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Influence of the starch content in the viscoelastic properties of surimi gels

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Abstract

Changes in viscoelastic properties as a function of the wheat starch content of crab sticks from Alaska Pollock and Pacific Whiting surimi determined from transient and oscillatory measurements were studied. Based on the frequency dependence of the complex shear modulus (G^{*}), the two types of sticks were discriminated in terms of gel stiffness (A_n) and the difference ($G0' - G0''$) as a function of starch content. Creep and recovery tests allowed gel strength, S, to be determined from the relation modulus, $G(t)$. This body of parameters provides an interesting method for the industrial assessment of the nominal quality of surimi and its derivatives.

Overall, the tests revealed that stiffness and hardness in the product increase with increasing starch contents. Specifically, the optimum starch content for Alaska Pollock sticks was found to be 11%, above which the product becomes unacceptably hard and brittle. By contrast, the optimum starch content for Pacific Whiting sticks was 11–15%, which reflects a decreased gelling capacity of this type of surimi.

Keywords: Wheat starch; Viscoelasticity; Gel strength

1. Introduction

High-priced fishery products are becoming increasingly scant or even nearly unavailable in developing countries by effect of the massive overexploitation of some species. However, the demand for fish in both developed and developing countries continues to rise. As a result, the only choice for some is the use of previously scarcely accepted fish species with many bones, very soft muscle, a very small size or a very high content in fat. Such species, which, based on recent reports from FAO, account for roughly 50% of all industrial catches, have traditionally been rejected for marketing. Making them species acceptable for consumers entails their prior technological processing in order to alter their appearance; this usually involves extracting their muscle and transforming it in order to improve its commercial acceptance. The starting material used to this end usually consists of minced fish and, especially, surimi. Surimi washed minced fish muscle, which consists of salt-soluble myofibrillar protein, has unique gelling properties that make it useful as a food base in seafood analogues (Benjakul, Chantarasuwan, & Visessanguan, 2003). Alaska Pollock (*Therma chalcogramma*) and Pacific Whiting (*Merluccius productus*) are the two most widely used fish species for the production of surimi and surimi seafood in the USA (Yoon, Gunasekaran, & Park, 2004).

Surimi is an intermediate in the manufacturing of various analogues of high-priced products such as shrimps, scallops, lobsters, elvers and crab legs. Surimi sticks are recognized as a major source of nutrients and have grown substantially in use in response to the increasing demand for low-cholesterol, low-fat foods (Borderías & Pérez-Mateos, 2005; Moosavi-Nasab, Alli, Ismail, & Ngadi, 2005). These products are gel-based protein composite foods that are prepared by incorporating ingredients such as starch, egg white proteins, salt and vegetable oils into a continuous

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Nomenclature

SD	standard deviation	$J(t)$	shear compliance (Pa^{-1})
γ	shear strain (dimensionless)	$G(t)$	relaxation function (Pa)
σ	shear stress (Pa)	$S(t)$	gel strength (Pa s^n)
μ_{ins}	instantaneous viscosity (Pa s)	n	relaxation exponent
G^*	complex modulus (Pa)	v	frequency
G'	storage modulus (Pa)	ω	angular frequency
G''	viscous modulus (Pa)		

protein matrix. The textural properties of seafood are affected by the physico-chemical properties, distribution and volume fraction of the added ingredients, and also by their interactions with the protein gel matrix (Lee, 2002). Starch is the most widely used filler ingredient of surimi products by virtue of its high capacity to swell and hold water; this helps maintain gel strength with a reduced amount of surimi and ensures storage stability in refrigerated or frozen crab sticks (Montero & Gómez-Guillén, 1996; Park, 2000). An accurate knowledge of the rheological properties of crab sticks, which has not yet been established, is very important for the surimi industry. Thus, using an appropriate starch concentration is crucial with a view to obtaining a widely acceptable product. The surimi industry currently tends to use a proportion of starch of 11% in its products. The potential influence of the starch content of crab sticks on their rheological properties does not seem to have been studied in detail to date, however.

Viscoelastic properties are important in relation to the engineering design of continuous processes, the development of new products and quality control during surimi seafood processing. Dynamic rheological testing is widely used by the food industry (Steffe, 1996) for various purposes including the characterization of the effect of starch on surimi gels (Kong, Ogawa, & Iso, 1999; Ma, Grove, & Barbosa-Cánovas, 1996; Yoon et al., 2004). Some authors (Kong et al., 1999;Ma et al., 1996; Montero & Gómez-Guillén, 1996) have examined the influence of starch on the gelation capacity of surimi. Also, small-amplitude oscillatory shear measurements and transient tests have widely used to characterize the rheological behaviour of various food gels (Tovar et al., 2003,2004; Yoon et al., 2004; Zhang et al., 2005).

In this work, we expanded previous studies of our group by examining the influence of the starch content in surimi from Alaska Pollock and Pacific Whiting on its viscoelastic properties. Our specific purposes were (a) to study the dependence of the dynamic rheological properties of the products on their starch content with a view to establishing the optimum proportion of starch to be used; and (b) to identify viscoelastic quantities related to gel strength from static and oscillatory test measurements with a view to providing the fishery industry with a useful method for assessing and improving the quality of surimi derivatives.

2. Material and methods

2.1. Preparation of samples

Surimi from a cold-water fish species (Alaska Pollock) and a temperate-water species (Pacific Whiting) was used to prepare crab sticks. Table 1 shows the technical characteristics of the two types of surimi as supplied by their manufacturers. Samples were prepared at a pilot plant of a Spanish firm that produces surimi and surimi seafood. The sticks studied contained 55% surimi, 25–33% water, 2% egg white, 1.3% salt, *ca.* 1% vegetable oil and flavourings, and 7%, 11% or 15% starch.

In order to avoid damaging the blender, frozen surimi samples were allowed to thaw to a temperature never exceeding 0 °C. To this end, product blocks were stored in a refrigerator overnight, subjected to an air-stream at room temperature or placed on trays through which water at 30 °C was circulated. Then, the surimi was blended with the ingredients in the previous proportions, the starch being previously suspended in water to facilitate hydration. The temperature was kept below 10 °C throughout in order to avoid denaturation of proteins and facilitate gel formation; this was no problem in the test enclosure, which was a factory room conditioned at *ca.* 8 °C.

The next step involved extruding the raw surimi-ingredient paste in the cooking roller, which was heated at 95–98 °C in order to ensure formation of a thermal gel. In this way, a solid sheet 25 cm wide × 1.2–1.5 cm thick was obtained; immediately, the conveyor belt carrying the extruded sheets entered a water vapour-saturated atmosphere to prevent the paste from drying out.

Then, the sheets were allowed to cool to room temperature and slit lengthwise by means of rollers, the bottom portion being fringed as a result. Next, a mechanical system was used to coil the sheets about their shorter side –

Table 1
Technical specifications of the manufacturers for the two types of surimi studied

Surimi	Impurities (no. films/40 g)	Gel strength (g cm)	Colour (L^*)	Colour (b^*)	Humidity
AP	5–30	⩾500	>74	>4.0	75 ± 1
PW	10–26	⩾440	>72	<8.5	76 ± 1