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High pressure processing alters water distribution enabling the production of reduced-fat and reduced-salt pork sausages

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ABSTRACT

High pressure processing (HPP) was used to explore novel methods for modifying the textural properties of pork sausages with reduced-salt, reduced-fat and no fat replacement additions. A 2 × 7 factorial design was set up, incorporating two pressure levels (0.1 or 200 MPa) and seven fat levels (0, 5, 10, 15, 20, 25 and 30%). Sausages treated at 200 MPa exhibited improved tenderness at all fat levels compared with 0.1 MPa treated samples, and the shear force of sausages treated at 200 MPa with 15 or 20% fat content was similar to the 0.1 MPa treated sausages with 30% fat. HPP significantly changed the P_2 peak ratio of the four water components in raw sausages, resulting in improved textural properties of emulsion-type sausages with reduced-fat and reduced-salt. Significant correlations were found between pH, color, shear force and water proportions. The scanning and transmission micrographs revealed the formation of smaller fat globules and an improved network structure in the pressure treated sausages. In conclusion, there is potential to manufacture sausages with reduced-fat and reduced-salt by using HPP to maintain textural qualities.

1. Introduction

Fat is a critical food component in meat products that plays an important role in affecting sensory and functional characteristics, such as cooking loss, water holding capacity, and textural properties, and also acts as a precursor for certain flavors (Ventanas, Puolanne, & Tuorila, 2010). As there is a growing awareness of the link between diet and health, there is an increasing demand for low-fat meat products. Normally, reducing fat in meat products can be achieved by using leaner meat parts, increasing the amount of water or other substances, such as fat replacers being either protein- or carbohydrate-based (Tomaschunas et al., 2013). Several authors have studied the effects of different types of functional fibers as fat replacer in cooked meat products, however many consumers prefer meat products without any additives (Toldra & Reig, 2011). Using water alone to replace fat, however, can result in such problems as color changes of the product and a higher cooking loss (Claus, Hunt, & Kastner, 1989). To overcome these problems, water could be added as a replacement but needs to be in combination with other treatments, such as with the use of high pressure treatment or dense phase carbon dioxide (Jimenez, 1996).

Depending on the conditions selected, high pressure processing (HPP), a non-thermal technology, has always been used (50 MPa–600 MPa) to inactivate microorganisms and to denature enzymes and structural proteins which can lead to positive effects on textural quality and sensory characteristics (Al-Bandak, Dermesonlouglou, Taoukis, & Oreopoulou, 2011). Studies have shown that HPP can affect the texture and gel-forming properties of myofibrillar structures, which have been correlated with altered water distribution, particularly in emulsion-type sausages (Chattong & Apichartsrangkoon, 2009).

Emulsion-type sausages are made by the comminuting and emulsification processing methods. Moderate denaturation of meat proteins during thermal and/or pressure application processes has enabled improvements in texture and flavor of emulsion-type products which meet consumers' requirements for sensory properties and for nutrition (Cofrades, Antoniou, Solas, Herrero, & Jimenez-Colmenero, 2013). Textural properties and water distribution characteristics are two important properties of emulsion-type meat products and have been widely investigated (Caneque et al., 2004). Changes in the state of the water contained within the meat occur simultaneously through temperature/pressure induced protein denaturation and structural shrinkage (Sun, Zhou, Zhao, Yang, & Cui, 2011). Furthermore, certain physical properties such as texture and color can be affected, correlating to water distribution and mobility in meat products. In conclusion, textural properties are changed by protein denaturation which has been correlated with altered water distribution in emulsion-type sausages (Morin, Temelli, & McMullen, 2004). However, there is little information available regarding the effectiveness of HPP to change water distribution in reduced-fat and reduced-salt sausages to modify their textural properties.

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In previous studies, it was found that the application of HPP (200 MPa for 2 min at 10 °C), as a pre-treatment before cooking, was suitable for further reduced-salt beef and turkey sausage product development, in terms of overall optimal benefits, such as good texture and low cook loss (Jacky, Chan, & Omana, 2011; Sikes, Tobin, & Tume, 2009). The main objective of this study was to determine the water distribution characteristics in reduced-fat and reduced-salt raw batters treated by high pressure processing before cooking that might modify the textural properties of the cooked reduced-fat and reduced-salt pork sausage products.

2. Materials and methods

2.1. Ingredients

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

2.2. Preparation of raw sausages

The preparation procedures for raw sausages were as follows: protein levels were maintained throughout by replacing fat with water; added fat levels were 0, 5, 10, 15, 20, 25 and 30%. Raw pork sausages were prepared by cutting lean pork (3.5 kg) and back fat (1.0 kg) separately into 0.5 cm pieces. The cut pieces of fat and lean meat, together with 30, 25, 20, 15, 10, 5 and 0% cold water, respectively, were placed in a bowl cutter along with 1% salt and were cut until a fine emulsion was obtained. The reference amounts customarily consumed per eating occasion (RACC) of the Food and Drug Administration considers '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 contents were referred to as 'reduced-fat and reduced-salt raw sausages'. These cooked batters were referred to as 'reduced-fat and reduced-salt cooked sausages'. 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. The batters were then vacuum packaged with a polyamide/polyethylene membrane (oxygen permeability <1 $cm^3/m^2/h$ at 20 °C) and stored at 4 °C. This procedure was repeated thrice (N = 3).

2.3. Application of HPP

Pressure treatment, as a pre-processing step, was applied to modify the water distribution characteristics in raw sausages that might modify the textural properties of the cooked reduced-salt and reduced-fat pork sausages. 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 thermostated jacket. Raw pork sausages were subjected to 200 MPa for 2 min at 10 °C, and were later compared to non-pressure treated controls (0.1 MPa, atmosphere pressure). During the processing, the pressure was increased at a rate of 20 MPa/s. Pressure was maintained for 2 min and then released to 0.1 MPa in 15 s. Upon 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 (0.1 MPa) were held in water at 14 °C for 2 min and then also stored at 4 °C until required for analysis. Measurements of pH, color and LF-NMR were performed on raw sausages to determine the effects of HPP (0.1 or 200 MPa) and fat contents (0, 5, 10, 15, 20, 25 and 30%) on the appearance and water distribution characteristics, which would affect the final products' qualities.

2.4. pH

Raw batters were homogenized (10 g sample in 90 g water) and pH was determined using a digital pH meter fitted with a combination electrode (glass body with spear tip) with temperature compensation (Microprocessor pH meter, Hanna HI9025c, Portugal).

2.5. Color

The color of raw sausages was evaluated as lightness (L^*), redness (a^*) and yellowness (b^*) using a HunterLab Miniscan Model Spectrocolorimeter, with a D65 illuminant at 10° (Konica, Japan). Six measurements for each of the three replicates were taken for these coordinates. And according to Khan et al. (2014), *Whiteness* was calculated by following formula:

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

2.6. Water mobility and compartmentalization

LF-NMR relaxation measurements were performed using a NMR-PQ001 (Niumag Corporation, Shanghai, China) at a measurement temperature of 32 °C. The raw sausage samples (2 g) were placed in glass tubes (15 mm in diameter) and then inserted into the NMR probe. Carr–Purcell–Meiboom–Gill (CPMG) sequences were employed to measure spin–spin relaxation time T_2 according to the method of Villacis, Rastogi, and Balasubramaniam (2008). Typical pulse parameters were as followed: τ-value (time of between 90° and 180° pulses) of 250 μs. Data from 12,000 echoes were acquired as 32 scan repetitions. The repeat time between subsequent scans was 6.5 s. The multi-exponential decay curve was obtained from NMR relaxation processing, and multi-exponential fitting analysis was performed using the program Multi Exp Inv Analysis (Niumag Corporation, Shanghai, China).

2.7. Cooked sausage preparation

Cooking was conducted 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 transferred to 4 °C until required for determination. Emulsion stability, shear force, SEM and TEM of the cooked sausages were tested to determine the effect of high pressure and fat content on the textural and microstructural properties of the final products.

2.8. Emulsion stability

Triplicate samples of meat batter samples from each treatment were analyzed for emulsion stability using the modified method of Choi et al. (2010). A 15 mesh sieve (50 mm diameter) was placed in the middle of a pre-weighed graduated glass tube. Approximately 30 g of the meat batter was weighed on the sieve in glass tubes, which were then covered. Triplicate samples from each treatment were cooked at 75 °C for 30 min. Cool to approximate 4 ± 1 °C to facilitate fat and water layer separation. The water and fat, which separated at the bottom of graduated glass tube, were measured in milliliters and calculated as a percentage of the original weight of batters. Water loss and fat loss for each treatment were determined by calculating the weight difference using the following equation:

$$\text{Water loss}(\%) = \text{the water layer}\ (m_l)/\text{raw meat batter weight}\ (g) \times 100$$