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Effect of high pressure on reduced sodium chloride surimi gels

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ABSTRACT

Following the dietary recommendations for the reduction of salt consumption, the present study considered several surimi gelation processes and the influence of high pressure (HHP) on reduced salt content gels. Suwari (S) and heated-induced definitive gels with setting (SQ) and without (Q) were prepared with three different high hydrostatic pressure treatments (0, 150 MPa and 300 MPa) and with two different salt percentages (0.3% and 3%).

The protein denaturation and/or unfolding induced by HHP processing of samples with reduced NaCl content was similar to that observed when a higher level of NaCl was used. Gel microstructure became more compact and denser with increasing NaCl content and higher HHP, what resulted in more luminous (L^*) gels.

Mechanical and sensory properties of reduced-NaCl gels were improved by the application of 300 MPa, reaching similar values to the gel made with higher NaCl content. The gelation profiles of the surimi pastes indicated that samples made with lower NaCl content produced stronger networks that were as stable as the ones with higher NaCl content.

1. Introduction

In the gelation process proteins undergo unfolding and denaturation followed by protein association, forming a three dimensional network which entraps water molecules and thus produces a gel. Sodium chloride is commonly used to solubilize the myofibrillar proteins and to induce protein unfolding. Depending on the proportion of NaCl employed for this purpose, the resulting gels will exhibit different textures; gels made with a low proportion of salt tend to be poorer because the protein is not adequately solubilized (Park, 2005). On the technological side, gel based products are normally made with 2–3% NaCl, and thus their physicochemical properties are highly suited to this kind of products (Lanier, Yongsawatdigul, & Carvajal-Rondanelli, 2014).

When seeking to follow dietary recommendations, the tendency is to focus on reducing the amount of salt in any product as excessive salt consumption induces cardiovascular problems and hypertension (EFSA, 2005; NAOS Strategy, 2005). In applying these recommendations, various different techniques are required, sometimes in combination with additives, to improve gelation. This poses a considerable challenge from a technological standpoint, since myosin protein gelation always requires prior myosin solubilization, and NaCl plays a very important role to that respect (Lanier et al., 2014).

To overcome this challenge, different methods have been tested. Commonly, it has been studied the replacement of Na^+ in surimi gels with other cations such as K+, Mg2+ or Ca2+ (Tahergorabi & Jaczynski, 2012) and the use of mineral salt mixtures in meat products (Ruusunen, M., Vainionpää, J., Lyly, M., Lähteenmäki, L., Niemistö, M., Ahvenainen, R. et al., 2005) and fish with different results (Desmond, 2006; Pansalt®, Lo®, Morton Lite Salt®, etc). In this sense, the search for new methods to reduce salt content, such as could be high hydrostatic pressure (HHP), would be an interesting alternative.

The application of high hydrostatic pressure (HHP) can improve surimi and fish muscle mince gelation by inducing protein aggregation, which is characterized by side-to-side interactions of proteins due to a decrease in protein volume (Sun & Holley, 2010). Depending on the intensity of the treatment, HHP can destabilize non-covalent protein–protein interactions and promote the dissociation of oligomeric proteins, the formation of more complex systems and the unfolding and breakdown of others. These effects are particularly pronounced at the tertiary and quaternary protein structure levels (Chapleau, Mangavel, Compoint, & Lamballerie-Anton, 2004; Huppertz, Fox, & Kelly, 2004; Jaenicke, 1987; Jimenez-Colmenero & Borderias, 2003; Moreno, Cardoso, Solas, & Borderías, 2009). In this connection it has been reported that

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hydrogen bonds will form at pressures below 150 MPa, while at higher pressures (>200 MPa) ionic interactions and particularly hydrophobic interactions predominate (Huppertz et al., 2004; Pérez-Mateos, Lourenco, Montero, & Borderias, 1997). All these HHP-induced protein–protein bonds and interactions play an important role in the gelation process and in the final properties of the resulting gels.

The main objective of this work was to reduce the NaCl content in the surimi gelling process from the regular level (3%) to 0.3% with a view to making healthier products using mild high hydrostatic pressure (150 MPa and 300 MPa) as a treatment.

2. Materials and methods

2.1. Raw material

To elaborate the gels it was used Alaska Pollock surimi (*Theragrachalcogramma*) which was supplied by Angulas Aguinaga (Guipuzcoa, Spain) in frozen blocks of 20 Kg.

The only ingredient used to elaborate the gels was Sodium chloride (Panreac, Quimica, S.A.; Barcelona, Spain).

2.2. Proximate analysis

Ash, fat, crude protein and moisture content of Alaska Pollock surimi was determined (AOAC, 2000) in quadruplicate. Crude protein content was measured by a LECO FP-2000 Nitrogen Determinator (Leco Corporation, St Joseph, MI, USA).

2.3. Sample preparation

Alaska Pollock Surimi was chopped into pieces of 15–20 g and homogenized in a Stephan homogenizator at 1500 rpm/10 min (Stephan UMC 5, Stephan Machinery, Germany) with two different NaCl concentrations: 0.3% (Lot A) and 3% (Lot B). Homogenization was performed in vacuum conditions and the temperature was controlled so as not to exceed 12 °C throughout the process. Each dough was stuffed into 35 mm Krehalon casings (Amcor group Flexibles Hispania S.L., Barcelona, Spain). Afterwards, the control sample was left untreated (0 MPa) and the others were pressurized at 150 Mpa and 300 MPa (Stansted Fluid Power CTD, FPG 7100:-2C. Stansted, UK.), 10 min at 10 °C. After isostatic high pressure processing (HHP), a part of each batch was stored at 5 °C for 24 h to obtain a suwari gel (S) which is a gel gradually formed with a slightly transparent appearance (Sen, 2005). Another part was heated (90 °C/30 min) to obtain a definitive gel (Q) (gel thermally treated so that its properties are definitive), and the rest stored at 5 °C/24 h and heated (90 °C/30 min) to obtain definitive gels after setting (SQ). Samples were coded as shown in Table 1.

2.4. Differential scanning calorimetry

Thermal behaviour of surimi samples was monitored using a differential scanning calorimeter (DSC Q1000, TA Instruments, New Castle, USA). Samples were placed in hermetically sealed aluminium pans. The approximate sample weight was around 10 mg as determined by an electronic balance (Sartorius ME235 S, Goettingen, Germany). The samples were scanned in triplicate at 10 °C/min from 5 °C to 110 °C under a dry nitrogen purge at 50 mL/min. Second scans were recorded after cooling (30 °C/min) down to 5 °C to check for residual/new effects. The water content of each individual sample was determined by desiccation at 105 °C to normalize thermal data to dry matter content. Temperature, T_{peak} (°C) and enthalpy of transition ΔH (J/g_{dm}) were determined for each sample.

Table 1
Coding of the samples as a function of the different formulations and treatments.

Lot	Sample	NaCl (%)	Pressure (MPa)	Temperature treatment (setting conditions)
Lot A	A0-S	0.3	0	5 °C/24 h
	A0-Q			90 °C/30 min.
	A0-SQ			5 °C/24 h + 90 °C/30 min.
	A150-S		150	5 °C/24 h
	A150-Q			90 °C/30 min.
	A150-SQ			5 °C/24 h + 90 °C/30 min.
	A300-S		300	5 °C/24 h
	A300-Q			90 °C/30 min.
	A300-SQ			5 °C/24 h + 90 °C/30 min.
Lot B	B0-S	3	0	5 °C/24 h
	B0-Q			90 °C/30 min.
	B0-SQ			5 °C/24 h + 90 °C/30 min.
	B150-S		150	5 °C/24 h
	B150-Q			90 °C/30 min.
	B150-SQ			5 °C/24 h + 90 °C/30 min.
	B300-S		300	5 °C/24 h
	B300-Q			90 °C/30 min.
	B300-SQ			5 °C/24 h + 90 °C/30 min.

The letters and numbers in the code correspond (in order) with: -NaCl: A (0.3%), B(3%); -Pressure: 0, 150, 300 MPa and Treatment: S (5 °C/24 h), Q (90 °C/30 min), SQ (5 °C/24 h + 90 °C/30 min).

2.5. Fourier transform infrared spectroscopy

Infrared spectra between 4000 and 650 cm^{-1} were recorded using a Perkin–Elmer Spectrum 400 Infrared Spectrometer (Perkin–Elmer Inc., Waltham, MA, USA) equipped with an ATR prism crystal accessory. The spectral resolution was 4 cm^{-1}. Measurements were performed at room temperature using 1 mg of each gel sample, which was placed on the surface of the ATR crystal, and pressed with a flat-tip plunger until spectra till suitable peaks were obtained. All experiments were performed in triplicate. In order to increase spectra resolution, a second-derivative spectrum was determined, in which the minimum sharp will correspond to maxima intensity region in the original spectrum. Background interference was eliminated using the Spectrum software version 6.3.2 (Perkin–Elmer Inc.).

2.6. Determination of sulfhydryl groups content

Determination of sulfhydryl groups was carried out according to the method described by Ellman (1959). Briefly, 0.5 g of sample was homogenized in 10 ml of buffer (50 mM Tris-HCl pH:8) for 30 s at high velocity (Ultraturrax Ika T25; IKA Working Inc., Willington, NC, USA).

An aliquot of 1 ml of the homogenate was added to 9 ml of Ellman's buffer (50 mM Tris-HCl pH 8 containing 0.6 M NaCl, 6 mM EDTA, 8 M urea and SDS 2%) and this was centrifuged for 15 min at 10,000 × *g*. 40 μl 0.01 M DTNB (5,5′-dinitrobis [2-nitrobenzoic acid]) was added to a 3 ml aliquot of the supernatant. The mixture was then incubated at 40 °C/20 min and the absorbance was measured at 412 nm (UV-VIS Spectrophotometer, SHIMADZU CORP). Sulfhydryl content values were obtained by dividing the value of the absorbance by the molar extinction coefficient (EM = 13,600 M/cm). All determinations were carried out in triplicate and the results were expressed in terms of micromoles of sulfhydryl per grams of sample.

2.7. Scanning electron microscopy (SEM)

For microscopic examination 2–3 mm cubes were cut. The samples were then fixed (1:1 v/v) in formaldehyde (4%) and glutaraldehyde (0.2%) in 0.1 M phosphate buffer (pH 7.3) and