also taken from each strip and immersed into 2 g/100 mL formalin prior to histological observation (~12 h). After measuring the color, the remaining portion of meat was used for pH and water-holding capacity (WHC) measurements. The other three strips were used to determine drip loss, cooking loss and shear force.

2.4. pH

Five-gram samples from three sample strips were added to 20 mL of distilled water and homogenized for 3 min. The pH of the samples was determined using a pH meter (Model S220, Mettler Toledo GmbH, Greifensee, Switzerland) calibrated with pH 4 and pH 7 buffer solutions (Daejung Chemicals & Metals Co., Ltd., Shiheung, Korea).

2.5. Thawing loss and cooking loss

Prior to freezing, fresh meat strips were weighed. After thawing (after 48 h for control), the surface exudate was gently wiped out using a tissue, and the meat sample was weighed again. Thawing loss was expressed as a percentage ratio of the thawed weight to the initial weight of the sample. Drip loss of control stored at 4 °C for 48 h was compared with thawing loss of treatments. The meat strips were separately packaged again using a plastic bag and cooked in a 75 °C water bath for 30 min. The cooked meat was cooled at ambient temperature (~18 °C) for 30 min, and the surface exudate was also wiped out. The cooking loss was determined from the percentage weight ratio of before versus after cooking.