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Application of high pressure to chicken meat batters during heating modifies physicochemical properties, enabling salt reduction for high-quality products

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A B S T R A C T

The effect of heating under pressure (HUP) conditions (0–400 MPa, 75 °C, 30 min) and sodium chloride (0–2.0 g/100 g) on the appearance, texture, water-loss, sensory attributes and microstructure was investigated. The results showed that the application of pressure had a major effect on HUP-treated samples, but the effects of salt on HUP-treated samples were much less obvious than on those found for heat-only samples. Regardless of salt content, the application of HUP treatment at 200 MPa improved the gel qualities, resulting in a glossy, rigid gel with low-water loss and high acceptability, while treatment at 400 MPa resulted in coarse, loose gels with high water loss and low acceptability. Scanning electron microscopy (SEM) of the samples indicated that high pressure contributed to the disruption of myofibrils and the formation of a finely stranded gel network both within and outside muscle fibers. These findings indicated that high pressure, rather than salt, was the main factor affecting the quality of chicken meat batter when heated under high pressure. Application of HUP at a specified pressure was an excellent process for producing low-salt comminuted meat products; but excessive high-pressure resulted in inferior quality.

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1. Introduction

There is increasing demand from consumers and public health organizations to reduce the salt content (particularly sodium chloride) in meat products. Excessive salt intake has been linked to high blood pressure and to other cardiovascular diseases (Delahaye, 2013). Processed meat products are the second largest contributor to dietary salt intake, accounting for more than 20% of the total (Verma & Banerjee, 2012). Reducing the salt content in meat products will help reduce salt intake from the current average of approximately 10 g salt/day to 5 g salt/day, an amount recommended by World Health Organization (WHO) (Delahaye, 2013; WHO, 2012). However, salt is an essential additive in meat products because of its effects on flavor, texture and preservation. Salt reduction may reduce the product quality. The development of salt-reduced meat products, that maintain the quality of the meat, is a challenge. High pressure processing (HPP) has attracted attention in recent years for its ability to increase the solubilization of meat proteins, thus increasing the binding properties of meat batters (Iwasaki, Noshiroya, Saitoh, Okano, & Yamamoto, 2006). However, HPP alone cannot achieve a suitable texture without heating because the HPP-induced gel is only stabilized by non-covalent cross-links and is soft and highly flexible (Cando, Herranz, Javier Borderias, & Moreno, 2015). Therefore, pressure treatment, with a simultaneous, or subsequent, cooking step, has been proposed to process meat batters, including salt-reduced meat batters.

Many studies have demonstrated that pressure treatment before heating can be used to produce low-sodium comminuted

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meat products (Crehan, Troy, & Buckley, 2000; O'Flynn, Cruz-Romero, Troy, Mullen, & Kerry, 2014; Sikes, Tobin, & Tume, 2009). However, the possibility of simultaneously using a combined heating and pressure treatment (heating under pressure, HUP) to produce low-sodium comminuted meat products remains unknown.

The effect of high pressure and salt content needed to be carefully examined before this processing technology can be used in the meat industry. Our goal in this study was to evaluate the possibility of reducing the salt content in gel-type meat products by HUP treatment by compared with normal heating, and the effect of high pressure and salt on the quality properties of chicken meat batters.

2. Materials and methods

2.1. Materials

Fresh chicken breast meat (*Pectoralis major*) weighing about 6 kg was purchased from Jiangsu Tyson Foods Co. Ltd. Inc. and transported to laboratory, at 2–8 °C, within 24 h of slaughtering. All chemicals used were of analytical grade, except for sodium chloride (Jiangsu Salt Industry Group Co., Ltd.) and sodium tripolyphosphate (Xuzhou Tianjia Food Chemical Co., Ltd.), which were food grade.

2.2. Batter preparation

The chicken breast meat was trimmed to remove the visible fat and connective tissue, cut into strips and minced through a 5-mm plate using a mincer (MOD TC/12E, Sirman, Marsango, Italy). The mince was divided into three batches of equal weight. Raw meat batters were prepared as follows: the minced meat (80 g/100 g) was comminuted with sodium chloride (0, 1, and 2 g/100 g) and sodium tripolyphosphate (0.3 g/100 g) for 1 min in a bowl chopper (BZBJ-15, Expro Stainless Steel Mechanical & Engineering Co., Ltd.) at 1450 rpm/min without ice flakes. In the next step, the mixture was chopped again for 4.5 min with varying amounts of ice flakes ranging from 17.7 to 19.7 g/100 g. During the cutting process, the meat batter was maintained at a temperature below 13 °C.

The batter was vacuumed by using a vacuum packager (DC800-FB-E, Promarks Inc., Ontario, US) to remove the air and then filled into 26-mm diameter polyamide casings (Hebei Zhongcheng Packaging Materials Co., Ltd.) using a filling machine (SV-3, Hakka Brothers Machinery Co., Ltd., Guangzhou, China). The sausages were linked approximately every 20 cm, and the mean weight was approximately 120 g. Finally, the sausages were individually vacuum-sealed (DC800-FB-E, Promarksvac Corporation, California, USA) in retort bags (Hangzhou Brilliant Packaging Products Integrity) and then subjected to high-pressure processing. Before HPP, the samples were cooled and stored in a 2–4 °C cold room to inhibit microbial growth; the storage duration was less than 24 h.

2.3. Sample treatment

High-pressure processing was performed in a 0.3-L capacity high-pressure vessel (S-FL-850-9-W/FPG5620YHL, Stansted Fluid Power Ltd., Stansted, UK) with circulating water from a thermostat-controlled bath circulator (ILB-WCS, STIK Shanghai Co., Ltd.). Pressurization rate was 5 MPa/s. The temperature increase (approximately 3°C/100 MPa), resulting from adiabatic compression, was controlled by adjusting the initial temperature of the compression fluid. The batters, with an initial temperature of 2 °C, were inserted into the chamber, and then heated under pressure (200 or 400 MPa) for 30 min to 75 °C before being removed from the chamber. The loading and unloading times for the samples were approximately 15 s and 30 s, respectively. The heat-only samples were heated in a water bath (TW20, JULABO Technology Co. Ltd., Seelbach, Germany) at 75 °C and ambient pressure (0.1 MPa) for 30 min. All samples were cooled under running tap water and then stored at 0–4 °C until they were used for further analysis.

2.4. Water holding capacity

Cooking loss was determined by weighing individual samples before ($W_{before\ cooking}$) and after ($W_{after\ cooking}$) processing, and the loss was expressed as a percentage of the original weight:

$$\text{Cooking loss (\%)} = (W_{before\ cooking} - W_{after\ cooking})/W_{before\ cooking} \times 100$$

Centrifugal loss was measured using the protocol described by Villamonte, Simonin, Duranton, Cheret, and de Lamballerie (2013) with minor modifications. Briefly, approximately 10 g of samples was weighed ($W_{before\ centrifugation}$) and wrapped with filter paper and centrifuged at 10,000×*g* for 10 min at 10 °C (Allegra 64R, Beckman Coulter Inc., California, USA). After removing the filter paper, the sample was reweighted ($W_{after\ centrifugation}$). The centrifugal loss was calculated as the percentage of weight loss relative to its initial weight:

$$\text{Centrifugal loss (\%)} = (W_{before\ centrifugation} - W_{after\ centrifugation})/W_{before\ centrifugation} \times 100$$

2.5. Gel hardness

Gel hardness was determined by texture profile analysis (TPA) according to the procedure of Trespalacios and Pla (2007) on a TA-XT plus texture analyzer (Stable Micro Systems Ltd., UK) with a 50-mm cylindrical probe (P/50, aluminum, flat bottom) at ambient temperature (approximately 20 °C). Cylindrical samples of gel (24 mm in diameter, 20 mm in height) were axially compressed to 40% of their original height using a crosshead speed of 1 mm/s.

2.6. Sensory evaluation

An eight-member, internally trained taste panel of food science students was used to evaluate the sensory characteristics of cooked chicken batter products. Panelists were asked to score appearance, texture, flavor and overall acceptability of the warmed samples on a nine point hedonic scale (1, extremely undesirable; 9, extremely desirable).

2.7. Scanning electron microscopy (SEM)

Samples for SEM were cut into small cubes (0.5 mm × 1 mm × 3 mm) and were fixed with glutaraldehyde (2.5 g/100 g) in a 0.1 M phosphate buffer solution (pH 7.0). After fixing 24 h, the cubes were sliced into thin slices (0.2 mm × 0.5 mm × 1 mm). Ethanol dehydration, freeze-drying and sputter-coating were performed according to the procedure of Cao, Xia, Zhou, and Xu (2012). These specimens were observed with a scanning electron microscope (S-3000N, Hitachi, Tokyo, Japan).

2.8. Statistical analysis

The determinants were performed with at least 3 replicates, and the results are expressed as the mean ± standard deviation (SD). Analysis of variance (ANOVA) was performed using Statistical Analysis System 9.0 (SAS Institute Inc., Cary, NC, USA), and the differences were evaluated using Duncan's new multiple range test

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