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Effect of chilled and freezing pre-treatments prior to pulsed electric field processing on volatile profile and sensory attributes of cooked lamb meats

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ABSTRACT

This research aimed to gain better understanding on the effects of chilling and freezing prior to pulsed electric field processing (PEF) on volatile profile and sensory attributes of different cooked lamb muscles (i.e. shoulder, rib and loin). Lamb samples were treated at electric field strength of 1–1.4 $kV \cdot cm^{-1}$, specific energy of 88–109 $kJ \cdot kg^{-1}$, frequency of 90 Hz, pulse width of 20 μs and pulse number of 964. The results showed that prolonged storage time and frozen–thawed pretreatment led to significant increases in volatile compounds due to lipid and protein oxidation. PEF also resulted in significant changes of volatile compounds in different meat cuts. Temporal dominance of sensations (TDS) showed that both storage and PEF treatment affected the temporal flavor of meaty and oxidized flavor attributes. Particularly, longer storage period was associated with oxidized flavor, while PEF treated samples were associated with browned, juicy, livery, and meaty flavor attributes.

1. Introduction

Consumers demand lamb meat that is lean and palatable with good nutritional attributes. These three key drivers influence the purchase and "willingness to pay" decisions of consumers (Pethick, Banks, Hales, & Ross, 2006). Pulsed electric field (PEF) technology is a non-thermal processing method with low energy requirements that minimizes quality deterioration of food. PEF is an emerging food processing technology, which has been widely investigated in terms of its potential for industrial pasteurization of liquid food such as beer, fruit juice and milk (Bermúdez-Aguirre, Fernández, Esquivel, Dunne, & Barbosa-Cánovas, 2011; Milani, Alkhafaji, & Silva, 2015; Timmermans et al., 2014).

Recently, extensive studies have been conducted on muscle foods. It has been reported that the use of PEF in muscle foods (especially in beef) can enhance cell permeability due to electroporation and consequently enhance proteolysis that contributes to tenderisation (Bekhit, van de Ven, Suwandy, Fahri, & Hopkins, 2014; Suwandy, Carne, van de Ven, Bekhit, & Hopkins, 2015; Jaeger, Balasa, & Knorr, 2008; Toepfl, Heinz, & Knorr, 2007). Lopp & Weber (2005) reported that PEF treatment (3.5 $kV \cdot cm^{-1}$, 20 Hz, 5 s) enhanced tenderness of beef *triceps brachii* muscles. However in another research (O'Dowd, Arimi, Noci, Cronin, & Lyng, 2013), PEF treatments (1.1–2.8 $kV \cdot cm^{-1}$, 5–200 Hz, 12.7–226 $kJ \cdot kg^{-1}$) did not result in instrumental texture changes in beef *semitendinosus* muscle. Up to now, no research has been carried out on determining the effect of PEF processing on lamb meat.

Flavor and tenderness are the most appreciated characteristics of lamb meat (Alfonso, 2000). It is also the most important factor that determines acceptability in other species, such as beef (Boleman et al., 1997). Flavor is a very important quality attribute for lamb meat (Crouse, 1983), followed by tenderness. One of the main reasons that some consumers reject lamb meat is its characteristic flavor (Martínez-Cerezo, Sañudo, Panea, & Olleta, 2005). Many studies have investigated the effects of dietary supplementation and cooking methods on the volatile compound profiles of meat (Rivas-Cañedo et al., 2013; Vasta et al., 2013; Roldán, Antequera, Martín, Mayoral, & Ruiz, 2013). (Z)-2-heptenal, 2,5-dimethylpyrazine, (Z)-2-decenal and (E,E)-2,4-decadienal contribute to roasted meat odor in grilled lamb meat (Bueno et al., 2011). During storage, lipid oxidation can produce undesirable volatiles such as 2-nonenal, hexanal and 2-octenal, which causing rejection by the consumer (Calkins & Hodgen, 2007; Campo et al., 2006). A recent study (Faridnia et al., 2015) reported that freezing pretreatment with and without PEF greatly affected the volatile profile of beef *semitendinosus* muscle. Therefore, further studies are required to investigate the effects of chilled and freezing pre-treatments prior

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to PEF processing of different lamb cuts on the volatile profile and the subsequent sensorial properties of the lamb cuts.

Foods do not only undergo a series of physical and chemical reactions during mastication and salivation, but also change in the perception of aroma, taste, flavor and texture. It is well known that the way the food breaks in the mouth affects both the perception of its texture and consumer preferences (Albert, Salvador, Schlich, & Fiszman, 2012). Conventional static sensory assessment is only carried out at a single point evaluation by panelist and it could significantly miss product information. To overcome this drawback, the Temporal Dominance of Sensations (TDS) method has been developed to study the temporal dimensions of flavor perception in the mouth to understand the impact of sensory perception over the time of consumption. TDS panelist does not require lengthy training and moreover several attributes can be evaluated simultaneously by TDS (Di Monaco, Su, Masi, & Cavella, 2014). This methodology has been used to study the perception of food such as fish sticks (Albert et al., 2012), low-sodium Mozzarella cheese (Rodrigues, Gonçalves, Pereira, Carneiro, & Pinheiro, 2014), bread (Panouillé, Saint-Eve, Déléris, Le Bleis, & Souchon, 2014), wines (Meillon et al., 2010), and sausage (Devezeaux de Lavergne, Derks, Ketel, de Wijk, & Stieger, 2015).

The purpose of this present study was to evaluate the effects of chilled and frozen–thawed pre-treatments prior to PEF processing on the flavor and sensory characteristics of cooked lamb meats. In addition, different lamb cuts namely shoulder, loin and rib were used in this study to understand whether the type of lamb cuts influenced the treatment effects on volatile compounds and sensory profile.

2. Materials and methods

2.1. Preparation of meat materials

Chilled and frozen–thawed lamb meat shoulder (*Infraspinatus*), rib (*Longissmus*) and loin (*Longissmus*, *Psoas major*) were used in this study (Fig. 1). For chilled meat, two animals (mean cold carcasses weight of 140.5–150.5 kg) were obtained from a local butchery (Dunedin, New Zealand). The chilled meat was stored at 4 °C for 48 h after slaughter. For frozen–thawed meat, two animals were obtained at 48 h post-mortem from AgResearch (Hamilton) (mean cold carcasses weight of 140.5–150.5 kg) and then vacuum packed and stored at −20 °C for about 3 months until use. Prior to PEF processing, the frozen samples were thawed overnight at 4 °C.

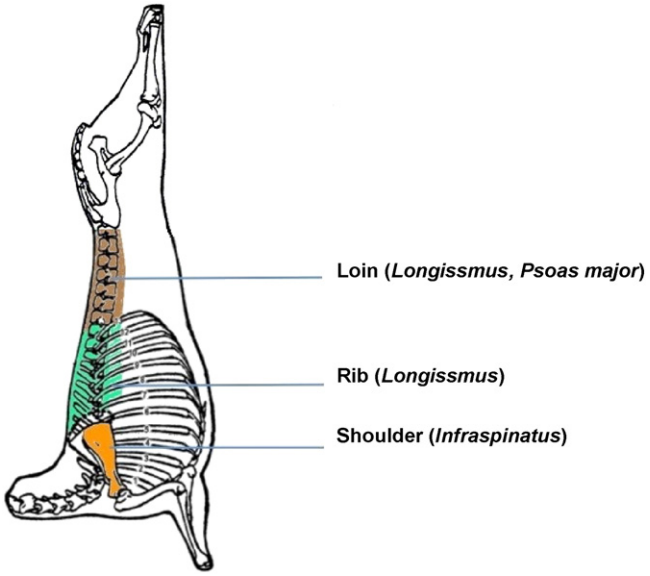

Fig. 1. Major muscles in each lamb meat cut.

2.2. Pulsed Electric Field (PEF) treatment

The PEF batch treatment chamber (6 cm height × 4 cm width × 6 cm length) was used and the lamb samples were processed in a pilot plant scale PEF system (Elcrack-HVP 5, DIL Quakenbruck, Germany). Stainless steel parallel electrodes were used with a distance gap of 4 cm. To ensure the direct contact between the meat samples and the electrodes, a special cutting mold with the same dimension of the PEF chamber was used to cut the meat. The meat was the carefully positioned between 2 electrodes to ensure direct contact in the PEF chamber. Both chilled and frozen–thawed samples were divided into two groups. One of which was subjected to pulsed electric field (PEF) treatment (chilled-PEF and frozen thawed PEF) and another retained as 'control' (no PEF treated) sample (chilled-control; frozen thawed control). Muscles were cut parallel to the fiber direction to fill the PEF chamber for both control (no PEF) and PEF treated samples. Control samples were the samples without PEF treatment for both chilled and frozen samples. The fiber direction was arranged in such way that it was perpendicular to the electric current. The weight of sample was approximately 62 ± 5 g.

A preliminary experiment was carried out to determine the PEF processing parameters by assessing the visual quality of samples immediately after PEF treatment, and determining the stability of current delivery (that results in no electrical arcing) to samples during PEF treatment. Lamb samples (chilled and frozen thawed) were treated at the electric field strength of 1–1.4 $kV \cdot cm^{-1}$, specific energy of 88–109 $kJ \cdot kg^{-1}$, pulse width of 20 μs, frequency of 90 Hz, and pulse number of 964 (Table 1). The pulse shape (square wave bipolar) was monitored on-line using an oscilloscope (Model UT2025C, Uni-Trend Group Ltd., Hongkong, China) during PEF treatment. The temperature of the samples before and after treatment was monitored using temperature loggers (Grant Squirrel SQ800, Cambridgeshire, UK). The initial temperature was maintained at 4 °C. The electrical conductivity (σ) and pH of lamb samples pre- and post- PEF treatment were determined by inserting the twin probes of a hand held meat conductometer (LF-STAR, R. Mathäus, Germany) and a calibrated pH probe (HANNA HI 98140, Woonsocket, USA) directly into the samples at three different positions, respectively. Duplicate readings were taken for each sample before and after PEF treatment to monitor the temperature, electrical conductivity and pH of the meat.

The samples were coded as shown in Table 1. Each treatment for each lamb muscle was conducted in 6 replicates independently. After each treatment muscle sample was vacuum packed in polyethylene plastic bags and immediately stored at 4 °C for 0 and 7 days storage. Afterwards, the samples were stored at −20 °C before further analysis.

2.3. Determination of lipid oxidation using TBARS

The extent of lipid oxidation in meat samples was measured using the Thiobarbituric acid reactive substances (TBARS) method as described by (Nam & Ahn, 2003). Minced meat (5 g) was homogenized with 15 mL of deionized distilled water using a homogenizer (L5 M-A Laboratory Mixer, Silverson®) at 14,000 rpm for 30 s. One milliliter of the meat homogenate was transferred to a test tube and 50 μL of butylated hydroxytoluene (7.2% *w*/*v* in ethanol) and 2 mL of thiobarbituric acid (TBA)–trichloroacetic acid (TCA) (20 mM TBA - 15% (*w*/*v*) TCA) were added. The mixture was vortexed and then incubated in a boiling water bath for 15 min to develop color. Then samples were subjected to cooling for 10 min, and then vortexed before being centrifuged for 15 min at 2500 g. The absorbance of the resulting upper layer was measured at 531 nm against a blank prepared with 1 ml deionized water and 2 ml TBA/TCA solution. The amount of TBARS was expressed as milligrams of malondialdehyde per kilogram of meat. A standard curve was constructed using tetraethoxypropane (TEP) (ranging from 41.76–62.64 umol/l) and mean values are given for triplicate samples (n = 3).