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FULL PAPER

Quality attributes of Black-Chin Tilapia (*Sarotherodon melanotheron*) surimis treated with different cryoprotectants

[1,*]Perdio, A.C., [2]Valerio, R.B., [3]Consigna, M.J.S., [4]Llave, D.S., [2]Gonzales, A.J.V. and [4]Turtur, M.L.

[1]*College of Arts and Sciences, Bataan Peninsula State University (BPSU)-Main, City of Balanga, Bataan 2100 Philippines*
[2]*College of Technology, BPSU-Main, City of Balanga, Bataan 2100 Philippines*
[3]*Institute of Fisheries and Aquatic Sciences, BPSU-Orani, Orani, Bataan 2112 Philippines*
[4]*Department of Arts and Sciences, BPSU-Orani, Orani, Bataan 2112 Philippines*

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Abstract

This baseline investigation tried four surimi formulations using three common cryoprotectants namely sucrose, sorbitol and sodium tripolyphosphate for Black-Chin Tilapia (*Sarotherodon melanotheron*), an invasive species and known prolific pest in Philippine farm ponds, and then compared the quality attributes of the products across formulations and against those reported from previous studies that utilized more popular species in surimi processing. The quality parameters analysed were pH level, functional properties (water holding capacity, foamability and emulsifiability) and gel strength and elasticity. The surimi formulation that yielded the best quality attributes was the 6% sucrose with 0.5% STPP. The formulation yielded a pH value of 6.33-6.47, a water holding capacity of 3.87-3.98 mL/g, a foaming capacity of 23.06-30.70%, a foaming stability of 13.31-15.19%, an emulsifying capacity of 47.50-47.83%, an emulsifying stability of 81.17-85.00%, a folding test score of 5.00, and a biting test score of 9.00. Still, a better understanding of the effects of different concentrations of cryoprotectants (presently used and other kinds) on the functionality of *S. melanotheron* surimi is recommended to rationally improve the quality attributes. Also, frozen storage analyses are needed for several and longer periods to see how long the *S. melanotheron* surimi can withstand freezing for specific formulations. It is concluded that *S. melanotheron* surimi, with the right formulations, can be at par with quality with those made from traditional raw materials.

1. Introduction

Surimi is a Japanese term for carefully processed minced fish flesh widely utilized as a base raw material for a variety of products known for unique textural properties and high nutritional values. Originating from Japan, the surimi industry has been spreading to many countries (Vidal-Giraud and Chateau, 2007; Nopianti *et al*., 2010). In the Philippines, the popularity of surimi-based products is apparent in the commercialization of processed minced fish flesh delicacies, the most recognizable of which are fish ball, fish stick, and fish cake. According to a report on the status of the surimi industry in Southeast Asia (Siriraksophon *et al*., 2009), the Philippines has been contributing 12% to the regional production of surimi raw materials from low-value demersal fish families. But since the supply of these traditional raw materials has been unstable and unpredictable not only in the Philippines but regionwide (Siriraksophon *et al*., 2009; Siriraksophon, 2017), viable alternative species must be sought to help the country's surimi industry fully take off.

Surimi can be produced from both marine and freshwater fish species (Fahrizal *et al*., 2018). Commonly, certain species are used for surimi processing due to their easy capture and low price. In the province of Bataan in the Philippines' Central Luzon region, *S. melanotheron*, an invasive species also known as Black-Chin Tilapia, has been plaguing farm ponds, multiplying fast and competing for feeds meant for cultured fish species such as Milk Fish or *Chanos chanos* and Nile Tilapia or *Oreochromis niloticus* (Ordoñez *et al*., 2015; Sotelo, 2013). It is a cichlid that is capable of

*Corresponding author.
Email: *adperdio@up.edu.ph*

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inhabiting fresh to brackish water environments and is very opportunistic (Ordoñez *et al.*, 2015). It was found to be the most dominant fish species by an ichthyofaunal survey of the Orani River, the major water source for a significant number of fish farms in northern Bataan (Romero *et al.*, 2016). Meanwhile, based on the Philippine Bureau of Fisheries and Aquatic Resources data on catch monitoring among Central Luzon landing sites, the catching of *S. melanotheron* increased enormously from 7,495.27 kg in 2018 to 65,939.94 kg in 2019. The proliferation has been compromising the carrying capacity of local farm ponds causing losses to fish farmers based on anecdotal accounts. Due to its reputation as a pest, the fish species costs very cheaply in local markets, ranging from 0.2-0.4 US dollars per kilogram. Its bland taste, whitish flesh, and presumably high protein content similar to other Tilapia species (Andana, 2018) make it a potential raw material for surimi utilization.

Surimi is prepared by collecting the fish flesh, mincing it, washing the mince and then stabilizing it using cryoprotectants. Thus, the most important constituents of surimi are its protein content and cryoprotectants. Muscle proteins, mainly myofibrillar proteins, determine their functionality, however, these get degraded during frozen storage. Their structural integrity is protected during this event by the addition of cryoprotectants. In the process, the functional properties of surimi are enhanced as well. Cryoprotectants can perform these by preventing myofibrillar proteins from denaturation during frozen storage. The proteins get covered by hydrated cryoprotectant molecules, resulting in increased protein hydration and decreased breakdown of protein structure (Nopianti, 2010; Dey and Dora, 2011). Common cryoprotectants used in surimi processing are sucrose, polyols or sugar alcohols and phosphates (Yoo, 2014; Walayat *et al.*, 2020; Zhang *et al.*, 2020).

The development of *S. melanotheron* into a surimi main ingredient presents a means to control its infestation of Philippine farm ponds, and at the same time, support the emerging local surimi industry by introducing a very cheap and abundant raw material. Also, no reports about processing *S. melanotheron* into a higher-value product were found in the literature. Research on the utilization and even consumption of the species was virtually unavailable. Recognizing these, a research project on the development of *S. melanotheron* into a surimi-based product was commissioned by the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD), one of the three sectoral planning councils of the country's Department of Science and Technology (DOST). The present study worked on developing *S. melanotheron* into surimi and then compared the quality attributes of the products made from four different combinations of three common cryoprotectants such as sucrose, sorbitol and sodium tripolyphosphate (STPP). Quality parameters such as pH level, functional properties (water holding capacity, foamability and emulsifiability) and gel strength and elasticity were evaluated after two weeks of frozen storage. The quality attributes yielded were also compared against those reported from previous studies that utilized more popular species in surimi processing. The purpose was to evaluate whether surimi developed from *S. melanotheron* can be comparable in functional quality with those made from traditional raw materials.

2. Materials and methods

2.1 Materials

Fresh *S. melanotheron* species caught from infested fishponds of Orani town in Bataan province, the Philippines as surimi base ingredient. Food grade sucrose, sorbitol and STPP as surimi cryoprotectants. Cold distilled water and sodium chloride (NaCl) for the wash water.

2.2 Raw material sourcing and post-harvest processing

The fish used in the present study were sourced from two 2-4 m deep tilapia grow-out ponds located in Orani, Bataan (14.811898,120.537822). The sites were selected primarily due to their apparent infestation by *S. melanotheron* and hence their capacity to supply the needed amount of raw materials. Fish samples were caught using net traps and gill nets. The caught fish were kept directly in insulated plastic cooler boxes with a fish/ice ratio of 1:1 (w/w) and then were transported immediately to the laboratory in BPSU-Orani (20-30 mins travel time) for sorting and post-harvest processing. Only standard-size fish (5 pcs/kg) were processed in this study. They were scaled, filleted and de-skinned by hand. The de-skinned fillets were immediately washed with cold water (<5°C) to remove the blood and slime layer (epidermis) and then were minced thoroughly. The minces were kept in polyethylene bowls until surimi processing.

2.3 Surimi processing

The minces were sub-divided into four sets and were subjected to identical washing treatment. All were washed thrice using a mince/water ratio of 1:3 (w/w), with a wash water pH and temperature of 7.0±0.5 and <5°C respectively. NaCl (0.25%) was also added to the final wash water to enhance dewatering efficiency after washing (WHO, 2020). Each wash cycle was done in 15

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mins (10 for stirring and 5 for settling). Multiple washing was performed in this study to remove the characteristic slight muddy taste of tilapia meat and to lessen the level of impurities and extraneous materials that may negatively affect the gel strength and colour of the surimi products.

All washed minces were dewatered through filtration using a nylon screen. Further dewatering was done by manually pressing the minces. The dewatered minces were then treated with varying amounts/absence of sucrose, sorbitol and STPP (Table 1 for exact formulations). The produced surimi was formed into blocks inside polyethylene boxes and then were kept in frozen storage (-15°C) for two weeks before analyses.

2.4 Power of hydrogen level

In this study, the surimi samples' pH level was determined using electrometry following the standard method of analysis in AOAC (2016). The pH values were reported based on 10% w/v aqueous.

2.5 Functional properties

The surimi samples were powdered for better handling and flexibility at the functional properties testing. After being thawed overnight at room temperature using tap water, the samples were dried via a hot air oven (60±5°C) for 6 hrs or until their moisture content reached about 5%. The dried samples were turned into powder using a powdering machine and a screen mesh. The powder produced was kept in air-tight containers until analysis.

The following functional properties were analyzed: water holding capacity (WHC), foaming capacity (FC), foaming stability (FS), emulsifying capacity (EC), emulsifying stability (ES) and gel strength and elasticity. WHC refers to surimi's ability for water retention. FC pertains to the surimi's foamability by volume, while FS refers to its ability to stabilize the foam produced after a specific time. EC describes the surimi's emulsifiability by volume, while ES pertains to its ability to hold the emulsion produced after being subjected to heat and then cooling.

For WHC, 1 g sample was mixed with 40 mL 3% NaCl solution using a vortex mixer and then was centrifuged for 5 mins at 6000-7500 rpm. The resulting supernatant was poured into a calibrated graduated cylinder. WHC was calculated using the formula below. It was reported as ml of water retained by 1 g of surimi powder.

WHC = Original NaCl Solution Volume – Volume of Supernatant

For FC and FS, a 2 g sample was mixed with 100 mL distilled water for 1 min using a commercial blender. The resulting foam was carefully transferred into a calibrated graduated cylinder. FC and FS were calculated using the formula below:

FC = (Foam Volume / Original Sample Volume) × 100

FS = (Foam Volume Post 30 Minutes / Original Sample Volume) × 100

For EC, 5 g sample was emulsified with 20 mL cold (4°C) distilled water and 20 mL sunflower oil for 1 min and then was transferred into a 50 mL calibrated centrifuge tube. Then, the emulsion was centrifuged at 6000-7,500 rpm for 5 mins. ES was determined using the same procedure except that the emulsion was heated for 30 mins (80°C) in a water bath followed by cooling in tap water for 10 mins before centrifugation. Both EC and ES were calculated using the formula below:

ES or EC = (Emulsion Volume Post Centrifugation / Original Emulsion Volume) × 100

2.6 Gel quality

Gel strength and elasticity, two of the most important indicators of surimi quality, were evaluated through folding and biting tests. These two sensorial tests were done similarly to the methods described by Shaviklo and Johannsson (2006).

After being thawed overnight at room temperature using tap water, the surimi samples were cut into small pieces, mixed with NaCl (2.5%) and then ground using a meat silent bowl cutter for 10 mins or until a pasty consistency was attained. The pastes produced were stuffed ala sausage into casings. The stuffed pastes were placed in a water bath (70°C) for 20 mins or until a gel-like texture was achieved. The gels produced were cooled in an ice-water mixture and then subjected to testing.

Table 1. *S. Melanotheron*-based surimi processing formulations

Base Ingredient	Wash Water pH, Temperature and NaCl %	Washing Treatment	Cryoprotectant
Standard size *S. melanotheron* mince	7.0±0.5 and <5°C; 0.25% NaCl in the third wash cycle	Three cycles; 15 minutes (10 for stirring and 5 for settling) per cycle	8% sucrose 4% sucrose + 4% sorbitol 8% sucrose + 0.5% STPP 4% sucrose + 4% sorbitol + 0.5% STPP

STPP: Sodium tripolyphosphate

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The folding test was done by folding a representative piece of 5 mm thick slice from each surimi gel sample, slowly in half and then in half again while examining them for signs of structural failures or cracks. Any structural changes were rated using five-stage merit marks where the minimum amount of folding required to produce gel crack determined the score. Following was the scale used: 5 (no crack occurs even when folded in four); 4 (no crack occurs when folded in two, but crack occurs when folded in four); 3 (no crack occurs when folded in two but splits when folded in four); 2 (crack occurs when folded in two); and 1 (splits into two when folded in two). Trained panelists served as respondents.

For the biting test, the same respondents in the folding test were asked to bite on front teeth another 5 mm thick slice from each of the surimi gel samples to evaluate its resilience upon touch to teeth and cohesiveness upon bite. The following 10-stage merit marks was used in rating quality: 10 (extremely strong); 9 (very strong); 8 (strong); 7 (slightly strong); 6 (fair); 5 (slightly weak); 4 (weak); 3 (very weak); 2 (extremely weak); and 1 (incapable to form gel).

2.7 Statistical analysis

The present study utilized a completely randomized research design in which only one factor (the surimi formulation) was investigated on its effect on surimi pH, functional properties and gel quality. Statistical analysis was conducted using the IBM SPSS Version 20.0 for Windows. Data were represented as means ± standard errors. The test for significant differences was done using One-way Analysis of Variance at $\alpha = 0.05$. Post hoc analyses were performed using Fisher's Least Significant Difference Test.

3. Results and discussion

3.1 Power of hydrogen values

Data in Table 2 indicated that the STPP-formulated surimi samples had pH values (6.33-6.47) within the ideal range of 6-7. This pH range allows surimi to achieve the needed gel-forming ability, gel strength and cohesiveness as this pH range is where myofibrillar proteins can dissolve optimally (Saputra *et al.*, 2021). Beyond this pH range, either in a more alkaline state (pH>7) or in a more acidic state (pH<6), the protein gelling properties will be sub-optimal (Park and Chinnan, 1995). The values for the STPP-treated surimi samples were also significantly higher ($P \leq 0.05$) than the ones produced without STPP (4.41-4.47). Accordingly, it can be said that the addition of STPP in the formulation helped improve the pH level and such was consistent with the reports of Hui (2006). Also, in a previous study by Wangtueai (2014), it was reported that STPP as a lone additive gave the best physicochemical characteristics and sensorial qualities to frozen *O. niloticus* fillets due to its water retention enhancing ability.

Table 2. Power of hydrogen level of the surimi samples after frozen storage

Formulation	pH (10% w/v
8% sucrose	4.41 ± 0.01^b
4% sucrose + 4% sorbitol	4.47 ± 0.08^b
8% sucrose + 0.5% STPP	6.33 ± 0.01^a
4% sucrose + 4% sorbitol + 0.5% STPP	6.47 ± 0.01^a

Values are expressed as mean ± standard error of triplicate analysis. Values with different superscript in the same column are significantly different at $\alpha = 0.05$.

The pH values of STPP-formulated samples in the present study were lower than those obtained by Nopianti *et al.* (2012) for Threadfin Bream or *Nemipterus japonicus* surimis treated with 6% sucrose and 0.3% STPP (7.04) and the ones treated with 6% sorbitol and 0.3% STPP (7.05). They were also lower than those reported by Huda *et al.* (2011) for *N. japonicus* surimi incorporated with 3% to 12% polydextrose and 0.3% STPP (7.03 to 7.05). *N. japonicus* is the second most used species for surimi production after the Alaska Pollock or *G. chalcogrammus* (Vidal-Giraud and Chateau, 2007). It is important to mention however that the pH values from previous studies cited came from surimi samples that were subjected to less than two weeks of frozen storage.

3.2 Water holding capacity

WHC is an important functional property of surimi as it determines gelation quality. Also, weight losses during frozen storage such as cook loss and thaw loss are related to WHC and have implications on food quality changes (Abdullah, 2005). Data in Table 3 showed that the STPP-formulated surimi samples had WHC (3.87-3.98 mL/g) significantly higher ($P \leq 0.05$) than the ones without STPP (2.34-2.36 mL/g). The data for STPP-formulated samples surpassed the values reported by Huda *et al.*, (2012) for *N. japonicus* surimi formulated with 6% sucrose (2.8 mL/g) and the ones formulated with 6% sorbitol (2.6 mL/g). However, the present results were lower than the values obtained by Abdullah (2005) for *N. japonicus* surimi treated with 3.5% sucrose, 0.075% sodium pyrophosphate and 0.075% STPP (>5 mL/g). The WHC values reported in the previous studies cited were obtained from powdered surimi like the present study's samples, however, the duration of frozen storage was not reported in the former. Nevertheless, the present and past reports suggest that combining phosphates such as STPP with other cryoprotectants can enhance surimi WHC.

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3.3 Foaming properties

Foam is a bi-phasic colloidal system with a continuous liquid phase and dispersed gas phase. The foaming properties of surimi are related to its proteins' ability to create a strong stabilizing film between these two phases, decreasing the interfacial tension between them, hence promoting foam formation and stability (Zayas, 1997; Foegeding and Davis, 2011). These properties are very important as they give surimi the flexibility to be used in producing a wide variety of food products. As can be seen in Table 3, all STPP-formulated surimi samples in the present study had FC (23.06-30.70%) significantly higher (P≤0.05) than the ones without STPP (17.91-19.51%). Almost the same trend can be seen with FS. All samples with STPP had FS (13.31-15.19%) significantly higher (P≤0.05) than those with no STPP (3.25-5.48%). Noticeably among the samples with STPP, the one with sorbitol had FC and FS (23.06 and 13.31% respectively) significantly lower (P≤0.05) than those without sorbitol (30.39 and 15.19% respectively). Similarly, between the samples with no STPP, the one with sorbitol had FS (3.25%) significantly lower (P≤0.05) than the one with sorbitol (5.48%).

The highest FC values in the present study were lower than those for *N. japonicus* surimi treated with 3.5% sucrose and 0.15% phosphate (34.60%) but were comparable with those for the similarly formulated Purple-spotted Big Eye or *Priacanthus tayenus* (29.90%) and Lizardfish or *Saurida tumbil* (28.80%) surimi in the previous study by Huda *et al.* (2001). *P. tayenus* and *S. tumbil* are also popular species used in the processing of export quality surimi (Vidal-Giraud and Chateau, 2007). For FS, the figures for the STPP-formulated samples in the present study were far higher than the reported values for *N. japonicus* surimi treated with 6% sucrose (>5%) and the ones treated with 6% sorbitol (>5%) in a separate study by Huda *et al.* (2012). It is worth mentioning that the values for foaming properties reported in the previous studies cited came also from powdered surimi samples and had unreported frozen storage lengths.

The higher foamability of *N. japonicus* surimi may be related to the different drying methods used before FC analysis. The use of freeze-drying in the previous study cited may have protected the *N. japonicus* myofibrillar proteins from denaturation than the oven-drying had for *S. melanotheron*'s in the present study. Meanwhile, the negative effect of sorbitol on FC and FS in the present research may be attributed to the impairing effect of polyols on protein foamability. While sorbitol is a proven cryoprotectant, a previous study by Mingzhe *et al.* (2017) reported that protein and polyol interaction can induce a structural change in the former that can weaken foam formation. The polyols compact and strengthen the proteins but at the same time can decrease their ability to adsorb at the foam gas-liquid interface. This impairing effect is further enhanced by increasing polyol concentration.

3.4 Emulsification properties

As with FC and FS, determining surimi emulsification properties is important to determine whether it can be a useful emulsifier in processed food production. As shown in Table 3, the surimi samples with STPP had EC (47.50-47.83%) significantly higher (P≤0.05) than those without STPP (43.17-44.33%). Similarly, the surimi samples with STPP had ES (81.17-85.00%) significantly higher (P≤0.05) than those without STPP (44.83-45.83%). The results suggest that STPP helped enhance the emulsification properties of the surimi samples, which would have naturally degraded during the frozen storage due to myofibrillar protein denaturation. Denaturation impairs the emulsification properties of myofibrillar proteins by altering the hydrophilic/hydrophobic protein residue ratio (Foegeding and Davis, 2011). On the contrary, optimum protein emulsification is attained when there is a balance between them (Santana *et al.*, 2017).

The present study's EC values for STPP-formulated samples were below the ones previously obtained by Huda *et al.* (2012) for *N. japonicus* surimi treated with 4% sucrose (60%) and the ones treated with 4% sorbitol (55%). However, the highest ES values in the present study far exceeded the ones reported from the same previous work (>50%). Consistently, the highest EC values obtained in the present study were lower than the values earlier obtained by Abdullah (2005) for *N. japonicus* surimi treated with 3.5% sucrose, 0.075%

Table 3. Functional properties of surimi samples after frozen storage

Formulation	WHC (mL/g)	FC (%)	FS (%)	EC (%)	ES (%)
8% sucrose	2.36±0.04^{b}	19.51±2.04^{c}	5.48±0.32^{c}	43.33±0.83^{b}	45.83±0.33^{c}
4% sucrose + 4% sorbitol	2.34±0.04^{b}	17.91±0.80^{c}	3.25±0.31^{d}	43.17±1.74^{b}	44.83±0.33^{c}
8% sucrose + 0.5% STPP	3.87±0.05^{a}	30.39±0.63^{a}	15.19±0.51^{a}	47.83±0.33^{a}	85.00±1.44^{a}
4% sucrose + 4% sorbitol + 0.5% STPP	3.98±0.04^{a}	23.06±0.92^{b}	13.31±0.35^{b}	47.50±1.26^{a}	81.17±1.96^{b}

Values are expressed as mean ± standard error of triplicate analysis. Values with different superscript in the same column are significantly different at $\alpha = 0.05$.

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sodium pyrophosphate and 0.075% STPP (60%), but the ES values were far higher than the ones reported in the same previous research (66%). It should be mentioned that the values reported in the previous studies cited came from surimi samples that were powdered but had unreported frozen storage durations.

3.5 Gel quality

Table 4 shows the folding and biting test results of surimi gels produced in the present work. As can be seen, all STPP-incorporated samples had mean merit marks significantly higher than those without STPP. For the folding test, the STPP-formulated samples had mean merit marks of 5.00. This means that the surimi gels did not crack even when folded into four. The samples were very strong and hence of high gel quality. Meanwhile, those without STPP had mean merit marks of only 2.00 indicating that they exhibited cracks when folded in two. These samples had poor gel quality. For the biting test, all samples with STPP had mean merit marks of 9.00, indicating that they were strong to the bite, were highly elastic and hence of very good quality. On the other hand, all samples with no STPP had mean merit marks of 6.00-7.00, indicating that they were not so strong and hence of fair gel quality only.

Table 4. Folding and biting tests merit scores of surimi gel samples after frozen storage

Formulation	Merit Score	
	Folding Test	Biting Test
8% sucrose	2.00±0.00	7.00±0.00
4% sucrose + 4% sorbitol	2.00±0.00	6.00±0.00
8% sucrose + 0.5% STPP	5.00±0.00	9.00±0.00
4% sucrose + 4% sorbitol + 0.5%	5.00±0.00	9.00±0.00

Scores for folding test are based on a 5-stage merit mark; biting scores are based on 10-stage merit marks.
Values are expressed as mean ± standard error of five replicates.

The values obtained for the STPP-formulated gels in the folding test showed that the present samples have gel quality better than those produced from *N. japonicus* surimi treated with 6% sucrose and 0.3% STPP (4.00) reported by Nopianti *et al.* (2012) after 1 month of frozen storage, and those produced from *N. japonicus* surimi incorporated with 3-12% polydextrose and 0.3% STPP (4.00) reported by Huda *et al.* (2011) after 1 week of frozen storage. Surimi made from *N. japonicus* represents about 45% of Japanese imports coming largely from Southeast Asia (Vidal-Giraud and Chateau, 2007).

4. Conclusion

This investigation tried four surimi formulations for *S. melanotheron* using three common cryoprotectants namely sucrose, sorbitol and STPP, and the one with the best quality attributes was the 6% sucrose with 0.5% STPP based on this study's results. Notably, the use of sorbitol in the other formulations impaired the foaming properties of the respective samples. The formulations with STPP yielded comparable figures for pH, water retention ability, foaming properties, emulsification properties and gel quality with previous studies that utilized more popular species such as *N. japonicus*, *P. tayenus* and *S. tumbil*, although the previous reports came from different/unreported frozen storage lengths. Nonetheless, it is concluded that surimi developed from *S. melanotheron*, with the right formulations, can be at par in quality with those made from traditional raw materials. Still, a better understanding of the effects of different concentrations of cryoprotectants (presently used and other kinds) on the functionality of *S. melanotheron* surimi is recommended to rationally improve the quality attributes. Also, frozen storage analyses are needed for several and longer periods to see how long the *S. melanotheron* surimi can withstand freezing for specific formulations. The present study was only able to investigate a baseline frozen storage of two weeks due to stringent mobility constraints brought on by the ongoing Corona Virus Disease 2019 pandemic.

Conflict of interest

The authors hereby declare no conflict of interest on this present work.

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References

Abdullah, A. (2005). Functional properties of surimi related to drying methods. *Malaysian Applied Biology Journal*, 34(2), 83-87.

Andana, C.P. (2018). Protein Functional Properties of

Tilapia Fish (*Oreochromis mossambicus*) Surimi Powder Made with Oven Drying Method. Indonesia: Unika Soegijapranata Semarang, Doctoral Dissertation.

Dey, S.S. and Dora, K.C. (2011). Suitability of chitosan as cryoprotectant on croaker fish (*Johnius gangeticus*) surimi during frozen storage. *Journal of Food Science and Technology*, 48(6), 699-705. https://doi.org/10.1007/s13197-010-0197-8

Fahrizal, N., Arpi, N., Rohaya, S. and Febriani, R. (2018). Surimi from freshwater fish with cryoprotectant sucrose, sorbitol and sodium tripolyphosphate. *IOP Conference Series: Earth and Environmental Science*, 207, 012046 https://doi.org/10.1088/1755-1315/207/1/012046

Foegeding, E.A. and Davis, J.P. (2011). Food protein functionality: A comprehensive approach. *Food Hydrocolloids*, 25(8), 1853-1864. https://doi.org/10.1016/j.foodhyd.2011.05.008

Huda, N., Abdullah, A. and Babji, A.S. (2001). Functional properties of surimi powder from three Malaysian marine fish. *International Journal of Food Science and Technology*, 36(4), 401-406. https://doi.org/10.1046/j.1365-2621.2001.00473.x

Huda, N., Abdullah, R., Santana, P. and Yang, T.A. (2012). Effects of different dryoprotectants on functional properties of threadfin bream surimi powder. *Journal of Fisheries and Aquatic Science*, 7 (3), 215-223. https://doi.org/10.3923/jfas.2012.215.223

Huda, N., Leng, O.H. and Nopianti, R. (2011). Cryoprotective effects of different levels of polydextrose in threadfin bream surimi during frozen storage. *Journal of Fisheries and Aquatic Science*, 6 (4), 404-416. https://doi.org/10.3923/jfas.2011.404.416

Hui, Y.H. (2006). Handbook of Food Science, Volume 4, Technology and Engineering. United Kingdom: CRC Press. https://doi.org/10.1201/b15995

Mingzhe, P., Xianjun, M., Lianzhou, J., Dianyu, Y. and Tianyi, L. (2017). Effect of cosolvents (polyols) on structural and foaming properties of soy protein isolate. *Czech Journal of Food Sciences*, 35(1), 57-66. https://doi.org/10.17221/35/2016-CJFS

Nopianti, R., Huda, N. and Ismail, N. (2010). Loss of functional properties of proteins during frozen storage and improvement of gel-forming properties of surimi. *Asian Journal of Food and Agro-Industry*, 3(6), 535-547.

Nopianti, R., Huda, N., Fazilah, A., Ismail, N. and Easa, A. (2012). Effect of different types of low sweetness sugar on physicochemical properties of threadfin bream surimi (*Nemipterus* spp.) during frozen storage. *International Food Research Journal*, 19(3), 1011-1021. https://doi.org/10.3923/ajft.2011.19.30

AOAC. (2016). Official Methods of Analysis. 20th ed. Method 2000.01. Retrieved on August 19, 2019, from AOAC Website: www.eoma.aoac.org

Ordoñez, J.F.F., Asis, A.M.J.M., Catacutan, B.J. and Santos, M.D. (2015). First report on the occurrence of invasive black-chin tilapia *Sarotherodon melanotheron* (Ruppell, 1852) in Manila Bay and of Mayan cichlid *Cichlasoma urophthalmus* (Gunther, 1892) in the Philippines. *BioInvasions Record*, 4(2). https://doi.org/10.3391/bir.2015.4.2.08

Park, H.J. and Chinnan, M.S. (1995). Gas and water vapor barrier properties of edible films from protein and cellulosic materials. *Journal of Food Engineering*, 25(4), 497-507. https://doi.org/10.1016/0260-8774(94)00029-9

Romero, C.S., Villaflor, K.C., dela Rosa, D. and Corpuz, M.N.C. (2016). Environmental variables affecting the riverine ichthyofaunas and macroinvertebrate communities in Orani river system (Tala-Silahis continuum) Bataan, Philippines, presented at the 2nd International Conference in Research, Education, Management, and the Social Sciences. Subic Bay Freeport Zone, Philippines.

Santana, P., Zilda, D.S. and Huda, N. (2017). Physicochemical properties of surimi powder made from threadfin bream (*nemipterus japonicus*) with various dryoprotectants added. *Journal of Fundamental and Applied Sciences*, 9(2S), 866-844. https://doi.org/10.4314/jfas.v9i2s.54

Saputra, E., Tjahjaningsih, W. and Abdullah, A.A. (2021). The effect of washing on the making of surimi and kamaboko tilapia (*Oreochromis* sp). *IOP Conference Series: Earth and Environmental Science*, 679, 012023. Ltd. https://doi.org/10.1088/1755-1315/679/1/012023

Shaviklo, G.R. and Johannsson, S.R. (2006). Quality assessment of fish protein isolates using surimi standard methods. Retrieved from website: https://www.grocentre.is/static/gro/publication/7/document/reza06prf.pdf

Siriraksophon, S. (2017). Issues and challenges in sustainable development of fisheries of the Southeast Asian Region: Important demersal fishery resources: Raw materials for surimi. Retrieved on September 11, 2021, from the Southeast Asian Fisheries Development Center Website: http://repository.seafdec.org

Siriraksophon, S., Pangsorn, S. and Laong-manee, P. (2009). The surimi industry in Southeast Asia: Trend and demand for raw materials. Retrieved on August 19, 2019, from the Southeast Asian Fisheries Development Center Website: http://repository.seafdec.org

Sotelo, Y. (2013). ‘Gloria’ an abomination in Bataan fishponds. Retrieved on August 19, 2019, from website: http://newsinfo.inquirer.net

Vidal-Giraud, B. and Chateau, D. (2007). World surimi market. Vol. 89. Rome Italy: Globefish Research Programme, Food and Agricultural Organization.

Walayat, N., Xiong, H., Xiong, Z., Moreno, H.M., Nawaz, A., Niaz, N. and Randhawa, M.A. (2020). Role of cryoprotectants in surimi and factors affecting surimi gel properties: a review. *Food Reviews International*, 38(6), 1103-1122. https://doi.org/10.1080/87559129.2020.1768403

Wangtueai, S., Tongsiri, S., Maneerote, J. and Supaviriyakorn, W. (2014). Effect of phosphate on frozen Nile tilapia fillets. *Food and Applied Bioscience Journal*, 2(3), 203-215.

World Health Organization (WHO). (2020). Code of practice for fish and fishery product. Retrieved on August 19, 2019, from: http://www.fao.org/3/a1553e/a1553e00.htm

Yoo, B.J. (2014). The effect of Cryoprotectants on the properties of Pacific Sand Lance *Ammodytes personatus* Girard surimi during frozen storage. *Fisheries and Aquatic Sciences*, 17(3), 291-298. https://doi.org/10.5657/FAS.2014.0291

Zayas, J.F. (1997). Functionality of Proteins in Food. Switzerland: Springer. https://doi.org/10.1007/978-3-642-59116-7

Zhang, B., Yao, H., Qi, H. and Ying, X.G. (2020). Cryoprotective characteristics of different sugar alcohols on peeled Pacific white shrimp (*Litopenaeus vannamei*) during frozen storage and their possible mechanisms of action. *International Journal of Food Properties*, 23(1), 95-107. https://doi.org/10.1080/10942912.2019.1710533

