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Instrumental Quality Attributes of Alaska Pollock Derived Surimi Gels with Sweet Potato Starch

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Cover Page Footnote

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1. Introduction

Sweet potato (*Ipomea batatas L.*) is a dicotyledonous plant that is popularly cultivated in tropical and subtropical regions (Lu et al., 2020). The starch content of sweet potato ranges between 50 – 90% on a dry basis and forms the major ingredient used in the formulation of food such as snacks, bakery products, noodles, jelly, vermicelli, and edible films (Gou et al., 2019). Besides the fact that sweet potato starch (SPS) is used as an ideal caloric food, it contains bio-functional compounds like hydroxycinnamic acid, chlorogenic acid, isochlorogenic acid, cinnamic acid, and caffeic acid that have been reported to confer health benefits such as anti-inflammatory, anti-diabetic and anti-carcinogenic (Lu et al., 2020).

Surimi is stabilized myofibrillar proteins obtained from mechanically deboned fish flesh that is washed with water and preserved with cryoprotectants (Park & Morrissey, 2000). Surimi like other muscle proteins is composed of myofibrillar proteins, sarcoplasmic proteins, and stroma proteins (Tahergorabi, & Hosseini 2017). One of the major functional properties of the proteins is the gelation or gel-forming ability of the proteins. By definition, a gel is a diluted system with no steady-state flow. In the other words, it is not fully liquid nor solid. It is an intermediate phase (Damodaran, Parkin, & Fennema, 2007). Previous studies have shown that myofibrillar proteins are the major contributor to the gelation properties of the surimi gels. Upon heating, surimi forms a thermo-reversible gel which means it does not melt with increasing the temperature (Tahergorabi, & Jaczynski, 2012; Park & Lin 2005). The process of surimi production negatively affects the gel-forming capacity and by extension the overall consumer acceptability (Dong et al., 2019). Starches such as corn (Hou et al., 2019), sweet potato (Dong et al., 2019), konjac glucomannan (Zhang, Li, Wang, Xue, & Xue, 2016), highly resistant rice starch (Yang, Wang, Wang, & Ye, 2014), and tapioca (Tee & Siow, 2017) have been reported to play gel enhancing role in surimi-starch systems. However, this interaction might have advantages and drawbacks. Protein and polysaccharide can form complexes without the disruption of the gel network. The functional properties, structure, and composition of protein molecules are affected by the interaction between protein-water-polysaccharide complex because the

polysaccharide and the protein has a large number of ionizable side-chains, and these side-chain groups have different shapes, conformation, sizes, flexibility, and net charge at a given pH and ionic strength (Gonzalez-Jordan, Thomar, Nicolai, & Dittmer, 2015; Ji, Xue, Zhang, Li, & Xue, 2017). In a protein-polysaccharide-water complex, interfacial characteristics, solubility, and gel-forming capacity depend on the interaction between the biopolymers with water and themselves. However, Ji, Xue, Zhang, Li, and Xue (2017) posited that the gelling characteristics of surimi may be affected by an aqueous dispersion of hydrocolloids. Starches generally have been reported to improve textural and rheological properties, storage stability, gel strength and increase hydrodynamic volume of frozen surimi-based products (Dong et al., 2019).

Starch properties such as high gelatinization temperature and the ratio of amylose to amylopectin can adversely affect the gel strength of surimi protein. For example, tapioca starch has been reported to have high gelatinization temperature (75 and 95°C) (Xiao, Shen, Luo, Ren, Han, & Xie, 2020), during the process of surimi production starches with high gelatinization temperatures yields surimi with weak gel strength which is ascribed to the complete inability of the starch granules to swell (Hunt, Getty, & Park, 2009). The ratio of amylose to amylopectin can also directly affect the gel strength in a food system. Amylose creates defects by decreasing the overall gel strength, while amylopectin strengthens the structural network of the gel systems by contributing to granule swelling (Hunt et al., 2009). Yang and Park (1998) reported that larger particle-sized starch granule contributes to gel strength. Challenges such as high gelatinization temperatures and small particle size can be mitigated by using starch with low gelatinization temperature and large particle size granules such as SPS. Potato starch was reported to have higher amylopectin than amylose (Hunt et al., 2009), indicating that it can be applied as a suitable texture enhancer in surimi protein gel formulation. Incorporation of SPS into surimi protein improved microstructural properties and significantly increased gel strength by increasing water holding capacity and exerting turgor pressure on the gel network (Kong, Ogawa, & Iso, 1999). Although SPS has been used in surimi formulation in the past, some of the studies showed contradictive results due to the inappropriate design of experiments. In most of

these studies, the protein (surimi content) and the SPS are experimental variables which means by increasing the SPS content the protein concentration of the surimi gels decreased. As a result, the samples developed with lower protein contents may show poorer textural attributes. Hence, in this study, silicon dioxide (SiO_2) was incorporated into the surimi paste as an inert filler primarily to maintain the protein content at a constant level in all the treatments (Tahergorabi, Beamer, Matak, & Jaczynski, 2012) and only changed the SPS as a variable to fully understand the impact of this formulation. Silicon dioxide has been recognized as a safe food additive by the USFDA [21CFR177.2420], WHO as well as the European Food Safety Authority (EFSA). The EFSA allocated E551 as an E number for SiO_2 (EFSA, 2018). Therefore, this study aimed to determine 1) The proximate composition, 2) Cooking loss, 3) Texture profile analysis and Kramer shear force, 4) Water holding capacity and tristimulus color coordinates of surimi protein gels formulated with different concentrations of SPS.

2 Materials and methods

2.1 Surimi production

Alaska pollock derived frozen surimi block was purchased from Trident Seafood Corp. (Shilshole Avenue, Seattle, WA). The surimi blocks were cut into approximately 800 g per unit, placed in plastic bags (8"×10", 3 MIL) and vacuumed using a vacuum sealer (Vacu-Fresh TC-420-F-G-C; CA, USA) for 2 min at -1.01×10^{-5} Nm^{-2} to remove solubilized air and air pockets, and stored at -80°C until it was ready for use. Before storage, the moisture content of the surimi block was estimated to be 75.92 g/ 100 g using the AOAC method (1995).

2.2 Formulation of surimi paste

Surimi paste was formulated according to the method of Alakhrash, Anyanwu, and Tahergorabi (2016) with slight modification. Briefly, the frozen surimi was chopped using a universal food processing machine (Model UMC5, Stephan

Machinery Corp., Columbus, OH) fitted with a double layer cooling jacket and temperature controller maintained between 1-4°C during chopping. Surimi myofibrillar protein was extracted using 2% NaCl (Morton non-iodized salt, Morton International Inc., Chicago IL), the myofibrillar protein obtained was further chopped for 30 sec at low speed. The moisture content was adjusted to 78% by incorporating cold distilled water into the surimi paste. Sweet potato starch (SPS) (Wako Pure Chemical Industry, Richmond, VA. USA) was introduced into the surimi paste at four controlled concentrations (**Table 1**). The SPS, SiO_2, and the surimi paste were chopped together at low speed for 60 sec to achieve a homogenous blend. Before vacuum packing the surimi, it was chopped at high speed under pressure (0.5 bar) for 180 sec and the surimi paste was prepared in 1000 g batches. Surimi paste prepared using this approach were used to formulate heat-set surimi gel. The heat-set surimi gel was formulated according to the method of Alakhrash, Anyanwu, and Tahergorabi, (2016) without modification.

Table 1

Surimi formulation table. Batters with different levels of Sweet potato starch were formulated to contain 78% moisture and a constant amount of surimi paste and salt.

Sweet potato Starch (g/1000 g)	Inert filler-SiO_2 (g/1000 g)	Surimi (g/1000 g)	Water (g/1000 g)	Salt (g/1000 g)	Batch weight (g)
0 (control)	80	480	420	20	1000
20	60	480	420	20	1000
40	40	480	420	20	1000
60	20	480	420	20	1000
80	0	480	420	20	1000

*Control (surimi gel without added sweet potato starch).

2.3 Proximate composition

The moisture content of the surimi gel was determined gravimetrically by drying a known weight of the sample in a vacuum oven (Cascade TEK, Irving, TX) for 3 h at 105°C. The ash content of the surimi gel was determined by incinerating about 3 g of sample in a muffle furnace (Lindberg/Blue, Thermo Scientific, Waltham, MA) for 24 h at 550 °C, and the ash content was calculated and expressed as g/100 g. The fat content of the surimi gel was determined by dehydrating a known weight of the sample and then extracting the lipid content in a Soxhlet for 9 h using petroleum ether.

2.4 pH measurement

For the pH determination, approximately 5 g of the sample was homogenized in a 50 mL centrifuge tube containing 15 mL deionized water, then the pH was measured using a hand-held pH meter (Oak, Vernon Hills, IL). Before each measurement, the pH meter was calibrated.

2.5 Cooking loss and water holding capacity

The cooking loss of the surimi gel was assayed according to the method of Park et al. (2013) with slight modification. Briefly, approximately 6 g of the surimi gel was cooked at 90ºC for 30 min, the weight of the sample after cooking was recorded and the cooking loss was calculated using equation 1. The water holding capacity (WHC) was conducted as described by Park and Lin (2005) without modification and calculated according to equation 2.

$$Cooking\ loss\ (\%) = \frac{Initial\ weight\ (g) - Final\ weight\ (g)}{Initial\ weight\ (g)} \times 100 \qquad eq(1)$$

$$WHC(\%) = \frac{Total\ moisture\ content\ (g) - Expressible\ water\ content\ (g)}{Total\ moisture\ content\ (g)} \times 100 \qquad eq(2)$$

2.6 Texture properties

Texture analysis of the heat set surimi gels was performed using a texture analyzer (TA-XT2, Texture Technologies Corp., Scarsdale, NY). The surimi gel was cut into cylindrical shapes measuring 25 mm in height and 20 mm in diameter. Each cylinder was compressed axially in two consecutive cycles at 50% compression rate with a plunger 70 mm in diameter moving at a speed of 127 mm/min. The following parameters were extrapolated from the force-time curve, chewiness, springiness, resilience, cohesiveness, gumminess, and hardness. Hardness is defined as the resistance of food during a bite. While the ability of a food sample to maintain its form and size after compression or a bite is defined as springiness. The chewiness is a measure of the energy used in chewing and the resistance of the product during chewing is called cohesiveness. The strength required during chewing is measured by gumminess and resilience is a measure of how well a product regains its original position. Hardness is expressed as Newton (N/m), while other parameters are dimensionless. Before the analysis, the samples were equilibrated at room temperature for 1 h.

Kramer shear test is a popular and widely applied instrumental food texture testing machine that was developed in 1951 (Timbers, Voisey, & Kloek, 1985) to simulate the single first bite in a food system chopped in small cylindrical shapes. Surimi gel cut into cylindrical shapes measuring 80 mm in height and 20 mm in diameter were used for the Kramer shear test, The Kramer shear machine is fitted with a Kramer cell attachment (TA-XT2, Texture Technologies Corp., Scarsdale, NY). The Kramer shear cell contains five slots at the base with a corresponding number of blades measuring 70 mm in width and 3.0 mm in thickness. For the instrumental measurement, a known weight of the surimi samples was placed directly under the shear blades and the maximum force (N/g) required to shear the gels was measured at 127 mm/min crosshead speed. Each treatment was conducted six times.

2.7 Tristimulus color values

Before the determination of the color characteristics of the surimi gels, the samples were acclimatized to the surrounding room temperature for 2 h. The surimi gels chopped into cylindrical shape measuring 19 mm in diameter and 25 mm in height were used to conduct the color analysis using a Minolta Chroma colorimeter (Model CR-300, Minolta Camera Co, Ltd., Osaka, Japan). The L* coordinate which measures lightness, a* coordinate which measures the color spectrum between red and green, and the b* coordinate which measures the color spectrum from yellow to the blue of the surimi gel were determined according to the CIE (Commission Internationale d'Eclairage of France) color system. The whiteness of the gels was calculated according to the following equation (Tahergorabi & Jaczynski, 2012; Tahergorabi, Sivanandan, Beamer, Matak, & Jaczynski, 2012).

$$Whiteness = 100 - [\,(100 - L*)^2 + a^{*2} + b^{*2}\,]^{1/2}$$

2.8 Statistical analysis

One-way analysis of variance (ANOVA) was conducted using the SPSS package (IBM SPSS for Windows, version 22.0, SPSS Inc., Chicago, IL). A significant difference between treatment and control means was evaluated using Duncan multiple range test with the level of statistical significance set at $p \leq 0.05$. All analyses were conducted in triplicate unless otherwise stated and data were reported as mean ± standard deviation (SD).

3 Results and Discussion

3.1 Proximate composition

The result of the proximate composition is presented in **Table 2**. The moisture content (MC) of surimi gels increased by the addition of SPS. However, there were no statistically significant differences among the MC of surimi gels when 2, 4, and

6% of SPS was incorporated ($p > 0.05$). The lowest MC observed in all the treatments was the 8% SPS fortified surimi gels (78 ± 1.81). According to Morris, (1992) when potato starch is added, the starch granules absorb water, and the water is trapped within the gel network due to heat denaturation of myofibrillar proteins. However, according to Liu, Nie, and Chen (2014) when too much starch (more than 6%) is added to the surimi it increases the pressure within the surimi gels which leads to syneresis and moisture release of surimi gels. This is probably the reason we observed a reduction in MC content when 8% SPS was added.

Table 2

Effect of sweet potato starch on proximate composition and pH, expressible water of surimi gels

Treatment	Sweet potato starch (g /100 g)				
	0	2	4	6	8
Moisture	79.76 ± 1.63^{b}	95.66 ± 0.57^{a}	94.0 ± 0.00^{a}	95.33 ± 0.68^{a}	78.76 ± 1.81^{b}
Fat	0.33 ± 0.07^{a}	0.33 ± 0.42^{a}	0.33 ± 0.07^{a}	0.68 ± 0.28^{a}	0.19 ± 0.14^{a}
Ash	0.89 ± 0.00^{c}	0.95 ± 0.00^{ab}	0.94 ± 0.00^{b}	0.96 ± 0.01^{a}	0.97 ± 0.01^{a}
pH	7.15 ± 0.02^{a}	7.01 ± 0.02^{a}	6.98 ± 0.05^{a}	6.96 ± 0.05^{a}	6.70 ± 0.01^{b}
Expressible Water	0.25 ± 0.00^{a}	0.02 ± 0.00^{b}	0.03 ± 0.02^{b}	0.03 ± 0.02^{b}	0.01 ± 0.00^{b}

Data are represented as ± mean values standard deviation (n = 3). Different letters within the same row indicate a significant difference (set at $p < 0.05$) using Duncan multiple range test. Control (0*).

The fat concentration of the SPS fortified surimi gel is given in **Table 2**. There was no significant difference between the fat content of the control and other treatment levels ($p > 0.05$). However as expected the fat concentration of surimi gels is negligible, this is primarily because surimi proteins are defatted during the formulation process (Alakhrash et al., 2016). The ash content of the surimi gels is shown in **Table 2**. Although the ash content of the SPS fortified surimi gels was

marginally different among the treatments ($p < 0.05$), the control showed the lowest ash content. It seems the mineral contents of SPS contributed to increasing the ash content of surimi gels since by increasing the concentrations of SPS the ash content was increased. The mineral content of the sweet potato starch used in this study is potassium (196.39 mg/100g), calcium (190.7 mg/100g), magnesium (80.20 mg/100g), and sodium (50.01 mg/100g) according to the manufacturer. Increasing the concentration of SPS led to a systematic reduction in the pH of the protein gels, however, the 2 - 6% SPS fortified surimi gels did not show a significant difference ($p > 0.05$) in pH (**Table 2**).

3.2 Expressible water

The result of the expressible water (EW) is given in **Table 2**. Expressible water is the amount of liquid a protein gel gives off after the application of mild force (10 kg/cm^2) (Park & Lin 2005). There was no significant difference between the EW of the SPS fortified surimi gels ($p > 0.05$). However, compared to the control, the EW of the treatments was significantly lower ($p < 0.05$). Incorporation of starch into surimi has been reported to reduce the EW content of surimi gels (Yang et al., 2014). The authors attributed the reduction of expressible moisture to the high-water absorbing capacity of starch molecules and the hydrophobic groups that interact with free water consequently changing its state to bound water.

3.3 Water holding capacity (WHC) and cooking loss

The result of the water holding capacity is presented in **Figure 1**. The WHC in surimi gels is dependent on the kind and number of protein-water interaction sites occurring in the gel system (Dong et al., 2019). Although increasing the concentration of SPS resulted in increased WHC in the treatment sample, the 2-6% SPS fortified surimi gel did not show a significant difference ($p > 0.05$). The 8% SPS fortified surimi gel displayed the highest WHC ($p < 0.05$) suggesting that the SPS may have augmented the water retention capacity of the protein gel. These results are in support of EW results. Dong, Huang, Pan, Wang, Prakash, and Zhu.

(2019) reported a similar result. However, they posited that the enhanced WHC observed in the surimi gel can be ascribed to the swelling of SPS granules during heating. Furthermore, protein gelation can physically and chemically bind water molecules in the gel system thereby limiting the free water available for starch gelation (Hunt et al., 2009).

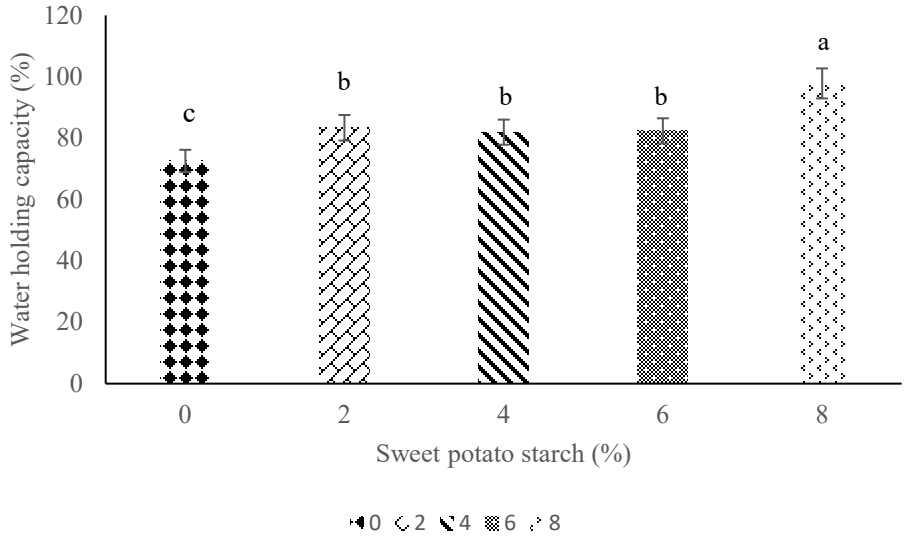

Figure 1. Effect of sweet potato starch incorporation on water holding capacity of surimi gels. Data are represented as mean values ± standard deviation (n = 3). A significant difference (set at $p < 0.05$) are indicated by the letters on the small bars using Duncan multiple range test. Control (surimi without added sweet potato starch), 2 g/100 g (2%), 4 g/ 100 g (4%), 6 g/ 100 g (6%), and 8 g/ 100 g (8%) surimi gels.

The result of the cooking loss of the SPS fortified surimi gel is shown in **Figure 2**. Incorporation of 2%, 4%, and 8% of SPS in the surimi gel displayed no significant difference among the treatments when compared with the control sample ($p > 0.05$). However, the lowest cooking loss occurred when 6% of SPS was added to surimi gels. The addition of salt solubilizes the surimi, and it forms a continuous matrix when water is added. Once the SPS is added to this matrix it acts as a filler and fills the gel. Due to the hydrophilic nature of the starch, it absorbs water and expands upon heating. However, the expansion is restricted by the gel

matrix which creates pressure within the gel. This pressure also leads to a higher gel strength. However, studies showed that if more than 6 g/100g starch is added then the pressure will be reduced due to syneresis and moisture loss after cooking (Lee & Kim, 1986; Park, 1997). This might be the reason that cooking loss is increased when 8% of SPS is added to the surimi. This also confirms the results of TPA hardness as well as Kramer shear force which show an increase in gel strength. Contrary to our study, Yang, Wang, Wang, and Ye (2014), reported that surimi protein gel fortified with 8% highly resistant rice starch showed the lowest cooking loss. The disparity between our result and the above-mentioned study could be due to the use of three pre-incubation temperatures (4, 25, and 40°C) at different periods and the type of starch employed in their study (Dong et al., 2019). Incorporation of SPS in surimi gels confers a protective effect on the steaming stability and prevent water loss during cooking.

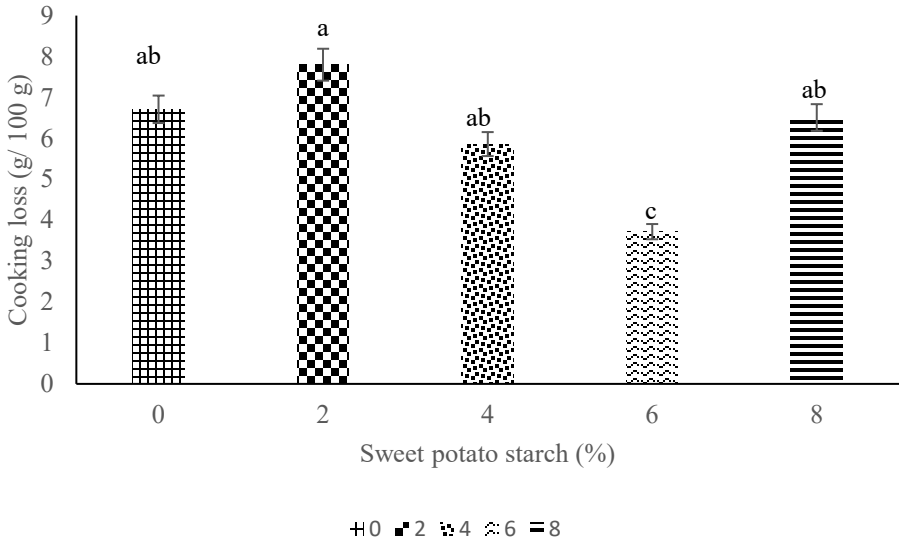

Figure 2. Effect of sweet potato starch incorporation on cooking loss of surimi gels. Data are represented as mean values ± standard deviation (n = 3). A significant difference (set at $p < 0.05$) are indicated by the letters on the small bars using Duncan multiple range test. Control (surimi without added sweet potato starch), 2 g/100 g (2%), 4 g/ 100 g (4%), 6 g/ 100 g (6%), and 8 g/ 100 g (8%) surimi gels.

3.4 Textural properties

Texture profile analysis (TPA) is an experimental technique used to determine textural parameters such as chewiness, cohesiveness, hardness, springiness, resilience, and gumminess. The results of the texture profile analysis are shown in **Table 3**. The hardness of the SPS fortified surimi gel showed a systematic increase as the SPS concentration increased. The maximum hardness was observed in the 8% SPS fortified surimi gel ($p < 0.05$). The increase in the hardness of the surimi gel can be attributed to the large granules in SPS that absorb water from the protein matrix which results in swelling and consequently a stronger texture (Tee & Siow, 2017). Resilience measures the recovery of a sample from deformation both in terms of speed and force derived (Liu, Nie, & Chen, 2014). The resilience of the SPS fortified surimi gel was significantly higher than the control ($p < 0.05$). The 4 – 8% SPS fortified surimi gels did not show a significant difference ($p > 0.05$), however, the 2% surimi gel displayed the highest resilience. The gumminess and chewiness showed a fluctuating pattern as the SPS concentration increased (**Table 3**). The 8% SPS fortified surimi gel displayed the highest chewiness and gumminess compared to the control and other treatments ($p < 0.05$). A similar result was obtained by Dong et al., (2019) where the maximum chewiness value was obtained at the highest SPS level of incorporation (10%). The ability of a sample to return to its original position and shape after deformation force has been applied is referred to as springiness (Tee & Siow, 2017). The springiness of the SPS fortified surimi gels was significantly higher than the control sample ($p < 0.05$) **Table 3**. This result suggests that the ability to recover after deformation may be solely attributed to the presence of starch molecules in the surimi gels. There was no significant difference in the cohesiveness of all the SPS fortified surimi gels ($p > 0.05$), however, they were higher than the control ($p < 0.05$).

Kramer shear force was used to determine the gel strength of the SPS fortified surimi gels (**Figure 3**). As the concentration of the SPS increased, a non-systematic trend was observed in the surimi gels. Between the SPS treated samples, the 4% SPS fortified gel required the minimum force before shearing commences while the 6% SPS fortified gel required a maximum force well above 30 N/g to commence

shearing. Generally, the SPS fortified surimi gels were significantly higher than the control ($p < 0.05$), indicating that the increased gel strength must have been conferred by the SPS. In the report of Dong et al. (2019), a similar result was obtained where the penultimate addition level (8%) displayed the highest gel strength. This increased gel strength can be ascribed to the strong phosphate linkages present in SPS. Tee et al. (2017) reported that the increased gel strength conferred by SPS is due to the presence of linkages between phosphate groups and amylopectin.

Table 3

Effect of sweet potato starch on the texture profile analysis of surimi gels.

	Sweet potato starch (g/ 100 g)				
Treatment	0*	2	4	6	8
Hardness	6.17 ± 0.41^{c}	10.30 ± 0.41^{b}	10.33 ± 0.18^{b}	13.30 ± 1.34^{a}	14.22 ± 2.27^{a}
Resilience	0.34 ± 0.11^{c}	0.43 ± 0.04^{a}	0.39 ± 0.08^{b}	0.40 ± 0.02^{b}	0.41 ± 0.03^{b}
Cohesiveness	0.62 ± 0.04^{b}	0.73 ± 0.01^{a}	0.70 ± 0.01^{a}	0.71 ± 0.03^{a}	0.72 ± 0.03^{a}
Springiness	0.93 ± 0.02^{c}	0.97 ± 0.02^{a}	0.96 ± 0.00^{ab}	0.94 ± 0.01^{bc}	0.95 ± 0.02^{abc}
Gumminess	3.83 ± 0.46^{c}	7.55 ± 0.37^{b}	7.17 ± 0.09^{b}	9.50 ± 1.20^{a}	9.68 ± 1.22^{a}
Chewiness	3.58 ± 0.43^{c}	7.35 ± 0.32^{b}	7.03 ± 0.13^{b}	8.99 ± 1.19^{a}	9.17 ± 1.21^{a}

Data are represented as ± mean values standard deviation (n = 3). Different letters within the same row indicate a significant difference (set at $p < 0.05$) using Duncan multiple range test. Control (0*).

Table 4

Tristimulus color (L* a* b*) and whiteness values of surimi gels with and without the sweet potato starch

Treatments	Sweet potato starch (g /100 g)				
	0	2	4	6	8
L*	87.44 ± 0.62[b]	85.03 ± 0.26[c]	86.48 ± 0.19[ab]	82.43 ± 0.60[a]	76.99 ± 0.55[a]
a*	-0.21 ± 0.06[b]	-1.83 ± 0.07[a]	-1.28 ± 0.04[a]	-2.23 ± 0.08[a]	-3.28 ± 0.00[a]
b*	6.57 ± 0.11[b]	3.05 ± 0.03[d]	5.3 ± 0.17[b]	3.8 ± 0.15[c]	-0.57 ± 0.17[e]
Whiteness	85.82 ± 0.13[a]	84.61 ± 0.39[b]	85.42 ± 0.14[a]	81.88 ± 0.07[c]	76.75 ± 0.60[e]

Data are represented as ± mean values standard deviation (n = 3). Different letters within the same row indicate a significant difference (set at $p < 0.05$) using Duncan multiple range test. Control (0*).

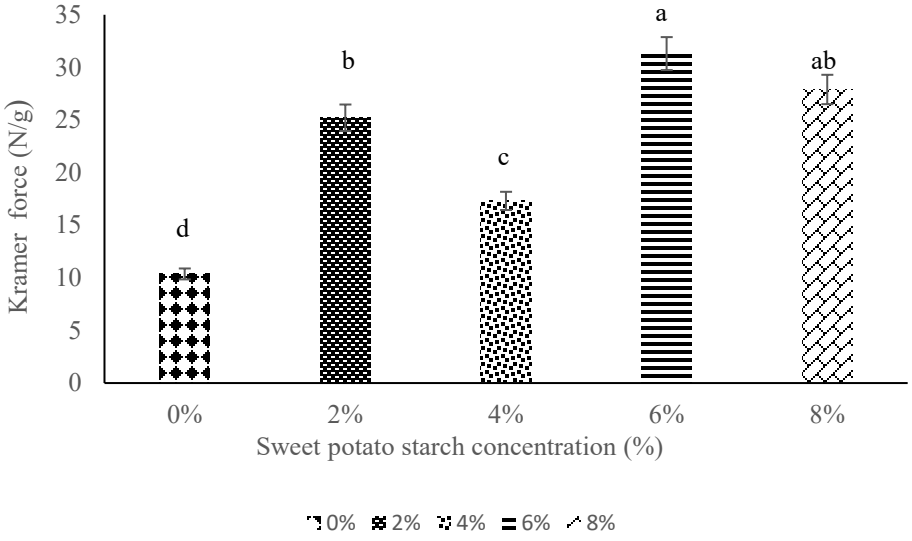

Figure 3. Impact of sweet potato starch incorporation on Kramer shear force of surimi gels. Data are represented as mean values ± standard deviation (n = 3). A significant difference (set at $p < 0.05$) are indicated by the letters on the small bars using Duncan multiple range test. Control (surimi without added sweet potato starch), 2 g/100 g (2%), 4 g/ 100 g (4%), 6 g/ 100 g (6%), and 8 g/ 100 g (8%) surimi gels.

3.4 Tristimulus color values

The tristimulus color coordinates of the SPS fortified surimi gel is presented in **Table 4**. Color is an especially important sensorial property that plays a crucial role in the overall quality determination of surimi gels. The lightness of the surimi gel decreased with the increasing concentration of the SPS. The highest lightness was displayed at the 4% SPS fortified surimi gel ($p < 0.05$) while the 8% SPS fortified surimi showed the lowest lightness value. This observed reduction in lightness can be attributed to the Maillard reaction occurring between reducing sugar and free amino acid in the surimi gel (Yang et al., 2014). Dong et al. (2019) reported that surimi gels having excellent quality are characterized by high lightness (L*), and whiteness standards with low yellowness values (b*). The * values of the SPS fortified surimi gels displayed increased greenness as the SPS concentration increased. While no significant difference was observed in all the treated samples ($p > 0.05$). The b* values showed a nonsystematic pattern as the SPS concentration increased. The highest yellowness (b*) in the SPS fortified surimi gel was observed in the 4% SPS surimi gel while the 8% SPS fortified surimi gel showed blueness. Contrary to our study, Dong, Huang, Wang, Prakash, and Zhu (2019) reported a systematic decrease in the b* values of surimi gel as the SPS concentration increased. The difference between our results may lie in the fish species used for surimi production. The whiteness of surimi gel is an important property that can be used to determine the quality of surimi gels. The whiter the intensity of fish-based products the more it is perceived to be fresher and of high quality (Tee & Siow, 2017). The whiteness profile of the SPS fortified surimi gel is presented in **Table 4**. The whiteness of the 2% SPS fortified gel is significantly lower than the control ($p < 0.05$). However, beyond the 4% addition level the whiteness decreased with increasing concentration of SPS. Minimum whiteness was observed in the 8% SPS fortified surimi gel. The incorporation of starch into the fish-based product has been reported to reduce whiteness intensity (Tee & Siow, 2017). The authors attributed it to the formation of translucent gel due to swollen starch granule that allows more transmittance of light. Summarily, the incorporation of SPS into the surimi protein

gel did not improve the lightness and whiteness profiles, however, it did reduce the yellowness of the protein gels.

Conclusions

The physical and chemical properties of surimi gel fortified with SPS was studied. Proximate parameters such as fat showed marginal presence while the moisture content increased when 2%, 4%, and 6% SPS were added. The pH and expressible water content reduced as the concentration of SPS increased. Lightness and whiteness properties were negatively impacted as the starch concentration increased. Textural properties such as hardness, resilience, cohesiveness, gumminess, and chewiness were positively impacted by SPS. The Kramer shear force did not augment the result of the texture profile analysis however, fortifying the surimi gel with SPS improved the cooking loss and water holding capacity. It appears the addition rate of 6 g/100g SPS is the best concentration for obtaining optimal physical properties of surimi gel derived from Alaska pollock. Although the results of the study are encouraging, it is recommended to perform a sensory assessment of the surimi gels as well.

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