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Effects of high voltage electric field thawing on the characteristics of chicken breast protein

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A B S T R A C T

High voltage electric field (HVEF) is one of the recent thawing technologies. This study involved the application of a multiple point to plate electrode system at different voltages and electrode gaps (1.5, 2.25, and 3 kV/cm electrical field strengths), to thaw frozen chicken breast. The parameters associated with the quality of protein during HVEF thawing were investigated, and compared with the conventional still air thawing (control). The results showed the application of HVEF significantly decreases the thawing time. The thawing and drip losses decreased, then increased by elevating electric field strength, and the least cook loss was resulted in control. Higher myofibrillar protein solubility and water holding capacity were observed at the starting voltage of corona and maximized at 2.25 kV/cm. Differential scanning calorimetry thermograms revealed HVEF-treated samples at 2.25 kV/cm showed less protein denaturation. HVEF thawing at optimum voltages and electrode gaps can maintain the quality of delicate products.

1. Introduction

Today, the consumption of poultry meat, as a popular source of high value animal protein, has increased (Jayasena et al., 2013). Chicken, as a white meat, is considered superior in health to red meat, due to its relatively lower contents of fat, cholesterol, and urea (Jaturasitha et al., 2008). The meat composition is very important to the final product. Following water, protein is the most important constituent of animal bodies (Cercel et al., 2015). Chicken breast is comprised of about 20–23% protein, and 70–80% water (Prasanna Kumar and Sahitya Rani, 2014). The interaction of water and proteins plays an important role in retaining the meat structure. Thus, moisture retention and water holding capacity have been among the most important quality parameters measured for meat products (Zhuang et al., 2008).

Since poultry is susceptible to decay, freezing is a most preferred technique to preserve meat for long periods of time (Akhtar et al., 2013). The methodology and techniques used for the freezing and thawing processes play an important role in the quality retention of frozen foods. Conventional thawing generally occurs more slowly than freezing, potentially causing further damages to frozen food texture (Alizadeh et al., 2009). Drip loss, cooking loss, and the decrease of water holding capacity are some of the consequences of conventional thawing. Novel technologies have been proposed to avoid the destructive effects of heat and long thawing time on food flavor, color, and nutritional value by non-thermal systems (Orlowska et al., 2014). High voltage electrostatic field (HVEF) is one of these technologies which could be applied for thawing frozen foods (Ohtsuki, 1991). The HVEF process is based on the production of an electrical wind by corona discharge. In this method, air is ionized in a needle-plate electrode system by corona discharge. The ions produced in a small area around the needle electrodes are then accelerated by an electric field and the resulting momentum is transferred from the air ions to the neutral air molecules to move the bulk fluid into the surface (Dalvi et al., 2016).

Previous studies have reported the effects of electrostatic field for inhibiting microbial growth (Sale and Hamilton, 1967; Hsieh et al., 2010), preserving the food freshness through increasing its shelf-life (Bajgai et al., 2006; Hsieh and Ko, 2008; Singh et al., 2012); and drying foodstuffs (Cao et al., 2004; Taghian Dinani

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et al., 2014). In the case of the thawing process, it has been found out that the application of HVEF could reduce the thawing and cooking losses of pork tenderloin meat (He et al., 2013). It was also realized that HVEF could reduce the duration of frozen pork and chicken thawing (−3 °C) to 2/3 of the time required for still air thawing (He et al., 2013; Hsieh et al., 2010). Moreover, it was reported that HVEF thawing can affect the protein solubility (Mousakhani-Ganjeh et al., 2015). However, the side effects of HVEF on rapid food thawing have not been studied.

Due to the importance of retaining functional properties of meat proteins during thawing and its effects on the appearance, sensory, structural and microbial characteristics of the final product, this study was mainly focused on investigating the changes that are possibly made in chicken breast during thawing under HVEF and comparing this technique with the conventional still air thawing method (Akhtar et al., 2013). To accomplish these goals, drip loss, thawing loss, evaporation loss, cooking loss, as well as the protein solubility and water holding capacity of the chicken breast samples under different electrostatic field strengths were considered. In addition, the thermal stability of the proteins was determined by applying differential scanning calorimetry (DSC) to explain how HVEF can influence protein denaturation during thawing.

2. Materials and methods

Fresh chicken breast with a specific slaughter age were provided from the same slaughterhouse, at the same slaughter time, then transferred to the laboratory inside an ice bath. All chemicals used in this study were purchased from Merck Co. (Germany).

2.1. Sample preparation

Skinless and boneless chicken breast was cut into cubes ($2 \times 2 \times 2\ cm^3$) by a knife. All chopped samples were frozen by a freezing tunnel with forced air circulation at −30 °C and 1 m/s air velocity, after vacuum packaging in polyethylene bags. The frozen samples were kept at −18 °C until use.

2.2. HVEF experimental apparatus

The experimental apparatus of HVEF comprised a high voltage power generator-which was adjusted with a high voltage controller to output a high voltage from −50 to 50 kV and a maximum current of 5 mA (Ls50KV5mA, China), a treatment chamber and a multiple point to plate electrode system. The ground plate electrode was a $20 \times 15\ cm^2$ rectangle copper plate. The sharp points of 16 needles (0.4 mm in dia.), which were connected to the positive pole of a high-voltage power unit, formed the corona discharge electrode. The treatment chamber was placed in cold incubator for temperature control (Wisecube, WIG-105, Korea). The electric field strength was varied by changing the voltage and the gap between the two electrodes. The experimental apparatus for HVEF system implementation is shown in Fig. 1.

2.3. Thawing

Different voltages, from the corona starting voltage to the breakdown voltage at different electrode gaps, were used for thawing. The applied voltages for the experimental groups were 4.5, 6.75, and 9 kV; 6.75, 9, 10.125, and 13.5 kV; and 9, 13.5, and 18 kV, and the discharge gap was set at 3, 4.5 and 6 cm, respectively. The electric field strengths were 1.5, 2.25, and 3 for the applied voltages (equation (1)).

$$\textit{Electric field strength} = \frac{\textit{Voltage}}{\textit{Gap}} \quad (1)$$

15 frozen cubes of chicken breast weighing about 35 gr were thawed under HVEF for each treatment. Frozen chicken breast cubes were placed on the rectangular plate electrode and the electric field was generated between the two electrodes. The control sample was placed on the same plate electrode without the electric field in the treatment chamber. Temperature was monitored during the process by optical fiber thermocouple (FOB 651A, Canada). For stabilizing thermocouple, before freezing, a pore was created in the geometrical center of each prepared cut of chicken by some needles, and after freezing, the needles were removed from the samples. Optical fiber was positioned in the geometrical center of each sample and remained constant by sticking.

Thawing was considered completed when the center temperature reached to 0 °C. The time required to raise the central temperature of the frozen chicken breast cubes from −18 °C to 0 °C, was taken into account as the thawing time.

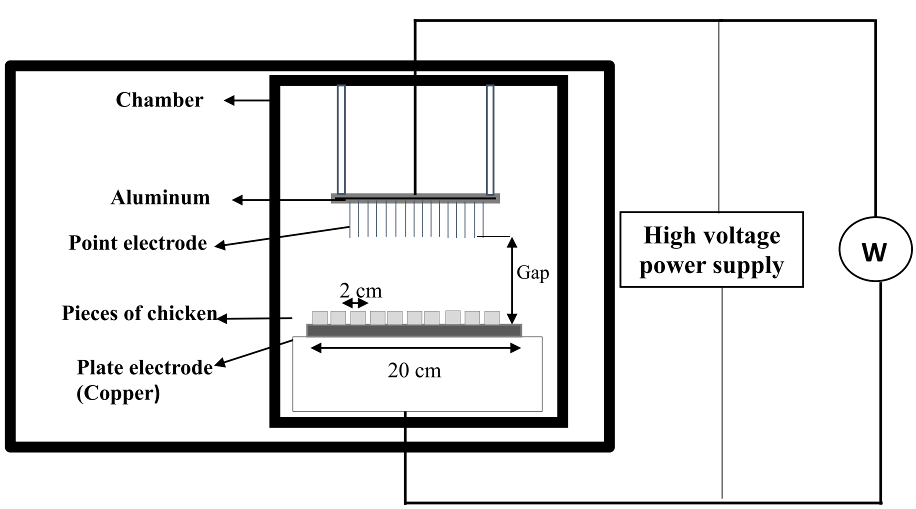

Fig. 1. Schematic diagram of the HVEF treatment apparatus used in this experiment.