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Effect of high pressure on cooking losses and functional properties of reduced-fat and reduced-salt pork sausage emulsions

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ABSTRACT

This study investigated the use of high pressure processing (HPP) for enhancing the functional properties of reduced-fat (20%) and reduced-salt (1%) sausages without the need for additives. The effects of different HPP treatments (100 to 400 MPa) at 10 °C for 2 min on cooking losses, color, textural properties, salt solubility of myofibrillar proteins, rheological properties and microstructure of pork sausage emulsions were compared with the Control (0.1 MPa). The results showed that HPP contributed to a decrease in cooking losses as well as altered color and enhanced textural properties, and also decreased the protein solubility of myosin and actin. Pressure increased G′, G″ and tan δ, and formed a more regular and filamentous microstructure, especially at 200 MPa. In addition, the sensory evaluation exhibited that there was no significant difference between the commercialized emulsion-type sausages and the 200 MPa pressure treated sausages with 20% fat and 1% salt. It was concluded that HPP significantly improved the functional properties of reduced-fat and reduced-salt pork sausages, and the optimum conditions was 200 MPa at 10 °C for 2 min.

Industrial relevance: For health reasons, there is a need to reduce fat and salt contents of processed meat products. Using HPP (especially 200 MPa), a meat emulsion-type product with low fat and salt was successfully produced, which retains its expected functional quality attributed of objective texture, color and rheological property, etc. Importantly this is achieved with a marked reduction in cooking loss when cooked thus providing the manufacturer with greater product yield.

1. Introduction

Functional properties, such as the stability of emulsions and the formation of gels, are affected by the protein behavior, structure, conformation, as well as surface hydrophobicity or the hydrophobicity ratios, and interactions between the proteins with other food components such as salt, water and fat (Chan, Omana, & Betti, 2011; Lakshmanan, Parkinson, & Piggott, 2007; Wackerbarth, Kuhlmann, Tintchev, Heinz, & Hildebrandt, 2009). Recently, there have been growing demands for healthier meat products with reduced fat and sodium contents, but the functional properties of the reduced-fat and reduced-salt meat products were affected negatively (Barrios-Peralta, Perez-Won, Tabilo-Munizaga, & Briones-Labarca, 2012). Normally, reducing fat in meat products can be achieved by using leaner meat parts and increasing the amount of water and/or other substances, such as fat replacers being either protein- or carbohydrate-based, whereas reducing salt of NaCl can be achieved by using other kinds of additives as taste enhancers, protein binders and preservatives (Tomaschunas et al., 2013).

High pressure processing, as it is convenient, natural, and safe and needs less or no use of preservatives and chemical additives, has gained much interest of food processor and consumers to alter the functional properties of reduced-fat and reduced-salt emulsion-type sausages (Bolumar, Enneking, Toepfl, & Heinz, 2013; Tokifuji, Matsushima, Hachisuka, & Yoshioka, 2013). A number of researchers have investigated the effects of HPP on meats and meat products to reduce salt content (O'Flynn, Cruz-Romero, Troy, Mullen, & Kerry, 2014), while there was little information available regarding the effectiveness of HPP to reduce cooking loss and alter the textural properties of both reduced-fat and reduced-salt pork sausages. Therefore, the main objectives of this study were to (a) minimize cooking loss of the sausages having 20% fat content and 1% salt content with application of HPP, (b) evaluate textural properties of sausages and rheological properties of batters with 20% fat content and 1% salt content over a range of pressure treatments varying from 100 to 400 MPa compared with the Control (0.1 MPa), (c) compare the sausages with 20% fat content and 1% salt content subjected to varying pressures from 0.1 to 400 MPa, with

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those commercialized emulsion-type sausages and (d) determine the protein changes and microstructures of gels that might account for any altered functional properties. This study will serve as basis for adaptation in the meat products of emulsion-type sausage processing industry, for enhanced product yield and improved texture with reduced fat and salt.

2. Materials and methods

2.1. Materials

Pork meat and high-grade pork back fat were purchased from Su Shi group (Nanjing, China). Pork meat (*M. vastus intermedius*, round muscle) was trimmed free of connective tissues, and immediately stored at −18 °C. For each trial, the frozen pork was thawed at 4 °C for 24 h prior to preparation of the batter.

2.2. Preparation of batters

Meat batters containing 20% fat and 1% salt were prepared in this work. The pork meat batter was prepared by pure lean pork (3.5 kg), back fat (1.12 kg), cold water (0.95 kg), salt (0.056 kg) and pepper (0.036 kg), according to the method of Kang et al. (2014). The reference amounts customarily consumed per eating occasion (RACC) of Food and Drug Administration consider 'reduced-sodium' to be at least 25% less sodium per RACC, and 'reduced-fat' to be at least 25% less fat per RACC (Hoadley & Rowlands, 2014). Normally, emulsion-type sausages have 30% fat and 2–3% salt content (Villamonte, Simonin, Duranton, Cheret, & Lamballerie, 2013). Therefore, the raw meat batters used in this study with 20% fat and 1% salt content were referred to as 'reduced-fat and reduced-salt batters'. These cooked batters were referred to as 'reduced-fat and reduced-salt sausages'. The procedure used was as follows: pure lean pork and back fat were separately cut into 0.5 cm pieces. Then the cut pieces of fat and lean meat, together with 10% (v/w) cold water were placed in a bowl cutter along with 1% salt and cut until a fine emulsion was obtained. The temperature was maintained below 12 °C at all times. The batters were then stuffed into 24 mm diameter sausage casings and linked every 150 mm, giving each sausage an approximate weight of 60 g, and the weight was accurately calculated as m_1. The batters with sausage casings were vacuum packaged within polyamide/polyethylene membranes (oxygen permeability <1 $cm^3/m^2/h$ at 20 °C) and then stored at 4 °C. This procedure was repeated on 3 separate occasions (n = 3). The samples of meat batters were divided into 5 parts, which were prepared for pressure treatment varying from 0.1 (atmosphere pressure, Control), 100, 200, 300 to 400 MPa, respectively.

2.3. Application of HPP

High-pressure processing was carried out in a 0.3 L capacity 850 Mini FoodLab high pressure vessel (Stansted Fluid Power Ltd., UK). Water was used as the pressure-transfer medium and the whole system was cooled to an initial temperature of 10 °C by a thermo stated jacket. Meat batters were subjected to 100, 200, 300 or 400 MPa for 2 min at 10 °C and were compared to non-pressure treated Controls. During the processing, the pressure was increased at a rate of 20 MPa/s. The pressure was maintained for 2 min and then released to 0.1 MPa in 15 s. Upon the release of pressure and removal from the vessel, the samples were kept at 4 °C. During the HPP, adiabatic heating resulted in an increased temperature of approximately 4 °C and so Control samples were held in water (0.1 MPa) at 14 °C for 2 min and then also stored at 4 °C until required for analysis. Rheological properties and SDS-PAGE of proteins were performed on batters.

2.4. Sausage preparation

Cooking was done in a water bath at 80 °C for 15 min to achieve an internal temperature of 72 °C. All cooked samples were then cooled to room temperature and then transferred to 4 °C until required for determination. After peeling the vacuum packing bag and cleaning the water outside the sausage casing, the weight was accurately calculated as m_2. Cooking losses, textural properties and SEM evaluation were performed on sausages. Color was assessed on both batters and sausages.

2.5. Composition analysis and cooking losses

The composition analysis of this emulsion-type sausages were conducted with Foss LAB Meat/Food Composition fast analyzer (FOSS Ltd., Denmark). About 200 g samples were put in a round transparent platform (14.0 cm diameter and 2.0 cm height). Protein, moisture and fat (g) were evaluated and recorded.

Cooking losses for each treatment were determined by calculating the weight difference using the following equation: cooking losses (%) = $(m_1 - m_2) / m_1 \times 100$.

2.6. Color

Color measurements were conducted with upper, central and lower positions of core samples both in batters and sausages (2.2 cm diameter and 2.0 cm height) using a HunterLab MiniScan model Spectrocolorimeter (Konica, Japan) calibrated against a white tile. Lightness (L^*), redness (a^*) and yellowness (b^*) was evaluated and recorded. '*Whiteness*' was calculated as follows:

$$Whiteness = 100 - \left[(100 - L^*)^2 + a^{*2} + b^{*2}\right]^{1/2}.$$

2.7. Textural analysis

Texture profile analysis (TPA) of the sausages was determined using a TA-XT plus texture analyzer (Stable Micro System Corporation, UK) using the procedure described by Kim, Jin, Mandal, and Kang (2011). After peeling off the casing, TPA was performed using the central cores with a diameter of 2.2 cm and the height of 2.0 cm of each sausage. A crosshead speed of 5 mm/s was used and each sample was axially compressed to 50% of its original height using a two cycle compression with the P/50 probe (Sikes, Tobin, & Tume, 2009). This procedure enabled the estimation of certain attributes of the sausages such as hardness (N), chewiness (N), springiness (mm), cohesiveness and resilience. Hardness (N), maximum force required to compress the sample; chewiness (N), hardness × cohesiveness × springiness; springiness (mm), ability of the sample to recover its original form after deforming force was removed; cohesiveness, extent to which the sample could be deformed prior to rupture; and resilience, area during the withdrawal of the first compression divided by the area of the first compression (Marchetti, Andres, & Califano, 2014; Shao, Zou, Xu, Wu, & Zhou, 2011).

2.8. Sensory evaluation

Five items regarding the sensory evaluation of the pork meat gels were evaluated by 30 panelists, including appearance, aroma, texture, flavor and overall acceptance. The panelists were trained following the Chinese standard GB/T 22210-2008 (criterion for sensory evaluation of meat and meat products), and screened for their abilities to recognize different quality grades of emulsion-type sausage. All the tasting sessions were done at the same time of each test day in a quiet room with a mixture of natural and fluorescent lamp, with no interactions between panelists. Sausage samples of each treatment were placed in