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Effects of high hydrostatic pressure processing parameters and NaCl concentration on the physical properties, texture and quality of white chicken meat

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ABSTRACT

The effect of high hydrostatic pressure (HHP) conditions (pressures: 0–300 MPa and times: 60–180 s) and sodium chloride (NaCl) concentrations (0–2.5 g/100 g) on physical and quality properties (pH, water activity (a_w), expressible moisture (EM), cooking loss (CL), color, and texture) of white chicken meat before and after thermal treatment were investigated. NaCl concentration, HHP treatment and their interaction influenced the properties studied to different extents. The interaction between NaCl and HHP statistically significantly affected pH, but not a_w. A combined effect between NaCl addition and HHP in reducing EM was observed at 300 MPa, thus more water was bound to the meat system. Overall, NaCl at lower concentrations along with HHP treatment improved white chicken meat color and texture. HHP process can be used to compensate for the reduction of NaCl in chicken meat with keeping the physical and quality attributes at required levels.

Industrial relevance: The results from this study can be used when developing HHP processes for white chicken meat and its products as an alternative to reducing their salt content while maintaining the physical attributes, ensuring meat functionality and quality.

1. Introduction

Meat processors have attempted to meet consumer demand for low salt products. The current public health recommendation in most countries is to reduce salt intake from about 9–12 g/day to 5–6 g/day (He, Burnier, & MacGregor, 2011). Evidence shows that such a reduction in salt intake lowers blood pressure and risk of cardiovascular disease (Strazzullo, D'Elia, Kandala, & Cappuccio, 2009). This evidence comes from different types of studies including epidemiological (Poulter et al., 1990), population based intervention (Lifton, 1996), and genetic studies (Denton et al., 1995). However, salt, such as sodium chloride (NaCl), is an essential ingredient in food products, especially in meat products, where it is not only used as flavoring agent but is also responsible for the achievement of desired textural properties (Desmond, 2006). Pszczola (2010) reported that NaCl improved tenderness and juiciness of processed meat products because NaCl activates proteins causing an increase in hydration and water-binding capacity. Excessively low NaCl content in meat products can result in unstable emulsions with poor texture and low water binding capacity. In addition, NaCl and other salts in raw or processed meats play an important role in slowing down microorganisms' growth including pathogenic organisms. For example, sodium chloride is used in combination with sodium lactate and sodium diacetate in ready-to-eat meats in order to prevent the growth of *Listeria monocytogenes* and lactic acid bacteria (Taormina, 2010). The evidence from Terrell (1983) showed that a reduction of the salt level by 50% (from 2.5% to 1.25%) in ground pork resulted in a slight increase in the *Lactobacillus* spp. growth. It has been also reported that salt reduction can change palatability attributes such as saltiness, flavor intensity and juiciness (Matulis, McKeith, Sutherland, & Brewer, 1995). Consequently, reduction of salt content may affect water-holding capacity, texture, sensorial attributes, stability and shelf-life and impact on the acceptability by consumers and meat processors. Therefore, the reduction of salt, such as NaCl, in meat products present significant challenges to develop meat products maintaining their quality attributes in an acceptable and affordable manner and assuring food safety (Clemens, 2012).

According to the recommendations of Sodium Reduction Strategy (SRS) for Canada, the identification of "alternatives to sodium, considering safety and functionality, and including technological innovations and alternative food processing strategies" is one of three domains of research questions to be addressed (Health Canada, 2010). Therefore, technologies and formulation hurdles that enable the reduction of salt while retaining the safety, stability and functionality of meat products are in demand.

High hydrostatic pressure (HHP) is considered to be an alternative method to compensate for salt reduction, because HHP processing, apart from contributing to the reduction of microbial counts and extending shelf-life, has effects on the proteins of chicken meats that

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contribute to quality, such as physical and texture attributes of the products (Farkas & Hoover, 2000; Huang, Lung, Yang, & Wang, 2014; Kovac, Diez-Valcarce, Hernandez, Raspor, & Rodríguez-Lázaro, 2010). Jimenez-Colmenero, Fernandez, Carballo, and Fernandez-Martin (1998) reported that the use of pressures at 200 and 400 MPa for 30 min and, even at low ionic strength, caused an increase in the water- and fat-binding properties of chicken batter. The use of high pressures at and above 600 MPa may induce lipid oxidation, at pressures lower than 500 MPa chicken products characteristics are closer to those of non-treated ones during cold storage (Ma, Ledward, Zamri, Frazier, & Zhou, 2007; Orlien, Hansen, & Skibsted, 2000; Wiggers, Ohlson, & Skibsted, 2004). Villacis, Rastogi, and Balasubramaniam (2008) showed that HHP up to 300 MPa is efficient for salting turkey breast meat, resulting in improved texture characteristics. Ozturk, Govindasamy-Lucey, Jaeggi, Johnson, and Lucey (2013) reported that the textural, rheological and microbial properties of reduced and low salt cheddar cheese were affected by HHP. O'Flynn, Cruz-Romero, Troy, Mullen, and Kerry (2014) reported that the pressure treatment at 150 MPa for 5 min at room temperature showed the great potential for reducing phosphate levels in low fat breakfast sausages to 0.25% without significant changes in their functionality. However, sufficient research has not been conducted on the potential use of HHP to reduce or to substitute for salt, sugar and fat in processed foods.

The purpose of this study was to investigate the effects of high hydrostatic pressure processing conditions, in combination with salt (NaCl) at low concentrations, on the physical properties of non-treated and HHP-treated white meat products, using chicken as a testing meat. In order to eliminate the pronounced effect of color change due to myoglobin denaturation, a protein that is responsible for the majority of the red color in meat, white chicken meat was chosen for this study. NaCl was used as the testing salt due to its wide usage. The results would provide information to understand the relationship between the changes of the physical properties of non-treated and HHP-treated meat, such as pH, water activity (a_w), expressible moisture (EM), cooking loss (CL), color, and texture properties with various NaCl concentrations and subjected to different HHP conditions (pressure and treatment time) at ambient temperature. The results can contribute to the optimization of salt content and pressure levels to produce high quality white meat products with lower salt concentration on the commercial scale.

2. Materials and methods

2.1. Sample preparation

White ground chicken meat obtained from Hilltop Acres Poultry Products Inc., Waterloo, Ontario, was vacuum packed and stored frozen at −20 °C in 2 kg lots until further use. The samples were vacuum packaged in VAK 3 R general purpose pouches (Winpak Ltd., Winnipeg Manitoba, Canada) composed of 20 micron nylon/55 micron polyethylene with an oxygen transmission of $52 \cdot 10^{-6}$ m^3 m^{-2} 24 h^{-1}. Prior to use the samples were thawed at 4 °C in a walk-in cooler.

Raw chicken batters were prepared by weighing out the ground chicken and adding NaCl (Sigma Aldrich) to give final concentrations of 0.0, 1.5, 2.0 and 2.5% NaCl (w/w or g/100 g) to the samples of groups 1 and 3 (as described below). The chicken samples were mixed using a Cuisinart SM-70C Stand Mixer (Cuisinart, Woodbridge Ontario, Canada) equipped with a flat mixing paddle. The samples were mixed for 5 min at a speed setting of 2. After 2.5 min the mixer was stopped, and then a spatula was used to manually mix before starting another 2.5 min to ensure homogeneity. The samples were kept on ice to cool down. One-hundred grams of samples were weighed out, vacuum sealed and put back in the 4 °C cooler overnight to equilibrate (Chan, Omana, & Betti, 2011). The initial water activity (a_w) of raw chicken meat was 1.000 ± 0.001.

Three groups of samples were prepared in order to study the isolated effects of salt and HPP treatments and their combined effects:

1- Samples with NaCl added without being subjected to HHP treatment
2- HHP treated samples without addition of NaCl
3- Samples containing NaCl subjected to HHP treatment

Samples from the three groups were subjected to thermal treatment (described in Section 2.2.2).

Hereafter, the chicken samples prior to any treatment or salt addition would be called non-treated samples. A scheme of the experimental design is presented in Fig. 1.

2.2. Methods

2.2.1. HHP treatment

For the HHP treatments of samples from groups 2 and 3, five sample pouches (100 g each) were removed from the 4 °C cooler for each test and placed in the sample basket of the pilot scale 2 L High Pressure Food Processor (Flow Autoclave Systems Inc., Columbus, Ohio, USA). The samples were subjected to high pressure treatments of 50, 100, 200 or 300 MPa for 60, 120 or 180 s. The HHP unit is equipped with a built-in thermocouple to control temperature of distilled water that was used as a compression fluid at ambient temperature. The initial temperature of the packaged samples was equilibrated to 4 °C. According to the thermocouple reading, there was no increase in temperature of water higher than ambient due to compression in the range of pressures studied. After treatment, the samples were placed back in the 4 °C cooler until the physical and quality measurements were performed. One sample was kept as a control for each treatment and did not undergo HHP treatment.

2.2.2. Thermal treatment and cooking loss determination

In order to simulate a cooking process that chicken meat emulsion would undergo after HHP treatment, part of the meat from groups 1, 2 and 3 was subjected to thermal treatment (tt-samples). The results were compared to the non-thermally treated samples (non-tt) in order to understand the effects of NaCl and HHP processing on the properties of final processed meat products. Twenty-five grams of sample were weighed into 50 mL plastic centrifuge tubes for thermal treatment. The tubes were placed in a water bath at 95 °C and heated for 15 min to ensure that the internal temperature of the sample reached 75 °C. Sample temperature was monitored and recorded using a thermocouple attached to an Agilent 34907A Data Acquisition/Switch Unit (Agilent Technologies Inc., Loveland, Colorado, USA). The thermocouple was placed in the center of the sample. After the thermal treatment, the samples were allowed to cool down for 15 min and placed in a 4 °C refrigerator overnight to equilibrate. After overnight equilibration, the sample tubes were weighed and the cooking losses (CL) were calculated using the following equation (Omana, Plastow, & Betti, 2011):

$$CL\ (\%) = \left(\frac{\text{initial weight} - \text{final weight}}{\text{initial weight}}\right) \times 100.$$

The following determinations (Sections 2.2.3 to 2.2.6) were performed on the samples before the thermal treatment (non-tt) and after the thermal treatment (tt).

The texture profile analysis (Section 2.2.7) and the cooking loss (CL) (Section 2.2.2) determinations were performed only for the tt-samples.

2.2.3. pH measurement

The pH of the non-tt and tt-samples was measured using an Orion 3 star pH meter (Thermo Fisher Scientific Inc. Beverly, MA) equipped with a Ross spear tip pH glass electrode. Five grams of sample were blended with 25 mL of distilled water using a Brinkman Polytron Homogenizer Model PT 10/35 (Brinkman Instruments, Mississauga, Ontario Canada). The pH of the slurry was recorded (Stewart, Fletcher, Hamm, & Thomson, 1984).