

Physicochemical Properties of Fish-meat Gels Prepared from Farmed-fish

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Fish-meat gel is being produced mostly relying on surimi and raw materials imported from Southeast Asia and North America and present in small amount in local markets. In this study, common farmed local fishes were examined as stable and reliable sources of surimi for fish-meat gel production. For testing, five main farmed-fish of Korea, namely; Bastard halibut (*Paralichthys olivaceus*), Red sea bream (*Pagrus major*), Korean rockfish (*Sebastes schlegeli*), Common mullet (*Mugil cephalus*), and Finespotted flounder (*Pleuronichthys cornutus*) were used following a traditional washing process. The quality of the surimi was determined by the values of water content, whiteness index, gel strength and impurity. Accordingly, fish-meat gel and surimi quality experiments were carried out by measuring compressive and texture properties, expressible moisture content, Hunter color scale values and SDS-page protein patterns. Also gel characteristics were compared with that of FA and RA grade surimi (Alaska Pollock). Fish-meat gels were prepared by salt mincing the farmed-fish surimi with NaCl (2% w/w) and moisture adjustment to 84% by ice water adding. Prepared fish-meat paste was filled into 20-25 cm long polyvinylidene chloride casings and heated at 90°C for 20 min. The whiteness values of fish-meat gels produced from surimi were increased by using farmed-fish and became comparable to that of FA Alaska Pollock gel. Among all tested farmed-fish, *P. olivaceus* and *P. major* exhibited better properties than RA Alaska Pollock and similar properties to FA Alaska Pollock. Therefore, current data suggests that fish farming can be an efficient and sustainable fish-meat source for fish-meat gel production in Korea.

Key words : Alaska Pollock, aquaculture, farmed-fish, fish-meat gel, surimi

Introduction

Surimi is a Japanese word to define the washed and minced deboned fish meat with some preservatives such as sorbitol, sucrose and polyphosphates [20, 27]. Quality of the produced surimi is defined by the rheological properties that are varying depending on the fish species, meat quality, salt content, additives and processing methods [11]. Surimi is mainly used for the manufacture of seafood substitute products to imitate the more expensive ones such as crab legs and fish fillet. Surimi-based foods have been consumed worldwide due to their high nutritious properties along with affordable prices. Surimi production is usually carried out

in bulk amount and produced surimi is shipped to smaller factories to be utilized in manufacturing the surimi-based seafood. In this context, although the properties of raw surimi is to be at a certain desired level, physicochemical properties of the final product harness a higher importance as it will be the one to be commercially available widely.

Fish-meat gels are one of the mainly desired surimi-based products, a base for other commercial products, which is prepared by salting and heating of surimi into gel-like form. Fish-meat gels are highly demanded in food industry because of the ease of utilization for imitate seafood products as well as food additive for increased nutritious values [21].

Most of the commercial products demand white-meat fish more compared to other fish species which makes the industry depending on the white-meat fish forage [7, 18]. Alaska Pollock is one of the most desired white-meat fish due to its high quality meat in terms of taste and texture [10]. On the other hand increased demand for surimi-based foods has resulted in a decline for the availability of fish meat, particularly due to overfishing. However, in order to

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match the certain quality criteria that Alaska Pollock provides, farmed-fish surimi and derived products are needed to be studied and compared before utilization in high-scale production. Catch of the undesired fish species are reported to be increasing while Alaska Pollock catch is declining in last decade, urging for future actions to be taken in order to supply the white-meat fish demand, particularly quality surimi production [12].

Aquaculture of several marine organisms is an upcoming trend in seafood industry. Efforts in culturing the highly demanded marine organisms have been increased in recent years [3]. The farming of fish is one of the most common aquaculture methods that supply the fish market with products raised in ponds, tanks or sea enclosures. Recent developments in aquaculture technology and the types of fish that can be farmed provided alternative ways for quality and sustainable production of surimi without relying on the supply of wild Alaska Pollock catch [19]. Main concern about the substitution of Alaska Pollock with farmed-fish products from aquaculture is the quality of the final product. In order to substitute Alaska Pollock in surimi production while not sacrificing the quality of the final products, five highly farmed-fish species; namely, Bastard halibut (*Paralichthys olivaceus*), Red sea bream (*Pagrus major*), Korean rockfish (*Sebastes schlegeli*), Common mullet (*Mugil cephalus*), and Finespotted flounder (*Pleuronichthys cornutus*) were compared with two grades (FA and RA grades) of Alaska Pollock in terms of surimi and fish-meat gel properties. Hence, to match the quality of Alaska Pollock-derived surimi and fish-meat gel products, current study focused on the comparison of surimi and fish-meat gel from five different farmed-fish and two grades of Alaska Pollock in terms of whiteness, texture profile and gel properties.

Materials and Methods

Materials

Five kinds of farmed-fish such as Bastard halibut (*P. olivaceus*), Red sea bream (*P. major*), Korean rockfish (*S. schlegeli*), Common mullet (*M. cephalus*), and Finespotted flounder (*P. cornutus*) were purchased at a local market in Busan and used in preparing the conventional washed surimi.

By comparison, frozen Alaska pollock surimi *Theragra chalcogramma* (FA and RA grade; Seongjin Fishery Food Co. Ltd., Busan, Korea) were used in preparing the fish-meat gel. Surimi was cut in blocks of approximately 500 g, sealed

in a vacuum package, and stored at 20°C until use. Polyvinylidene chloride casing was purchased from Ikjin Corp. (Kureha, Seoul, Korea). Potassium chloride and sodium chloride were purchased from Junsei Co., Ltd. (Tokyo, Japan).

Surimi preparation by conventional washing process

Washed surimi was prepared by conventional washing process. The farmed-fish was headed, eviscerated by washing, deboned manually and minced for 2 min in a silent cutter (Hanil Co. Ltd., Seoul, Korea). The fish mince was washed in cold water in a 1:3(w/w) ratio of mince to cold water, continuously mixed for 10 min at 0-4°C and dewatered using centrifuge in 8,000× g for 30 min at 4°C. The washing process was repeated three times. Adding 0.2% NaCl was carried out in the last washing step. Finally, excess of water was removed manually by squeezing using cheesecloth layers. Before freezing, 4% sorbitol, 4% sucrose and 0.2% sodium triphosphate were added as cryoprotectants in the washed surimi. Surimi was portioned in blocks of approximately 500 g, vacuum-packed and stored at until use.

Preparation of fish-meat gels

Fish-meat gels were made using the washed farmed-fish surimi and Alaska Pollock surimi with NaCl. Washed and frozen surimi was tempered in a chilled room, chopped into small pieces of 2×2×2 cm³ and ground by a refrigerated food cutter (Hanil Co. Ltd., Seoul, Korea) for 2 min at high speed. NaCl (2.0% w/w) were added to the ground surimi and homogenized for 3 min at slow speed. Then, the final moisture content was adjusted to 84% by adding ice water, 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±2°C for 20 min. After heating, the fish-meat gels were immediately cooled in ice water (0-4°C) for 10 min to stop any further action due to heating. The gels were stored overnight at 4°C before analysis.

Determination of whiteness

The fish-meat gels were sliced at a thickness of 1.5 cm and color values were 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).

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

Determination of expressive moisture content

Expressible moisture contents of gel samples were measured by the method of Benjakul et al. [2]. The cylindrical gel samples were cut into a thickness of 5 mm, weighed, and placed into three pieces of filter paper (No.1, Whatman International Ltd., Maidstone, UK) at the bottom and two pieces on the top of the gel sample. The samples were weighted under 5 kg for 2 min. Expressible moisture content was calculated and expressed as percentage of gel sample weight.

Gel quality

Prepared washed surimi was cut into cylindrical samples (26 mm in diameter and 3 mm in height) and subjected to compressive test with a Rheometer (Type COMPAC-100II; Sun Science Co., Tokyo, Japan) using a spherical plunger (5 mm in diameter) with a compression speed of 60 mm/min.

The prepared fish-meat gels were cut into cylindrical samples, 25 mm in height and 26 mm in diameter, tempered at 20°C and subjected to a compression test with a Rheometer (Type COMPAC-100II; Sun Science Co., Tokyo, Japan) using a cylindrical plunger (25 mm in diameter) with up to 10 mm of compressive strain and a compression speed of 60 mm/min.

The gel quality of the surimi and gels was assessed by measuring the breaking force (g), deformation (mm) and gel strength (g/cm^2) from stress-strain curve.

Textural properties

Texture analysis of fish-meat gels was carried out using a texture analyser (Model COMPAC-100II, Sun Science Co., Tokyo, Japan). The prepared fish-meat gels were equilibrated at room temperature (20-23°C), cut into cylindrical samples, 25 mm in height and 26 mm in diameter and tested. Springiness, cohesiveness, chewiness and brittleness were measured by the texture analyser equipped with a cylindrical plunger (50-mm diameter) with a compression speed of 60 mm/min.

For measuring cutting strength, the gels were cut into small disk (20×20×15 mm) and subjected to cutting test using the texture analyser with a compression speed of 60

mm/min.

SDS-polyacrylamide gel electrophoresis (SDS-PAGE)

The protein patterns of surimi and fish-meat gels were analysed using SDS-PAGE [13, 22]. Gels (0.5 g) were solubilized in 5 ml of SDS-urea buffer pH 8 (20 mM Tris-HCl, containing 8 M urea, 2% SDS, and 2% β -ME) using homogenizer at speed of 10,000x g for 30 sec. The homogenate was incubated in boiling water for 2 min, continuously stirred for 16-24 hr at room temperature and centrifuged at 10,000 x g for 20 min. Protein contents in the supernatants were assayed using bovine serum albumin as standard based on the method of Bradford assay. The protein 6 μg per lane were separated onto the polyacrylamide gel made 100 g/l running gel and 40 g/l stacking gel and performed by electrophoresis using a voltage of 120 V constant at ambient temperature. After separation, the proteins were subjected to stain in Coomassie brilliant blue R-250 solution for 30 min and destained with 250 ml/l methanol and 100 ml/l acetic acid in water for 1 hr. The protein band intensity was visualized using a Davinch-Chemi imagerTM (CAS-400SM, Seoul, Korea).

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 $p < 0.05$.

Results and Discussion

Color attributes

One of the main properties of the quality surimi and surimi-based products is the whiteness. Therefore, several color values of Alaska Pollock and farmed-fish products, particularly whiteness values were compared. Whiteness of the surimi and fish-meat gels is a crucial property for a desired final product. Hence, most of the surimi manufacturing processes include addition of whitening agents in order to reach a defined whiteness level of Alaska Pollock meat [25]. We have compared the five kinds of farmed-fish surimi and fish-meat gels with Alaska Pollock surimi and fish-meat gels according to Hunter color values (Table 1). All compared fish species had a higher whiteness value than RA grade

Alaska Pollock but there was not any notable whiteness comparable to FA grade in surimi. However, in case of fish-meat gels, whiteness of *P. olivaceus*, *P. major* and *S. schlegeli* were 90.73±0.31, 89.18±0.85 and 89.28±0.75 while the whiteness of FA grade Alaska Pollock fish-meat gel was 87.06±0.70. The whiteness of the processed surimi is known to change depending on heating process, salt concentration and whitening agent addition. As seen on Table 1, production of fish-meat gel increased the whiteness values notably. Although surimi whiteness values of farmed-fish were only comparable to RA grade Alaska Pollock, final product of fish-meat gel provided results better than FA grade Alaska Pollock for three of the fish, while remaining two were still had higher values than RA grade Alaska Pollock. There are several methods such as addition of whitening agents such as calcium carbonate, titanium dioxide [1], plant-based proteins and modified heating processes to increase the whiteness of surimi and fish-meat gels in order to obtain a desirable final product when Alaska Pollock was substituted [8]. Fish-meat gels produced using *P. olivaceus*, *P. major* and *S. schlegeli* had the color values better than FA grade Alaska Pollock gels without the addition of any extra agents or protein additives. Whiteness of aforementioned farmed-fish gels were 90.73, 89.18 and 89.28, respectively, according to Hunter color scale while FA grade Alaska Pollock had a whiteness value of 87.06. Also, in terms

of lightness *P. olivaceus*, *P. major* and *S. schlegeli* were observed to have values of 89.58, 88.62 and 88.73, respectively, compared to 87.34 value of FA grade Alaska Pollock.

Gel properties

Gel properties of raw surimi and final surimi product are main characteristics for measuring the quality of the product and the efficiency of production methods. Desired characteristics of final surimi product, particularly following the gelling process with heating and salting are defined in terms of gel strength, breaking force and deformation [14]. First, gel properties of surimi products from Alaska Pollock and farmed-fish were compared (Fig. 1). Raw surimi ought to possess lower gel strength and elasticity compared to fish-meat gels prepared from surimi. Gel strength of FA and RA grade Alaska Pollock surimi was higher than all of the farmed-fish while only *P. olivaceus* and *P. major* were able to show close gel strength to RA grade Alaska Pollock. Same manner was observed with breaking force and deformation levels with exception of *M. cephalus* which exhibited a three-fold higher breaking force than all other surimi products.

Surimi is produced to be used for further production of seafood products, mainly following a heat-set gelling process with salt and heat bath which induce the formation of actomyosin gel from myofibrillar part of the surimi [14]. Heating process and addition of salt are known to give the

Table 1. Hunter color values of surimi and fish-meat gels prepared from farmed-fish

Group	Fish	L	a	b	Whiteness
Surimi	A	84.73±0.65 ^a	-5.02±0.02 ^e	4.88±0.10 ^c	70.08±0.43 ^a
	B	67.75±1.42 ^{cb}	0.37±0.08 ^a	9.27±0.58 ^a	39.93±0.47 ^d
	C	70.82±0.60 ^d	-2.64±0.19 ^{bcd}	8.01±0.42 ^{ab}	46.80±1.46 ^c
	D	69.77±2.89 ^d	-1.85±1.53 ^b	7.47±3.30 ^{ab}	47.36±11.03 ^c
	E	63.52±1.37 ^d	-2.41±0.05 ^{bc}	5.06±0.45 ^c	48.34±1.67 ^c
	F	69.10±2.69 ^c	-0.08±0.91 ^a	2.49±1.07 ^d	61.62±2.62 ^b
	G	70.36±2.68 ^b	-3.376±0.16 ^d	6.748±1.29 ^{bc}	50.11±2.95 ^c
Fish-meat gels	A	87.34±0.79 ^b	-3.20±0.03 ^c	0.09±0.12 ^c	87.06±0.70 ^a
	B	84.66±0.68 ^c	-2.45±0.04 ^a	4.58±0.07 ^a	70.92±0.69 ^g
	C	89.58±0.36 ^a	-3.44±0.02 ^d	-0.38±0.04 ^e	90.73±0.31 ^a
	D	88.62±-0.83 ^a	-3.13±0.05 ^b	-0.19±0.06 ^d	89.18±0.85 ^d
	E	88.73±0.61 ^a	-2.48±0.04 ^a	-0.19±0.11 ^d	89.28±0.75 ^c
	F	82.68±0.62 ^d	-4.06±0.05 ^f	3.85±0.62 ^b	71.14±0.46 ^f
	G	81.19±0.83	-3.13±0.11	-1.42±0.37	85.46±0.53 ^e

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

^{a-e}Values with different letters in the column indicate statistically significant differences at the *p*<0.05 level, according to Duncan’s multiple-range test.

A, FA grade Alaska Pollock (*Theragra chalcogramma*); B, RA grade Alaska Pollock (*Theragra chalcogramma*); C, bastard halibut (*Paralichthys olivaceus*); D, Red sea bream (*Pagrus major*); E, Korean rockfish (*Sebastes schlegeli*); F, Common mullet (*Mugil cephalus*); G, Finespotted flounder (*Pleuronichthys cornutus*).

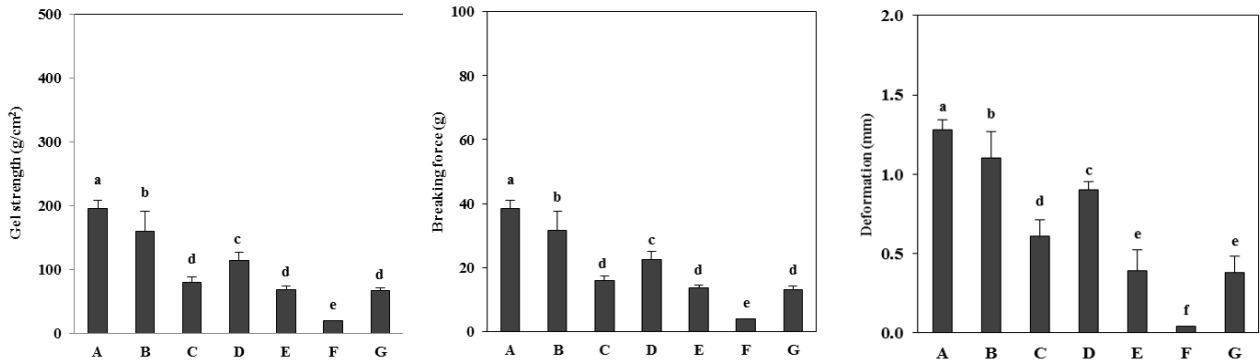


Fig. 1. Gel strength of surimi prepared with five different farmed-fish species and Alaska Pollock. A, FA grade Alaska Pollock (*Theragra chalcogramma*); B, RA grade Alaska Pollock (*Theragra chalcogramma*); C, bastard halibut (*Paralichthys olivaceus*); D, red sea bream (*Pagrus major*); E, Korean rockfish (*Sebastes schlegeli*); F, Common mullet (*Mugil cephalus*); G, Finespotted flounder (*Pleuroinchthys cornutus*). Values are means±SD (n=3). ^{a-e} Means with the different letters are significantly different (p<0.05) by Duncan's multiple range test. g/cm²=area value of plunger

texture to fish-meat gels through this protein degradation. Therefore, the gel properties of fish-meat gel from Alaska Pollock and farmed-fish were compared as well (Fig. 2).

Expectedly, preparation of fish-meat gels provided the gelling along with strength and elasticity. Low quality Alaska Pollock was, however, showed a very less elevation in gel

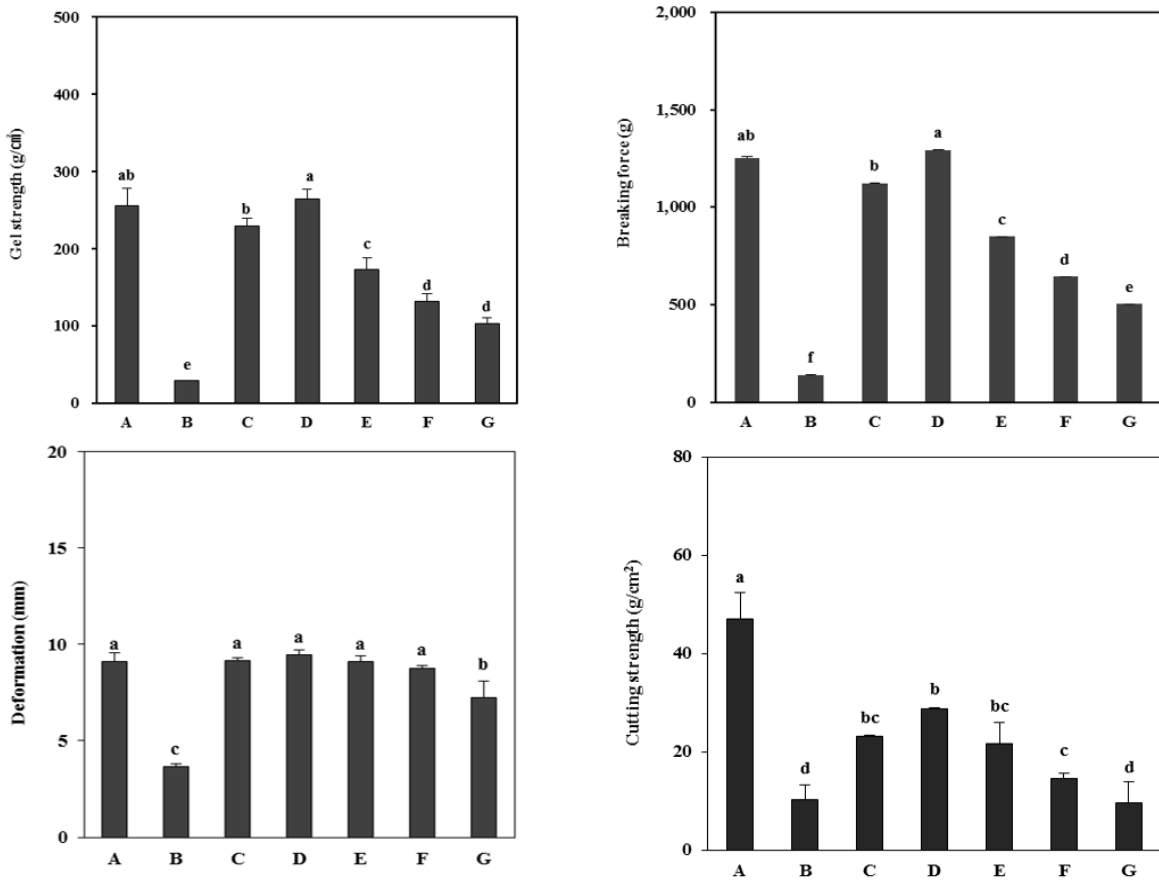


Fig. 2. Gel properties of fish-meat gels prepared using five different farmed-fish species and Alaska Pollock. A, FA grade Alaska Pollock (*Theragra chalcogramma*); B, RA grade Alaska Pollock (*Theragra chalcogramma*); C, bastard halibut (*Paralichthys olivaceus*); D, red sea bream (*Pagrus major*); E, Korean rockfish (*Sebastes schlegeli*); F, Common mullet (*Mugil cephalus*); G, Finespotted flounder (*Pleuroinchthys cornutus*). Values are means±SD (n=3). ^{a-f} Means with the different letters are significantly different (p<0.05) by Duncan's multiple range test.

properties while producing the fish-meat gels from raw surimi. On the other hand, both *P. olivaceus* and *P. major* gels were observed to gain an important strength and elasticity exerted as gel strength and breaking force, respectively. Strength and elasticity of *P. olivaceus* and *P. major* were statistically in the same level with FA grade Alaska Pollock.

Even though comparison of raw surimi properties showed a comparable quality for farmed-fish to RA grade Alaska Pollock, culture fishes were shown to be clinically provide same gelling quality with that of FA grade Alaska Pollock, doing so without inclusion of any additives or protein extracts. Gel strength and elasticity are main characteristics of a quality and desired fish-meat gels in terms of production of commercial food based on raw surimi.

Fish-meat gels made from farmed-fish were shown to possess the properties of Alaska Pollock products following the same processing methods inclusion of no other additives. Although color and gel properties are important factors for both raw surimi and fish-meat gel, main point that makes Alaska Pollock desirable for surimi industry lies in the texture profile of the final products [23]. High quality of Alaska Pollock as a favorable fish-meat gels source is mostly characterized by five different points such as hardness, springiness, cohesiveness, chewiness and brittleness. Therefore, farmed-fish gels were compared with FA and RA grade Alaska Pollock in terms of aforementioned criteria (Table 2). Alaska Pollock fish-meat gels texture profile is often accepted as a reference point for a desired fish-meat gel. Replacement of Alaska Pollock usually needs to go along with addition of soy or cattle protein extract and similar additives in order to match the Alaska Pollock gels texture profiles [4]. Comparison of farmed-fish suggested that fish-meat gels

prepared from farmed-fish could match the Alaska Pollock quality, not only in RA grade but also in FA grade. FA grade Alaska Pollock had hardness, springiness, cohesiveness, chewiness and brittleness of 561.9 ± 39.6 (g/cm²), 88.3 ± 1.4 (%), 71.2 ± 2.1 (%), 1881.5 ± 346.1 (g) and 166055 ± 30649 (g), respectively. Overall comparison pointed out that *P. olivaceus* and *P. major* were two main contenders to match the high quality Alaska Pollock texture profile in fish-meat gel. *P. olivaceus* had 89.1 ± 1.8 (%) and 69.3 ± 1.4 (%) values for springiness and cohesiveness, which are statistically similar level to that of FA Alaska Pollock, and in other criteria also notably close to reference values, too. Also, *P. major* exhibited 557.6 ± 12.5 (g/cm²), 86.4 ± 5.3 (%), 71.8 ± 0.1 (%), 1494.0 ± 104.7 (g) and 128803 ± 1092 (g) values for hardness, springiness, cohesiveness, chewiness and brittleness, respectively, which are all in statistical significance level in terms of likeliness of Alaska Pollock texture profile.

Texture profile of the surimi products define the favorableness of the manufactured seafood and as important as the gel and color properties in the eyes of the customers. Most of the surimi source substitutes such as beef, soy, crab and squid protein did not possess the desired texture profile although they had the proper gel strength and whiteness due to addition of whitening and gelling agents. However, heating process of fish-meat gels preparation affects the texture profile of raw surimi significantly along with pH and salt concentration [5]. High quality texture profile of farmed-fish, comparable to Alaska Pollock, provided valuable potential as the fish-meat gels kept the similar texture profile of high grade Alaska Pollock following heating and salting process.

Table 2. Texture profile of fish-meat gels prepared with five different kinds of farmed-fish

Fish	Hardness (g/cm ²)	Springiness (%)	Cohesiveness (%)	Chewiness (g)	Brittleness (g)
A	561.9 ± 39.6^a	88.3 ± 1.4^a	71.2 ± 2.1^{ab}	$1,881.5 \pm 346.1^a$	$166,055 \pm 3,0649^a$
B	156.9 ± 7.3^e	62.5 ± 4.0^a	22.8 ± 1.4^d	$86.5 \pm 8.4b^e$	$5,420 \pm 871^e$
C	501.4 ± 11.2^b	89.1 ± 1.8^a	69.3 ± 1.4^{ab}	$1,198.4 \pm 63.6^{bc}$	$106,853 \pm 7,765^{bc}$
D	557.6 ± 12.5^{ab}	86.4 ± 5.3^a	71.8 ± 0.1^{cd}	$1,494.0 \pm 104.7^{ab}$	$128,803 \pm 1,092^{ab}$
E	380.3 ± 18.6^c	86.8 ± 2.8^a	65.1 ± 1.5^{bc}	919.6 ± 93.4^{cd}	$81,195 \pm 7,594^{cd}$
F	299.9 ± 17.2^d	86.8 ± 0.4^a	61.4 ± 5.1^c	703.9 ± 6.7^b	$61,116 \pm 335^d$
G	284.1 ± 12.3^d	85.8 ± 0.1^b	67.3 ± 4.1^{abc}	635.0 ± 94.8^d	$54,513 \pm 8,169^d$
H	537.1 ± 20.5^{ab}	87.2 ± 3.3^a	73.6 ± 3.9^a	$1,705.9 \pm 113.7^a$	$148,467 \pm 14,764^a$

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

A, FA grade Alaska Pollock (*Theragra chalcogramma*); B, RA grade Alaska Pollock (*Theragra chalcogramma*); C, bastard halibut (*Paralichthys olivaceus*); D, Red sea bream (*Pagrus major*); E, Korean rockfish (*Sebastes schlegelii*); F, Common mullet (*Mugil cephalus*); G, Finespotted flounder (*Pleuronichthys cornutus*).

Protein patterns

Although fish-meat gels from farmed-fish could possess the Alaska Pollock fish-meat gels' texture profile and gel properties, protein profiles would defined the quality of the final product in the seafood industry. Fish-meat gels made from farmed-fish were shown to be able to compete with the FA grade Alaska Pollock in fish-meat gels production, owing to their comparable attributes in color, gel and texture properties. However, in order to provide a full insight on whether farmed-fish is an acceptable substitute to Alaska Pollock, protein profiles were compared with Alaska Pollock.

Fish-meat gels are prepared through the degradation of myofibril parts of the fish muscle and forming actomyosin gels. However, these changes in protein profile come with a drastic change in the water-holding capacity of the meat. Water is mainly hold in meat through protein bindings, especially by myofibrils [9, 17]. Retaining the moisture is arguably the one of the most important quality criteria for raw meat products. Hence, we have compared the water-holding capacities of fish-meat gels prepared from farmed-fish to gels prepared from Alaska Pollock by means of expressible moisture (Fig. 3). Expectedly, quality of Alaska Pollock was observed by expressible moisture as FA grade Alaska

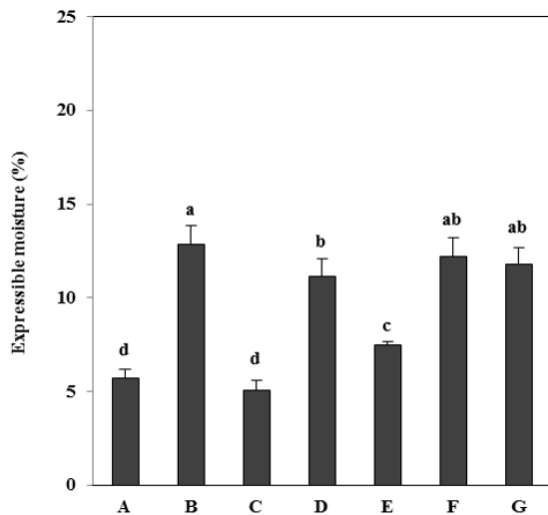


Fig. 3. Expressible moisture of fish-meat gels prepared using five different farmed-fish species and Alaska Pollock. A, FA grade Alaska Pollock (*Theragra chalcogramma*); B, RA grade Alaska Pollock (*Theragra chalcogramma*); C, bastard halibut (*Paralichthys olivaceus*); D, red sea bream (*Pagrus major*); E, Korean rockfish (*Sebastes schlegeli*); F, Common mullet (*Mugil cephalus*); G, Finespotted flounder (*Pleuronichthys cornutus*). Values are means \pm SD ($n=3$). ^{a-c} Means with the different letters are significantly different ($p<0.05$) by Duncan's multiple range test.

Pollock gel was able to show twofold less expressible moisture content compared to RA grade Alaska Pollock. *P. olivaceus* gel showed a similar water-holding capacity to that of high grade Alaska Pollock along with *S. schlegeli*. Among the rest, *P. major* had the highest water-holding properties. All farmed-fish had lower expressible moisture content than RA grade Alaska Pollock.

In addition to expressible moisture, SDS-page protein profiles of farmed-fish and Alaska Pollock were compared in order to observe the protein quality of farmed-fish in comparison with FA and RA grade Alaska Pollock (Fig. 4). Results indicated that both surimi and fish-meat gel from farmed-fish had the sufficient fish protein to be comparable to Alaska Pollock surimi and fish-meat gel. Content of the fish protein in surimi and fish-meat gels are directly linked with their value as a food. Nutritious properties of commercial surimi products were defined by their fish protein contents [24]. Molecular weight based SDS-PAGE analysis is a common method to show the protein patterns in order to detect the fish protein as well as addition of other protein source [6]. Surimi protein pattern indicated that *P. olivaceus*, *P. major* and *S. schlegeli* had higher fish protein content compared to both FA and RA grade Alaska Pollock (Fig. 4A). However, production of gels from surimi changed the protein content balance too, as heating and salt were expected change the protein content (Fig. 4B). Nonetheless, fish protein levels of fish-meat gels were still in close proportion to that of FA grade Alaska Pollock in terms of *P. olivaceus* and *P. major* gels. Other fishes were not comparable to FA grade but exhibited a protein pattern comparable to RA grade Alaska Pollock. Actin levels also indicated the gel production process affected the properties of surimi probably due to heating and salting.

In summary, surimi and fish-meat gel production require a defined set of quality criteria to match in order to be favorable in both manufacture and consumption levels. Alaska Pollock is in high demand for fish-meat gels production due to its refined color, gel, texture profiles and protein pattern. However, declining Alaska Pollock catch due to overfishing direct the manufacturers to substitutes. Addition of whitening agents and different protein sources were adapted in order to produce surimi products without relying on white-meat fish sources. However, addition of these non-fish protein and additives also come with affected texture and protein profiles for end products. Up to date, several freshwater, sea and farmed-fish have been studied for surimi production

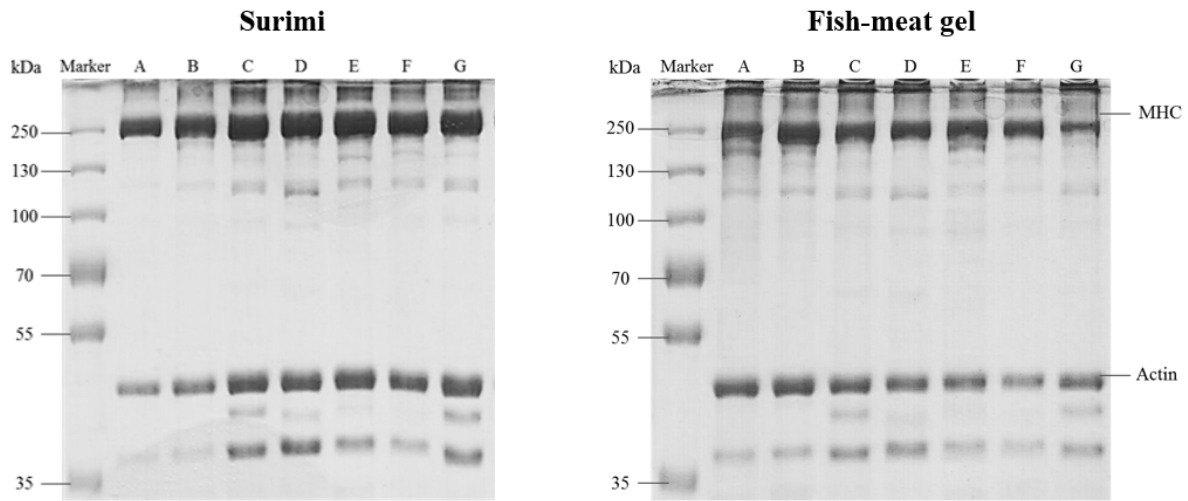


Fig. 4. SDS-PAGE protein pattern of surimi and fish meat gels prepared from five different farmed-fish species and Alaska Pollock. A, FA grade Alaska Pollock (*Theragra chalcogramma*); B, RA grade Alaska Pollock (*Theragra chalcogramma*); C, bastard halibut (*Paralichthys olivaceus*); D, red sea bream (*Pagrus major*); E, Korean rockfish (*Sebastes schlegeli*); F, Common mullet (*Mugil cephalus*); G, Finespotted flounder (*Pleuroinchthys cornutus*).

and compared to Alaska Pollock in terms of quality. Although the overall quality has been somewhat matched with the other white meat fish, high quality surimi has not been successfully substituted with other fish species apart from sea-origin white meat fishes [16, 26]. Aquaculture farming of several fish species provides an easy way to obtain seafood sources without depending on wild catch. Surimi production is also being introduced with farmed-fish to replace Alaska Pollock. Current study showed that, surimi and fish-meat gels prepared from farmed-fish, particularly *P. olivaceus* and *P. major* provided valuable meat for surimi and fish-meat gels production. Both species were resulted in surimi which matches the whiteness and gel quality of Alaska Pollock FA grade surimi. Also, protein patterns and texture profiles of culture fish-meat gels were in that same quality of Alaska Pollock and in more favorable properties than that of earlier studies species [15]. In conclusion, aquaculture farming of fish can be an efficient solution for providing sustainable and quality alternatives to Alaska Pollock in surimi production.

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초록 : 해수어를 활용한 연제품의 제조 및 물리화학적 특성

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연제품 제조에 이용되는 어육원료는 저가의 연육이 국내에서 일부 생산되고 있으며 대부분은 동남아산 또는 북아메리카산 등의 수입산에 의존하고 있다. 본 연구에서는 연제품용 어육 원료의 안정적인 수급과 고품질 연제품 개발을 위한 방안으로 우리나라에서 주로 양식되고 있는 어종의 고급 연육 및 연제품 소재로서의 가능성을 검토하였다. 양식어종인 광어(*Paralichthys olivaceus*), 도미(*Pagrus major*), 조피볼락(*Sebastes schlegeli*), 숭어(*Mugil cephalus*), 도다리(*Pleuronichthys cornutus*)를 원료로 하여 전통 수세법으로 연육을 제조하였다. 연육의 품질과 등급은 수분함량, 백색도, 겔 강도, 불순물의 함량 등에 의해 결정되어진다. 따라서 이들 해수어 유래 연육의 겔 형성능 및 품질은 겔 강도, 텍스처 실험, 백색도, 수분유출정도 및 SDS-page pattern 측정을 통해 검토하였다. 또한 이들 결과는 명태연육(FA급과 RA급)의 겔 특성과 비교하였다. 겔 특성을 검토하기 위해 미리 준비한 5 종류의 해수어 유래 연육에 2% NaCl를 첨가하여 소금갈이를 한 후 전체 수분함량이 84%가 되도록 졸 형태로 제조하였다. 졸 형태의 연육을 polyvinylidene chloride 필름에 20-25 cm 길이로 충전한 후 90°C에서 20분간 가열하여 소시지 형태의 어육 겔을 제조하였다. 연육을 이용한 어육 겔의 제조에 의해 연육의 겔 강도와 백도는 증가하였다. 해수어 유래 연육의 겔 특성을 비교한 결과 광어와 도미가 가장 높은 겔 강도와 파단 강도를 나타내었으며, 수분 이수율은 광어에서 가장 낮게 나타났다. 전체적으로 해수어 유래 연육은 RA급 명태연육에 비해 높은 겔 형성능을 나타내었으며, 광어와 도미는 FA급 명태연육과 비슷한 정도의 겔 특성을 나타내었다. 이상의 결과로부터 광어와 도미를 이용한 고품질 연제품의 개발 가능성을 확인할 수 있었다.