

Gel and Texture Properties of Fish-meat Gel Prepared with *Pagrus major* in Comparison to Different Grades of Alaska Pollock

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Fish-meat gel is an intermediate product used in a variety of surimi-based seafood. One of the most-used raw materials of fish-meat gel is Alaska Pollock due to its high-quality meat in terms of gel strength and texture. However, increasing demand for fish-meat gel, along with overexploitation of the wild catch Alaska Pollock, has put the industry in need of low-cost sustainable alternative sources for fish-meat gel. *Pagrus major* (PM) is a widely aquacultured fish known for having white meat that is low in fat. The current study compares the quality of fish-meat gel prepared from aquacultured PM to that of high and mid-grade Alaska Pollock fish-meat gel. Gels were compared in terms of gel strength, texture, color, and protein pattern. Results indicated that fish-meat gels prepared from PM were superior to Alaska Pollock fish-meat gels with regard to gel strength, hardness, springiness, chewiness, cutting strength, and breaking force. In addition, although not matching in quality, PM exhibited a cohesiveness, whiteness, and expressible moisture content comparable to Alaska Pollock of both grades. Protein pattern analysis also showed that PM and Alaska Pollock fish-meat gels had similar protein profiles before and after gel preparation. Therefore, *P. major* is suggested as a potential substitute for Alaska Pollock in fish-meat gel production.

Key words : Alaska Pollock, aquaculture, fish-meat gel, *Pagrus major*, surimi

Introduction

A variety of surimi (minced fish-meat)-based seafood production heavily depends on the fish-meat gel as an intermediate product prepared from different types of fish paste [20]. Production of high quality fish-meat gels is mainly a preferred method for seafood imitation products such as crab legs and fish fillet. Demand of the current seafood market is pretty high for fish-meat gel derived commercial seafood products due to a lot of benefits such as low cost, savory taste, high nutritious value, ease of production, store and transportation [14, 15]. However, quality of the final product can vary notably in terms of color, hardness, chewiness and flavor. Production process and the fish species used for production are the main criteria that define the fish-meat

gel quality [16]. Preparing the fish-meat gel includes a number of steps namely; washing, deboning, mincing, salting, heating and gelation which all have parts on the gel and texture properties of the outcome. Beside all the advantages and benefits of fish-meat gels and surimi products, there are some concerns and shortages that the industry faces mostly through the overfishing in order to supply the elevated demand [10].

Since the white-meat fish is always demanded relatively more compared to other fish catches, Alaska Pollock is the most desired raw material for fish-meat gel production in today's market. Texture, strength, fat concentration, hardness of fish-meat gels prepared from Alaska Pollock have been the main checkpoints of why it plays the main role in fish paste and surimi industries [7, 18, 22]. The high quality product and demand of white-meat fish products come with overexploited fish forage which expectedly causes environmental and cost-wise concerns.

Aquaculture is an up and coming method for supplying the demand of variety of seafood to several industries. From fish to algae, numerous species have been subjected to aquaculture techniques in order to create a sustainable source

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for high-demand industries [4]. In this context, fish farming is being credited a promising alternative to fishing with similar if not superior benefits of wild catch fish to seafood-related fields. Markets have been filled up with aquaculture products that were raised in indoor or outdoor tanks, enclosed pools or sea enclosures. Naturally with such high production rates, fish paste, fish-meat gel and surimi contain more farmed fish than that of wild catch and still continue to hold its place as a top choice for favorable and affordable seafood choice [12]. However, high quality surimi products made from Alaska Pollock are still in high demand and research efforts mainly directed into a successful substitution of white-meat from Alaska Pollock with a local, affordable and sustainable source [8, 21]. In this connection, current study focuses on the possibility of *Pagrus major*, a highly farmed aquaculture fish in Korea, as a successful substitute for Alaska Pollock in fish-meat gels. *P. major* is a common dietary fish, with white-meat and low fat content. It is also being farmed heavily and supplied to local markets in high amounts. Accordingly, a comparison of fish meat-gel from *P. major* with that of different grades of Alaska Pollock in terms of gel and texture qualities is the main goal of this study on the way to find a reliable source for high quality fish-meat gel production.

Materials and Methods

Materials

P. major aquacultured in Tongyeong, Korea were used for experiments. Alaska Pollock fish-meat gels were prepared from frozen surimi stocks (high - FA and mid - RA grade) which were purchased from Seongjin Fishery Food Co. Ltd. (Busan, Korea). Polyvinylidene chloride casing was purchased from Ikjin Corp. (Kureha, Seoul, Korea). Potassium chloride and sodium chloride were purchased from Junsei Co., Ltd. (Tokyo, Japan).

Fish-meat gel preparation

The minced fish-meat was prepared according to a traditional washing process to remove water-soluble proteins and other impurities. The washed meat was minced with 2.0% salt ice-water and the mince was washed in cold water prior to dewatering process through centrifugation (8,000x g, 30 min, 4°C). Finally, excess of water was removed manually by squeezing using cheesecloth layers. Sorbitol, sucrose and sodium triphosphate were added for cyroprotection to the

final product. Final minced fish-meat was vacuum-packed and stored at -20°C until further use.

Vacuum-packed fish-meat was chopped into blocks with approximate volume of 8 cm³ and ground with a refrigerated food processor (Hanil Co. Ltd., Seoul, Korea). During grounding process 2.0% NaCl (w/v) were added to homogenate. Final moisture content of the homogenate were adjusted to 80% by adding ice cold water during the final steps of grounding to obtain the fish-meat paste. Paste was then filled into polyvinylidene chloride casings and heated in 90±2°C water bath for 20 min. Heating process was then followed by an immediate cooling down in ice water (0-4°C) for 10 min to stop any further reaction. The gels were labeled as PM (*P. major* fish-meat gel), FA (FA grade Alaska Pollock) and RA (RA grade Alaska Pollock), and stored overnight at 4°C before analysis.

Determination of gel attributes

Fish-meat gels were cut into 25 mm high and 26 mm wide cylinders and brought to room temperature. Samples were analyzed 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 attributes of gels were evaluated by measuring the breaking force (g), deformation (mm) and gel strength (g/cm²) from stress-strain curve.

Determination of texture profile

A texture analyzer (Model COMPAC-100II, Sun Science Co., Tokyo, Japan) was used to assess the texture profile of fish-meat gels. Cylindrical fish-meat gels (25 mm in height, 26 mm in diameter) at room temperature were analyzed with cylindrical plunger (50 mm diameter) with a compression speed of 60 mm/min. Springiness, cohesiveness, chewiness and brittleness were measured directly through texture analyzer. For cutting strength evaluation fish-meat gels were cut into disks (20×20×15 mm) and subjected to cutting strength test by the texture analyzer with a compression speed of 60 mm/min.

Determination of whiteness

The fish-meat gels were cut into a cylindrical sample with a thickness of 15 mm and color values of the samples were determined using the Color Difference Meter (Lovibond Tintometer Model RT 300; Tintometer Ltd., Salisbury, UK).

The Hunter color parameters of L (lightness), a (redness/greenness), and b (yellowness/blueness) were recorded ($n=5$) and whiteness was calculated by the Park equation [15].

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

Determination of expressive moisture content

The method of Benjakul et al. [2] was used to calculate the expressible moisture content of the gels. Gels were cut into a cylindrical sample with 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. The samples were pressed under a 5 kg force for 2 min. Expressible moisture content was calculated and expressed as percentage of gel sample moisture to weight.

SDS-polyacrylamide gel electrophoresis (SDS-PAGE)

The protein profile of fish-meat gels were assessed by SDS-PAGE [2]. Fish-meat 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 a homogenizer at speed of 10,000x g for 30 sec. Then the homogenate was incubated in boiling water for 2 min prior to continuous stir for 24 hr at room temperature and centrifugation at 10,000x g for 20 min. Protein amount of the supernatants were calculated using bovine serum albumin as standard based on the method of Bradford (1976). The proteins were transferred into lanes (6 μ g per lane) and separated on the polyacrylamide gel made of 100 g/l running gel and 40 g/l stacking gel by electrophoresis using a voltage of 120 V constant at room temperature. Following separation, the proteins were stained with Coomassie brilliant blue R-250 solution for 30 min and de-stained with 250 ml/l methanol and 100 ml/l acetic acid in water for 1 hr. The protein bands were 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

In order to overcome the problems in fish-meat gel production for seafood market such as declining wild catch, a sustainable substitute for Alaska Pollock with similar qualities is a recent research trend. In this context, properties of the fish-meat gel prepared from *P. major* were evaluated and compared to that of Alaska Pollock. Fish-meat gel from *P. major* (PM) was tested for its gel and texture characteristics and the obtained data was compared with fish-meat gels from two different grades (FA, RA) of Alaska Pollock. Prepared fish-meat gels were analyzed for four main qualities namely; gel, texture, biochemical and color attributes.

Gel attributes

Properties of the gels prepared from *P. major* and Alaska Pollock were evaluated and compared under the criteria of gel strength, hardness, breaking force and deformation. Aforementioned gel properties are directly affected with the preparation process and conditions. In all four criteria (gel strength, hardness, breaking force and deformation) PM was superior to both grades of Alaska Pollock fish meat gel (Fig. 1). PM was significantly stronger and harder with a bigger breaking force than FA and RA grade Alaska Pollock. In addition, deformation properties were at statistically comparable levels.

Common methods to match the gel properties of Alaska Pollock includes addition of extra gelation agents, protein extracts and similar additives. PM was observed to be a high quality gel making source comparable and even better than Alaska Pollock without any additives. Gel strength of PM was 327.97 ± 35.36 g/cm² while the strength of FA grade Alaska Pollock was a mere 282.37 ± 4.27 g/cm² (Fig. 1A). Hardness, breaking force and deformation values of 703.37 ± 56.67 g/cm², 1610.00 ± 137.49 g and 9.31 ± 0.27 mm, respectively are presenting a promising trait for PM when compared to 595.77 ± 36.76 g/cm², 1353.33 ± 66.58 g and 9.26 ± 0.12 mm values of Alaska Pollock for same criteria respectively (Fig. 1B, Fig. 1C, Fig. 1D). Among all tested criteria, gel strength is a main characteristic that is a concern for storing and transportation of fish-meat gels safely [6]. And superiority of PM over Alaska Pollock in gel strength, adds notable value to the fish-meat gel from *P. major*.

Texture profile

Texture profile of the final product is one of the main

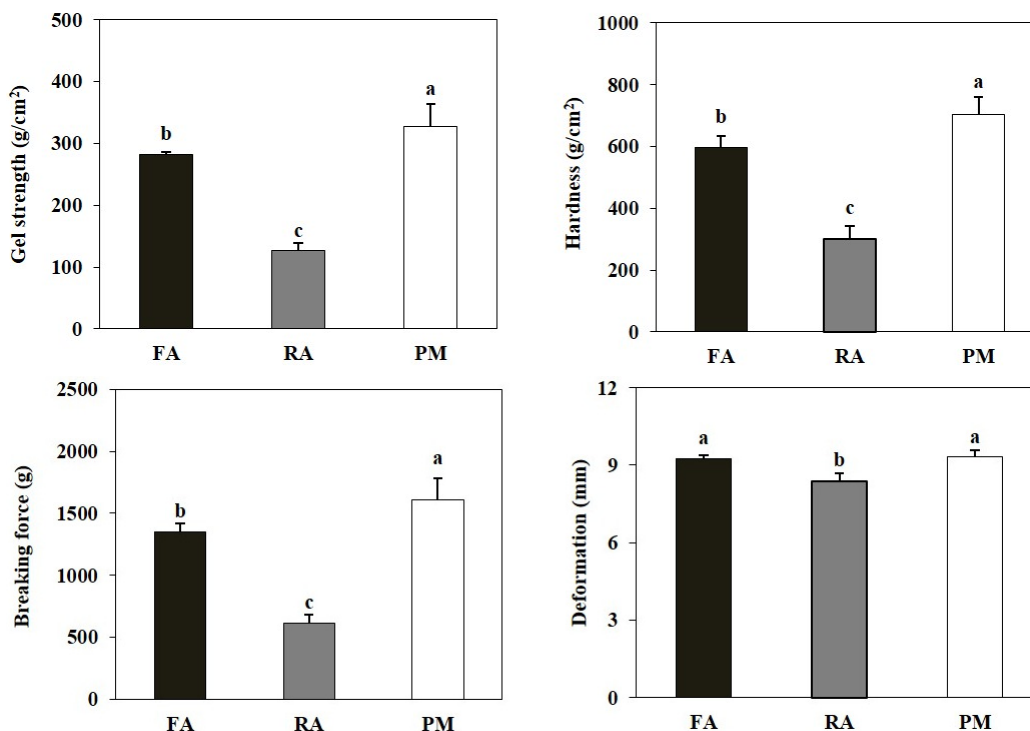


Fig. 1. Gel attributes of fish-meat gels prepared from *P. major* (PM) and Alaska Pollock of FA and RA grade. Values are means±SD (n=3). ^{a-c} Means with the different letters are significantly different (p<0.05) by Duncan’s multiple range test.

properties that defines the favorability of the product. The high quality of Alaska Pollock fish-meat gel is credited to its desired values at hardness, springiness, cohesiveness, chewiness and brittleness [7]. Numerous additives such as soy, beef or squid proteins to surimi products may help to obtain the desired the gel properties and whiteness [5]. Although addition of other sources of proteins provide beneficial effects, cost-wise it adds another raw material source that needs to be supplied other than that of fish-meat itself. Alaska Pollock fish-meat gels are often regarded as the top quality in terms of texture profile. Hence, the substitutes for fish-meat gel preparation often fall short of high quality Alaska Pollock and stay comparable to mid to low grade Alaska Pollock fish-meat gel. PM was tested for its texture profile in terms of hardness, springiness, cohesiveness, chewiness and brittleness and compared to FA and RA

grade Alaska Pollock in same terms (Table 1). Results indicated the PM was superior to FA grade Alaska Pollock in every tested criteria. 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(%), 1,881.5±346.1(g) and 166,055±30,649(g), respectively while PM showed the texture profile of 561.9±39.6(g/cm²), 88.3±1.4(%), 71.2±2.1(%), 1,881.5±346.1(g) and 166,055±30,649(g) for hardness, springiness, cohesiveness, chewiness and brittleness, respectively. Heating during the fish-meat gel preparation is primarily behind the texture profile followed by pH and salt concentration which also affect the taste and favorability directly [13]. Although substitutes match the gel properties of Alaska Pollock under similar preparation processes, they require alterations and additives in order to match the certain texture profile. Considering the values, PM was sug-

Table 1. Texture profile of fish meat gels prepared *P. major* (PM) and Alaska Pollock of FA and RA grade

Fish-meat gels	Hardness (g/cm ²)	Springiness (%)	Cohesiveness (%)	Chewiness (g)	Brittleness (g)
FA	595.77±36.76 ^b	85.34±3.82 ^a	71.39±2.11 ^a	1483.47±63.23 ^b	131710.73±3274.97 ^a
RA	300.33±42.04 ^c	84.84±4.45 ^a	51.03±6.53 ^b	543.93±6.53 ^b	48845.44±9054.59 ^b
PM	703.37±56.67 ^a	89.05±0.94 ^a	73.98±2.26 ^a	1551.00±316.42 ^a	137945.06±26781.03 ^a

Values are means±SD (n=5).

^{a-c}Means with the different letters are significantly different (p<0.05) by Duncan’s multiple range test.

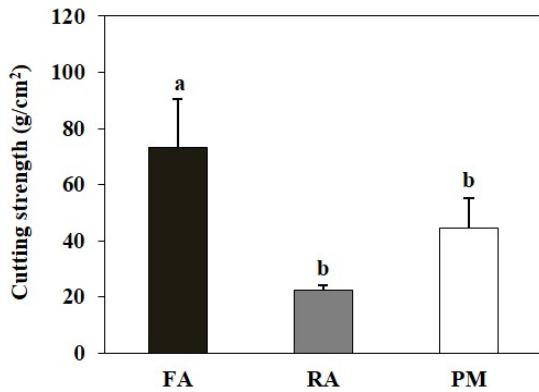


Fig. 2. Cutting strength of fish-meats prepared from *P. major* (PM) and Alaska Pollock of FA and RA grade. Values are means±SD (n=3). ^{a-b} Means with the different letters are significantly different (p<0.05) by Duncan’s multiple range test.

gested to possess the texture profile of FA grade Alaska Pollock. High quality texture profile of *P. major*, comparable to and even better than Alaska Pollock, provided valuable potential as the aquacultured *P. major* fish-meats preserved the favorable texture and gel attributes of FA grade Alaska Pollock in the face of same heating and salting process. Another concern for the gelation process is the cutting strength. The cutting strength of the fish-meats is correlated to the firmness of the prepared samples. Alaska Pollock fish-meats gels are known to maintain their cutting strength following gelation process unlike other sources which tend to possess lower cutting strength. The higher force for cutting which means a higher cutting strength, is in accordance with higher protein content of the fish-meats gels. Cutting strength is a direct result of firmness and proper gelling of the samples, as well. Comparison of cutting strengths of PM and FA grade Alaska Pollock fish-meats gels provided slightly promising results. Cutting strength of PM was calculated to be 44.45±10.72 g/cm² against the 73.33±17.32 g/cm² of FA grade Alaska Pollock and 22.22±1.92 g/cm² of RA grade (Fig. 2). Although cutting strength of PM was lower than that of FA grade Alaska Pollock, it was significantly better than that of RA grade.

As it may seem as a drawback for PM, significantly higher cutting strength from RA grade still holds potential for *P. major* to be a substitute for Alaska Pollock.

One of the points that affects the quality of the fish-meats gel is whiteness. Whiteness of the fish-meats gel is a crucial attribute for a favorable and accepted commercial product. Therefore, most of alternative surimi production methods require the addition of external whitening agents [1]. Considering, whiteness of the PM was compared to that of FA and RA grade Alaska Pollock fish-meats gels. Alaska Pollock fish-meats gel had a whiteness values of 77.72±0.31 while PM had a whiteness of 69.05±0.48 in Hunter color values (Table 2). Expectedly whiteness of Alaska Pollock was significantly higher than that of PM. However, in terms of RA grade Alaska Pollock which had a 62.71±0.04 whiteness, PM was nevertheless superior which makes it a fish-meats source with matching quality in terms of whiteness.

Protein pattern

In order to provide a better understanding to perceive the final product of *P. major* fish-meats gels to present it as a sustainable source against Alaska Pollock, protein patterns and expressible moisture contents were compared. Although, gel attributes and texture profiles of gels were comparable, appeal of the gels to the end-user also requires the matching quality of the nutrition and taste. Gel forming process degrades the myofibril of fish meat to form actomyosin gels which changes the protein profile [19]. This changed status of protein pattern results in a severe change in the water-holding capacity of the product which is carried out by myofibril bindings mainly. Raw meat products are hailed as quality products as much as they could retain the moisture even after the gel forming process [9]. In this manner, the expressible moisture contents of PM and Alaska Pollock fish-meats gels were compared. As expected from the low-fat quality meat of Alaska Pollock both FA and RA grade Alaska Pollock gels exhibited a relatively high expressible moisture content of 7.52±0.68% and 7.74±1.41%, respectively (Fig. 3). On the other hand PM was observed to be prom-

Table 2. Whiteness of the fish meat gels prepared from *P. major* (PM) and Alaska Pollock of FA and RA grade

Fish-meats gels	Lightness	Redness	Yellowness	Whiteness (L-3b)
FA	86.21±0.15 ^b	-3.70±0.05 ^a	2.83±0.12 ^c	77.72±0.31 ^a
RA	81.32±0.24 ^c	-3.24±0.03 ^a	6.20±0.07 ^a	62.71±0.04 ^c
PM	86.75±0.18 ^a	-3.36±0.44 ^a	5.90±0.20 ^b	69.05±0.48 ^b

L, lightness; b, yellowness/blueness. Values are means±SD (n=5). ^{a-c} Means with the different letters are significantly different (p<0.05) by Duncan’s multiple range test.

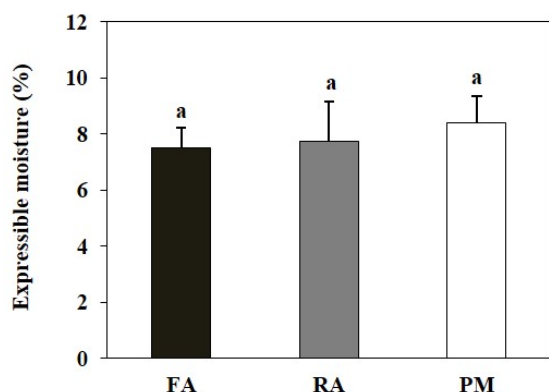


Fig. 3. Expressible moisture content of fish-meat gels prepared from *P. major* (PM) and Alaska Pollock of FA and RA grade. Values are means±SD ($n=3$). ^a Means with the different letters are significantly different ($p<0.05$) by Duncan's multiple range test.

inently moist with $8.40\pm0.94\%$ moisture content.

Along with expressible moisture, SDS-page protein profiles of fish-meat gels were prepared and compared. In order to evaluate the effect of gel-making process, protein profiles were analyzed for each step. In particular protein patterns were depicted for raw fish meat (F), fish-meat surimi (FM), fish-meat sol (salted fish-meat surimi) (S) and fish-meat gel (G). It has been reported that myosin heavy chain plays an important role in gel forming ability of the meat products [11]. Recent studies also indicated that actin-myosin interaction is equally important for gel formation although actin itself has no role in gelation [17]. Benjakul et al. [3] indicated that several other proteins such as tropomyosin are also tak-

ing parts in the ability of gel formation during the production of meat products. In this context, FA and RA grade Alaska Pollock was compared to PM in terms of SDS-page protein patterns of aforementioned myosin heavy chain, actin and tropomyosin proteins (Fig. 4). Salting and mincing of the surimi and gel forming resulted in elevated amounts of MHC, actin and TM, in each step respectively. Gels made from both Alaska Pollock and *P. major* showed very similar MHC and TM profiles. On other hand, PM actin levels were not significantly affected by gelation, nonetheless, in comparable levels with that of Alaska Pollock. Raw-fish meat from *P. major* exhibited relatively lower actin levels along MHC and TM compared to fish-meat surimi and fish-meat sol. Expected changes of MHC levels from R to S confirmed the proper gel forming process and firmness of the products. Heating and salting processes were expected to change the protein patterns during fish-meat gel production. Hence, the salted and minced fish-meat surimi sol was also included in the protein pattern analysis. The levels of MHC and TM compared to actin for S were in a similar fashion to both surimi and fish-meat gel indicating a preserved protein pattern and a proper gelation process. Compared to both grades of Alaska Pollock, *P. major* sourced meat was subjected to a drastic changes of MHC and TM levels during surimi production. It suggests that although *P. major* is a creditable substitute source for fish-meat gel production, in terms of surimi seafood it still needs optimization in order to match the protein patterns of Alaska Pollock.

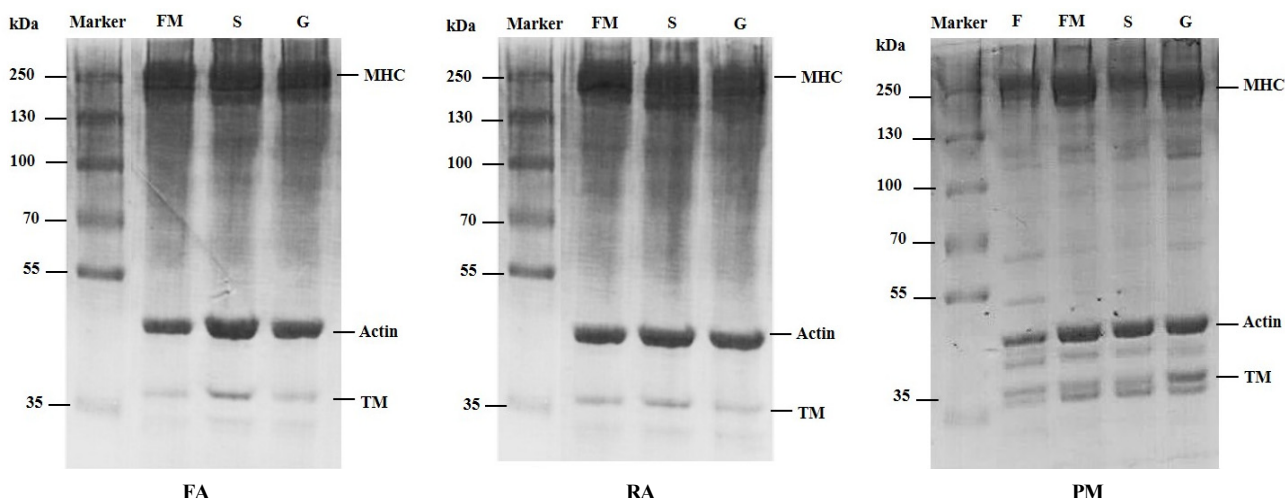


Fig. 4. SDS-page protein pattern of fish-meat gels prepared from *P. major* (PM) and Alaska Pollock of FA and RA grade. F: raw fish-meat, FM: minced fish-meat surimi, S: fish-meat sol, G: fish-meat gel, MHC: myosin heavy chain, AC: actin, TM: tropomyosin.

Briefly, surimi and fish-meat gel industry demand certain quality criteria in order to provide favorable products to customers. Alaska Pollock has always been the main choice for high quality fish-meat products due to superior attributes of its meat that was observed during the gel formation and at the final product. However, overfishing and higher costs urge the producers for sustainable alternative sources to be used in fish-meat gels instead of Alaska Pollock. Up to date, particular actions have been taken to match the Alaska Pollock quality like different protein additives, whiteness agents, alternative gel forming processes. As aquaculture fish farming is a raising trend to supply the market with low-cost quality fish-meat, using these fish for fish-meat gel preparation is also an up and coming fashion. In order to find a suitable substitute for Alaska Pollock that can provide the similar qualities, *P. major* was analyzed and compared to two grades of Alaska Pollock. Results indicated that fish-meat gels prepared from *P. major* is superior to that of high quality Alaska Pollock in many criteria such as gel strength, chewiness, brittleness while being competitively comparable in remaining criteria. In conclusion, aquacultured *P. major* possess a promising potential to be a successful source for producing high quality fish-meat gels.

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초록 : 도미를 활용하여 제조한 연제품의 겔 및 texture 특성

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본 연구에서는 연제품용 어육 원료의 안정적인 수급과 고품질 연제품 개발을 위한 방안으로 우리나라에서 주로 양식되고 있는 도미를 이용하여 제조한 연육의 어육 겔 특성을 측정하여 도미의 연제품 소재로서의 가능성을 검토하였다. 현재 우리나라에서는 연제품 제조에 이용되는 어육원료는 주로 수입에 의존하고 있으며 국내에서는 저가의 연육이 일부 생산되고 있다. 수입 연육의 경우 대부분 동남아 및 북아메리카로부터 수입한 냉동 연육이 사용되고 있다. 연육의 품질과 등급은 수분함량, 백색도, 겔 특성 등에 의해 결정되어진다. 따라서 본 연구에서는 양식어종인 도미(*Pagrus major*)를 원료로 하여 전통 수세법으로 연육을 제조하였으며, 도미 유래 연육을 이용하여 어육겔 형성능 및 품질 특성을 겔 강도, 텍스처 실험, 백색도, 수분유출정도 및 SDS-page pattern 측정을 통해 검토하였다. 이들 결과는 FA급과 RA급의 시판용냉동명태연육을 이용하여 제조한 어육 겔 특성과 비교하였다. 겔 특성을 검토하기 위해 연육에 2% NaCl를 첨가하여 전체 수분함량이 80%가 되도록 하여 90°C에서 20분간 가열한 소시지 형태의 어육 겔을 제조하였다. 도미 유래 연육의 어육 겔 특성은 stress-strain curve로부터의 겔강도, cutting strength, breaking force 등의 결과 및 텍스처 실험을 통한 springiness, cohesiveness, chewiness, brittleness 등의 결과로부터 확인할 수 있었다. 도미 유래 연육의 어육 겔 특성은 시판용 명태연육(FA급과 RA급)의 어육 겔 특성과 비교하였다. 도미연육의 사용은 RA급의 명태연육에 비해 높은 겔 형성능을 나타내었으며, FA급의 명태연육과는 비슷한 정도의 겔 특성을 나타내었다. 이상의 결과로부터 도미를 이용한 고품질 연제품의 개발 가능성을 확인할 수 있었다.