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Thesis for the Degree of Master of Engineering

Physicochemical and Sensory Properties of Surimi as a Main Ingredient of Snacks

by

Jiyeon Chae

Department of Food Science & Technology

The Graduate School

Pukyong National University

February, 2021

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수리미가 주원료인 스낵의 이화학적 및 감각적 특성

Advisor: Prof. Suengmok Cho

by

Jiyeon Chae

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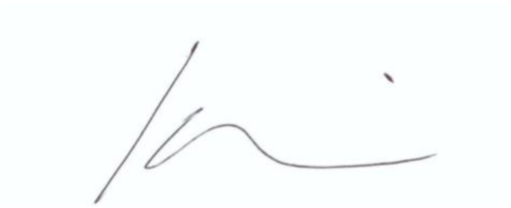
Approved by

(Chairman) Seon-Bong Kim Ph. D.



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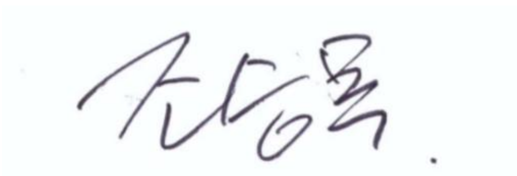

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수리미를 주원료로 하여 제조한 스낵의 이화학적 및 관능적 특성

채지연

부경대학교 대학원 식품공학과

요약

본 연구의 주 목표는 주로 널리 사용되는 수리미의 종류와 등급에 따라 생선 스낵을 제조할 때 겔 강도와 특성에 따라 어떠한 영향을 미치는지 조사하는 것이었다. 7 종류의 수리미 생선 스낵으로 특성을 조사하였다. 열풍 건조가 시작된 후 240분부터 모든 수리미 반죽의 건조가 거의 완료된 것으로 나타났다. TB (Threadfin bream)은 열로 인한 설탕의 갈변으로 스낵의 외관 색도에 영향을 미친다. 스낵의 중요한 요소 인 경도는 선형 팽창도가 높은 LF (Lizard fish)에서 가장 낮았으며, 이는 두께 팽창도에 반비례하고 기름 함량이 가장 높았다. 경도, 선형 팽창도, 두께 팽창도 수리미의 겔 강도와 상관 관계가 없었다. 관능 평가에서 TB (Threadfin bream) 스낵은 전반적으로 가장 기호도가 높았다. 전자 혀를 사용한 전체적인 맛 강도는 AP 샘플 그룹에서 높았습니다. 전자 코 시스템은 샘플에서 29 개의 화합물을 식별했다. 2-Ethyl-3,6-dimethylpyrazine 은 감각 묘사에서 무취 인 것을 제외하고 휘발성 화합물에서 가장 높은 상대적 함량을 가졌다. PCA 패턴 분석, 다변량

분석을 통해 휘발성 화합물의 패턴과 각 샘플의 맛 성분이 성공적으로 분리되었다.

Introduction

Surimi is stabilized myofibrillar proteins obtained from deboned fish flesh (Park, 2000). Briefly summarizing surimi manufacturing process, fish fillets are washed and minced, and then fish mince refined and dewatered. Finally, cryoprotectants are added to the refined fish mince, and it is molded and frozen (Okazaki & Kimura, 2014; Park, 2000). The addition of cryoprotectants in the manufacture of surimi makes it possible to commercially store surimi without losing its gel-forming ability (Yoon & Lee, 1990).

Surimi has been used as a main ingredient in various foods with elastic texture (Gao et al., 2018). Therefore, gel strength of surimi is the most important property to determine its quality grade (Yoon & Lee, 1990). Surimi-based foods include imitation crab sticks (crab-flavored surimi seafoods), fish cakes, fish sausages, and fish balls (Morrissey et al., 2000; Benoit & Denis, 2007). Until now, studies on surimi-based products have been focused on effects of ingredients and processing conditions on rheological characteristics, such as gel strength and texture profiles (Bashir et al., 2017).

Meanwhile, surimi can be also used for fish snacks or grain-based snacks without gel formation. In order to prepare fish snacks or fortify protein of the grain-based snacks, dried surimi powders have been applied as a main or supplementary ingredient (Santana et al., 2012). The fish snacks have been developed and commercialized in Asia mainly Southeast Asia region. Most studies on the fish snacks deal with quality characteristics and manufacturing processes based on non-frozen surimis or surimi powders (Ramesh et al., 2018). The limits of previous studies on the fish snack are to use non-frozen surimis and to test tropical fish species, whereas the frozen surimis from various fish species including cold-water fishes have been commercially distributed worldwide.

Therefore, in the present study, we prepared fried fish snacks using commercial frozen surimis from Alaska pollock, Pacific whiting, threadfin bream and lizard fish. In order to investigated physicochemical and sensory properties of the fish snacks, drying property, appearance, expansion, hardness, oil content, sensory evaluation, electronic tongue and electronic nose were measured.

Materials and Methods

1. Materials

Alaska pollock (AP, *Gadus chalcogrammus*), Pacific whiting (PW, *Merluccius productus*), Threadfin bream (TB, *Nemipterus spp.*) and Lizardfish (LF, *Saurida spp.*) surimis were used a main material for the fried fish snacks, and their information is shown in Table 1. The frozen surimis were divided into 600 g weight of blocks used for this study and sealed. It was then stored at -80°C in a deep freezer (CLN-52U, Nihon Freezer Co., Ltd., Saitama, Japan) until needed. Tapioca starch was purchased from Daejin food Co., Ltd. (Chungnam, South Korea). Baking powder was purchased from Ottogi Co., Ltd. (Anyang, South Korea). Salt was purchased from Sajo Co., Ltd. (Seoul, South Korea). Palm oil was purchased from Lottefoods Co., Ltd. (Seoul, South Korea). All chemicals and reagents used in this study were of an analytical grade.

Table 1. Information and specification of surimi samples used.

Surimi	Grade	Region	Ingredients	Manufacturer
Alaska pollock (AP) (*Gadus chalcogrammus*)	FA	USA	sorbitol, sucrose, SPP, SPR	Clacier Fish Company (Seattle, WA, USA)
	A	USA	sorbitol, sucrose, SPP, SPR	American Seafoods Company (Seattle, WA, USA)
	RA	USA	sorbitol, sucrose, SPP, SPR	American Seafoods Company (Seattle, WA, USA)
Pacific whiting (PW) (*Merluccius productus*)	A	USA	sorbitol, sucrose, DEW	American Seafoods Company (Seattle, WA, USA)
Threadfin bream (TB) (*Nemipterus spp.*)	FA	Vietnam	sucrose (6%), SPP (0.3%)	Hoa Thang Seafood Co., Ltd. (Vung tau, Vietnam)
	AA	Vietnam	sucrose (6%), SPP (0.25%)	Aoki Seafood Co., Ltd. (Kien Giang, Vietnam)
Lizard fish (LF) (*Saurida spp.)*	SA	Vietnam	sucrose (6%), SPP (0.25%)	Aoki Seafood Co., Ltd. (Kien Giang, Vietnam)

SPP: Sodium Polyphosphate, SPR: Sodium Pyrophosphate, DEW: Dehydrated Egg White.

2. Preparation of surimi snacks

Surimi snacks were prepared according to the method. The surimi (60 g) was blended for 1 min in a hand blender (HR1673, Philips, Hungary). Tapioca starch (1.5 g), baking powder (1 g) and water (28.5 g) were added and blended for another 5 min. The resulting dough was then placing a 2 mm thick stainlesssteel molding frame with a circular hole (3 cm in diameter) on a silicone support plate, the mixed raw materials were coated with a spatula and molded. Then dried at 50°C for 4 h using an air dryer (WFO-700, EYELA Co., Japan). To obtain puffed snacks, the dried sample were deep-fried in palm oil at 190°C for 40 s using a fryer (BS-1820-DF, BSW Co., China).

3. Proximate compositions

Proximate compositions were determined using standard analytical methods by described by AOAC (2012). Moisture content was determined by the oven drying method. The amount of crude protein in a sample was determined by the micro-Kjeldahl method, Lipid content was determined by Soxhlet extraction, Ash content was determined by the dry-ashing method. All analyses were done in triplicate.

4. Gel strength

Surimi gel strength was determined using standard methods by described by CODEX (2015). 1.5 kg of freeze repair was placed in a polyethylene bag, the bag was sealed and then tempered so that the temperature rises to about -5 °C below room temperature (20 °C). The samples were tested with a hand blender (HR1673, Philips, Hungary), then 3% salt was added here and further ground, crushed for at least 10 minutes to make a homogenized meat paste. A 30 mm polyvinylidene chloride tube was spread flat and filled with about 150 g (about 20 cm long) of meat paste using an 18 mm diameter stuffing tube and tied both ends of the tube. The test material was heated in hot water at 84-90 ° C for 30 minutes. Immediately after the heat treatment was completed, the test material was put in cold water, cooled sufficiently, and left at room temperature for at least 3 hours. A rheometer (Model CR-100D, Sun Scientific Co., Ltd., Tokyo, Japan) was used to measure the gel strength and deformability of the surimi gel strength test sample. It used a spherical (plunger) with a diameter of 5mm and a speed of 80mm/min. About 10 readings were made for 7 samples of each treatment.

5. Moisture content and drying rate

In order to observe the drying characteristics of the raw material of the dried surimi mixtures, the moisture content of the raw material was measured until 6 hours of drying in a 50 °C hot air dryer. (WFO-700, EYELA Co., Japan). Moisture content was determined according to standard methods (AOAC, 2012). Each measurement was repeated 3 times to obtain an average value (%, g/100g).

6. Color

A chromaticity instrument (SP60, Lovibond Co., UK) was employed to measure the surface color of the fish snacks. A white standard board was used for calibration. The color values were expressed as L* (brightness), a* (redness) and b* (yellowness). Five fish snacks were analyzed for each substitution level.

7. Hardness

A texture analyser (CT3 4500, Brookfield Engineering Laboratories, Inc., USA) equipped with a spherical probe of diameter 18 mm was used to determine the crispiness of the fried fish crackers (n = 10). The trigger and speed of the probe was set at 6.8g and 0.5 mm/s, respectively. The dried slices were fried in oil and the fried fish snacks were put above a support rig and penetrated using the spherical probe.

8. Scanning Electron Microscopy (SEM)

Microstructure of fish snacks was visualized using a scanning electron microscopy (SEM). Snacks were fixed to a sample with a gold layer using an ion sputter device (Hitachi, E-1010, Tokyo, Japan), and viewed by SEM (JSM-6490LV, JEOL Ltd., Tokyo, Japan) at an accelerating voltage of 15 kV.

9. Linear expansion and thickness expansion

The expansion of the snacks was determined in triplicate based on the method by Kawas & Moreira (2001). The dried snacks are marked with four lines across using a permanent marker pen (Oil magic ink, Monami Co., Ltd., Yongin, Korea) and the lines were measured before and after frying in oil at 190°C. The thickness was measured using a steel caliper (MG Tool Company, NY). About 5 readings were made for 7 fish snacks of each treatment. The percentage expansion was calculated as follows:

$$\text{Expansion}\,(\%) = \frac{\text{Length after frying - Length before frying}}{\text{Length before frying}} \times 100$$

10. Oil content

Oil content was measured by Soxhlet extraction using petroleum ether (Tran, 2007). About 3 readings were made for 7 samples of each treatment test was performed in average values taken.

11. Sensory evaluation

Sensory evaluation of the samples was evaluated in terms of color, crispiness, oiliness, taste, aroma and overall acceptability. Each attribute was evaluated using a 9-point hedonic scale, where 9 is excellent and 1 is extremely poor. A 10-number panel (Gender: 5 females and 5 males, Age: 21-26 years), all of whom were experienced in the sensory evaluation of surimi snacks to understand the used descriptors in the same way before tests, was appointed to score the 6 sensory attributes, respectively. Each sample composed of 7 snacks was served to every panelist.

12. Electronic nose

Volatile compounds in samples were investigated by electronic nose system (HERACLES Neo, Alpha MOS, Toulouse, France). Each 3 g of ground sample in headspace vial was stirred by 500 rpm speed at 50°C for 20 min for extracting volatile compounds. Each 2,000 μL of volatile vapor was transferred to injection port in a gas chromatography. Analytical column was MXT-5 and acquisition time was 230 s, trap absorption temperature was 20°C, and incubation was at 50°C for 10 min, respectively. Identification of each volatile compound was determined by AroChemBase (Alpha MOS, Toulouse, France) based on retention index with Kovat's index library and retention time. All analyses were performed in 5 times. Discriminant pattern of volatile compounds in samples were investigated by PCA analysis (Boo et al, 2020).

13. Electronic tongue

An electronic tongue system (E-tongue, ASTREE II, Alpha MOS, Toulouse, France) with 7 kinds of sensors were applied for the investigation the compounds associated with basic taste intensity and pattern of sample sets. Two sensors, SPS and GPS sensors, were considered as reference sensors. SRS (sourness), STS (saltiness), UMS (umami), SWS (sweetness) and BRS (bitterness) sensors corresponded for 5 basic tastes. Ground 10 g of each sample was extracted with 100 mL distilled water at 60 °C for 10 min with mild agitation, and the extract was eluted with Whatman No. 1 filter paper (GE Healthcare, Little Chalfont, UK). The taste intensity was analyzed for 120 sec with dipping sensors. Each analysis was repetitive for five times and taste patterns were analyzed by principal component analysis (PCA). The taste responses from each sensor were calculated as relative scores ranged 1 to 12. PCA analysis was given for the resulted taste distribution and the results were shown in a radar plot, which indicates relative comparison among the tastes (Boo et al, 2020).

14. Statistical analysis

The results are expressed as mean ± SD. All statistical comparisons were made by means of one-way ANOVA test followed by Duncan's test with the level of significance of 0.05. The statistical software, SPSS 22.0 (SPSS Inc., USA), was used for analysis. Differences between the means were considered statistically significant when $p < 0.05$.

Results and Discussion

1. Proximate composition and gel strength of surimis

In order to evaluate basic specification of the used surimis, proximate composition and gel strength were measured. Moisture content of all surimis showed values within the range of 73-76% (Table 2). Among quality properties of surimi, protein content is considered as an important indicator (Wei et al., 2018). AP (17.1-18.2%) and PW (18.6%) showed higher protein content than TB (14.2-15.3%) and LF (16%). The result of proximate composition of surimis was similar to the previous study (Luo et al., 2004).

Among various physical properties of surimi, gel strength is the most important quality indicator because it is used for gel formation in foods including the imitation crab stick (Laura and Clara, 2009). Generally, the manufacturers assign quality grade of surimi, such as SA, FA, A and RA as the gel strength value (Velazquez et al., 2008). AP and TB surimis are most widely used in the world (Park, 2005). AP (542-1023 g·cm) showed higher gel strength than TB (209-524 g·cm) (Fig. 1), and this result was observed in the other studies (Wenjun Kong, 2016; Wangtueai & Noomhorm, 2009). PW and LF showed the highest (1356 g·cm) and the lowest (140 g·cm) gel strength.

Table 2. Proximate composition of surimi samples.

Surimi	Grade	Proximate composition (%)			
		Moisture	Crude protein	Crude lipid	Crude ash
AP	FA	74.10±0.03^{b}	17.44±0.14^{d}	0.94±0.03^{ab}	0.50±0.02^{a}
	A	73.84±0.04^{b}	18.22±0.09^{e}	1.24±0.43^{bcd}	0.65±0.02^{c}
	RA	74.49±0.14^{c}	17.10±0.32^{d}	0.96±0.05^{ab}	0.51±0.01^{a}
PW	A	73.22±0.09^{a}	18.64±0.37^{f}	0.82±0.04^{a}	0.84±0.010^{e}
TB	FA	76.88±0.39^{e}	14.18±0.22^{a}	1.07±0.11^{abc}	0.96±0.01^{f}
	AA	75.39±0.19^{d}	15.33±0.03^{b}	1.42±0.04^{cd}	0.70±0.02^{d}
LF	SA	75.31±0.08^{d}	16.01±0.02^{c}	1.61±0.01^{d}	0.56±0.01^{b}

The different letters mean significantly different ($P<0.05$).
AP: Alaska pollock, PW: Pacific whiting, TB: Threadfin bream, LF: Lizard fish.

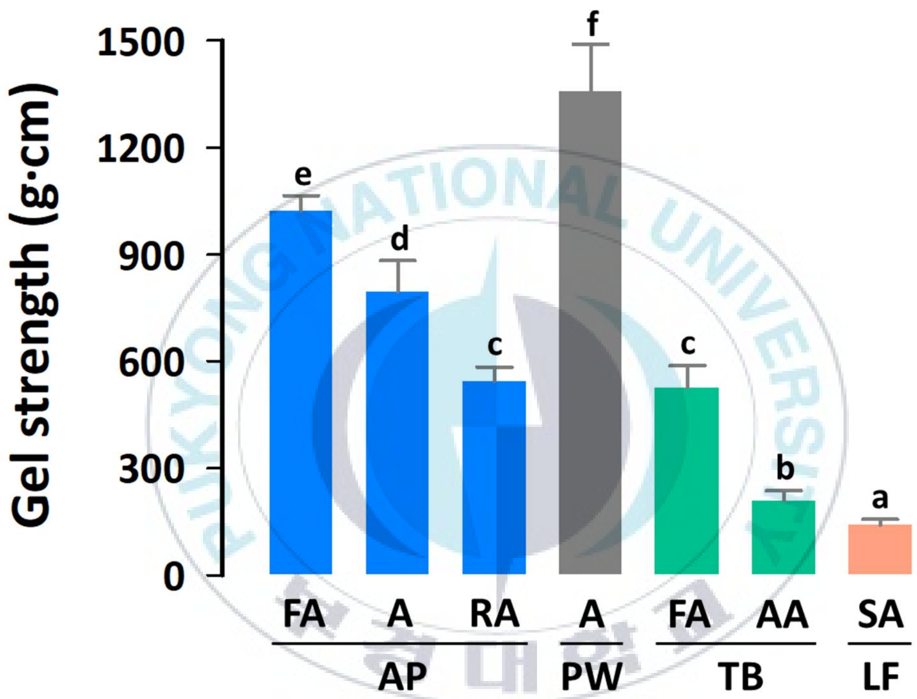

Figure 1. Gel strength of surimi samples. The different letters indicate significant differences ($p < 0.05$). AP, Alaska pollock; PW, Pacific whiting; TB, Threadfin bream; LF, Lizard fish.

2. Drying property of surimi mixtures

For preparation of the fish snacks, there are two important processes: drying of surimi mixture with ingredients and frying of the dried intermediate product (Kaewmanee et al., 2015). The moisture content of the dried intermediate products has a great influence on the physicochemical and sensory properties on the fried fish snacks (Sman & Broeze, 2013). In addition, low drying rate leads an increase in production cost (Huang & Zhang, 2012). Therefore, it is important to investigate drying behavior of the surimi mixture for manufacturing fish snacks.

Changes in moisture contents (%) of the different surimi mixtures as a function of drying time (m) are shown in Fig. 2. The drying curves of all the samples showed the similar tendency, and the coefficients of determination of the drying curve equation were over 0.9 (data not shown). The drying rate was increased from 30 to 120 m, and was decreased after 120 m. It was found that drying of all surimi mixtures was almost completed from 240 m after the hot-air drying started. This drying behavior pattern of the surimi mixtures with moisture content of around 76.3-81.2% was also observed in drying of the high-moisture food (Giner, 2009). The moisture contents of the intermediate products (surimi mixtures) dried for 240 m had a range of 8.3-10.1%. This is a moisture content similar to that obtained by hot-air drying the mixture to 11% to obtain intermediate dried product, according to a study in which crackers were made by adding fish meat (Kaewmanee et al., 2015). In our previous study (Kim et al.,2019), it was found that texture and overall acceptance of the surimi snacks were increased as decrease in moisture content of the dried intermediate products to 10%. In this study, the same amount of moisture was added for preparation of surimi mixture; however, it is necessary to determine the addition amount of moisture considering moisture content of the surimi used and quality properties of the fish snacks.

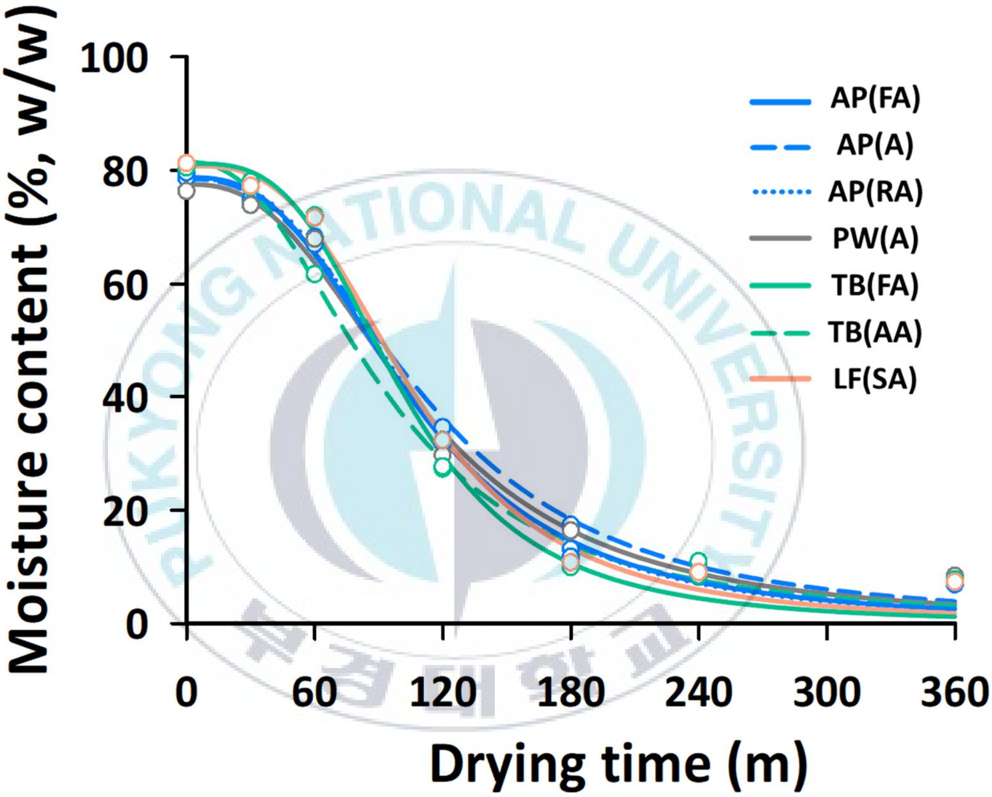

Figure 2. Drying property of surimi mixtures during hot-air drying. AP, Alaska pollock; PW, Pacific whiting; TB, Threadfin bream; LF, Lizard fish.

3. Color and appearance of surimi snacks

Color is one of the important quality characteristics of snacks because the color of snack products is closely related to sensory preference (Ahza et al., 2015). Appearance of the dried intermediate products and appearance and Hunter color values of the fried surimi snacks are shown in Figs. 3A, 3B and 3C, respectively. As expected, original color of the frozen surimis affected the colors of the dried intermediate products and the final fried surimi snacks. The fish snacks, which were made of AP and PW surimis with high whiteness value, showed relatively light brown colors (Fig. 3B), and showed high L-values. Among the fish snacks from AP surimis, RA, which is made from the recovery fish meat, had significantly lower L-value than those of FA and A. Generally, RA is one of the lowest surimi grades, and has a lot of impurities and low whiteness (Ahn et al., 2019).

TB and LF fish snacks showed deep brown colors compared to the fish snacks from AP and PW surimis. In particular, considering their colors of the dried intermediate products, browning was accelerated by deep frying processing. All the commercial frozen surimis contain cryoprotectants including sucrose, sorbitol and their blend (Park, 2005). TB and LF surimis had only 6% sucrose without sorbitol. It seems that the browning of sugar caused by heat affects the external color of snacks (Onipe et al., 2018). LF fish snack showed lighter brown color than TB fish snack due to its high extension value. Based on these results, in order to produce the fish snacks with desirable color, fish species and content and type of cryoprotectants are importantly considered.

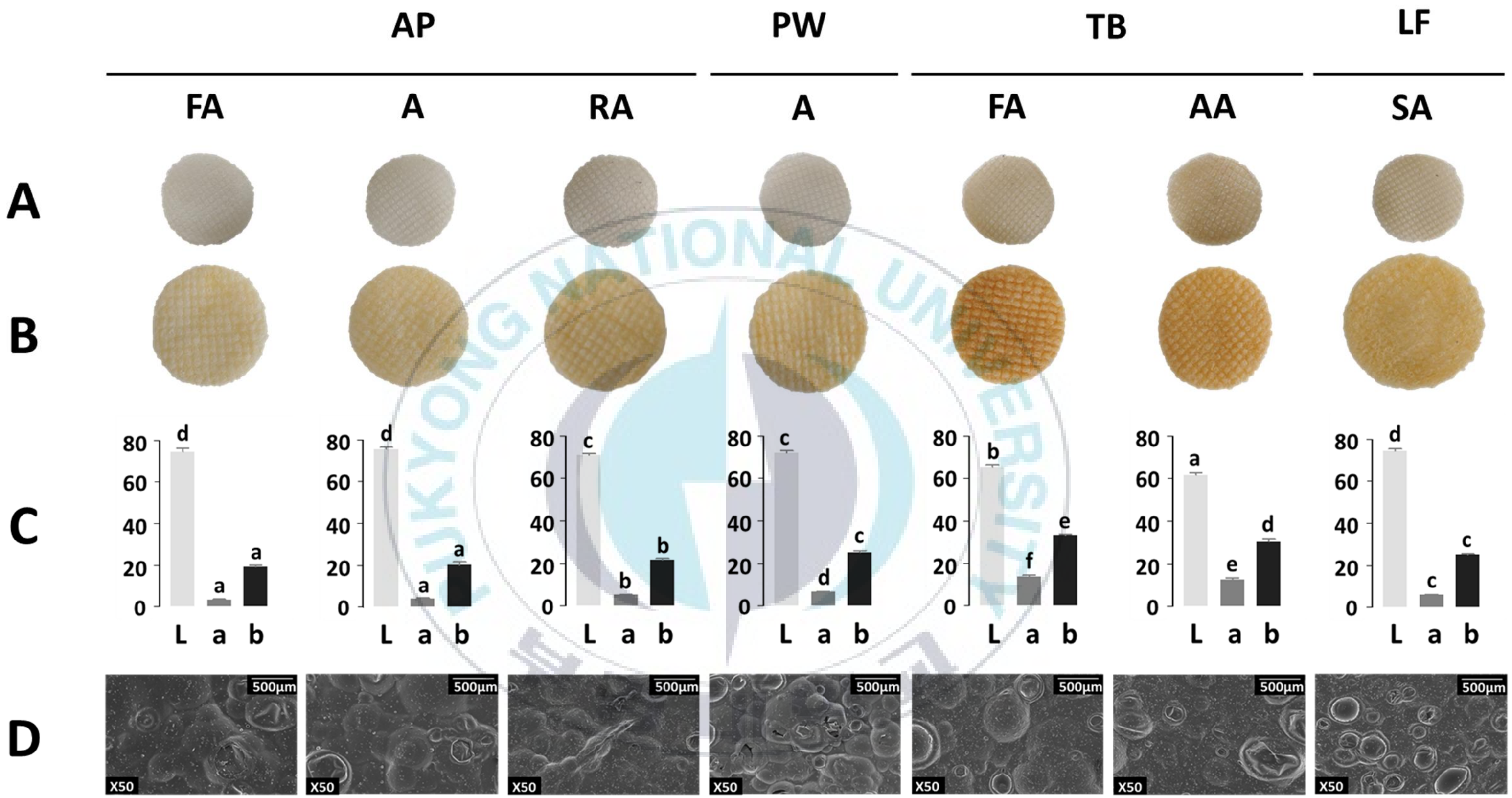

Figure 3. (A) Visualization of the intermediate dried products fish snacks. (B) Visualization of the final fried products with fish snacks. (C) Hunter color values of the final fried products with different types of surimi. The different letters indicate significant differences (P<0.05). (D) SEM micrographs of the final fried products with different types of surimi. AP, Alaska pollock; PW, Pacific whiting; TB, Threadfin bream; LF, Lizard fish.

4. Hardness, expansion and oil content of the surimi snacks

In the fried snacks, hardness is an important factor. Texture is closely related to the microstructure of the snacks (Ahza et al., 2015). Hardness was the highest with FA (633.88 g·cm) A (629 g·cm) of AP, and LF was the lowest. As a result of examining the correlation with the gel strength, the higher the gel strength, the higher the hardness of the snack was, but the R^2 value was not as high as 0.55. In the case of AP (FA) and AP (A) snacks with high hardness, there were fewer blisters, but the LF with the lowest hardness had more blisters. In our previous study (Chae et al.,2019), The more blister, the lower the hardness was reported.

Ramesh (2018) reported that expansion of a fried snack is an important of texture and increasing the linear expansion increases the crispiness value of the fried snack, indicating that the hardness value is low. This was similar in this study. For different fried surimi snacks, linear expansion was found to be in proportion to thickness expansion (Figs. 4B and 4C). This result was observed in the previous other studies (Ramesh, 2018). It was found that linear and thickness expansions did not correlate with gel strength of surimi (Figs. 4F and 4G). Therefore, it is judged that there is no need to consider the gel strength of surimi for the expansion of the snack.

The linear expansion of snacks and oil content are correlated (Noorakmar et al., 2012). The oil content in all samples before frying was close to 0% (data not shown). Oil content after frying shown in Fig. 4D. Samples with a linear expansion value of 33-44% excluding LF showed an oil content of 22-33%. This was comparable to the oil content of a similar study (Kaewmanee et al., 2015). LF with a linear expansion value of 55% had the highest oil content value of 50%. It had a large surface in contact with the oil.

In recent years, there is a trend to reduce oil intake for health (Arslan et al., 2018). It can be seen LF is a snack material that is not suitable for rancidity, storage and health. In Fig. 4H, oil content and hardness have a correlation. This is because the more oil is absorbed, the softer the snack is, so the hardness is lowered (Omidiran et al., 2019). Therefore, it seems necessary to consider the control of oil content for the hardness of fish snacks.

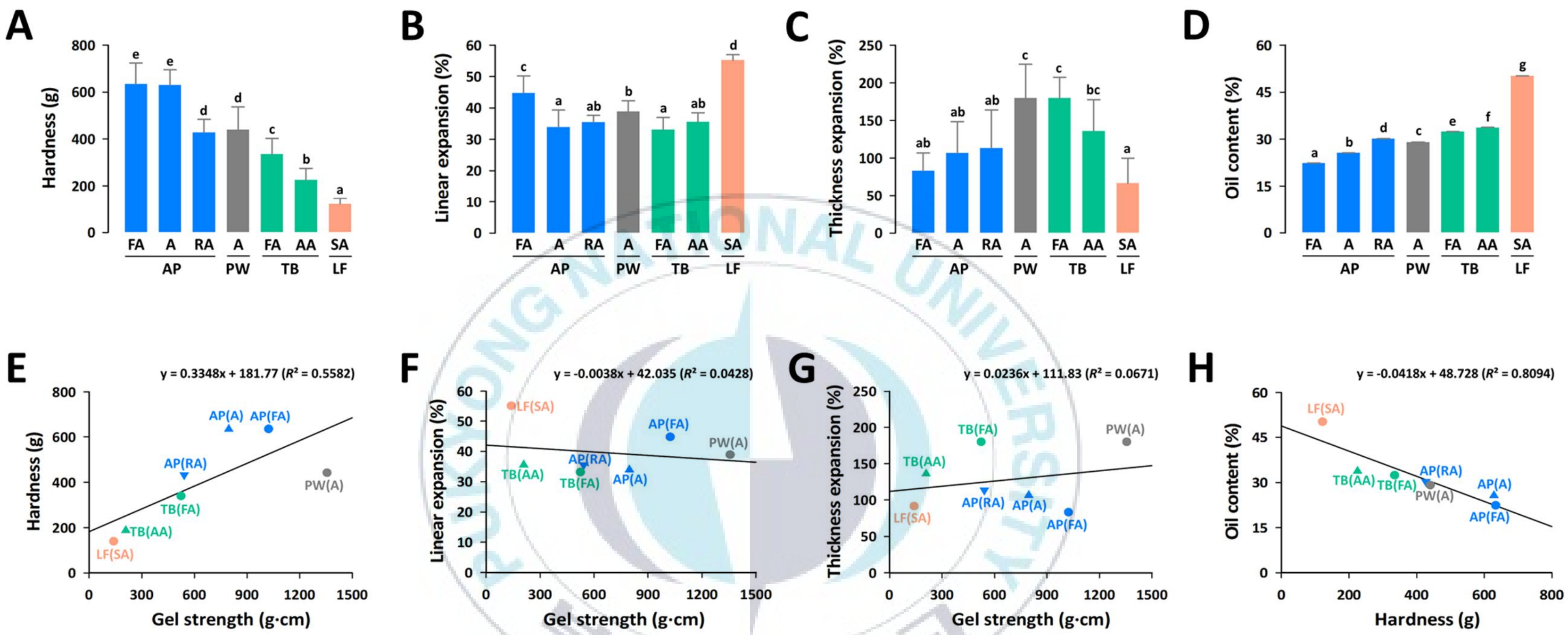

Figure 4. (A) Hardness of the final fried products with different types of surimi. The different letters indicate significant differences ($p < 0.05$). (B) Linear expansion of the final fried products with different types of surimi. The different letters indicate significant differences ($p < 0.05$). (C) Thickness expansion of the final fried products with different types of surimi. The different letters indicate significant differences ($p < 0.05$). (D) Oil content of the final fried products with different types of surimi. The different letters indicate significant differences ($p < 0.05$). (E) A correlation between gel strength and hardness. F A correlation between gel strength and linear expansion. (G) A correlation between gel strength and thickness expansion.

(H) A correlation between thickness hardness and oil content. AP, Alaska pollock; PW, Pacific whiting; TB, Threadfin bream; LF, Lizard fish

5. Sensory evaluations of the surimi snacks

Sensory evaluation for the fried surimi snacks was shown in Fig. 5A.

In overall acceptance, TB was the highest and LF was the lowest. This reason is thought to be due to the crispiness and oiliness. LF showed very low preference in crispiness and had a oily taste and poor taste due to its high oil content.

In color, TB was the highest and AP was the lowest. This was found to be because the browning reaction felt delicious. For samples other than TB, it is necessary to induce browning by adding more sugar or increasing the frying time.

In crispiness, LF with the lowest hardness value was the lowest. This is the snack had a thin thickness and was broken before the texture properties were felt. TB was the highest, and it was found that the hardness value was high in the range of 225-334 g.cm. The other samples had no sensory significant difference.

There was no significant difference between Taste and Aroma in all snacks, and TB was relatively high. Oiliness was high in LF. This showed the same trend as the oil content. However, due to the wide surface, there was no significant difference in sensuality.

This is for Asian Korean panelists, and it is expected that different results may be produced depending on the country in terms of taste, aroma, and color.

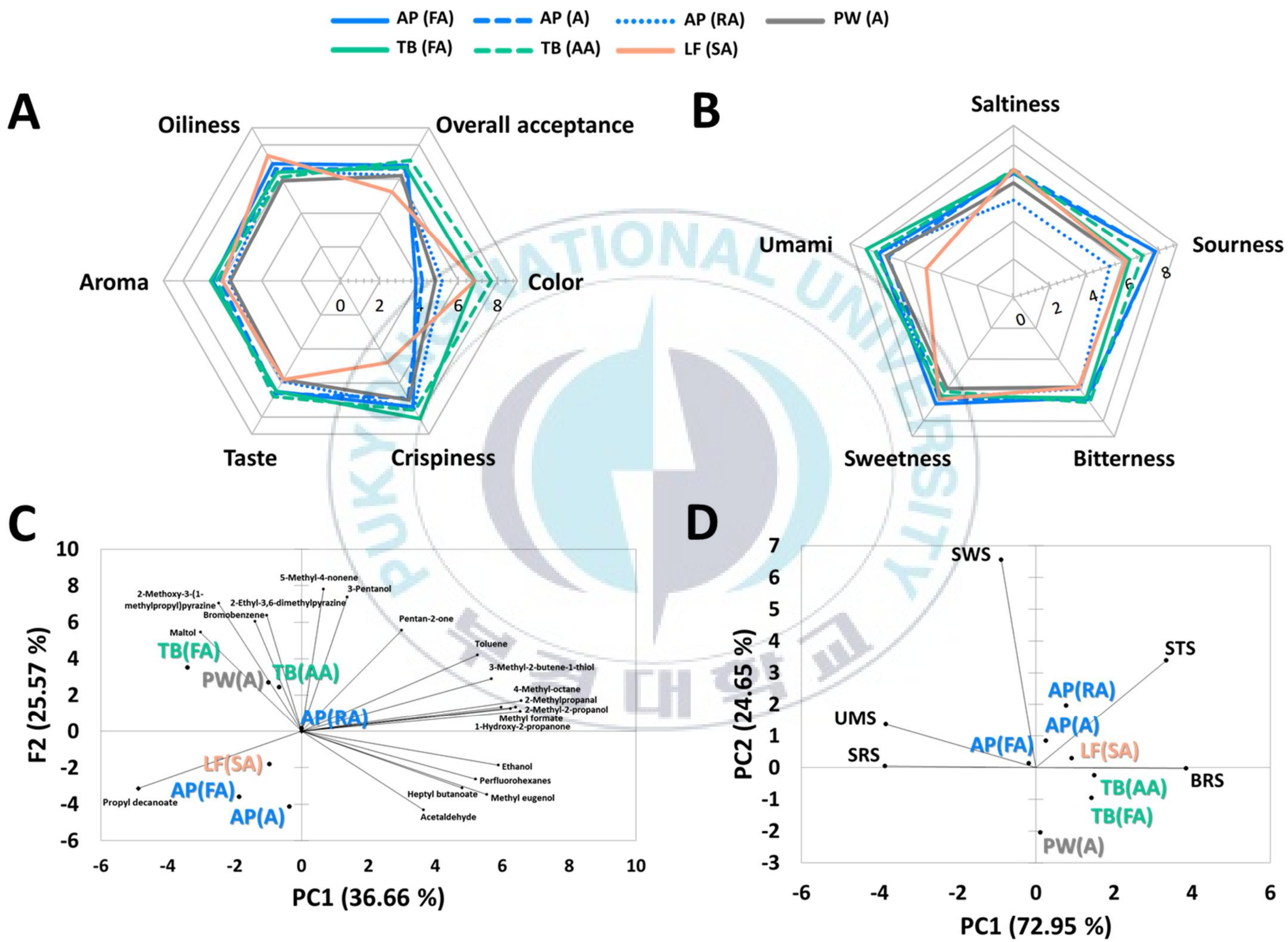
AP (FA)
AP (A)
AP (RA)
PW (A)
TB (FA)
TB (AA)
LF (SA)
A
Oiliness
Overall acceptance
Aroma
Color
Taste
Crispiness
0
2
4
6
8
B
Saltiness
Umami
Sourness
Sweetness
Bitterness
C
F2 (25.57 %)
PC1 (36.66 %)
5-Methyl-4-nonene
3-Pentanol
2-Methoxy-3-(1-methylpropyl)pyrazine
2-Ethyl-3,6-dimethylpyrazine
Bromobenzene
Pentan-2-one
Maltol
Toluene
3-Methyl-2-butene-1-thiol
4-Methyl-octane
2-Methylpropanal
2-Methyl-2-propanol
Methyl formate
1-Hydroxy-2-propanone
Ethanol
Perfluorohexanes
Heptyl butanoate
Methyl eugenol
Acetaldehyde
Propyl decanoate
TB(FA)
PW(A)
TB(AA)
AP(RA)
LF(SA)
AP(FA)
AP(A)
D
PC2 (24.65 %)
PC1 (72.95 %)
SWS
STS
UMS
SRS
BRS
AP(RA)
AP(A)
AP(FA)
LF(SA)
TB(AA)
TB(FA)
PW(A)

Figure 5. (A) Sensory evaluation of the final fried products with different types of surimi. Evaluation scale: 1 (very poor) to 9 (very good). (B) Radar plot for taste data of the commercial final fried products with different types of surimi. Data are shown as mean ± standard deviation (n=3). (C) Principle component analysis of the final fried products with different types of surimi identified by E-nose. (D) Principle component analysis of the final fried products with different types of surimi identified by E-tongue. AP, Alaska pollock; PW, Pacific whiting; TB, Threadfin bream; LF, Lizard fish.

6. Electronic nose and tongue of the surimi snacks

The e-tongue system was used to determine the taste components of samples and the results were shown in Fig. 5. Five basic taste intensities were compared using an electronic tongue system. Fig. 5B presents results on the taste intensities of the sample using an e-tongue. In case of sour taste (sourness), AP(FA) showed the highest 6.6, and TB(AA) samples showed the lowest strength of 4.6. The sourness is known to be recognized by hydrogen ion dissociated in food (Jeong et al., 2015). For the salty taste, it showed the highest 6.8 in AP(RA) and the lowest 5.6 intensity in the PW sample. The compound that expresses salty taste is known as NaCl (Jeong et al., 2015). Umami taste showed the highest 6.2 in AP(A) and the lowest 4.5 in TB(FA). Umami is one of the tastes used in the expression of "taste enhancer", and related compounds are known to be associated with amino acids, peptides, colines, and nucleotide (Jong et al., 2015). Sweetness was the highest 6.5 was shown in the AP (RA) sample and the lowest 5.7 strength in TB (FA). Sweetness is the most closely related taste in our daily table, mainly related to carbohydrates, sugar alcohols, amino acids, and peptides (Jong and others 2015). Bitterness was the highest 7.7 in TB (AA) and the lowest 5.7 intensity in AP (FA) and PW. The bitter taste is the most sensitive and low threshold concentration of the basic five tastes, and even the presence of a trace greatly affects the overall taste of the food (Jong et al., 2015). The overall taste intensity was high in the AP sample group and relatively low in the TB sample group.

The samples were analyzed using an electronic nose system to determine the volatile components of the samples, and the results were shown in Table 3. Electronic nose system identified 29 compounds in 7 samples. Among the 29 volatile components, perfluorohexanes, 5-methyl-4-nonene, 2-ethyl-3,6-dimethylpyrazine, acetaldehyde, methyl formate, propanoic acid, pentan-2-one, and terbacil were identified as the main volatile components. Especially, 2-ethyl-3,6-dimethylpyrazine was found to have the highest relative content, except for those that were odorless in the sensory description. The sensor description of 2-ethyl-3,6-dimethylpyrazine is known as burnt, cocoa, earthy, musty, nutty, potato, pungent, roast and is known as a compound produced in the non-enzymatic browning reaction, some of which are also known to be produced through Maillard reaction (Reinecius 2006). In the AP sample group, AP(FA) was determined to have a relatively low volatile content compared to AP (A) and AP (RA). In the TB group, TB (FA) was determined to have a relatively lower volatile content compared to TB (AA). Comparison of patterns with PCA analysis of volatile components by e-nose taste intensities by e-tongue and were shown in Figs. 5C and 5D, respectively. In Fig. 5C, the bi-plot produced by PCA for the volatile components shown in each sample was found to be 36.66% variance by PC1 and 25.57% variance by PC2. AP(FA), AP(A), and LF(SA) samples are highly correlated with propyl decanoate, and TB (FA), PW (A), TB (AA) are highly correlated with bromobenzene, 2-ethyl-3,6-dimethylpyrazine, 2-methoxyl-3-(1-methylpropyl)-pyrazine, and maltol. In addition, AP (RA) samples were found to be relatively less correlated with volatile compounds.

In Fig. 5D, the bi-plot by PCA for the taste components was shown and it showed a 72.95% of variance on PC1 and 24.65% of variance on PC2. In the bi-plot for the taste components, PC1 showed a higher separation compared to the volatile plot in Fig. 5C. At the correlation between the five basic tastes and samples, TB (AA) and TB (FA) samples were shown to be correlated to bitterness and saltiness. The AP (RA) had a correlation to saltiness and sweetness, and the AP (FA) was correlated to sourness and umami. In addition, PW (A) was found to have a relatively low correlation with five taste components. Through PCA pattern analysis, a multivariate analysis, the patterns of volatile compounds and taste components of each sample were successfully segregate

Table 3. The relative volatile compounds in snack samples using electronic nose.

Compounds	RT$^{1)}$ (RI$^{2)}$)	Sensory description	AP (FA)	AP (A)	AP (RA)	PW (A)	TB (FA)	TB (AA)	LF (SA)
Propane	14.77(313)	Odorless	0.11±0.03^{b}	0.15±0.03^{b}	0.14±0.02^{b}	0.15±0.03^{b}	0.25±0.03^{a}	0.20±0.06^{ab}	0.25±0.02^{a}
Perfluorohexanes	17.65(355)	Odorless	9.97±0.96^{cd}	16.14±1.16^{a}	12.31±1.04^{bc}	13.41±1.05^{b}	6.65±0.86^{e}	8.97±0.35^{de}	9.94±0.42^{cd}
Methyl formate	20.47(396)	Fruity, Plum	1.32±0.84^{c}	2.34±0.31^{bc}	2.52±0.38^{bc}	1.76±0.19^{bc}	2.53±0.31^{bc}	3.30±0.25^{b}	3.27±0.23^{b}
Acetaldehyde	22.69(428)	Fresh, Fruity, Pleasant, Pungent	2.85±0.82^{abc}	4.50±0.64^{a}	4.47±0.69^{a}	2.92±0.11^{abc}	2.03±0.35^{c}	2.69±0.17^{bc}	3.38±0.19^{abc}
Ethanol	23.83(444)	Pungent, Strong, Sweet, Weak	0.45±0.32^{b}	1.45±0.30^{ab}	0.76±0.34^{ab}	0.43±0.10^{b}	0.41±0.02^{b}	0.33±0.08^{b}	0.33±0.01^{b}
2-Methyl-2-propanol	27.35(495)	Camphor	0.30±0.01^{d}	0.48±0.27^{d}	0.68±0.17^{d}	0.32±0.01^{d}	1.90±0.25^{c}	2.05±0.03^{c}	3.27±0.08^{b}
2-Methylpropanal	28.29(509)	Burnt, Floral, Fresh, Fruity, Green, Pungent	0.34±0.05^{d}	0.65±0.31^{cd}	0.63±0.17^{cd}	0.43±0.03^{cd}	1.52±0.19^{bc}	1.95±0.05^{b}	1.85±0.03^{b}
1-Propanol	31.65(557)	Fermented, Fruity, Pungent, Musty	0.79±0.05^{ab}	0.98±0.19^{ab}	0.98±0.08^{ab}	1.06±0.12^{ab}	0.60±0.05^{b}	1.06±0.06^{ab}	1.21±0.04^{a}
1-Hydroxy-2-propanone	38.01(649)	Caramelized, Pungent, Sweet	0.18±0.07^{c}	0.16±0.07^{c}	0.19±0.12^{c}	0.14±0.07^{c}	0.63±0.13^{c}	1.13±0.18^{b}	1.51±0.22^{b}
Pentan-2-one	40.49(685)	Acetone, Etheral, Fruity, Sweet, Thinner, Woody	1.11±0.10^{bcd}	1.05±0.14^{cd}	1.33±0.07^{ab}	1.28±0.04^{abc}	1.29±0.07^{abc}	1.18±0.08^{abcd}	0.97±0.07^{d}
3-Pentanol	42.39(712)	Fruity, Green, Nutty, Oily, Sweet	0.29±0.01^{d}	0.29±0.01^{d}	0.40±0.01^{bc}	0.42±0.01^{ab}	0.40±0.02^{bc}	0.46±0.02^{a}	0.37±0.01^{c}
Propanoic acid	43.55(729)	Acidic, Pungent, Rancid, Soy, Vinegar	1.51±0.06^{c}	1.60±0.02^{c}	1.87±0.02^{b}	2.00±0.11^{ab}	1.48±0.06^{c}	2.04±0.03^{a}	1.90±0.01^{ab}
1,1,2-Trichloro-ethane	45.11(752)	Pleasant, Sweet	0.17±0.01^{a}	0.15±0.02^{a}	0.20±0.06^{a}	0.19±0.02^{a}	0.18±0.04^{a}	0.23±0.00^{a}	0.23±0.00^{a}
Toluene	47.47(786)	Caramelized, Etheral, Fruity, Pungent, Sweet, Synthetic	0.04±0.03^{d}	0.04±0.04^{d}	0.12±0.02^{c}	0.15±0.02^{c}	0.13±0.01^{c}	0.31±0.02^{b}	0.14±0.02^{c}
3-Methyl-2-butene-1-thiol	50.97(836)	Amine, Leek, Onion, Roast, Smoky, Skunky, Sulfurous	0.38±0.07^{b}	0.36±0.06^{b}	0.42±0.06^{b}	0.43±0.02^{b}	0.44±0.03^{b}	0.37±0.05^{b}	0.32±0.05^{b}
4-Methyl-octane	53.13(867)	Odorless	0.14±0.01^{b}	0.16±0.01^{b}	0.17±0.03^{b}	0.16±0.04^{b}	0.15±0.00^{b}	0.19±0.01^{b}	0.17±0.01^{b}
Ethylbenzene	54.13(882)	Floral, Sweet	0.38±0.02^{a}	0.39±0.03^{a}	0.44±0.02^{a}	0.45±0.01^{a}	0.38±0.02^{a}	0.43±0.03^{a}	0.38±0.02^{a}
Dihydro-2-furanone	55.77(905)	Caramelized, Creamy, Fatty, Oily, Pleasant, Sweet	0.11±0.01^{e}	0.09±0.01^{e}	0.24±0.01^{cd}	0.19±0.02^{d}	0.31±0.04^{c}	0.89±0.01^{a}	0.58±0.00^{b}
Bromobenzene	58.09(939)	Aromatic	0.50±0.09^{ab}	0.38±0.17^{b}	0.68±0.01^{ab}	0.72±0.07^{a}	0.73±0.05^{a}	0.76±0.06^{a}	0.59±0.04^{ab}
5-Methyl-4-nonene	62.19(998)	Odorless	6.32±0.07^{b}	6.04±0.31^{b}	7.47±0.25^{a}	8.39±0.25^{a}	8.42±0.45^{a}	7.80±0.43^{a}	6.06±0.08^{b}
2-Ethyl-3,6-dimethylpyrazine	68.16(1,084)	Burnt, Cocoa, Earthy, Musty, Nutty, Potato, Pungent, Roast	6.52±0.25^{c}	6.37±0.13^{c}	7.23±0.31^{bc}	8.67±0.18^{a}	8.62±0.52^{a}	7.45±0.49^{b}	4.92±0.12^{d}
Maltol	71.67(1,140)	Baked, Caramelized	0.15±0.01^{bc}	0.17±0.04^{abc}	0.16±0.01^{bc}	0.23±0.07^{ab}	0.26±0.03^{a}	0.18±0.03^{abc}	0.11±0.01^{c}
2-Methoxy-3-(1-methylpropyl) pyrazine	73.61(1,172)	Bell pepper, Carrot, Earthy, Green, Musty, Pepper, Pea	0.05±0.00^{bc}	0.07±0.03^{abc}	0.07±0.01^{abc}	0.12±0.04^{ab}	0.13±0.02^{a}	0.08±0.02^{abc}	0.02±0.03^{c}
Ethyl maltol	75.29(1,200)	Candy, Caramelized, Strawberry, Sweet	0.11±0.02^{c}	0.16±0.05^{abc}	0.17±0.06^{abc}	0.24±0.03^{a}	0.21±0.03^{ab}	0.13±0.02^{bc}	0.11±0.02^{c}
Heptyl butanoate	80.65(1,301)	Floral, Fruity, Green, Herbaceous, Sweet	0.55±0.01^{ab}	0.55±0.03^{abc}	0.53±0.03^{abcd}	0.54±0.01^{abc}	0.43±0.02^{cd}	0.41±0.10^{d}	0.46±0.02^{bcd}
Methyl eugenol	85.69(1,405)	Cinnamon, Fresh, Carnation, Clove, Spicy, Sweet	0.29±0.08^{ab}	0.35±0.08^{ab}	0.29±0.03^{ab}	0.28±0.06^{ab}	0.20±0.03^{b}	0.23±0.04^{b}	0.24±0.03^{b}
Propyl decanoate	89.49(1,489)	Fatty, Fruity, Green, Oily, Vegetable, Waxy, Woody	0.07±0.01^{a}	0.06±0.01^{a}	0.04±0.03^{a}	0.04±0.03^{a}	0.05±0.04^{a}	0.07±0.02^{a}	0.06±0.01^{a}
Methyl dodecanoate	91.33(1,531)	Coconut, Creamy, Fatty, Fruity, Floral, Mushroom	0.55±0.10^{a}	0.57±0.08^{a}	0.53±0.08^{a}	0.57±0.10^{a}	0.68±0.25^{a}	0.60±0.13^{a}	0.63±0.08^{a}
Terbacil	104.91(1,840)	Odorless	1.36±0.13^{a}	1.25±0.13^{a}	1.15±0.05^{a}	1.16±0.06^{a}	1.17±0.16^{a}	1.30±0.28^{a}	1.12±0.03^{a}

RT$^{1)}$: retention time, RI$^{2)}$: retention indices.

Conclusions

We demonstrated that the gel strength, which is the most important factor of surimi, is not an absolute factor when making fried fish snacks using surimi. It is important how to use it for color, etc., according to the characteristics of the country and situation. For fish snacks using surimi to be used more widely, further research is need. Therefore, our study is likely to be applied as basic data.

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Publications and Presentations

Publications

Chae, J., Jeong, C., Kim, S., Mun, S., Kim, S. B., Kim, Y. M., ... & Kwon, S. (2019). Effects of freeze molding on the quality characteristics of Alaska pollock Theragra chalcogramma surimi snacks. Korean Journal of Fisheries and Aquatic Sciences, 52(5), 445-451.

Chae, J., Kim, S., Choi, G., Kim, J., Lee, J., Kim, S. B., ... & Cho, S. (2019). Physicochemical Characteristics of Fried-fish Snacks with Different Types of Starch. Korean Journal of Fisheries and Aquatic Sciences, 52(6), 580-586.

Kim, S., Chae, J., Choi, G., Kim, J., Lee, J., Kim, S. B., ... & Cho, S. (2019). Optimizing the Drying Conditions of Surimi Snacks Using a Response Surface Methodology. Korean Journal of Fisheries and Aquatic Sciences, 52(6), 571-579.

Oral presentations

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Title: Effects of Freeze Molding on Quality Characteristics of Pollack (*Theragra chalcogramma*) Surimi Snack

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Title: Physicochemical Characteristics of Fried-fish Snacks with Different Types of Surimi

Poster presentations

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