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Effects of high hydrostatic pressure on the quality and safety of beef after the addition of conjugated linoleic acid

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ABSTRACT

We evaluated the effect of high pressure (HP) for infusing of conjugated linoleic acid (CLA) on the quality and storage stability of beef loin. To beef loins in a bag before sealing, CLA alone (1%; CLA), CLA + 0.15% lecithin (CL), or CL + 0.001% α-tocopherol (CLT) were poured into the bag, vacuum-packed, and HP-treated with 0.1, 300, 450, and 600 MPa for 5 min. CLA level, cooking loss, and pH were significantly increased, when pressure increased from 0.1 to 600 MPa. Increases in pressure levels and storage periods increased TBARS about 1.04 and 3.85 fold values. Total aerobic bacteria were not detected in HP treated samples (450 and 600 MPa). CL or CLT with HP (300 MPa) caused higher overall acceptance and willingness to buy. Hence, the addition of CLA with HP (300 MPa) can improve the nutritional and microbiological quality of beef loin with acceptable sensory quality.

Industrial relevance: High pressure (HP) processing is a safe and consumer-friendly preservation technology that can eliminate pathogenic and spoilage microorganisms and extends product shelf-life without detrimental effects of thermal processing or use of preservatives or additives. However, meat with lower intramuscular fat content can be rejected by some consumers due to the lack of suitable sensorial qualities. On the other hand, meat with higher intramuscular fat content, beef in particular, may also cause consumers' concern because of the elevated level of saturated fatty acids. This particular study demonstrated that HP in combination with the infusion of CLA can be used for the enhancement of nutritional and microbiological quality of beef. Based on the results, it can be suggested that not only the infusion of CLA but also other oils originated from plants in combination with HP treatment can modify fatty acid composition.

1. Introduction

Recent trends in meat consumption patterns have shown that commensurate with higher national incomes and improved living standards, more emphasis has been placed on the quality and health aspects of meat products. Recently, research into the fortification of meat and meat products with various biological supplements has been conducted (Kearney, 2010).

There has been an increased interest in food containing higher levels of polyunsaturated fatty acids (PUFAs) as they are considered to be functional ingredients in the prevention of coronary heart disease and other chronic diseases (Russo, 2009). Dietary conjugated linoleic acid (CLA) is of particular interest due to its beneficial effects on human health (Poulson, Dhiman, Ure, Cornforth, & Olson, 2004; Schmid, Collomb, Sieber, & Bee, 2006). CLA has been recognized as having anticarcinogenic and antioxidative properties in several animal models (Joo, Lee, Ha, & Park, 2002). In addition, Hur et al. (2004) reported that the CLA concentration was significantly increased by the addition of a substituted CLA source of fat. Substituted CLA fat sources improved the color stability, possibly by the inhibition of lipid and myoglobin oxidation (Fernández-Ginés, Fernández-López, Sayas-Barberá, & Perez-Alvarez, 2005).

Schmid et al. (2006) showed that the CLA content of pork, chicken, and horse meat is usually lower than 1 mg/g lipid. The highest CLA concentrations were found in beef (1.2 to 10.0 mg/g lipid) and lamb (4.3 to 19.0 mg/g lipid). Given that the daily ingestion of 3 g of CLA is effective for reducing body fat (Blankson et al., 2000), the CLA content in beef is considered insufficient to affect various physiological functions in the human body.

Lecithin is used in a wide variety of products including processed food, cosmetics, and pharmaceuticals. Commercial sources are predominantly vegetable oil seeds such as soybeans and sunflower seeds; however, for pharmaceutical and some dietary applications, egg yolk is also an important source of lecithin (Yamamoto & Araki, 1997). Lecithin is a source of omega-3 and essential fatty acids, which are low

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in most peoples' diets. The particular function of lecithin acts as an emulsifying agent within the digestive system, and it is added to food products as an emulsifier and stabilizer (Martín-Hernández, Bénet, & Marbin-Guy, 2005). Therefore, lecithin is expected to help CLA penetration, which can be inhibited by hydrophilic groups in meat such as sarcoplasmic protein or moisture.

High pressure (HP) processing is an attractive preservation technology that eliminates pathogenic and spoilage microorganisms and extends the shelf life of foods but has minimal effect on nutritional quality (Rubio, Martinez, Garcia-Gachan, Rovira, & Jaime, 2007). It therefore has a good potential for application in the meat industry (Garriga, Grèbol, Aymerich, Monfort, & Hugas, 2004; Kruk et al., 2011). HP is accepted as safe and consumer-friendly due to its capacity to eradicate microorganisms, regardless of the geometry of the product, without the formation of heat damage modification and the use of preservatives or additives (Rastogi, Raghavaro, Balasubramaniam, Niranjan, & Knorr, 2007; Zhang & Mittal, 2008). Sorenson et al. (2011) reported that HP could improve the eating quality of a chilled ready meal manufactured using a low-value beef cut, such as beef brisket. Recently, Jung et al. (2012) and Kruk et al. (2014) reported that HP enabled the penetration of vegetable oils into beef loin changing the fat content, fatty acid composition, and sensory quality. However, HP processing may accelerate lipid oxidation and change the color of the meat (Kruk et al., 2011).

Therefore, the objective of this study was to investigate the effect of HP treatment after adding CLA to low-grade beef, in order to develop manufacturing methods of higher valued meat products with increased safety and enhanced functionality. We aimed to increase the effect of CLA penetration into the meat by using lecithin, and α-tocopherol (TP) was added to inhibit accelerated oxidation arising from the implementation of lecithin and HP.

2. Materials and methods

2.1. Sample preparation

Beef loin (Korean beef quality grade 2) was purchased from a local market in Daejeon, South Korea, CLA (79% purity) was obtained from Lipozen Co., Hwaseong, Korea, and lecithin (LC grade) was derived from, Goshenbiotech Co., Namyangju, Korea. TP was purchased from Futurebiotics Co. (Torrance, USA). Vacuum-packed beef samples (−650 mm Hg in 10 × 10 cm low-density polyethylene/nylon vacuum bags with oxygen permeability of 22.5 mL/m^2/24 h atm at 60% RH/25 °C and water vapor permeability of 4.7 g/m^2/24 h at 100% RH/25 °C) were transported to the Korea Food Research Institute (Seongnam, Korea) in a cooled container. The vacuum pack was opened. For 20 g of beef loins in a bag before sealing, CLA alone (1%; CLA), CLA + 0.15% lecithin (CL), and CL + 0.001% TP (CLT) were poured into the bag, vacuum-packed again, and HP-treated with 0.1, 300, 450, and 600 MPa for 5 min. The control sample with no additive was also opened, vacuum-packed again, and treated by HP.

2.2. High pressure treatment

The vacuum-packed samples were immediately subjected to HP. Samples were placed in a pressure vessel, which was 9 cm in diameter and 32 cm in height with inner cylinder for loading sample (8 cm in diameter and 19 cm in height), submerged in hydrostatic fluid (Quintus food processor 6; ABB Autoclave Systems, Inc., Columbus, OH, USA) and pressurized at 300, 450 and 600 MPa for 5 min with the initial temperature of the pressure vessel set at 15 ± 3 °C. The hydrostatic fluid was a mixture of deionized water and water glycol type fire-resistant hydraulic fluid (Houghto-safe 620-TY, Houghton International Inc., Valley Forge, PA, USA). The rate of pressurization was 5–7 MPa/s and the pressure in the chamber was released within 10 s. Control samples were maintained under atmospheric pressure at 4 °C while the other samples were treated. Immediately after treatment, all samples were transported to the laboratory in a cooled container. Microbiological and chemical analyses were conducted immediately and the samples for sensory evaluation were stored at 4 °C for 3 days.

2.3. Surface color

The surface color of the beef loins was measured using a spectrophotometer with Spectra Magic Software (CM-3500d, Minolta, Tokyo, Japan) after 30 min of opening the package. The color of each sample (4 cm in diameter and 1.5 cm in thickness) was measured at three different locations using a large size aperture (30 mm, 112 diameter). The average value from the three measurements was considered as an observation number for a replication and expressed as L* (lightness), a* (redness), and b* (yellowness) on the Hunter color scale.

2.4. pH, cooking loss, fat and CLA content

pH measurements were carried out by adding 9 mL of distilled water to 1 g samples, homogenizing the mixture for 1 min at 1130 ×*g* using a homogenizer (T25 basic, Ika Co., Staufen, Germany) and results were recorded by a pH meter (750 P, Istek Co., Seoul, Korea). Cooking loss was obtained by submersing and heating samples in a hot water bath at 80 °C until the internal temperature reached 70 °C. The difference between the initial sample weight and the weight after cooking was considered as cooking loss. Crude fat content was measured according to the method of Soxhlet (AOAC, 1996).

The samples (1 g) were saponified with 1 N KOH in ethanol (20 mL) in a water bath (80 °C) for 1 h. After cooling, 10 mL of each sample was transferred to 50-mL tubes, vortexed with 6 N HCl (3 mL) and hexane (10 mL) for the extraction of fatty acid and then evaporated by N_2 gas (99.99%). After that, each mixture was methylated with 1 N H_2SO_4 in methanol (5 mL) in a water bath (50 °C) for 20 min. After cooling, 2 mL of 0.88% NaCl and hexane each was added to the same tubes, which were then centrifuged at 2090 ×*g* for 10 min. The top hexane layer containing FAME (fatty acid methyl esters) was transferred to another 15-mL tube, and dehydrated through anhydrous Na_2SO_4 in to a vial. CLA composition was then analyzed using a gas chromatograph (HP 7890, Agilent Technologies, Santa Clara, CA, USA). A split inlet (split ratio, 100:1) was used to inject the samples into a capillary column (30 m × 0.32 mm × 0.25 μm; Omegawax 320, Supelco, Bellefonte, PA, USA), and ramped over temperature was used for the analysis [the initial temperature (60 °C) was increased to 190 °C at 30 °C/min and then increased to 200 °C at 1 °C/min and finally increased to 250 °C at 5 °C/min and maintained for 10 min]. The inlet and detector temperatures were 260 °C and 280 °C, respectively. N_2 gas was used as the carrier gas at a constant flow rate of 1.0 mL/min.

2.5. Lipid peroxidation (2-thiobarbituric acid reactive substances, TBARS)

Lipid peroxidation was measured by the method of Jung et al. (2012). Samples (3 g) were homogenized in 9 mL of extract solution (7.5% trichloroacetic acid, 0.1% EDTA, and 0.1% gallic acid) and then centrifuged at 2090 ×g, 15 min on a centrifuge (UNION 32R, Hanil Science Industrial Co., Ltd., Korea). The supernatant (5 mL) was transferred to a test tube with 5 mL TBA/TCA solution (20 mM thiobarbituric acid in 15% trichloroacetic acid) with 50 μL 7.2% BHA. The mixture was heated in a water bath for 15 min at 90 °C. After cooling to 20 °C, the mixture was centrifuged (2050 ×*g*) for 15 min. The absorbance of the supernatant obtained after the centrifugation was determined by spectrophotometer (UV 1600 PC, Shimadzu, Tokyo, Japan) at 532 nm. Lipid peroxidation was expressed in mg malondialdehyde/kg meat.