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Effect of high pressure processing on the gel properties of salt-soluble meat protein containing $CaCl_2$ and κ-carrageenan

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ABSTRACT

The effects of high pressure processing (HPP) on the water-binding capacity and texture profile (TPA) of salt-soluble meat protein (SSMP) containing 0.2% $CaCl_2$ and 0.6% κ-carrageenan (SSMP-CK) gels were investigated. The results showed that 300–400 MPa improved water-binding capacity and decreased TPA parameters of SSMP-CK gels ($P < 0.05$), while 100 MPa could increase hardness and chewiness of the gels. The thermal transition temperature peak for the myosin head (T_{peak1}) of SSMP disappeared on addition of $CaCl_2$ and κ-carrageenan. 300 MPa produced a new peak, and caused a shift of the NH-stretching left peak and amide I and the disappearance of NH-stretching right peak. The destruction of network structure and the weakening of molecular interaction within the pressurized gels could result in the decrease of TPA parameters. Thus gelling properties could be modified by HPP, κ-carrageenan and Ca^{2+}. It is of interest to develop low-fat and sodium-reduced meat products.

1. Introduction

Meat is a good source of proteins, B-complex vitamins (such as thiamine, riboflavin), iron and phosphorous but a rather poor source of calcium (Cáceres, García, & Selgas, 2006). The development of low-fat and sodium-reduced meat products is an important development in the meat industry (Ma et al., 2012), using polysaccharide as a fat substitute and calcium as a sodium substitute (García-García & Totosaus, 2008; Selgas, Salazar, & García, 2009). The properties of food gel, such as meat products, are affected by proteins and polysaccharides (Bertrand & Turgeon, 2007), especially the interaction among them.

κ-carrageenan, as a linear sulfated polysaccharide and has been widely used in the meat industry to improve the gel properties (Chen, Jiang, Zhang, & Gerelt, 2007; Verbeken, Neirinck, Van der Meeren, & Dewettinck, 2005), for example, increasing water holding capacity (WHC) and hardness of salt-soluble meat protein (SSMP) gels (DeFreitas, Sebranek, Olson, & Carr, 1997). Anion polysaccharides (such as carrageenan) could influence the properties of meat protein gels by changing the ionic strength (Amako & Xiong, 2001; Montero & Pérez-Mateos, 2002), while cations affect the balance of attractive and repulsive forces between the molecules (Montero & Pérez-Mateos, 2002), which results in synergistic interactions of κ-carrageenan with myofibrillar proteins (Pietrasik & Jarmoluk, 2003).

Calcium chloride ($CaCl_2$), as a salt substitute, has been used to reduce the sodium content in meat products (Aliño, Grau, Fuentes, & Barat, 2010; Pojedinec et al., 2011). Calcium ion (Ca^{2+}), a typical cation, could interact with meat proteins (Pigott, Kenney, Slider, & Head, 2000), to improve the textural properties of meat products (Pérez-Mateos & Montero, 2002), and enhancement in nutritional value (Cáceres et al., 2006). The addition of $CaCl_2$ may reduce emulsion stability and cooking yield in emulsified meat products, and these properties are improved by the use of thickeners (Horita, Morgano, Celeghini, & Pollonio, 2011).

High pressure processing (HPP) could improve the functional properties of meat by enhancing moisture-protein or protein-protein interactions (Hong, Ko, Choi, & Min, 2008). Proteins or complex biopolymers subjected to HPP may have their structures modified by disrupting hydrophobic and electrostatic interactions (Molina, Papadopoulou, & Ledward, 2001). The change in protein conformation could influence denaturation, aggregation and gelation, resulting in a modification of textural properties and possible extension of shelf-life (Sikes, Tobin, & Tume, 2009). However, the complexes of bovine serum albumin with sulfated polysaccharide appear to protect the protein against pressure-induced aggregation due to disulfide bridge formation during or after HPP, and similar results were found at low ionic strength (Galazka, Smith, Ledward, & Dickinson, 1999). These results suggest that HPP does have promise in meat processing, but further studies are necessary in order to clarify the effects of HPP on complex systems, especially on meat products containing polysaccharide at low ionic strength.

SSMP directly affects the gel properties of meat products, and also has important roles in binding fat, water and meat pieces (Lakshmanan, Parkinson, & Piggott, 2007). The effects of HPP on the properties of pork muscle gels containing κ-carrageenan were investigated (Chen, Jiang, et

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al., 2007). Moreover, the effects of HPP and $CaCl_2$ on SSMP gels have been well researched (Ma et al., 2012). But, the effect of HPP on a compound system of κ-carrageenan, $CaCl_2$ and SSMP has not been reported. Further understanding of the characteristics of HPP on these compound SSMP gels is necessary for the development of low-fat, sodium-reduced meat products.

With the beneficial effects of sodium and fat reduction, calcium intake and HPP in mind, this work investigated the influence of HPP levels (0–400 MPa) on cooking loss (CL), WHC and textural properties (hardness, elasticity, cohesiveness and chewiness) of the SSMP gels containing κ-carrageenan and $CaCl_2$.

2. Materials and methods

2.1. Materials

κ-carrageenan (in powder, purity 99.8%), the viscosity of a 1.5% water solution (W/W) was above 0.01 Pa•S at 75 °C, was provided by Danisco (China) Co., Ltd. NaCl (≥99.5%) and $CaCl_2$ (≥96.0%) was purchased from Guangdong Xilong Chemical Co., Ltd., China, and $Na_5P_3O_{10}$ (≥95.0%) from Tianjin Bodi Chemical Holding Co., Ltd., China.

Pork meat (hind leg) was purchased from a local supermarket and visible fat and connective tissue were trimmed off. The trimmed meat was ground with a meat grinder (Shangyuan, SYP-MM 12, Guangdong Province, China) fitted with a plate with 6 mm diameter holes, and then packaged and placed in storage at −20 °C.

2.2. SSMP extraction

SSMP was prepared as described by Chen, Xu, and Wang (2007) and Ma et al. (2012) and all preparation steps were carried out at about 10 °C. The final SSMP concentrations were determined by a semi-micro-Kjeldahl method (N × 6.25), and then the protein content was adjusted to 8% with the isolation buffer.

2.3. Preparation of mixed SSMP gels

0.2% $CaCl_2$ and 0.6% κ-carrageenan were added into SSMP to form a mixture (SSMP-CK), and all mixtures contained 3% salt (NaCl). The mixtures were stirred well and then stored overnight (about 12 h) at 4 °C. These mixtures were then stuffed into casing (Nylon/PE, Φ19 mm) without entrapped air, and sealed for gelation. The final mixed gels were obtained as reported previously (Ma et al., 2012).

The samples of SSMP-CK were pressurized for 10 min by a HPP apparatus UUPF-750 (Baotou Kefa High Pressure Technology Co., Ltd., China) at 100–400 MPa and 29 ± 1 °C (Chen, Gerelt, Jiang, Nishiumi, & Suzuki, 2006). The pressurized SSMP-CK was subsequently heated (80 ± 1 °C, 30 min) for further gelling, and then cooled in water for about 10 min and stored overnight (about 12 h) at 4 °C for further measurement. Three runs for each treatment were carried out.

2.4. Water binding capacity (CL and WHC)

CL value of gels was measured as described by Pietrasik and Jarmoluk (2003). The chilled sample was removed from the casing and the gel was wiped with filter paper and weighed. CL was expressed as a percentage based on the raw stuffed net weight. The results of CL are the mean of three repeated trials.

WHC of the gels was determined as described by Ayadi, Kechaou, Makni, and Attia (2009) with a slight modification. Cylindrical gels (Φ19 mm × 10 mm) from three repeated trials were wrapped in filter paper (0.3–0.5 μm in aperture), and placed in a centrifuge tube (25 mm in inner diameter) with absorbent cotton in the bottom, and centrifuged at 960 ×*g* for 10 min at 4 °C. WHC was expressed as the ratio of gel weight after centrifugation to the initial gel sample weight. Results are the mean of six runs for each treatment.

2.5. Texture profile analysis (TPA)

Texture profile analysis was measured using a TA-XT plus Texture Analyzer (Stable Micro System Co., England) at room temperature (Ma et al., 2012). The TPA parameters, namely hardness (N), elasticity (dimensionless), cohesiveness (dimensionless) and chewiness (N), were computed and analyzed. Results are the mean of six cylindrical replicates (Φ19 mm × 10 mm) from three repeated trials.

2.6. Differential scanning calorimeter (DSC)

Thermal transition temperatures of SSMP, SSMP-CK, and 300 MPa + SSMP-CK (unheated and stored for about 12 h at 4 °C each sample) were measured by a Q200 DSC calorimeter (TA, USA) (Chen, Xu, et al., 2007; Ma et al., 2012). The temperature of each endothermic peak was recorded using Universal Analysis 2000 software (TA Instruments). The peak value of each endothermic temperature is the average of at least two replicates.

2.7. Fourier transform infrared (FT-IR) spectroscopy

The spectra of gel samples were obtained as described previously (Ma et al., 2012), and were recorded at ambient temperature (20 °C) with sixteen scans. Origin 7.5 software was used to analyze these spectra.

2.8. Confocal laser scanning microscopy (CLSM)

The protein network of mixed SSMP gels was non-covalently stained with Fluorescein Isothiocyanate isomer I (FITC, Sigma, USA) and the specimen was observed using a CLSM (Olympus, FV 10000, Japan) as described previously (Ma et al., 2012). Data from a representative area for each sample were taken using a 40× magnification objective. All measurements were carried out in triplicate and one of three parallel CLSM pictures was depicted.

2.9. Statistical analysis

Analysis of variances, means, and standard errors were determined using Excel 2003 (Microsoft Office Excel 2003 for Windows). Significance level of $P < 0.05$ was used to determine differences among treatments.

3. Results and discussion

3.1. Water binding capacity

3.1.1. CL

As shown in Fig. 1A, compared with the non-pressurized gel, the effects of 100–200 MPa on the CL of SSMP-CK gels were insignificant ($P > 0.05$), while 300–400 MPa obviously decreased the CL of the gels ($P < 0.05$). However, the difference between 300 MPa and 400 MPa was insignificant ($P > 0.05$).

The similar influence of higher pressure (>200 MPa) on the CL value of SSMP-CK gels was reported in pressurized pork meat gels, and the effect of HPP was not affiliated with that of κ-carrageenan on CL values of pork meat gels (Chen, Jiang, et al., 2007). These results implied that the CL of pressurized pork meat gels containing κ-carrageenan was highly correlated to that of SSMP-CK gels, and the decrease of SSMP-CK gel CL values directly resulted from HPP.

3.1.2. WHC

Compared with the control, the WHC of the SSMP-CK gel was not influenced by HPP ($P > 0.05$) (Fig. 1B), which was similar to the result for pork meat gels containing 0.25–1% κ-carrageenan (Chen, Jiang, et al., 2007).