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Assessing the textural properties of Pacific whiting and Alaska pollock surimi gels prepared with carrot under various heating rates

Ji Hoon Moon[a,b], Won Byong Yoon[b], Jae W. Park[a,*]

[a] Oregon State University, OSU Seafood Research and Education Center, 2001 Marine Dr. #253, Astoria, OR 97103, USA
[b] Department of Food Science and Biotechnology, College of Agricultural and Life Science, Kangwon National University, Chuncheon, Gangwon 200-701, Republic of Korea

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ABSTRACT

The effect of heating rates (3, 60 and 160 °C/min) on textural and physical properties of Pacific whiting (PW) and Alaska pollock (AP) surimi gels mixed with diced carrot (0%, 3%, 6%, and 9%) were investigated. Surimi-carrot mixed pastes were heated ohmically from 5 to 90 °C under three different heating rates and chilled immediately in ice/water. As heating rate increased, the hardness and cohesiveness value of PW surimi gels increased and those of AP surimi gels decreased. The hardness and cohesiveness value of PW and AP surimi gels prepared with diced carrot significantly decreased as the carrot content increased at all heating rates ($P < 0.05$). The shear force value of carrot heated at 160 °C/min showed the highest value in both species. The moisture loss (%) of surimi and carrots heated at 160 °C/min was significantly lower than other samples heated slowly. Scanning electron microscope revealed that the heating rate significantly influenced the microstructure of surimi gel and carrot in both species.

1. Introduction

Surimi, refined and stabilized fish protein, is an intermediate product used for surimi seafood. Gelation of fish protein is an important process in forming desired texture in surimi seafood. Pacific whiting (PW) surimi contains a high level of protease enzymes that degrade myofibrillar proteins when heated slowly, resulting in poor gel (Klesk, Yongsawatdigul, Park, Viratchakul, & Virolhakul, 2000). Cathepsin L in Pacific whiting surimi is the main protease responsible for the textural degradation (An, Weerasinghe, Seymour, & Morrissey, 1994) and has an optimum temperature of around 55–60 °C. Setting, the phenomenon of gel formation without heating, is subjected to incubation at 5–40 °C depending on the thermal stability of fish species (Niwa, 1992). This setting process is generally accepted as endogenous transglutaminase (ETGase) is responsible for inducing gel formation. ETGase in surimi is capable of catalyzing acyl transfer reactions by introducing ε-(γ-glutamyl) lysine cross-links between proteins (Lanier, Carvajal, & Yongsawatdigul, 2005) more effectively when heated slowly. These covalent cross-links play an important role in determining surimi gel texture. Current industrial cooking for testing gels (water bath heating at 90 °C for 30–40 min) is extremely slow (2–3 °C/min). Therefore, based on the production of fast heated products such as crabstick or fried fish cake, water bath heating overestimates the value of surimi containing no or least amount of protease enzymes (i.e., mid to high grade Alaska Pollock (AP) surimi), while it underestimates the value of surimi containing protease enzymes (i.e., PW surimi and most tropical surimi).

Ohmic heating generates heat internally due to its inherent resistance (Fryer, de Alwis, Koury, Stapley, & Zhang, 1993). It generates heat extremely fast or extremely slow in a homogeneous pattern (Bansal & Chen, 2006; Yongsawatdigul & Park, 1996). This advantage leads to the desired holding temperature in a short time, even for a few seconds and reduces the treatment time that is critical to avoid immoderate thermal damage. The application of ohmic heating in surimi and surimi seafood has also been investigated. Yongsawatdigul, Park, Kolbe, AbuDagga and Morrissey (1995) reported that the shear stress and shear strain of PW surimi gel heated in a 90 °C water bath for 15 min were significantly lower than those of ohmically heated without holding time. This was attributed to a rapid inactivation of endogenous protease by ohmic heating. Moreover, Yongsawatdigul and Park (1996) investigated the effects of linear heating rates on textural properties and myofibrillar proteins of PW and AP surimi and found that the shear stress of AP surimi gels increased as heating rate decreased, while the shear stress of PW surimi gels increased as heating rate increased. The heating rates used in surimi seafood processing are varied upon the geometry of finished products and heating methods. The heating rates

* Corresponding author.
E-mail address: Jae.Park@oregonstate.edu (J.W. Park).

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applied for crabsticks cooked in a thin sheet and fried fish cakes are approximately 160 and 60 °C/min, respectively. It is important to understand the effect of heating rate on surimi gelation for the process optimization of such products.

The addition of ingredients also influences the textural properties of surimi seafood. The main ingredients used for the development and modification of textural characteristics of surimi seafood are surimi, water, starch, protein additives, vegetable oil and hydrocolloids, flavorings, and colorings (Park, 2005). Shi et al. (2014) investigated the effect of vegetables oils (soybean, peanut, corn and rap oil) on the textural, color, microstructural, sensory and rheological properties of silver carp surimi gels and found that the breaking force of gels decreased, while expressible water and whiteness values were increased as vegetable oil increased. Moreover, Yoon, Park and Kim (1997) reported that the addition of starch improved shear stress of AP and PW surimi if used up to 6%. In the South Korea, *ahmook* (fried fish cake) is the largest surimi-based product, which is traditionally mixed with vegetable such as carrot, onion, garlic and onion. The addition of vegetable pieces can influence appearance, flavor as well as textural properties of finished surimi products. However, there are no studies on the utilization of unprocessed vegetables as a secondary ingredient in surimi seafood. For seafood industry, it is important to evaluate the textural properties of surimi and vegetables after heat treatment. Therefore, the objectives of this study were to (1) explore the role of carrot cubes in the physical properties of surimi seafood and (2) investigate the effect of heating rates (3, 60 and 160 °C/min) and carrot contents (0%, 3%, 6%, and 9%) on two major components (surimi and carrot) during surimi gelation.

2. Materials and methods

2.1. Materials

Pacific whiting (PW) (*Merluccius productus*; A grade) and Alaska pollock (AP) surimi (*Gadus chalcogrammus*, formerly *Theragra chalcogramma*; A grade) (NOAA, 2016) obtained from American Seafoods Company (Seattle, WA) and Arctic Storm (Seattle, WA), respectively. Surimi was cut into approximately 1 kg blocks, vacuum packaged and stored in a freezer (– 30 °C) prior to the experiment. Carrot purchased from a local market (Safeway, Astoria, OR) was stored in a refrigerator (5 °C) before cutting into approximately 3 mm cubes.

2.2. Surimi paste preparation

Frozen surimi block was partially thawed at room temperature for 30 min and cut into approximately 3 cm cubes (− 5 °C). Surimi was chopped at 1800 rpm for 1 min using a silent cutter (UM 5 Universal, Stephan Machinery Corp, Columbus, OH, USA). Chopping continued at 1800 rpm for 1 min with sodium chloride to extract myofibrillar proteins. Sodium chloride concentration was adjusted to obtain 2% in the mixture of surimi paste and carrot cubes (Table 1). The moisture content of surimi paste was adjusted to 78% by adding ice before chopping at 1800 rpm for 1 min. Paste was chopped at 3600 rpm for 3 min under vacuum (40–60 kPa) to eliminate air bubbles. During chopping, the temperature of pollock and whiting surimi paste was controlled to not exceed 5 and 15 °C, respectively. A dough blender (K5SS, KitchenAid, St. Joseph, MI, USA) was used to mix surimi paste with carrot cubes for 2 min. Carrot content was adjusted to 0%, 3.0%, 6.0%, and 9.0%. After mixing, the sample was transferred to a polyethylene bag and vacuum packed to remove air bubbles using a vacuum machine (Reiser VM-4142, Roescher Werke GMBH, Osnabrueck, Germany). The mixture was stuffed into polyvinyl chloride (PVC) tubes (diameter 3 cm and length 21 cm) using a sausage stuffer (The Sausage Maker, Buffalo, NY, USA).

Table 1
Formulation of surimi paste mixed with carrots.

	Ingredient	Carrot content (%)			
		0	3.0	6.0	9.0
Surimi paste	Surimi (g)	800.0	797.5	794.9	792.1
	Ice/water (g)	180.0	181.9	183.8	185.9
	Sodium chloride (g)	20.0	20.6	21.3	22.0
	Total (g)	1000.0	1000.0	1000.0	1000.0
	Moisture content (%)	78.0	78.0	78.0	78.0
	Salt content (%)*	2.0	2.1	2.1	2.2
Surimi paste + Carrots	Surimi paste (g)	1000.0	970.0	940.0	910.0
	Carrot (g)		30.0	60.0	90.0
	Total (g)	1000.0	1000.0	1000.0	1000.0
	Moisture content (%)**	78.0	78.3	78.7	79.0
	Salt content (%)	2.0	2.0	2.0	2.0

* Salt content varied to obtain a final salt content at 2.0% after mixing with carrots.
** Moisture content increased as the amount of carrot cubes increased.

2.3. Ohmic heating treatment

The surimi paste prepared with carrot cubes was heated ohmically (Fig. 1). Electrodes were inserted into both ends of the tube to obtain the sample length of 15 cm. One electrode was connected to an air cylinder (200 kPa pressure) to maintain solid contacts to both electrodes. The temperature at the geometric center of the samples was measured by a 30-gauge Teflon-sealed thermocouple (OMEGA Engineering Inc., Stamford, CT). The samples were heated from approximately 5 to 90 °C with three different voltage gradients that control heating rates: 3.3 V/cm (3 °C/min) 12.0 V/cm (60 °C/min) and 17.3 V/cm (160 °C/min). After heating treatments, samples were placed in a plastic bag, chilled immediately in ice/water for 15 min and stored overnight in a refrigerator (5 °C).

2.4. Moisture content

The moisture content was determined according to AOAC (2000). Surimi and carrot were separated from surimi-carrot mixed gels after heating before measuring the moisture content of surimi and carrot. Moisture loss (%) was calculated using Eq. (1) as follows:

$$Moistureloss(\%) = \frac{M_0 - M_H}{M_0} \times 100(\%) \quad (1)$$

where M_0 and M_H is the moisture content of unheated (raw) and heated surimi paste or carrot, respectively. All tests were performed in triplicate and the average values were used for further analysis.

2.5. Texture measurement

Texture profile analysis (TPA) has been widely used for the empirical analysis of a number of textural attributes of muscle foods and surimi gels (Kim, Park, & Yoon, 2005). For measuring textural property, surimi gels prepared with carrot samples were placed at room temperature for 2 h and cut into 30 mm long. Surimi-carrot mixed gel was placed on the platform and TPA was performed using a TA-XT texture analyzer (Stable Micro Systems, Surrey, UK) equipped with a flat probe TA-512 (diameter 12 mm). Our method was not like a conventional TPA test in which a diameter of plate is much larger than that of the sample. However, various researches were conducted using TSA with a probe smaller than the sample's diameter (Choi, Choe, Cho, & Kim, 2012; Lee & Min, 2002; Lee, 2012; Sánchez-Alonso, Solas, & Boderias, 2007; Yang, Wang, Wang, & Ye, 2014). The crosshead speed was set at 3 mm/s, the force applied at 50% strain and the resting time between strokes of the probe was 5 s. As all samples analyzed at 50% strain showed no sign of fracture, such scheme of an experiment might have