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Use of Konjac glucomannan as additive to reinforce the gels from low-quality squid surimi

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ABSTRACT

This paper reports a study of the influence of a Konjac glucomannan aqueous dispersion (*KAD*) as ingredient, at different alkalinity levels, on the thermal stability of low-quality squid surimi (*Dosidicus gigas*) and the viscoelastic properties of its gel. An increase in elastic (G') and viscous (G'') moduli at $T < 50$ °C, reflecting protein aggregation, and a strong decrease at $T > 50$ °C, reflecting structural damage, were observed in thermal gelation profiles of low-quality squid surimi. The contribution of 1% *KAD* (10%) to enhancement of gelation ability was assessed by evaluating the viscoelastic properties of the gels, with and without *KAD*, at increasing alkalinity levels. Gels with *KAD* at high-pH had the best rheological properties. Small amplitude oscillatory shear (SAOS) tests showed a significant decrease in rigidity, an increase in strain amplitude and a decrease in the frequency-dependence of G' and G''. These results were in agreement with instrumental texture analyses, meaning that *KAD* may be used to overcome the negative effect of the poor protein functionality of low-quality squid surimi and achieve better gels from them.*

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1. Introduction

Surimi consisting of a concentrate of salt-soluble myofibrillar proteins has unique gelling properties that make it useful as a base in seafood analogues and other gel-based food products. Surimi is made from many fish species, but Alaska pollock (*Theragra chalcogramma*) is the species that produces the best nominal quality of surimi (Park, 2005).

Research has shown that besides Alaska pollock and other fish, a cephalopod as giant squid (*Dosidicus gigas*) may also be used if subjected to specific chemical treatments (Sánchez-Alonso et al., 2007) and in fact there is now a small market for such surimi made under patent (Careche et al., 2005). Surimi from these species is of interest for its high processing yield, very low fat content, bland flavour and very white flesh. On the other hand, such surimi presents only moderate gel-forming capacity (no more than 400–500 g cm) (Sánchez-Alonso et al., 2007).

In a comparison of two patents dealing with squid surimi (Careche et al., 2005, 2006), the first based on acid solubilization followed by isoelectric protein precipitation and the second on muscle washing with an acid solution, Campo-Deaño et al. (2009, 2010) reported that myosin damage was greater in giant squid surimi made by isoelectric precipitation than in surimi made by acid washing. Nevertheless, isoelectric precipitation is the method that is normally used since it provides higher protein performance.

From the standpoint of food protein functionality, the formation of a protein–water–polysaccharide complex entails a change in the composition, structure and functional properties of the protein particles, since proteins and polysaccharides possess a large number of ionizable side chain groups and differ in shape, size, conformation, flexibility and net charge at a given pH and ionic strength. It has been shown that interactions of proteins with polysaccharides, and of various proteins with one another and with water, govern the solubility of biopolymers, their ability to form viscoelastic gels, and their behavior at interfaces (Damodaran and Paraf, 1997). This means that gelling characteristics of surimi from giant squid (*D. gigas*) can be enhanced using an aqueous dispersion of polysaccharide, such as Konjac glucomannan (*KGM*), even at a pH that is not the best for myofibrillar protein gelation, because the gelate *KGM* could reinforce the general gel (Xiong et al., 2009).

KGM is a neutral polysaccharide that is extracted from the tuber of *Amorphophallus konjac* C. Koch, consisting of β-1, 4-linked D-mannose and D-glucose at a ratio of 1.6:1, with about 1 in 19 units acetylated (Kato and Matsuda, 1969). *KGM* has a dual functionality: on the one hand it is highly beneficial for human health because of its indigestible dietary fiber content, which has been shown to play a role in weight reduction, modification of carbohydrate metabolism in diabetics and cholesterol reduction (Zhang et al., 2001).

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KGM also has the ability to reinforce gel hardness 8–10-fold in both whiting and pollock surimi (Park, 1996) and recently was verified its good cryoprotective effect on myofibrillar protein from grass carp (*Ctenopharyngodon idella*) during frozen storage (Xiong et al., 2009). Moreover *KGM* can form strong, elastic, heat-stable gels when heated with mild alkali (Dave et al., 1998).

In previous work (not published), carried out by the authors, it was studied the effect of *KGM* dispersion in water (10 wt.%) at several concentrations: 0%, 1%, 5% and 10% at alkali pH on the viscoelastic properties of giant squid surimi and their gels obtained at different thermal conditions. From textural and dynamic rheological data, it was found that considering the concentration influence at an alkali pH, viscoelastic magnitudes of raw and gel samples without *KGM* (0%) were statistically different of the rest, with poorer gel properties; but undistinguishable among samples with 1%, 5% and 10%, so 1% was chosen for the present work due to be the minimum quantity studied.

The objective was to improve the rheological characteristics of thermally induced gels from giant squid (*D. gigas*) surimi (processed by isoelectric precipitation) by adding 1% *KGM* dispersion in water (10 wt.%) to squid surimi at different pH values, to induce different levels of glucommannan deacetylation. To that end the viscoelastic properties of squid surimi gels, were compared with those of a gel made from medium-quality Alaska pollock surimi.

2. Materials and methods

2.1. Preparation of samples

2.1.1. Preparation of surimi

The squid surimi was produced by a method patented by Careche et al. (2005). Giant squid (*D. gigas*) was caught on the west coast of Peru and the surimi was processed there. To elaborate the surimi, some parts of the mantle, free of inner and outer skin, were cut into pieces and homogenized with a Stephan (Stephan und Sohne GmbH and Co., Hameln, Germany) model micro-cut, in a solution of H_3PO_4 (1:4) so as to produce a final pH of around 3. This solution was passed through a 100 μm filter to remove fasciae. Sodium bicarbonate was added to this filtered solution to bring the pH up to 5. The solution was then centrifuged in a decanter at 5000*g* (Alfa Laval Corporation AB, Lund, Sweden). Cryoprotectants (4% sorbitol + 4% sucrose) and 0.5% sodium tripolyphosphate were added to the protein precipitate and the sample was processed in a cutter CUTMIX 120 l STL vacuum cutter–mixer (K+G Wetter GmbH, Biedenkopf, Germany). The principal constituents of the squid surimi are shown in Table 1.

Alaska pollock (*Th. chalcogramma)* surimi (grade A) was supplied by a local factory. Its chemical composition is shown in Table 1.

2.1.2. Preparation of KGM aqueous dispersion

Konjac flour from *A. konjac* was purchased from Trades, Barcelona, Spain (code 048012). Glucomannan purity was 85 %.

Table 1
Soluble protein/total protein and chemical composition of two kinds of surimi: Alaska pollock (*AP*) and giant squid (GS).

	PS/PT (%)	Humidity (%)	Protein (%)	Lipid	Ash
AP surimi	$80.6^{a} \pm 2.2$	$73.8^{a} \pm 0.5$	$17.0^{a} \pm 0.4$	$0.30^{a} \pm 0.01$	$1.00^{a} \pm 0.10$
GS-surimi	$46.2^{b} \pm 6.0$	$74.8^{a} \pm 0.6$	$16.5^{a} \pm 0.3$	$0.30^{a} \pm 0.03$	$0.90^{a} \pm 0.07$

[a,b] Different letters in the same column for each magnitude indicate significant difference at $P < 0.05$. The rest of chemical composition, up to 100, correspond to the carbohydrates added as cryoprotectants.

Powdered *KGM* was dispersed in distilled water at room temperature for ~3 h. The dispersion was prepared in a *Taurus Mycook* homogenizer (1743 CAV S/N 2077828), slowly adding small quantities of powdered *KGM* 1 g every 20 min in water and stirring at low speed until the *KGM* concentration reached 10 wt.%.

2.1.3. Gel preparation

For control sample (*CS*) preparation, chopped semi-thawed squid surimi was homogenized in a cutter (Stephan UM5, Stephan u. Söne Gmbh & Co, Hameln, Germany) for 7 min with 0.65% $Ca(OH)_2$ (from Panreac Quimica SA, Barcelona, Spain) until neutral pH (6.4 ± 0.1) was reached. Then 3% NaCl (of total batter) was added and the mixture was homogenized for another 7 min. The raw paste was placed in cylindrical steel cells (diameter 2 cm × height 6 cm), then the cells were placed in a water-bath (Memmert WB 10, from Memmert GmbH+Co., KG, Schwabach, Germany) at 90 °C for 30 min. Afterwards the cells with the sample inside were placed in a water–ice slurry and finally kept refrigerated at 7 °C for 1 day.

For preparation of samples *A*, *B*, *C* and *D*, *KAD–surimi* paste was formulated using 1% of *KAD*, which was homogenized in a cutter for 7 min with enough $Ca(OH)_2$ until the pH reached: *A*: 6.4 ± 0.1, *B*: 8.5 ± 0.1, *C*: 9.7 ± 0.1 and *D*: 10.4 ± 0.1, respectively. The raw pastes were thermally processed in the same way as *CS* sample.

Alaska pollock surimi (pH = 6.8 ± 0.1) was thawed at 7 °C for 1 day then homogenized for 7 min with 3% NaCl. Thermal processing for gelation was the same as in other samples. The sample code of this gel is *AP*.

2.2. Analyses

2.2.1. Protein solubility

This was determined in triplicate, essentially according to the procedure of Ironside and Love (1958), by solubilizing the soluble protein in a chilled aqueous solution of 5% NaCl (Panreac Quimica SA, Barcelona, Spain). After solubilization the protein was quantified in a LECO FP2000 analyzer (Leco Corporation, St. Joseph, MI, USA) and the results were expressed as a percentage of soluble protein over the total protein.

2.2.2. Determination of pH

The pH was determined in quintuplicate using a Jenway 3520 pH meter (Essex, UK) with a Hamilton electrochemical sensor on a homogenate of surimi + 1% *KAD*.

2.2.3. Textural properties

Cylindrical samples (diameter 2 cm × height 3 cm) were removed from the cylindrical cells and tempered to about 20 °C. Gels were pierced to breaking point using a TA-XT2 Texture analyzer (SMS, Surrey, UK) with a 5 mm – diameter round-ended metal probe. Crosshead speed was 1 mm/s, and a 2 kg load cell was used. The load (as breaking force) and the depth of depression (as deformation) when the gel sample lost its strength and ruptured were recorded. All determinations were carried out at least in sextuplicate.

2.2.4. Small amplitude oscillatory (SAOS) shear measurements

Small deformation shear oscillatory testing was performed using a Bohlin CVO controlled stress rheometer (Bohlin Instruments, Inc., Cranbury, NJ), and a RS600 Haake rheometer (Thermo Electron Corporation Karlsruhe, Germany). The measurements were carried out using a parallel-plate geometry (20 mm in diameter and 1 mm gap). Definitive gels were cut into disk-shaped slices samples 20 mm in diameter and 1 mm thick with a 570 S.T.E slicer machine (Germany). Any excess sample protruding beyond the upper plate was carefully removed. Samples were allowed to rest for 15 min before analysis to ensure both thermal

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