

Effects of Carrageenan on the Gelatinization of Salt-Based Surimi Gels

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Abstract

The influence of carrageenan addition on the gelatinization of salt-based surimi gels was investigated by measuring compressive properties and Hunter color scale values. Hydrocolloid kappa (κ)-carrageenan at 0%, 0.2%, and 1.0% and NaCl (2% w/w), KCl (1.5% w/w), and a mixture of NaCl (2% w/w) and KCl (1.5% w/w), were added to Alaska pollock surimi. Gel compressive properties were assessed by measuring the breaking force and gel strength. The gelling property of κ -carrageenan-induced surimi gel was significantly increased by the incorporation of KCl rather than NaCl. The addition of κ -carrageenan increased the breaking force and gel strength of surimi gels. Gels with 1% κ -carrageenan and KCl had the highest breaking force and gel strength. The addition of κ -carrageenan caused an increase in the whiteness values of the surimi gels.

Key Words: Surimi gels, kappa-Carrageenan, Gel strength, Salt

Introduction

Surimi is defined as the deboned, water-washed, and minced fish meat with cryoprotectives such as sorbitol, sucrose and polyphosphates (Khan et al., 2003; Hunt et al., 2009). A mixture of fish meat protein and salt forms a three-dimensional protein network during the heating process due to cross-linking by the denaturation of protein molecules (Powrie and Tung, 1976; Kong et al., 1999a, 1999b). The rheological properties of surimi gel depend on the fish species, fish quality, salt content, additives, and processing methods (Okada, 1981; Kong et al., 1999a, 1999b). To better address the textural properties of surimi-based products for consumers, additives such as starch, beef plasma protein, gum, egg white, and soy protein have been used (Khan et al., 2003; Jafarpour et al., 2012).

Carrageenan has also been used as a gelatinizing additive to enhance the texture and water-holding capacity of water-based gel systems, dairy products, meat and poultry products, and seafood systems (Hunt and Park, 2013). Carrageenan is a sulfated and linear polysaccharide with a chemical structure consisting of repeating units of galactose and 3,6-anhydrogalactose (Trius and Sebranek 1996; Chiovitti et al., 1997; Hunt and Park, 2013). There are three forms of carrageenan, kappa (κ), lambda (λ), and iota (ι), and their gelling abilities are known to be affected by cations such as K^+ , Na^+ , and Ca^{2+} (Ortiz and Aguilera, 2004). The gelling ability of κ -carrageenan in aqueous solution is enhanced by K^+ , resulting in increased utility of κ -carrageenan in K^+ -induced products (Abbasi and Dickinson,

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2004; Ortiz and Aguilera, 2004).

Several studies have examined the interactions of refined carrageenan with fish protein and the effect of different types of cations in a fish protein-carrageenan system (Montero and Pérez-Mateos, 2002; Sariçoban et al., 2010; Brewer, 2012). However, few studies have investigated the interactions of carrageenan with Alaska pollock meat protein when affected by various salts. Therefore, in the present study we investigated the additional effect of κ -carrageenans on several salt-based surimi gels.

Materials and Methods

Materials

Frozen Alaska pollock surimi *Theragra chalcogramma* (RA grade; Seongjin Fishery Food Co. Ltd., Busan, Korea) and commercial hydrocolloid (refined κ -carrageenan, MSC Co. Ltd., Yangsan, Korea) were used in preparing the surimi gel. The surimi contained 4% sorbitol, 4% sucrose, and 0.3% sodium triphosphate, with 75% water content. Surimi was cut in blocks of approximately 500 g, sealed in a vacuum package, and stored at -25°C until use. Polyvinylidene chloride casing as purchased from Tokyu Hands Department Store (Kureha, Tokyo, Korea). Potassium chloride and sodium chloride were purchased from Junsei Co., Ltd. (Tokyo, Japan).

Preparation of surimi gel

Surimi gel was prepared using frozen surimi with κ -carrageenan, NaCl and KCl. Frozen surimi was tempered in a chilled room, chopped into small pieces of $2 \times 2 \times 2 \text{ cm}^3$, and ground by a refrigerated food cutter (Hanil Co. Ltd., Seoul, Korea) for 2 min at high speed. The different types of salt, 2% (w/w) NaCl, 1.5% (w/w) KCl, and their mixture of 2% (w/w) NaCl and 1.5% (w/w) KCl were added to the ground surimi and homogenized for 3 min at slow speed. Then, a hydrocolloid κ -carrageenan at a concentration of 0%, 0.2%, or 1.0%, and deionized water, were added

to each sample, followed by an additional 5 min of grinding at slow speed. The prepared fish meat paste was extruded into a polyvinylidene chloride casing. The stuffed casing was heated in a hot-water bath (HB-205WP; Hanbaek Scientific Co., Bucheon, Korea) at $90 \pm 2^{\circ}\text{C}$ for 30 min. After heating, the surimi gels were immediately cooled in ice water ($0-4^{\circ}\text{C}$) for 20 min to stop any further action due to heating. The gels were stored overnight at 4°C before analysis.

Determination of whiteness

The surimi gel was sliced at a thickness of 1.5 cm and color was determined using the Color Difference Meter (Lovibond Tintometer Model RT 300; Tintometer Ltd., Salisbury, UK). The Hunter color parameters such as L^* (lightness), a^* (redness/greenness), and b^* (yellowness/blueness) values were recorded ($n = 5$) and whiteness was calculated by the Park equation (Park, 1994).

$$\text{Whiteness} = (L^* - 3b^*)$$

Compression test

The prepared surimi gels were cut into small disks, 2.5 cm in height and 2.6 cm in diameter, tempered at 20°C , and subjected to a compression test with a Rheometer (Type COM-PAC-100; Sun Science Co., Tokyo, Japan), using a 5-mm diameter cylindrical plunger with up to 9 mm of compressive strain and a compression speed of 60 mm/min. The quality of the gels was assessed by measuring the breaking force (g), deformation (mm), and gel strength (g cm).

Statistical analysis

The data were expressed as means \pm standard deviation (SD). Differences between the means of the individual groups were analyzed by one-way analysis of variance (ANOVA) using the Statistical Analysis System, SPSS version 9.1 (SPSS Inc., Chicago, IL, USA) with Duncan's multiple range test; statistical significance was defined as $P < 0.05$.

Table 1. Hunter color values of 1% κ -carrageenan-added surimi gel as affected salts concentration

	Without 1% κ -carrageenan			With 1% κ -carrageenan		
	2.0% NaCl	1.5% KCl	2.0% NaCl + 1.5% KCl	2.0% NaCl	1.5% KCl	2.0% NaCl + 1.5% KCl
L^*	68.35 ± 1.34^b	47.80 ± 1.30^d	$55.97 \pm 1.69^{c,d}$	71.91 ± 1.07^a	56.21 ± 1.82^c	69.26 ± 1.07^b
a^*	-3.19 ± 0.11^c	-2.31 ± 0.18^b	-2.75 ± 0.13^a	-3.33 ± 0.03^d	-2.64 ± 0.15^a	$-3.33 \pm 0.03^{b,c}$
b^*	3.79 ± 0.42^a	2.90 ± 0.14^b	2.64 ± 0.17^a	2.64 ± 0.24^a	2.90 ± 0.14^b	2.64 ± 0.24^a
W	57.00 ± 2.59^b	39.10 ± 1.72^d	48.05 ± 2.2^c	60.66 ± 1.23^a	47.51 ± 2.24^c	61.34 ± 0.35^a

L^* , lightness; a^* , redness/greenness; b^* , yellowness/blueness; W, whiteness.

^{a-d}Values with different letters showed statistically significant differences at the $P < 0.05$ level, according to Duncan's multiple-range test.

Results and Discussion

Color attributes

The color parameters of surimi gels with/without κ -carrageenan were compared (Table 1). The color parameters were significantly influenced by the addition of different concentrations of κ -carrageenan. When κ -carrageenan was added, L^* values and whiteness of the surimi gels increased. NaCl-induced surimi gel with 1% κ -carrageenan showed the highest L^* values and whiteness and the lowest a^* and b^* values. However, the KCl-induced surimi gel showed lower L^* values and whiteness than the NaCl-induced surimi gel. In starch-added surimi gels, the changes in a^* values were considered to indicate significant changes in myoglobin denaturation (Zhang et al., 2013), while the changes in b^* values were considered to be due to the gelatinization and swelling ability of starch (Svihus et al., 2005). Gels became more opaque due to the expanding and swelling of κ -carrageenan granules in the presence of KCl, resulting in decreased gel lightness and whiteness.

Compressive properties

The influence of κ -carrageenan addition on the compressive properties of surimi gels containing NaCl, KCl, or the NaCl/KCl mixture was determined (Table 2). The compressive properties of surimi gels were assessed by measuring gel strength components, breaking force, deformation and gel strength; compression test results are shown in Fig. 1. The textural properties of surimi gels are controlled by the internal structure of the gel; *i.e.*, myofibrillar proteins and additives. Increasing the concentration of κ -carrageenan in surimi gels increased the breaking force significantly, the addition of κ -carrageenan to the KCl-induced surimi gel produced stronger gels than did NaCl addition; the highest breaking force was produced by addition of 1% κ -carrageenan to the KCl-in-

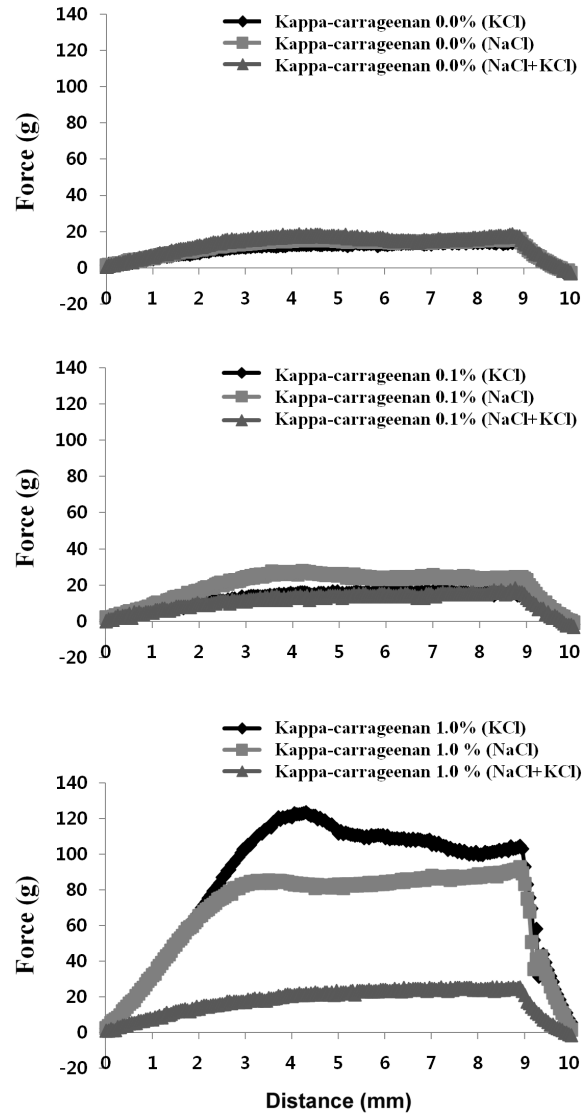


Fig. 1. Stress-strain curve from compression test of different salt-based surimi gels with κ -carrageenan.

Table 2. Effect of κ -carrageenan on compression property of surimi gels prepared with different salts

	κ -Carrageenan (%)	Breaking force (g)	Deformation (mm)	Gel strength (g cm)
2% NaCl	0	24.60 ± 3.91 ^d	4.22 ± 0.64 ^b	10.57 ± 3.09 ^c
	0.2	34.80 ± 4.92 ^d	4.33 ± 0.46 ^b	15.14 ± 3.11 ^c
	1.0	74.80 ± 4.02 ^b	5.08 ± 2.11 ^{a,b}	37.46 ± 1.33 ^b
1.5% KCl	0	39.80 ± 4.44 ^{c,d}	5.83 ± 1.39 ^{a,b}	22.83 ± 3.28 ^{b,c}
	0.2	44.60 ± 2.41 ^c	6.86 ± 2.23 ^a	30.47 ± 9.69 ^b
	1.0	122.50 ± 14.84 ^a	5.45 ± 2.64 ^{a,b}	66.13 ± 3.05 ^a
2% NaCl + 1.5% KCl	0	23.50 ± 2.43 ^d	3.66 ± 1.53 ^a	8.58 ± 3.55 ^c
	0.2	19.00 ± 2.65 ^e	4.20 ± 2.62 ^a	8.47 ± 0.67 ^c
	1.0	71.00 ± 7.18 ^b	3.50 ± 0.42 ^a	24.77 ± 3.25 ^{b,c}

^{a-e}Values with different letters showed statistically significant differences at the $P < 0.05$ level, according to Duncan's multiple-range test.

duced surimi gel. However, the NaCl/KCl mixture resulted in decreased breaking force compared to the KCl-induced surimi gel. Similar trends were observed in the strength of the surimi gels. Increasing the concentration of κ -carrageenan in surimi gels increased the gel strength, and addition of κ -carrageenan to the KCl-induced surimi gel resulted in greater strength than the NaCl-induced surimi gel. Furthermore, no particular trend of deformation was observed with increasing κ -carrageenan contents. Therefore, addition of κ -carrageenan with various salts did not improve deformation. These results indicate that as a salt source, KCl positively affects the gelling properties of the surimi gel. When comparing dynamic rheology results of salt-based fish protein systems (Hunt and Park, 2013), the addition of KCl to surimi gels with carrageenan resulted in an increased elastic modulus at a heating temperature of 80°C, compared to use of NaCl.

Carrageenan is gelatinized by a coil-helix transition. κ -carrageenan is structurally a sulfated galactan, and the addition of KCl induces the binding of alkaline ions (K^+) to the κ -carrageenan helix, resulting in partial neutralization of the sulfate groups (Montero and Pérez-Mateos, 2002; Ortiz and Aguilera, 2004). According to Penroj (2005), the polymer chains combine into double helices, which interlink to form relatively small domains on cooling. The domains form a three-dimensional network upon gelatinization, resulting in aggregation of the double helices and an increase in the gelling properties. In the carrageenan-induced fish protein system, competition between the fish protein and the carrageenan for the added salt and water-holding capacity occurs during heating. Additionally, the κ -carrageenan may distribute uniformly, concentrating the fish protein complex, and creating a stronger protein-hydrocolloid network in the presence of KCl, resulting in an increased gelling ability.

In conclusion, our data suggest that the gelling property of κ -carrageenan-induced Alaska pollock surimi was increased significantly by the incorporation of KCl rather than NaCl. The addition of κ -carrageenan increased the gel strength of surimi gels. Gels containing 1% κ -carrageenan and KCl had the greatest strength, while those containing 1% κ -carrageenan and NaCl showed a slightly lower strength. The addition of κ -carrageenan caused an increase in the whiteness values of the surimi gels. Further investigation is needed to better understand the role of KCl in the gelatinization of surimi gels.

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