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The Effects of Alkaline Treatment and Potato-Starch Content on the Quality of Fish Meat Paste Products Prepared from Pacific Sandlance *Ammodytes personatus* Girard

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Abstract

This study investigated the effects of the number of washes and alkaline treatments ($NaHCO_3$ concentrations) and the concentration of potato starch on the quality of fish meat paste products prepared from sand lance *Ammodytes personatus* Girard. We found significantly ($P<0.05$) higher ratings for the all textural parameters (hardness, brittleness, elasticity, and cohesiveness) of the sand-lance meat paste products (SLMPPs) that were washed three times with a 0.5% $NaHCO_3$ concentration. We determined that an 8% concentration of potato starch leads to the best textural properties in SLMPPs. As the amount of potato starch was increased, the redness values of SLMPPs decreased significantly ($P<0.05$), but the differences in the sensory evaluation parameters (texture, flavor, taste, and overall acceptability) between the SLMPPs were not significant.

Key words : Sand lance, Washing time, Alkaline treatment, Textural parameter, Potato starch

Introduction

Several manufacturing processes have been developed to improve the textural properties of fish meat paste products. These processes, revolve around repeatedly washing minced fish with chilled tap water (5-10°C) until most of water-soluble protein (WSP) is removed. Then, the washed minced fish is ground with 2.5~3.0% neutral salt to solubilize the myofibrillar protein (Sano et al., 1988), which generates a viscous sol known as fish meat paste. Subsequently, the fish meat paste is heated, turning the viscous sol to an elastic gel (Numakura et al., 1990). The final quality of fish meat paste products depends on the rheological properties of minced fish.

Many methods have been developed to enhance the textural properties of fish meat paste products. These entail modifications to the manufacturing procedures, such as the washing process and the two-step heating process (Fukushima et al., 2007) as well as the addition of food-grade ingredients in an attempt to improve the overall rheological properties of the final product.

The washing process of the minced fish is of great importance for the quality of the fish meat paste product in terms of its abilities to remove sarcoplasmic proteins, fat, blood, pigments and odorous substances as well as to concentrate myofibrillar proteins, which enhances the gel strength (Mendes and Nunes, 1992; Chaijan et al., 2004). Dark fleshed species, such as mackerel, exhibit high concentrations of lipids and myoglobin, which complicates the production of high quality fish meat paste products. Furthermore, given that the pH of dark-fleshed fish decreases during postmortem handling or storage, its gel-forming ability also gradually declines. To alleviate this problem, alkaline leaching has been used to raise the pH of muscle and to increase the efficiency with which lipids, pigments, blood, and sarcoplasmic proteins are remove (Shimizu, 1965). Shimizu (1965) reported that surimi that was made using alkaline leaching showed relatively high break-

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ing and deformation forces, compared to surimi made using conventional methods.

Additional to enhance the gel strength of fish meat paste products, a variety of food-grade ingredients such as bovine plasma protein, egg whites (Benjakul et al., 2001, 2004), starches (Kim and Lee, 1987; Yoon et al., 1997; Yang and Park, 1998; Tabilo-Munizaga and Barbosa-Cánovas, 2004; Yoon et al., 2004) and cross-linking transglutaminase (Benjakul and Visessanguan, 2003) have been added to surimi. The addition of bovine plasma protein and transglutaminase, generates undesirable effects on fish meat paste the flavor and color, of the fish paste product, whereas the addition of egg whites raises allergy tissued. Therefore, starch is the ingredient that is most frequently added to surimi to improve the textural properties of products (Kong et al., 1999). Kim and Lee (1987) reported that, among various starches, potato starch had the greatest gel-strengthening effect owing to its ability to bind relatively large amounts of water and thus to swell. Therefore potato starch has been added to surimi to increase its water content as well as to improve its textural properties (Yoon et al., 1997; Yang and Park, 1998; Tabilo-Munizaga and Barbosa-Cánovas, 2004; Yoon et al., 2004). Additionally, Yang and Park (1998) reported that the influence of starch on the texture of heat-induced surimi-starch gels was dependant on the concentration of starch.

Sand lance, a dark-muscled fish species, is found along the Gangwon coast. The total annual catch of this fish has exceeded 9,000 t/y since 1993. Given the lack of available methods for developing new products from sand lance, this fish has been used primarily to produce plain dried products, known as *gwuamegi*. Therefore, to increase the efficacy of utilizing this fish as a fishery resource, methods for manufacturing high-quality fish meat paste products are needed.

We examined the effects of alkaline treatment during the washing process, undertaken to raise the pH of minced sand lance, on the textural properties of the fish paste product. We also evaluated the effects of washing time and potato-starch concentration on the textural properties of the fish paste product.

Materials and Methods

Materials

Pacific Sandlance *Ammodytes personatus* Girard (average weight of 230-280 g) were caught off the Gangwon coast, stored in ice, and off-loaded approximately 36 h after capture. Upon arriving at the dock in Jumunjin, the fish were iced with a fish/ice ratio of 1:2 (w/w) and transported to the laboratory within 2 h, where they were washed and drained. The flesh was removed manually and used for the preparation of mince and fish paste product. Mince was prepared according to a slightly modified version of the method developed by Ryu et al. (1994). The flesh was minced to uniformity using a mincer with a hole with a 5-mm diameter. This substance was referred to as "unwashed mince."

The alkaline treatment of unwashed mince and the washing procedure

The alkaline treatment of unwashed mince was performed according to the method of described by Shimizu (1965). The mince was suspended in cold (5°C) alkaline solutions (0.1, 0.3, 0.5, or 0.7% $NaHCO_3$ solutions) at a mince/solution ratio of 1:5. The mixture was stirred gently for 15 min, and then left for 5 min, next, the upper solution was decanted and removed. This procedure was repeated three times. Control mince was prepared by washing it three times with only tap watert at 5°C. Finally, to assess effect of washing time on the textural properties of the fish meat paste product, the procedure of washing with tap water at 5°C was repeated one, three, five or seven times.

Preparation of the sand lance meat paste product (SLMPP)

SLMPPs were prepared according to a slightly modified version of the method described by Park et al. (1985a). The sand-lance mince (SLM) washed with $NaHCO_3$ solution or tap water was dewatered by centrifugation at 15,000 rpm for 10 min. The products were then mixed with 0%, 3%, 5%, 8%, 10%, or 15% potato starch and ground for 10 min. The ground samples (150 g) were packed in Krehalone casing film (*Ø* 3.0 cm) and then incubated at 40°C for 30 min, this was followed by heating at 90°C for 40 min and then cooling in tap water at 15°C.

Proximate analysis

The protein, fat, ash, and moisture content of all samples were measured. The nitrogen content was determined by the semi-Kjeldahl method (Association of Official Analytical Chemists, 1980). Total fat, ash, and moisture were analyzed using Association of Official Analytical Chemists methods (2005).

Analysis of protein composition

Protein composition was assessed according to the method described by Kim et al. (1982). Specially, the water-soluble protein (sarcoplasmic protein), salt-soluble protein (SSP, myofibrillar protein), stroma protein, alkali-soluble protein, and non-protein nitrogen concentrations of sand-lance meat and SLM were determined.

Texture analysis

The texture profile analysis (TPA) of SLMPPs was performed at ambient temperature with a rheometer (NRM-2010J; Fudoh, Tokyo, Japan) and a 1-kg cell. SLMPPs were cut using a wire knife (0.25 mm in diameter) into cylinders that were 30 mm in diameter and 20 mm in length. Each cylinder was compressed axially at 6-s intervals in two consecutive cycles of 70% compression, with a spherical plunger (Ø 5mm). The cross-head moved at a constant speed of 60 mm/min. On the basis of the TPA curves, the following texture parameters were calculated according to the method developed by Park et al. (1985a): hardness at 70% deformation, brittleness, elasticity, and cohesiveness.

Folding test

To investigate the binding structure of the SLMPP, a folding test was conducted according to the method described by the National Fisheries Institute (1991). The folding tests were performed by slowly folding a 3-mm slice of the SLMPP in half, and then folding it in half again to examine the structural rupture of the slice. The number of folds required to crack the slice was then scored from 1.00 to 5.00 and assigned to one of five classes: AA, A, B, C or D. Class AA (5.00) indicates high-quality and class D (1.00) refers to poor-quality fish meat paste products with respect to the cracking of the gel due to folding.

Color measurement

Color measurements of SLMPPs prepared with different potato-starch concentrations were performed in a Chroma Meter (Model CR-300; Minolta Co., Tokyo, Japan) at ambient temperature. Color L (lightness), a (redness "+" or greenness "-") and b (yellowness "+" or blueness "-") were measured using this equipment standardized with a Minolta standard-white reflection plate.

Sensory evaluation

SLMPPs prepared with different concentrations of potato starch were evaluated for texture, flavor, taste, and overall acceptability by 15 non-trained panelists. A five-point hedonic scale, in which a score of 1=signified "not like," 3=signified "neither like nor dislike," and 5=signified "liked very much," was used to rate sensory experience.

Statistical analysis

The experiment was replicated three times. Each replication tested three samples for texture parameters (TPA test and folding test), five samples for color measurements (L, a, and b), and three samples for sensory evaluation (texture, flavor, taste, and overall acceptability). The factors included five washing patterns, six $NaHCO_3$ concentrations, and six concentrations of potato starch. The least significant difference at 5% was applied to define significant differences between the mean values. All analyses were performed using SAS software version 8.1 (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

Proximate analysis

The approximate composition and protein content of the sand lance meat used in the experiment are shown in Table 1. Both moisture and protein were at high levels (73.3% and 20.2 %, respectively), whereas the lipids and ash content were at relatively low levels (5.2% and 1.3%, respectively). Additionally, myofibrillar and sarcoplasmic proteins accounted for 62.1% and 23.4% respectively, whereas alkali-soluble and stroma proteins accountes for 11.7% and 2.8%, respectively.

The effect of the number of washes on the properties of SLM and on the textural properties of SLMPPs

The differences in the components and the protein compositions of SLM washed with tap water for a variety of washing times are shown in Fig. 1. Specially, increasing the number of

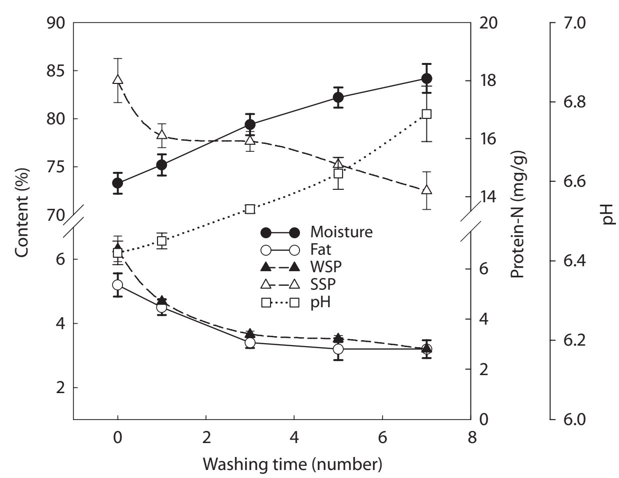

Fig. 1. Effect of washing time with tap water on compositive properties of SLM. SLM, Pacific sandlance mince; WSP, water-souble protein: SSP, salt-soluble protein.

Table 1. Proximate composition and protein composition of sand lance meat used in this experiment

Approximate composition (%)		Protein composition (%)	
Moisture	73.3	Sarcoplasmic protein	23.4
Crude protein	20.2	Myofibrillar protein	62.1
Crude lipids	5.2	Alkali soluble protein	11.7
Ash	1.3	Stroma protein	2.8
pH	6.4	Non-protein N (mg/g)	2.3

washes reduced the WSP, SSP, and fat content but increased the moisture content and pH value. The proportion of SSP, which enhances the gel strength of the SLMPP, drastically decreased with more than five washings, whereas the rates of decline in WSP and fat, which have undesirable effects on the textural quality of fish meat paste products were reduced. After three washes with tap water, the SSP content of SLM was reduced by 11.7% (from 18.0 to 15.9 mg/g) compared with that of unwashed mince, whereas the WSP content, decreased by 48.5% (from 6.8 to 3.5 mg/g).

Given that pH is one of the most important factors for producing strong elastic surimi gels, we measured whether the pH changed as a function of the number of washings. We found that the pH value increased (from 6.42 to 6.77) in almost direct proportion to the number of washings. This finding was in accordance with previously reported results, which suggested that the optimal pH for the creation of strong gels is approximately 6.2-6.8 for dark-muscled fish such as sardine (Park et al., 1985a).

The TPA parameters of SLMPPs prepared from mince washed with tap water a variable number of times are shown in Table 2. The hardness of the SLMPP ranged from 0.13 to 0.35 kg, whereas its brittleness ranged from 0.16 to 0.26 kg, its elasticity ranged from 2.5 to 3.6 cm, and its cohesiveness ranged from 0.40 to 0.58 cm. Significantly (P<0.05) higher ratings for hardness, brittleness, elasticity, and cohesiveness (0.35kg, 0.26 kg, 3.2 cm, and 0.52 respectively) were observed after three washings. Thus the number of washings appears to constitute one of the most important factors in the production of a gel made from strong elastic fish meat paste. The optimal number of washes for producing a strong gel in mackerel meat paste products has been reported to be three to five (Park et al., 1985b). The mackerel meat paste products with the greatest hardness emerged after five washes, and three washes produced the most ideal elasticity and chewiness. In this experiment, the textural properties of the SLMPP were accordance with its SSP and WSP content.

According to the folding test, the samples of the SLMPP washed more than three times showed the maximum value (5.00), indicating good gelling strength. Therefore, we concluded that three washes of SLM were the optimal for purpose of obtaining the most desirable SLMPP.

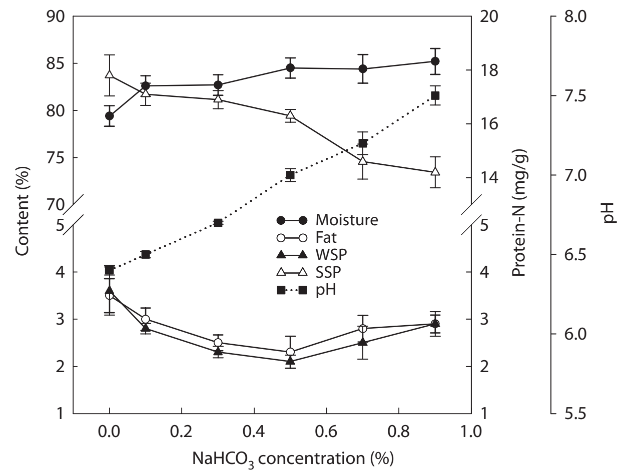

Fig. 2. Effect of $NaHCO_3$ concentration on compositive properties of SLM. SLM, Pacific sandlance mince; WSP, water-souble protein: SSP, salt-soluble protein.

Effect of alkaline treatment on the properties of SLM property and on the textural properties of SLMPPs

Changes in the overall composition and protein content of SLM washed with different concentrations of $NaHCO_3$ are shown in Fig. 2. The water content of the SLM increased slightly with increasing $NaHCO_3$ concentrations, whereas a linear increase in the pH values of SLMs was observed as the concentrations of $NaHCO_3$ were increased to 0.9%. The rate of decline in the SSP reduced as the $NaHCO_3$ concentration increased to 0.5%, whereas it increased at concentrations greater than 0.7%. The fat and WSP content of the SLM continuously decreased until the $NaHCO_3$ concentration reached to 0.5%; it then increased, at concentration greater than 0.7%.

The effects of the $NaHCO_3$ concentrations of the wash wa-

Table 2. Effects of the number of wash with tap water on the textural properties of SLMPP

Textural properties	Washing time (number)				
	0	1	3	5	7
Hardness (kg)	$0.13^{c} \pm 0.016$	$0.15^{ac} \pm 0.024$	$0.35^{a} \pm 0.017$	$0.33^{b} \pm 0.015$	$0.32^{b} \pm 0.013$
Brittleness (kg)	$0.10^{c} \pm 0.023$	$0.13^{bc} \pm 0.012$	$0.26^{a} \pm 0.024$	$0.24^{ab} \pm 0.030$	$0.21^{b} \pm 0.029$
Elasticity (cm)	$1.8^{d} \pm 0.14$	$2.2^{c} \pm 0.11$	$3.2^{a} \pm 0.23$	$2.8^{b} \pm 0.16$	$2.4^{bc} \pm 0.27$
Cohesiveness	$0.42^{c} \pm 0.025$	$0.46^{b} \pm 0.021$	$0.52^{a} \pm 0.019$	$0.46^{b} \pm 0.016$	$0.42^{c} \pm 0.013$
Folding test	$3.92^{c} \pm 0.013$	$4.30^{b} \pm 0.092$	$4.98^{a} \pm 0.002$	$4.79^{a} \pm 0.010$	$4.76^{a} \pm 0.012$

Means in rows followed by different letters are statistically different using LSD (α=0.05).
SLMPP, Pacific sandlance meat paste products; LSD, least significant difference.

ter on the textural properties of SLMPPs are shown in Table 3. Interestingly, continuous increases in the hardness and the brittleness of SLMPPs were observed as the concentration of $NaHCO_3$ increased to 0.5%, whereas these values decreased as the $NaHCO_3$ concentrations increased from 0.7% to 0.9%. The highest values for the hardness, brittleness, elasticity, and cohesiveness of the SLMPP emerged in the folding test at $NaHCO_3$ concentration of 0.5% and 0.3%. Given that the pH values of SLM after washing with 0.3 or 0.5% $NaHCO_3$ solutions were 6.7-7.0 (Fig. 2), the optimal pH for the creation of strong gels is approximately 6.7-7.0 for dark muscled fish such as mackerel and sardines (Park et al., 1985a, 1985b). That is, the highest hardness and toughness ratings for sardine meat paste products were observed at pH values of 6.7, and 7.0, respectively, for mackerel. We found that the hardness and elasticity ratings for the SLMPPs decreased with decreasing or increasing pH values, respectively, indicating that neutral salt-ground meat fish is essential for the formation of large quantities of cross-linked myosin-heavy chains, which contribute to elastic gels (Funatsu and Arai, 1991). Moreover, Chung et al. (1993) reported that the higher pH of Pacific whiting surimi gels tended to be associated with higher breaking strengths than did surimi gels with lower pH values, probably because myosin-heavy chain cross-linking is higher at pH 7.0 than at lower pHs (Funatsu et al., 1993).

In the folding test, SLMPPs prepared from SLM washed with 0.3 and 0.5% $NaHCO_3$ solutions scored the maximum value of 5.00, indicating good gelling strength.

Effects of the addition of potato starch on the quality of SLMPPs

The TPA results for SLMPPs prepared with different quantities of potato starch are shown in Table 4. Four parameters were measured; hardness, brittleness, elasticity, and cohesiveness. Hardness and brittleness generated significantly higher ratings as a function of increasing potato starch concentrations (P<0.05). Significantly increased values for elasticity and cohesiveness of SLMPP were observed with an 8% concentration of potato starch (P<0.05). Chen and Huang (2008) reported that adding starch increased the breaking force, deformation, and gel strength of kamaboko prepared from horse mackerel surimi. Additionally, Kim and Choi (2011) reported that the breaking force and deformation of squid surimi gel with starch were significantly higher than those of surimi gel without starch. Yang and Park (1998) confirmed that the shear-stress values in surimi gels continuously increased with increasing potato-starch concentrations until the starch concentration reached a certain level. These reports, suggested that the hardness and brittleness of SLMPP, which were increased

Table 3. Effects of the concentration of $NaHCO_3$ on the textural properties of SLMPP

Textural properties	$NaHCO_3$ concentration (%)					
	0	0.1	0.3	0.5	0.7	0.9
Hardness (kg)	$0.20^d \pm 0.018$	$0.20^d \pm 0.021$	$0.38^b \pm 0.024$	$0.40^a \pm 0.017$	$0.32^c \pm 0.025$	$0.20^d \pm 0.013$
Brittleness (kg)	$0.16^c \pm 0.012$	$0.18^{cd} \pm 0.010$	$0.23^b \pm 0.013$	$0.32^a \pm 0.011$	$0.25^b \pm 0.015$	$0.13^d \pm 0.010$
Elasticity (cm)	$3.2^b \pm 0.04$	$3.2^b \pm 0.02$	$3.3^{ab} \pm 0.03$	$3.6^a \pm 0.01$	$3.2^b \pm 0.04$	$2.5^d \pm 0.05$
Cohesiveness	$0.48^{cd} \pm 0.017$	$0.46^c \pm 0.020$	$0.54^b \pm 0.023$	$0.58^a \pm 0.025$	$0.46^c \pm 0.021$	$0.40^d \pm 0.019$
Folding test	$4.98^b \pm 0.002$	$4.92^b \pm 0.002$	$5.00^a \pm 0.000$	$5.00^a \pm 0.000$	$4.90^b \pm 0.010$	$4.89^b \pm 0.005$

Means in rows followed by different letters are statistically different using LSD (α=0.05).
SLMPP, Pacific sandlance meat paste products; LSD, least significant difference.

Table 4. Effects of the concentration of potato starch on textural properties of SLMPP

Textural properties	Potato starch amount (%)					
	0	3	5	8	10	15
Hardness (kg)	$0.38^f \pm 0.015$	$0.40^e \pm 0.019$	$0.46^d \pm 0.023$	$0.80^c \pm 0.027$	$1.02^b \pm 0.022$	$1.18^a \pm 0.036$
Brittleness (kg)	$0.28^e \pm 0.014$	$0.30^{de} \pm 0.013$	$0.38^d \pm 0.018$	$0.64^c \pm 0.011$	$0.84^b \pm 0.017$	$0.88^a \pm 0.023$
Elasticity (cm)	$3.2^d \pm 0.04$	$3.4^c \pm 0.02$	$3.5^b \pm 0.01$	$4.2^a \pm 0.02$	$3.7^{bc} \pm 0.02$	$3.4^c \pm 0.03$
Cohesiveness	$0.49^d \pm 0.023$	$0.57^c \pm 0.020$	$0.57^c \pm 0.018$	$0.96^a \pm 0.021$	$0.78^b \pm 0.017$	$0.60^{cd} \pm 0.022$
Folding test	$4.90^b \pm 0.002$	$4.95^b \pm 0.002$	$5.00^a \pm 0.000$	$5.00^a \pm 0.000$	$5.00^a \pm 0.000$	$4.97^b \pm 0.002$

Means in rows followed by different letters are statistically different using LSD (α=0.05).
SLMPP, Pacific sandlance meat paste products; LSD, least significant difference.

Table 5. Effect of the concentration of potato starch on Hunter's colors of SLMPP

Hunter's colors	Amounts of potato starch (%)					
	0	3	5	8	10	15
L	70.18[ab] ± 0.78	69.59[ab] ± 0.85	69.64[ab] ± 0.63	67.48[bc] ± 1.04	66.67[bc] ± 0.71	63.74[c] ± 0.73
a	-0.85[a] ± 0.070	-1.60[ab] ± 0.14	-1.72[b] ± 0.062	-1.90[c] ± 0.077	-2.02[d] ± 0.085	-2.07[e] ± 0.069
b	12.72[a] ± 0.49	10.64[b] ± 0.57	10.29[b] ± 0.85	10.20[b] ± 0.79	10.74[b] ± 0.68	10.64[b] ± 0.78

Means in rows followed by different letters are statistically different using LSD (α=0.05).
SLMPP, Pacific sandlance meat paste products; LSD, least significant difference.

Table 6. Sensory evaluation of SLMPP prepared with various amounts of potato starch

Sensory properties	Potato starch amount (%)					
	0	3	5	8	10	15
Texture	3.5[a] ± 1.04	4.0[a] ± 0.72	4.2[a] ± 1.31	4.4 ± 1.03[a]	4.3[a] ± 0.94	4.0[a] ± 1.21
Flavor	4.0[a] ± 1.32	4.0[a] ± 1.01	4.1[a] ± 0.93	4.5[a] ± 0.77	4.2[a] ± 0.95	3.7[a] ± 1.04
Taste	4.0[a] ± 0.95	4.1[a] ± 0.87	4.1[a] ± 0.89	4.2[a] ± 0.62	3.9[a] ± 0.78	3.6[a] ± 0.82
Overall acceptance	4.1[a] ± 1.23	4.1[a] ± 1.02	4.2[a] ± 0.73	4.5[a] ± 0.54	4.0[a] ± 0.85	3.7[a] ± 0.61

Means in rows followed by different letters are statistically different using LSD (α=0.05).
SLMPP, Pacific sandlance meat paste products; LSD, least significant difference.

with increasing potato starch, are due to the absorption of water by starch granules in the SLMPP. This process makes the SLMPP more rigid, which is why starch granules act as a filler reinforcement agent in surimi (Kim and Lee, 1987). Additionally, starch granules absorb water from their surroundings during heating, and the expanded starch granules exert pressure on the gel matrix, resulting in increased gel strength (Lee et al., 1992). However, contradictory results have been reported for white muscled fish such as Alaska Pollock and Pacific whiting (Tabilo-Munizaga and Barbosa-Cánovas, 2004); that is, the hardness values of these surimi gels made without potato starch were higher than those made with potato starch. The elasticity and cohesiveness values of the SLMPPs containing 8% concentrations of potato starch were highest ($P<0.05$). Conversely, the SLMPPs with 5%, 8% or 11% potato-starch concentrations received the highest ratings (5.00) in the folding test, indicating good gelling ability. Given these results, we suggested that the optimal concentration of potato starch for SLMPPs is 8%.

The Hunter's colors of SLMPPs prepared with different concentrations of potato starch are shown in Table 5. As the concentration of potato starch increased, the lightness values of the SLMPP decreased. Interestingly, the redness values of the SLMPP decreased significantly ($P<0.05$) as a function of increasing potato-starch concentrations. However, the yellowness values of SLMPPs did not appear to change with starch content.

The preference scores for the SLMPPs made with different concentrations of potato starch are shown in Table 6. We found no differences between SLMPPs with different potato-starch concentrations in the preference scores for texture, flavor, taste, and overall acceptability. Although a 10% addition in potato-starch content produced significantly ($P<0.05$) harder and more brittle SLMPP (Table 4), this manipulation had no effect on textural preferences.

Acknowledgments

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