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Physico-chemical properties and sensory quality of surimi from bigtooth pomfret (*Brama orcini*) at different washing cycles

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Abstract

In this study, the effects of different washing cycles on the physico-chemical and sensory properties of surimi from *Brama orcini* were determined. The isolated muscle from *B. orcini* was divided into five different treatment lots, WC0 (minced, no washing), WC1 (washing cycle 1), WC2 (washing cycle 2), WC3 (washing cycle 3), and WC4 (washing cycle 4) as washing cycle treatments. Both washed and unwashed samples have been added with cryoprotectants and analysed for physico-chemical and sensory evaluation. Results in this study highlighted that increased washing cycle (WC) improved the water-holding capacity of WC3 (88.89%) and WC4 (86.11%) samples, as compared WC0 (63.84%), WC1 (73.51%), WC2 (82.82%) samples (p<0.05). Three to four washing cycles (WC3, WC4) also favoured a significant reduction in the total ash levels (0.50, 0.45%), increased moisture content (71.5, 74.39%), decreased expressible drip losses (11.11, 13.89%), improved whiteness indices (52.46, 51.74%), and increased product over-all acceptability scores (7.12, 8.44) in surimi without compromising its yield (32.00, 31.23%) and total protein content (22.15, 20.84%). This study suggested that washing three times with cold saltwater (10-15°C) improved the physico-chemical and sensory properties of surimi from *B. orcini*.

1. Introduction

Surimi is a myofibrillar protein concentrate prepared after the mechanical separation of fish meat and bones, washing as one of the critical parameters, and mixing with cryoprotectants prior to frozen storage (Benjakul *et al*., 2005). The processing of low-value fish into surimi is a value-added step and conversion into a product with improved functional, textural, and colour properties. Surimi is a flexible intermediate that can be processed and shaped into traditional "kamaboko" products, shellfish substitutes, and seafood analogues (Park and Lin, 2005). The washing step of minced fish is crucial in surimi production because it removes fats, pro-oxidants, aroma compounds, water-soluble sarcoplasmic proteins, enzymes, and non-proteinaceous compounds yielding minced fish with enhanced sensorial properties (Lin and Park, 1997; Turan and Sönmez, 2010). Several studies have also used different washing media for established surimi production of various fish species such as carbonated water for mackerel (*Auxis thazard*) surimi (Somjid *et al*., 2017), alkaline saline media (NaCl and $NaHCO_3$) (Priyasomjiddarshini *et al*., 2017), and conventional cold water in tilapia (*Oreochromis niloticus*) (Priyadarshini *et al*., 2017; Saputra *et al*., 2021) and catfish (*Pangasius hypophthalmus*) (Hassan *et al*., 2017). Undeland (2016) also reported that washing minced fish for surimi production removes endogenous compounds that hamper surimi's functional properties and negatively affect both product quality and stability.

In Southeast Asian countries, surimi-based products are commercially available in the form of fish balls, fish cakes, fish sausages, fish burgers, and imitation crab sticks (Kok *et al*., 2002). Pangsorn *et al*., (2007) reported that demersal fishes such as *Nemipterus* spp., *Priacanthus* spp., and *Saurida* spp. are predominantly used as a raw material for surimi production considering both abundance and export-quality surimi product properties from these species. Among countries in Southeast Asia, Vietnam and Thailand dominate as the largest surimi-producing countries, while the Philippines despite having low production metrics has the potential for the development of surimi technologies considering its large fishery resources (Guenneugues and Ianelli, 2013).

Brama orcini or bigtooth pomfret is an epipelagic

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species distributed in tropical and subtropical seas in the Indo-Pacific region (Bos and Gumanao, 2013). In Panay Gulf, the abundance of *B. orcini* was reported from January to May (Babaran *et al*., 2009) while the most recent published frequent catch landings were reported from July to November (Motomura *et al*., 2017). Given these reports, *B. orcini* is still limited to local wet markets which are used only for direct food consumption (Bos and Gumanao, 2013). Underutilization calls for appropriate measures to maximize *B. orcini* during peak season, thus enabling local or small-scale emerging fish processors through diversified fisheries post-harvest strategies such as minced fish processing and surimi production. The post-harvest utilization of bigtooth pomfret is scanty to none, and most published studies in the literature are focused on elucidating the identification and biology of this fish species. To provide baseline information in developing potential value-added fishery products from *B. orcini*, this study determined the effect of different washing cycles on the physico-chemical and sensory quality of surimi from bigtooth pomfret.

2. Materials and methods

2.1 Preparation of surimi from Brama orcini

Brama orcini was purchased from a local wet market in Miagao, Iloilo, Philippines. Fresh fish samples were cleaned, beheaded, gutted, and washed thoroughly with tap water. The deboning process was conducted by passing the cleaned fish in a belt drum-type mechanical meat-bone separator. The isolated muscle was cleaned from bones, spines, scales, skin, and other extraneous matter before cutting the meat into small pieces. The minced muscle was divided equally into five different treatment lots namely WC0 (minced, no washing/ control), WC1 (washing cycle 1), WC2 (washing cycle 2), WC3 (washing cycle 3), and WC4 (washing cycle 4). Surimi was prepared thereafter according to Hassan *et al*. (2017), with slight modifications pertaining to the manual washing of surimi. Washing of WC1, WC2, WC3, and WC4 minced fish samples was conducted using saline cold water (0.3% NaCl, $^{w}/_{w}$) (1:3, fish: water ratio) at 10°C for 5 mins, every washing cycle. The dewatering process of the washed minced fish samples (WC1, WC2, WC3, and WC4) and the control (WC0) was performed on a 2-ply cheesecloth using a hydraulic pressing machine. The process yields of the control (WC0), and then washed (WC1, WC2, WC3, and WC4) minced fish samples were measured by dividing the weight of dewatered minced fish by the initial weight of minced fish, multiplied by 100. All treatments were then mixed with cryoprotectants such as 4% ($^{w}/_{w}$) sucrose, 4% ($^{v}/_{w}$) sorbitol, and 0.2% ($^{w}/_{w}$) sodium tripolyphosphate, and packed in sealed polyethylene bags. All samples were labelled as surimi (WC0, WC1, WC2, WC3, WC4) and stored at -25°C for subsequent physico-chemical and sensory analyses. All analyses were done in triplicate.

2.2 Physico-chemical analysis of surimi from Brama orcini

The total water-soluble protein contents of surimi samples were measured spectrophotometrically using Biuret protein assay. The absorbances of the samples were measured at 550 nm and bovine serum albumin (BSA) (at 10 mg/mL) was used as a standard (Krohn 2002). The total reducing sugar contents of surimi samples were analysed using a spectrophotometric redox colour reaction by Somogyi (1952). The absorbances of the samples were measured at 620 nm and glucose was used as a standard (at 1 mg/mL). Gravimetric analyses for moisture and total ash contents of samples were conducted according to AOAC (2000) procedures. The total moisture contents of surimi samples were analysed after a loss on drying at 105°C for 16 hrs. The total ash contents of surimi samples were determined after the complete combustion of all organic compounds in the furnace at 550°C. The total protein content in surimi was determined using a nitrogen-based Macro-Kjeldahl method (AOAC 2000). A 6.25 factor is used to convert percentage nitrogen (%) values to the total protein content of surimi samples. The pH values of surimi samples were measured using a benchtop pH meter (pHasion C-73X). A total of 5 g of homogenized sample were used, and the measurement of pH was carried out at 22±2°C. All analyses were done in triplicate.

The percentage of free and expressible drips and water holding capacity (%) of surimi samples were determined according to the procedure by Ng (1987), with slight modification. In the determination of percentage free drips, a cylindrical metal borer was used to cut circular surimi samples measuring 2 cm in diameter with a height of 0.5 cm each. Surimi samples were weighed (X), placed on a 2-ply Whatman No. 1 filter paper, kept in a petri dish at 4°C, and weighed (Y) after 2 hrs. The free drip was calculated based on Equation (1). In the determination of expressible drips, surimi samples were then placed between 3-ply Whatman No. 1 filter papers which are pressed (at 2 kg/ cm^2) for three minutes. Pressed samples were carefully removed and weighed (Z) to calculate the per cent expressible drip using Equation (2). Water holding capacity was calculated based on Equation (3).

$$\text{Free Drip (\%)} = ((X - Y)/X) \times 100 \quad (1)$$

$$\text{Expressible Drip (\%)} = ((X - Z)/X) \times 100 \quad (2)$$

$$\text{Water Holding Capacity (\%)} = 100 - \text{Expressible Drip (\%)} \quad (3)$$

The colour properties (L^*, a^*, b^*) of surimi samples

were measured using Konica Minolta CR-400 Chroma Meter. The L^* value (0-100) indicates lightness. On a^*, a $+a^*$ value indicates redness while a $-a^*$ value indicates greenness. On b^*, a $+b^*$ value indicates yellowness while a $-b^*$ value indicates blueness. Whiteness index (WI), redness index (RI), saturation index (SI) or colour intensity of surimi samples, and total colour difference (ΔE) of surimi samples were calculated based on Equations (4), (5), (6), and (7) as described by Chen *et al*. (1997). All analyses were done in triplicate.

$$\text{Whiteness Index} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2} \quad (4)$$

$$\text{Redness Index} = a^*/b^* \quad (5)$$

$$\text{Saturation Index} = (a^{*2} + b^{*2})^{1/2} \quad (6)$$

$$\text{Total Colour Difference } (\Delta E) = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^{*2})]^{1/2} \quad (7)$$

2.3 Sensory evaluation of surimi gels from Brama orcini

Surimi gels were prepared by mixing 100 g surimi samples with 2.5% ($^{w}/_{w}$) NaCl at 4°C, following a two-step gelation process adapted from Benjakul *et al*. (2002). Homogenous samples were then incubated in a water bath at 40°C for 30 mins, followed by heating at 90°C for 20 mins thereafter. Surimi gels were then cooled in an ice bath and stored at 4°C overnight. The surimi gels were then formed into sticks (at 3 mm thick and 1 cm length) and evaluated by semi-trained sensory panellists who are familiar and knowledgeable about the sensory attributes of surimi gels. Surimi gel samples were then assessed on a line scale based on the degree of perceived intensity (0, absent; 10, intense) for fishy odour, colour whiteness, gel firmness, gel springiness, and overall acceptability (0, disliked; 10, liked extremely). Separately, a 5-point folding test was performed to determine the elasticity of surimi samples (1, splits into two if folded in two; 2, cracks if folded in two; 3, no crack occurs if folded in two but splits if folded in four; 4, no crack occurs even if folded in two but cracks if folded in four; and 5, no crack even if folded in four).

2.4 Statistical analysis

Results were presented as Mean±Standard Deviation (SD), and all measurements were carried out in triplicate. The results were analysed using one-way analysis of variance (ANOVA) to determine significant changes in the physico-chemical and sensory properties of surimi from *B. orcini*. A post-hoc comparison test was conducted using Duncan multiple range tests (DMRT) at $p<0.05$. Linear relationships between parameters were determined using Pearson correlation (Bivariate) at $p<0.01$ and at $p<0.05$ (two-tailed). All statistical analysis was performed using IBM® SPSS® Statistics software version 27 (SPSS Inc., Chicago, IL, USA).

3. Results and discussion

The processing yields of surimi from *Brama orcini* are presented in Table 1. On average, after separating the meat and bones, isolated fish muscle from *B. orcini* yields 52.79% which may indicate the commercial potential for surimi processing. When divided into different treatment lots for washing and dewatering, the percentage yield of minced *B. orcini* muscle was highest in the unwashed sample (WC0) at 78.88%, followed by WC1 (at 72.75%), WC2 (at 61.63%), WC3 (at 61.70%), and WC4 (at 59.93%). A considerable decrease in yield (at -6.23%) was observed in WC1 since most of the remaining bones, spines, skin, blood, fat globules, and water-soluble sarcoplasmic proteins have been removed. A gradual decrease in yield was then observed after successive washing and dewatering of minced fish. Mincing yield is affected by several factors including fish species, maturity, season, and geographic location. The percentage yield of minced fish from *B. orcini* was lower as compared to the yield of minced fish from *Rachycentron canadum* (at 61-73%) (Hamzah *et al*., 2015) but higher as compared to the reported findings of Hassan *et al*., (2017) on *Pangasius hypophthalmus* surimi (at 18.7-29.0%).

The physico-chemical properties of surimi samples are shown in Figure 1. The total water-soluble proteins (Figure 1A) in surimi samples showed varying results, especially in WC0, WC3 and WC4 samples ($p<0.05$). Results also indicated that water-soluble proteins present in *B. orcini* surimi range from 63.70 to 74.50 mg/g. The protein solubility is considered one of the functional properties in surimi, hence the reduction of soluble proteins could be taken as a criterion of protein denaturation, thus three washing cycles are enough to produce surimi with good properties. Meanwhile, the total reducing sugar contents (Figure 1A) of surimi samples ranged from 0.004 to 0.012(%), which are nearly undetectable, especially in WC3 and WC4 samples. The total protein content (Figure 1B) of surimi samples (on a dry weight basis) ranged from 20.85% (WC4) to 23.83% (WC0). Results showed that the total

Table 1. Yields of isolated muscle from *Brama orcini* after mincing, dewatering, and at different washing cycle treatments

Parameter	Washing Cycles				
	WC0/Control	WC1	WC2	WC3	WC4
Yield (%)	78.88±0.10^{a}	72.75±0.10^{b}	61.63±0.00^{c}	61.70±0.10^{d}	59.93±0.00^{e}

Values are presented as mean±SD (n = 3). Values with different superscript are significantly different based on one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) ($p< 0.05$).

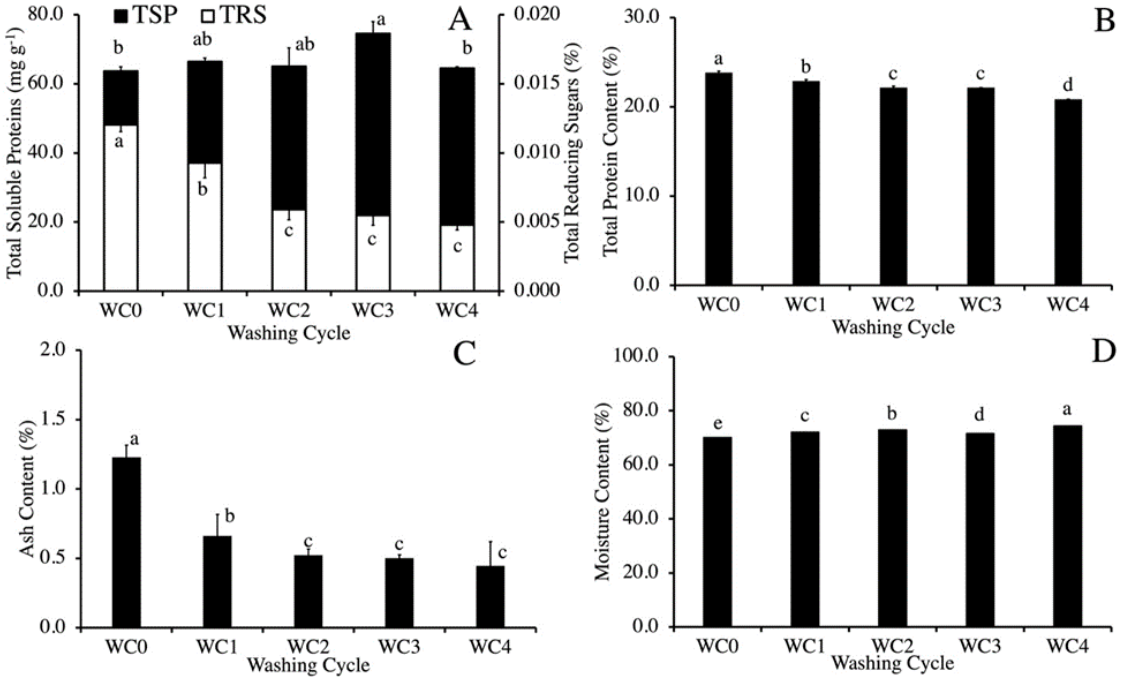

Figure 1. Chemical properties of surimi samples from *Brama orcini* at different washing cycles. Values are presented as mean±SD (n = 3). Bars with different alphabet notation are significantly different on one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) (p<0.05).

protein content decreased significantly with increased washing cycles (p<0.05). Similar observations were reported by Hassan *et al*. (2017) where the total protein content of *Pangasius hypophthalmus* surimi decreased from 18.90% to 12.93% after four washing cycles. Increasing washing cycles in surimi processing may decrease the total protein content of surimi samples but could be beneficial in improving the water retention properties of surimi since most of the sarcoplasmic proteins and non-gelling compounds have been removed (Haard *et al*., 1994; Zuraida *et al*., 2017). The total ash contents (Figure 1C) of surimi samples ranged from 0.45% (WC4) to 1.23% (WC0). Results in this study showed a significant reduction of total ash contents after first washing WC1 (at 0.66%) (p<0.05) while WC2 (0.52%), WC3 (0.50%), and WC4 surimi samples showed no significant differences from each other (p>0.05). Meanwhile, the total moisture content of surimi samples ranged from WC0 (at 70.05%) to WC4 (at 74.39%) and showed significant differences between treatment means (p<0.05). Results also showed that increasing washing cycles may decrease the yields of surimi samples, but it improves surimi's moisture content.

In Figure 2, the water retention properties and pH level of surimi samples are shown. Results in this study showed that the percentage free drip values (Figure 2A) of surimi samples were between 5.87% (WC3) and 15.42% (WC0). A similar trend was also observed in the expressible drip (Figure 1B) values of surimi samples which range from 11.11% (WC3) to 36.16% (WC0). Results in this study showed that the free and expressible drip values of WC2, WC3, and WC4 surimi samples are significantly lower as compared to the WC0 and WC1 surimi samples (p<0.05). The water-holding capacity (Figure 2C) of surimi samples ranged between 63.84% (WC0) and 88.89% (WC3) and showed that WC3 and WC4 (86.11%) samples have significantly higher water-holding capacity values as compared to the WC0 and WC1 samples (p<0.05). Given these results, increasing washing cycles (in WC3 and WC4) in the processing of surimi from *B. orcini* lowers free and expressible drips, thus, improving its water-holding capacity as compared to surimi under shorter washing cycles. The low expressible drip values of surimi can indicate the strength of the surimi gel network which can develop after subjecting the surimi to pressure, thus free drips occur when proteins become weaker due to changes in muscle cell structure and acidic pH conditions (Huff-Lonergan and Lonergan, 2005). Higher cross-links or surimi gel density networks also exhibit lower expressible drips (Mao and Wu, 2007). The meat pH (Figure 2D) of surimi samples ranged from 5.76 (WC0) to 6.49 (WC4). Results showed surimi samples have slightly acidic pH, and that the pH level increased significantly with an increasing number of washing cycles (p<0.05). Results in this study coincide with the reported pH range (6.10 to 6.44) in *Auxis thazard* surimi washed with carbonated water (Somjid *et al*., 2017).

The colour properties of surimi samples are presented in Table 2. The lightness (L*) values of surimi were lowest in the WC0 (at 41.92) and highest in the WC2 (at 52.89) samples. Results showed that WC2, WC3 (52.56), and WC4 (51.83) samples did not show

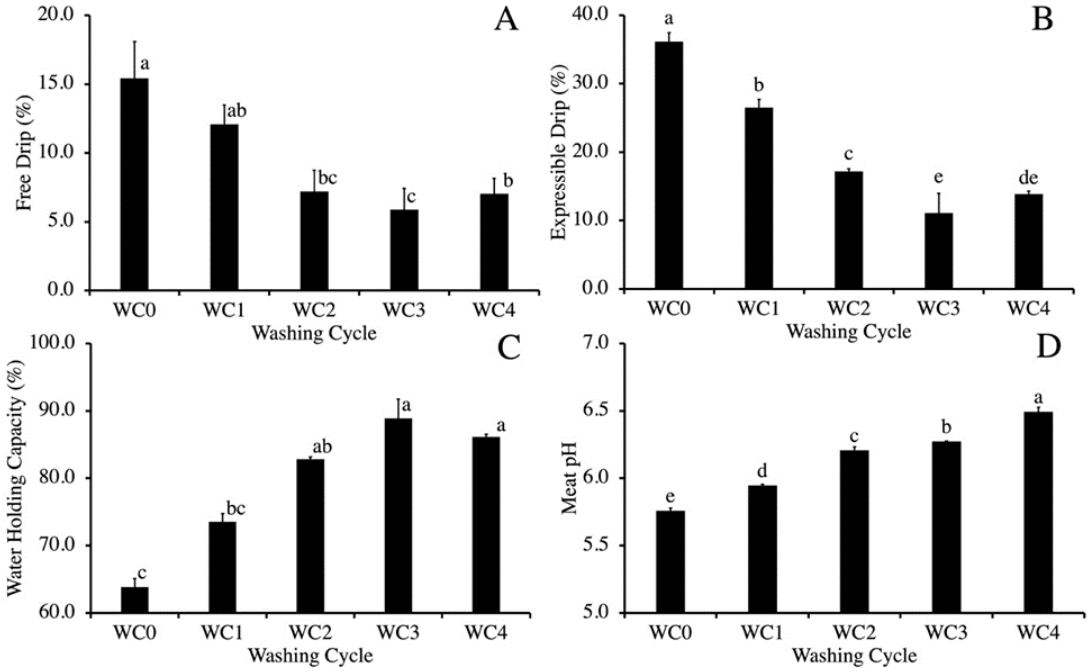

Figure 2. Water retention properties and pH level of surimi samples from *Brama orcini* at different washing cycles. Values are presented as mean±SD (n = 3). Bars with different alphabet notation are significantly different on one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) (p<0.05).

Table 2. Colour properties of surimi gels from *Brama orcini* at different washing cycles.

Parameter	Washing Cycles				
	WC0	WC1	WC2	WC3	WC4
*L**	41.92±0.56^{c}	47.58±0.67^{b}	52.89±0.53^{a}	52.56±1.53^{a}	51.83±1.05^{a}
*a**	-1.15±0.11^{a}	-1.12±0.15^{a}	-2.44±0.05^{bc}	-2.32±0.13^{b}	-2.57±0.03^{c}
*b**	5.68±0.21^{b}	6.25±0.27^{a}	4.21±0.24^{c}	3.97±0.20^{c}	2.90±0.24^{d}
WI	41.86±0.56^{c}	47.51±0.66^{b}	52.78±0.53^{a}	52.46±1.52^{a}	51.74±1.04^{a}
RI	-0.20±0.03^{a}	-0.18±0.03^{a}	-0.58±0.04^{b}	-0.58±0.06^{b}	-0.89±0.08^{c}
SI	5.80±0.20^{b}	6.35±0.24^{a}	4.86±0.21^{c}	4.60±0.14^{c}	3.87±0.18^{d}
ΔE	0.00 ± 0.00^{c}	5.71±0.80^{b}	11.15±1.03^{a}	10.84±2.07^{a}	10.41±1.50^{a}

Values are presented as mean±SD (n = 3). Values with different superscript are significantly different based on one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) (p< 0.05). *L**: Lightness, +*a**: Redness, -*a**: Greenness; +*b**: Yellowness, -*b**: Blueness, WI: Whiteness Index, RI: Redness Index, SI: Saturation Index, ΔE: Colour Difference.

significant differences from each other (p>0.05) but were found to be significantly higher as compared to WC0 and WC1 (47.58) samples (p<0.05). The redness (*a**) (from -1.12 to -2.57), yellowness (*b**) (from 2.90 to 6.25), redness index (RI) (from -0.89 to -0.18), and saturation index (SI) (from 3.87 to 6.35) values of surimi samples were low and could indicate the denaturation and removal of haem pigments initially present in the fish muscle (Chen *et al*., 1997). Chaijan *et al*. (2010) also reported similar RI values for short-bodied mackerel (*Rastrelliger branchysoma*) at -0.18. Meanwhile, the whiteness index (WI) of surimi samples ranged from 41.86 (WC0) to 52.78 (WC2). The whiteness indices of WC2, WC3 (52.46), and WC4 (51.74) samples did not show significant differences from each other (p>0.05) but were significantly higher as compared to WC0 and WC1 (47.51) samples (p<0.05). As compared to other studies, the WI of surimi from *B. orcini* is lower as compared to surimi obtained from *Sardinella albella* (64.51 - 69.85) (Vate and Benjakul, 2016), *Pangasius hypophthalmus* (61.71-73.59) (Hassan *et al*., 2017), and *Oreochromis niloticus* (65.65-72.23) (Priyadarshini *et al*., 2017), but were found to be similar when compared to frigate mackerel surimi, *Auxis thazard* (at 50.56) and Indian mackerel, *Rastrelliger kanagurta* (at 52.35) (Chaijan *et al*., 2010). Meanwhile, the colour difference (ΔE) values of WC2 (11.15), WC3 (10.84), and WC4 samples (10.41) were significantly higher compared to the WC1 sample (p<0.05) which inferred that colour intensity and saturation of surimi samples diminished significantly with increasing washing cycles.

The linear relationships between pairs of the physico -chemical properties of surimi samples are presented in Table 3. The overall yield was positively correlated to ash content (+0.91), protein content (+0.89), free drip (+0.82), expressible drip (+0.95), total reducing sugars (+0.93), *a** (+0.89), and saturation index (+0.84) values.

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Table 3. Matrices of the physico-chemical properties of surimi samples from *Brama orcini* at different washing cycles.

Parameter	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]
[B]	−0.77**												
[C]	+0.91**	−0.77**											
[D]	+0.89**	−0.901**	+0.841**										
[E]	−0.95**	+0.84**	−0.86**	−0.05									
[F]	+0.82**	−0.52*	+0.72**	+0.02	−0.75**								
[G]	−0.95**	+0.67**	−0.88**	−0.82**	+0.89**	−0.84**							
[H]	+0.95**	−0.67**	+0.89**	+0.16	−0.89**	+0.84**	−0.84**						
[I]	+0.93**	−0.74**	+0.86**	+0.03	−0.91**	+0.84**	−0.84**	+0.92**					
[J]	−0.25	−0.10	−0.30	−0.31	+0.15	−0.25	+0.25	−0.32	−0.26				
[K]	−0.95**	+0.71**	−0.93**	+0.05	+0.85**	−0.77**	+0.77**	−0.90**	−0.87**	+0.32			
[L]	+0.89**	−0.79**	+0.72**	+0.11	−0.95**	+0.65**	−0.65**	+0.80**	+0.81**	−0.07	−0.75**		
[M]	+0.84**	−0.64**	+0.61*	+0.25	−0.88**	+0.63*	−0.75**	+0.75**	+0.73**	−0.17	−0.68**	+0.97**	
[N]	−0.95**	+0.72**	−0.91**	+0.03	+0.86**	−0.75**	+0.88**	−0.88**	−0.86**	+0.34	+1.00**	−0.75**	−0.69**

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). A: Yield, B: Moisture, C: Ash, D: Protein, E: pH, F: Free Drip, G: Water Holding Capacity, H: Expressible Drip, I: Reducing Sugar, J: Soluble Protein, K: Whiteness Index, L: Redness Index, M: Saturation Index, N: Colour Difference.

However, the overall yield was negatively correlated to moisture content (−0.77), pH (−0.95), water holding capacity (−0.95), whiteness index (−0.95), and colour difference (−0.95) values. Results showed moisture content was positively correlated to pH (+0.84), water holding capacity (+0.67), whiteness index (+0.71), and colour difference (+0.72). A similar observation was reported by Huff-Lonergan and Lonergan (2005) where meat pH directly affects water-holding capacity. Previous reports showed that whiteness indices in surimi were directly correlated to water holding capacity, representing surimi with high moisture retention properties (Reppond and Babbitt, 1997; Park and Lin, 2005). Results also agreed with the reported findings of Hassan *et al*. (2017), where washed surimi samples with reduced total protein content had increased water retention and improved sensory properties.

The sensory properties of surimi samples are shown in Figure 3. The fishy odour scores (Figure 3A) of surimi samples ranged from 5.42 to 6.64 and did not have significant differences from each other (p>0.05). The whiteness scores (Figure 3B) of surimi samples were lowest in WC0 (at 4.63) and highest in WC4 (8.09), which agrees with the whiteness index values shown in Table 2. The gel firmness scores (Figure 3C) of surimi samples did not show significant differences between washed surimi samples (p>0.05), except for the WC0 sample (p<0.05). Meanwhile, gel springiness scores (Figure 3D) ranged from 3.65 to 8.18. Results showed that the WC4 sample manifested significantly higher gel springiness as compared to other samples (p<0.05), except the WC3 sample. Folding test (elasticity) scores (Figure 3E) ranged between 1.00 and 4.00 and showed that the WC4 sample exhibited higher elasticity among treatments (p<0.05). Washed surimi samples with elasticity could indicate better protein quality as compared to other treatments in this study. The folding test is subjective but considered as a preliminary test to differentiate high and low-grade surimi (Reppond and Babbitt, 1997).

The overall acceptability scores (Figure 3F) of surimi samples ranged from 4.59 to 8.44. The WC4 sample demonstrated a high likeability score which is significantly higher among the treatments in the study (p<0.05). This study suggested that good sensory attributes and acceptability of surimi samples from *B. orcini* can be improved with increased washing cycles. Correlation analysis (Table 4) also showed that surimi gel whiteness scores were positively correlated to gel firmness (+0.59), gel springiness (+0.63), elasticity

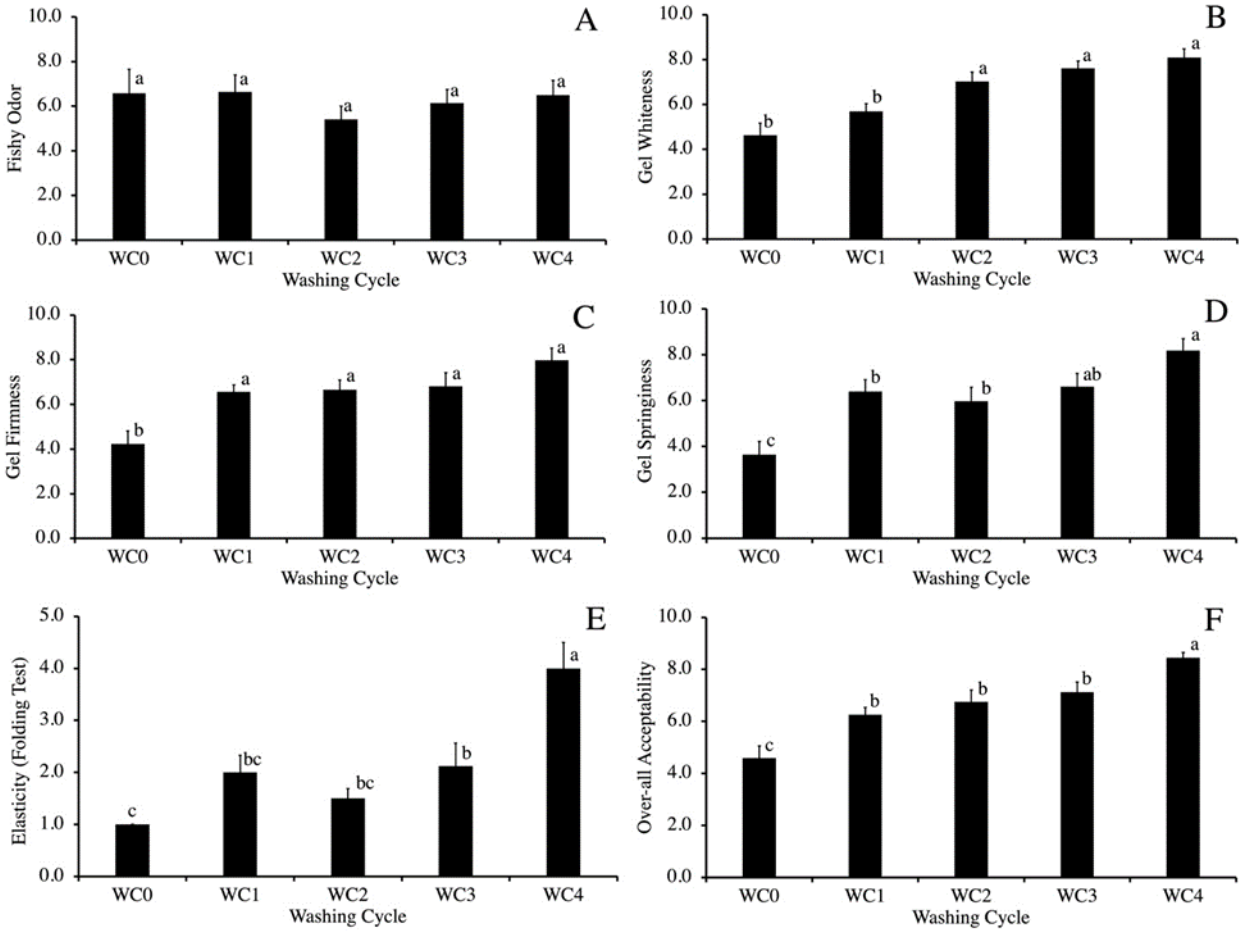

Figure 3. Sensory properties of surimi samples from *Brama orcini* at different washing cycles. Values are presented as mean±SD of semi-trained panellists. Bars with different notations are significantly different between treatment methods based on one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) (p<0.05).

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Table 4. Matrices of the organoleptic properties of surimi samples from *Brama orcini* at different washing cycles.

Parameter	[A]	[B]	[C]	[D]	[E]
[B]	+0.01				
[C]	+0.08	+0.59**			
[D]	−0.03	+0.63**	+0.78**		
[E]	−0.08	+0.52**	+0.57**	+0.61**	
[F]	−0.03	+0.78**	+0.76**	+0.83**	+0.65**

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). A: Fishy Odour, B: Whiteness, C: Gel Firmness, D: Gel Springiness, E: Elasticity, Folding Test, F: Over-all Acceptability.

(folding test) (+0.52), and overall acceptability (+0.78) scores. A high correlation was also found between surimi gel springiness and overall acceptability (+0.83) scores. Results thus demonstrated a good correlation between the whiteness and texture properties to the overall acceptability of surimi from *B. oricini*.

4. Conclusion

In conclusion, this study showed that *B. orcini* is a good raw material for surimi production and emphasized that three washing cycles may be recommended to improve its physico-chemical and sensory properties. Although Park *et al*. (2013) reported that two washing cycles are sufficient in producing high-quality surimi, results in this study suggested increasing washing cycles into three for *B. orcini* without compromising its yield and physico-chemical and sensory properties. In retrospect, since most of the published literature on *B. orcini* focuses on its biology, this study has provided baseline information as an alternative means for the utilization of this species, especially during peak season in the tropics.

Conflict of interest

The authors declare no conflict of interest.

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