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Research Article

Evaluation of the quality of fish burger produced from *Scomberoides commersonnianus* surimi during frozen storage

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Abstract

Fish burger was produced from sarm (*Scomberoides commersonnianus*) surimi and other ingredients. The physicochemical (chemical composition and pH, free fatty acid, peroxide value (PV), shrinking and cooking loss) and sensory attributes of the product were investigated during 90 days of frozen storage. Results showed that shrinkage in size increased significantly in fish burger from 7 to 8.47 percent at the end of frozen storage. Cooking loss increased significantly from 8 to 13.23 percent in fish burger after 90 days of frozen storage (p<0.05). The peroxide value (PV) in fish burger was 0.6 at the beginning of the storage but increased significantly to 2.4 meq/kg after 90 days of frozen storage. The level of free fatty acid and weight loss increased significantly in fish burger after frozen storage (p<0.05). Fish burger maintained the sensory properties after 90 days of frozen storage (p>0.05). SDS-PAGE confirmed more intensity of the protein bands in raw surimi than in fish burger. SDS-PAGE, indicating stability of the proteins, showed that protein bands in raw surimi were more intense than fish burger. SDS-PAGE indicated no major change in the intensity of protein bands in surimi and fish burgers after 90 days of frozen storage. Overall, the results revealed that fish burger produced from sarm surimi possessed desired sensory properties during frozen storage.

Keywords: Fish burger, Surimi, Chemical composition, Sensory analysis, Physicochemical properties, Frozen storage

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Introduction

It is well documented that diet plays an important role in prevention and treatment of some disease. Red meat and meat products have a negative effect on human health due to high content of fat, saturated fatty acids and cholesterol (Krichner *et al.,* 2000; Cashman and Hayes, 2017). Fat reduction in meat products has attracted great attention by meat industries worldwide in recent years because of health reasons (Carfora *et al.,* 2019). Among ready-to-cook meat products, the comminuted meat products contain high fat; therefore, it is essential for the meat industry to reduce the fat contents of meat products (Barbut *et al.,* 2016). Consumption and popularity of seafood has increased consistently during recent years since seafood is considered as low caloric healthy foods and a source of high-quality protein, essential fatty acids, and a range of macro and micronutrients for human diet (Borgogno *et al.,* 2017).

Surimi is a good fish protein ingredient to produce various seafood products (Sampels, 2015). Surimi production process involves several washes with cold water (5-10°C) for removing undesirable materials (such as bone, pigments, blood and fat, enzymes and sarcoplasmic proteins) of fish minces (Moosavi-Nasab *et al.,* 2005; Azadian *et al.,* 2012). Concentrated myofibrillar proteins are produced to improve gelling properties of fish mince and decrease fat deterioration and protein degradation (Benjakul *et al.,* 2002; Priyadarshini *et al.,* 2017). Surimi is starting material for traditional fish products, such as kamaboko, snacks, fish burger, etc. (Omura *et al.,* 2020). The most suitable fish species for fish products are white and low-fat fish with high gelling properties (Benjakul *et al.,* 2002; Yousefi and Moosavi-Nasab, 2014).

Fish burgers are one of the most acceptable food products in the world and are commonly used as ready-to-eat or precooked products (Paci *et al.,* 2018). Fish and Fish products are usually consumed after frozen storage. Freezing and frozen storage of fish and meat products are used for long preservation which leads to a minimal loss of quality during long-term storage. Although undesirable changes are controlled during frozen storage, but quality of myofibrillar proteins and lipids are changed (Siddaiah *et al.,* 2001; Khoshnoudi-Nia and Moosavi-Nasab, 2018).

According to a model presented by Godsalve *et al.* (1997) for muscle meat, the muscle proteins denature during cooking, thereby leading to a decrease in their water holding capacity and shrinkage of protein network. All kinds of meat shrink in size and weight during cooking due to fluid extrusion from the meat and evaporation from the meat surface. Cooking of meat causes both mass (cooking loss) and volume loss (Obuz and Dikeman, 2003). Quality factors such as shrinkage and fat loss of hamburger patty are considered as important quality criteria by consumers (Modi *et al.,* 2004; Serdaroglu and Degirmencioglu, 2004).

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Sarm (*Scomberoides commersonnianus*) is a popular species of white flesh fish with low price in Iran that is caught off Persian Gulf and Oman Sea. Utilization of sarm for surimi and surimi seafood production has not been investigated till now. In this research, fish burger was prepared from sarm surimi (60%) and other ingredients, and then physicochemical and organoleptic properties of fish burger were investigated and compared with beef burger, as a popular burger, during 3 months of frozen storage.

Materials and methods

Materials

All chemicals used in this study were analytical grade or the highest grade available and were obtained either from Sigma or Merck (Darmstad, Germany) and Fermentaz (Canada). All ingredients used for fish burger production were obtained from Tuji meat Industry Company or local markets. Beef burger was obtained from Sham Sham Co. (Sepidan, Fars, Iran).

Fish samples

Fresh sarm fish (*S. commersonnianus*), approximately 800-1200g, were obtained from local fish market (Shiraz, Iran). Fish were kept in ice, using fish: ice ratio of 1:2 (w/w) and transported to the pilot plant of Department of Food Science and Technology (School of Agriculture, Shiraz University), within 45 min. Then, they were washed, kept at 0°C and used for surimi production.

Surimi preparation

Surimi was prepared using the method of Moosavi-Nasab *et al.* (2005) with some modifications. First, fish were beheaded, gutted and hand washed. Skin and bones were removed manually and then fish flesh comminuted with a 4 mm steel plate in a mincer (Ravanshad, Iran). Minced fish was washed-dewatered three times with a ratio of 4:1 (water/mince); the washing time was 5 min. Temperature was maintained below 10°C by adding ice during washing process. After dewatering with cheese cloth as a filtering material, raw surimi was produced.

Production of fish burger

Three independent replicates of each batch were prepared. Weight of each batch was 1200g. Fish burger was out of a mixture of fish surimi (60%), margarine oil (8%), bread crumb (6%), gluten (1.5%), starch (2.5%), soy protein isolate (0.8%), onion (14%) salt (2%), and spice (e.g., black pepper, nutmeg, thyme, ginger) (5.2%). To obtain the base mixture, fish surimi, frozen onion and margarine oil were grounded by a 2.5 mm steel plate in a mincer (National-Iran) and then the mixture was transferred to a commercial mixer (National-Japan) where they were mixed for 20 min with salt and other additives. Mixing was performed at ambient temperature (27±2°C) to obtain a batter with uniform consistency. This mixture was shaped using a hand commercial burger

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marker (Ommas-Germany) to obtain burger with a weight of approximately 120g and 70 mm thickness and 127 mm diameter. Then, waxy paper was used for separating burgers. Fish burgers were put separately in a plate freezer (Dole-USA) on Aluminum foil for 30 min at -40°C and were rapidly frozen. Finally, the frozen samples were packaged using Ziploc plastic bags (2 patties per bag) and stored at -20°C. Polyethylene Ziploc plastic casing obtained from Polyethylene Co., Karaj, Iran, were used for stuffing of burgers. Fish burger slices were prepared with an average weight of 120g. Also, beef burger, as standard and acceptable samples, was obtained from Sham Sham Co. (Sepidan, Fars Province, Iran) to better evaluate and compare the properties of fish burgers.

Proximate analysis and pH

Percentages of moisture, ash, protein (N×6.25) and crude fat were determined in fresh surimi and fish burger before frozen storage according to Association of Official Analytical Chemists (AOAC, 1995) procedure. The pH value was measured using a pH meter (CG-824-Germany) based on the method of Carbonell and Lopez (2005). A suspension obtained by blending 15g of sample with 150 mL deionized water (for 2 min) was used for pH measurement.

Cooking loss

Weight of each sample was measured before and after cooking using the method of Orozvari and Tornberg (2004) with some modifications. Each kind of burger was cooked for 30 min on aluminum foil at 150°C. After cooking, the burgers were allowed to cool for 30 min. Percentage of cooking loss was determined for each sample by the following equation:

$$\%\,\text{Cooking Loss} = \frac{W_b - W_a}{W_b}$$

W_b=Weight of raw sample, W_a=Weight of cooked sample.

Diameter shrinkage

Percentage of shrinkage in diameter during cooking was determined by measuring the diameter of the burger at six points. The average was then calculated by the following equation (Orozvari and Tornberg, 2004),

$$\%\,\text{Diamter shrinkage} = \frac{D_b - D_a}{D_b} \times 100$$

D_b=diameter before cooking; D_a=diameter after cooking.

Weight loss

Weight loss was obtained for fish burgers in commercial freezer with air velocities between 2 and 3 m/s. It was possible to obtain inside air temperatures of -20°C. Fish burgers were weighed before and after freezing during frozen storage at -20°C. Weight loss was expressed as the weight change percentage during frozen storage (Orozvari and Tornberg, 2004).

Peroxide value

Hydroperoxide content was determined on total lipid extracts according to the

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method of Shantha and Decker (1994). Results were expressed in mg of peroxide equivalents per kg of total lipid extract.

Free fatty acids content

Free fatty acids (FFA) content was determined by titration (0.1M, NaOH) of the total lipid extracts (10g) after adding ethanol (15 mL) and using phenolphthalein as indicator. FFA content was calculated in % of total free fatty acid (AOCS, 1997). Rancidity parameters (PV and FFA) for fish burgers were measured on the 0, 1, 14, 30, 60 and 90 days of frozen storage.

*Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (*SDS-PAGE)

Samples for SDS-PAGE were prepared by mixing 20 mg of lyophilized fish surimi and fish burgers in 1 mL of sample buffer. The sample buffer consisted of Tris-HCl (0.5M, pH 6.8), glycerol, SDS (10%), 2-mercaptoethanol, and bromophenol blue (0.1%) in distilled water. Samples were heated for 5 min at 100°C and then cooled to room temperature before loading on the gel. A SDS-PAGE broad range molecular weight standard (10 to 200 KDa, Fermentaz, Canada) was used for determination of sample proteins molecular weight. The running buffer consisted of a Tris-glycine buffer containing SDS (1%). Electrophoresis was carried out at a constant current of 30 mA/gel, voltage of 400V at 15w. Gels were immersed in a fixing solution of 20% (v/v) methanol and 10% (v/v) acetic acid in water for 2h, stained with Coomassie Brilliant Blue R-250 (0.1% w/v) in 20% (v/v) methanol and 10% (v/v) acetic acid in water over night. Then, destaining was performed with the same fixing solution. The destained gels were stored in 7% (v/v) acetic acid and then were photographed (Moosavi-Nasab *et al.,* 2005).

Sensory evaluation

For determination of sensory quality of fish burgers, scoring test was used. Fish and burgers on days 0 and 90 of freezing storage were fried for 3 min in a frying pan using a common frying oil (Bahar, Tehran, Iran) and then subjected to sensory evaluation by 15 panelists (9 women and 6 men aged 25 to 35 years) consisting of scientists and post graduate students of Food Science and Technology Department, Shiraz University, Iran, to evaluate the sensory parameters (odor, texture, color, flavor and overall acceptability) of the samples. Each sample was coded with a randomLy selected 3-digit numbers. A 5 point hedonic scale was used where 4=excellent, 3=good, 2=average, 1=relatively poor and 0=poor. Water was served for mouth washing between evaluations of each sample (Chytiri *et al.,* 2004).

Statistical analysis

All experiments were repeated three times. Conventional statistical methods were used to calculate means and standard deviations. Data analysis was performed based on Analysis of Variance (ANOVA). Significant differences were ascertained using

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Duncan's Multiple Range Test (p<0.05). All statistical analyses were conducted by SPSS statistical package (SPSS 15, SPSS Inc., Chicago, IL, USA). Comparison between two kinds of burger was performed by Student's t-test method.

Results

Proximate analysis and pH

Percentages of moisture, protein, ash, fat content and pH value of fresh raw surimi and fish burger before freezing are shown in Table 1. Results showed that moisture value in raw surimi was much higher than that in fish burger (p<0.05). Protein value decreased significantly in fish burger compared to that in surimi (p<0.05). Fat content in raw surimi was significantly lower than that in fish burger. Ash value increased significantly in fish burger compared to that in surimi. There was significant difference between the pH values of fish burger and surimi (p<0.05).

Table 1: Proximate Analysis and pH of surimi and fish burger before freezing.

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	pH value
Surimi	79.9 ± 0.53 [a]	16.6 ± 0.21 [a]	1.1 ± 0.12 [b]	1.5 ± 0.10 [b]	6.9 ± 0.12 [a]
Fish burger	66.4 ± 0.36 [b]	13.0 ± 0.2 [b]	10.0 ± 0.20 [a]	2.5 ± 0.06 [a]	6.1 ± 0.12 [b]

Values are mean ± SD (n= 3). Values with different superscript letters in the same column are different (p<0.05).

Cooking loss

Cooking characteristics, including cooking loss, during frozen storage at -20°C are presented in Figure 1. The cooking loss of fish burger was significantly lower than that of beef burger. Moreover, storage time has significant effect on cooking loss (p<0.05). Freshly produced fish and beef burgers (0^{th} day) showed low cooking loss values in (8.00±1.00 and 16.5±0.5%, respectively) which increased gradually to 13.23± 0.25 and 24.77±0.25 after 3 months of frozen storage.

Diameter shrinkage

Shrinkage values of fish burgers were also lower than beef samples. Shrinkage values of samples increased significantly from 7.00±0.3 and 10.5±0.5 to 8.47±0.25 and 18.77±1.12 percent after 3 months storage at -20°C in fish burger and beef burger, respectively (Fig. 2).

Weight loss

Moisture migration from surface of fish burger was measured in the form of weight loss. Percentages of weight loss values of fish burgers stored at -20°C are shown in Figure 3. Weight loss of fish burgers increased significantly from 0.57±0.12% to 5.0±0.25% after 90 days of frozen storage. However, these amounts were much lower than those of beef burger (p<0.05; from 4.73±0.15 to 8.27±0.25 %).

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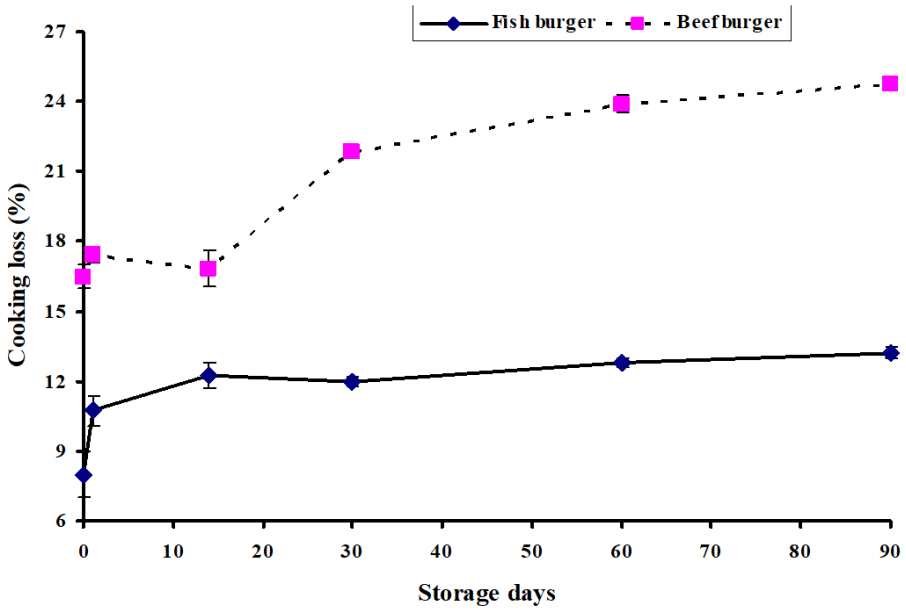


Figure 1: Cooking loss of fish and beef burgers during 90 days of storage at -20°C. Error bars show standard deviation.

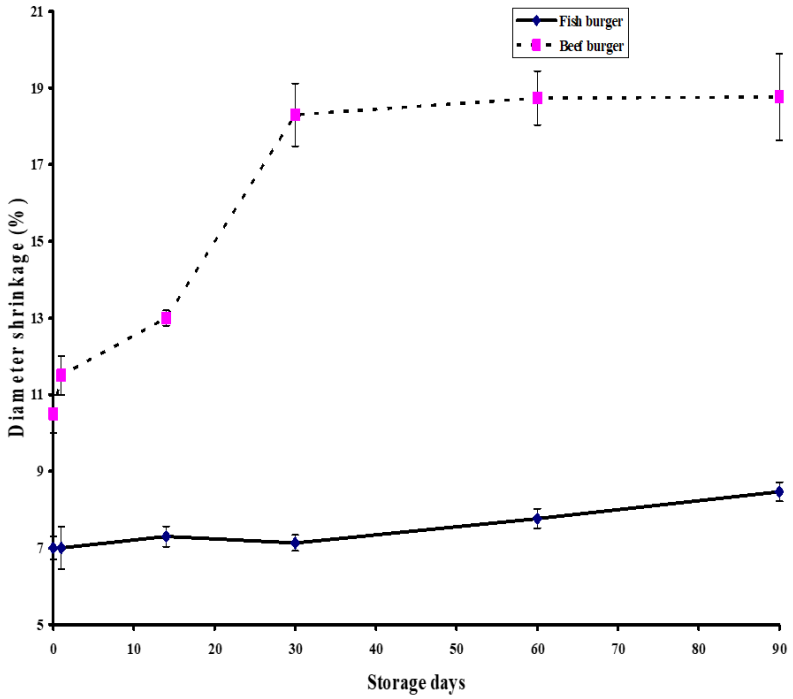


Figure 2: Diameter shrinkage of fish and beef burgers during 90 days of storage at -20°C. Error bars show standard deviation.

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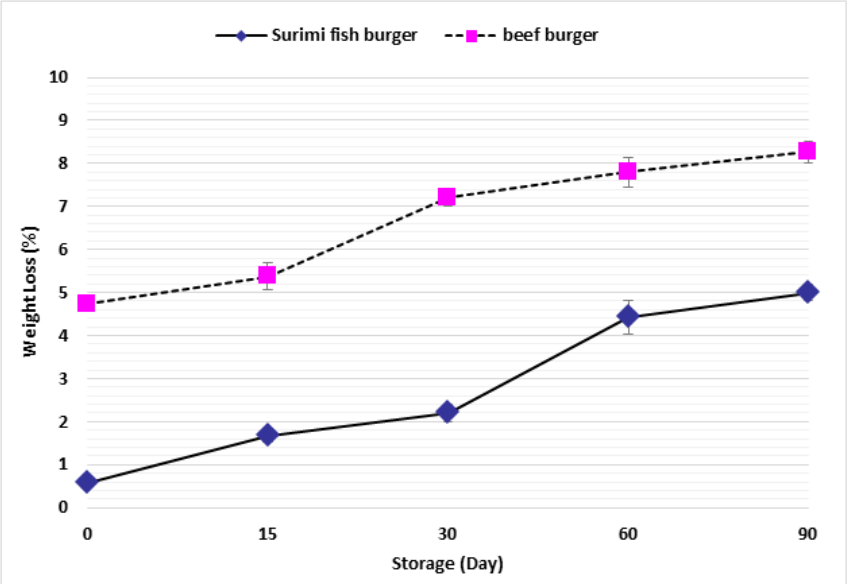


Figure 3: Weight loss of fish and beef burgers during 90 days of storage at -20°C. Error bars show standard deviation.

Free fatty acid

Changes in FFA value of raw fish burgers during frozen storage are presented in Table 2. FFA contents (as % of Oleic acid) of burgers increased during 90 days frozen storage from 1.93 and 8.76 to 12 and 41.33 in fish and beef burgers, respectively (p<0.05). FFA content of beef burger samples was significantly higher than that of fish ones (p<0.05).

Peroxide value

Concentrations of primary oxidation products (PV) during 90 days frozen storage are presented in Table 2. For fish and beef burgers, PV showed increasing trend (p<0.05). However, after 60 days of storage PV decreased. Furthermore, PV of fish burgers was lower than that of beef burgers (p<0.05).

Table 2: Free Fatty Acid (FFA) content and Peroxide Value (PV) of burgers during 90 days of frozen storage.

Samples	Days of storage					
	0	1	14	30	60	90
			FFA (% of Oleic acid)			
Surimi burger	1.93±0.31^{bF}	3.27±0.3^{bE}	4.67±0.31^{bD}	9.77±0.32^{bC}	11.10±0.36^{bB}	12.00±0.53^{bA}
Beef burger	8.67±0.31^{aF}	11.03±0.45^{aE}	13.67±0.42^{aD}	18.77±0.25^{aC}	28.00±2.00^{aB}	41.33±2.08^{aA}
			PV (meq O2/kg of oil)			
Surimi burger	0.60±0.10^{bE}	1.10±0.10^{bD}	1.60±0.10^{bC}	1.80±0.20^{bC}	2.80±0.20^{bA}	2.40±0.20^{bB}
Beef burger	1.00±0.20^{aE}	2.00±0.20^{aD}	2.57±0.12^{aC}	5.73±0.25^{aA}	5.77±0.25^{aA}	5.40±0.20^{aB}

*Different uppercase letters in each row show significant differences among storage days (p<0.05).
**Different lowercase letters on each column display significant difference between the two burgers (p<0.05).

SDS-PAGE analysis

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SDS-PAGE patterns of lyophilized raw surimi and fish burger during 90 days of frozen storage are presented in Figure 4. Myosin heavy chain (MHC, 194.6 KDa), the main unit of myosin, is the most important protein indicating the physicochemical characteristics of surimi. The intensity of myofibrillar proteins subunits such as MHC band with MW of 194.6 KDa, c-protein band with MW of 112.2 KDa, α-actinin band with MW of 109.6, actin with MW of 51.3 and myosin light chain (MLC) with MW of 14.6-18.1 KDa was higher in surimi compared to that in fish burger.

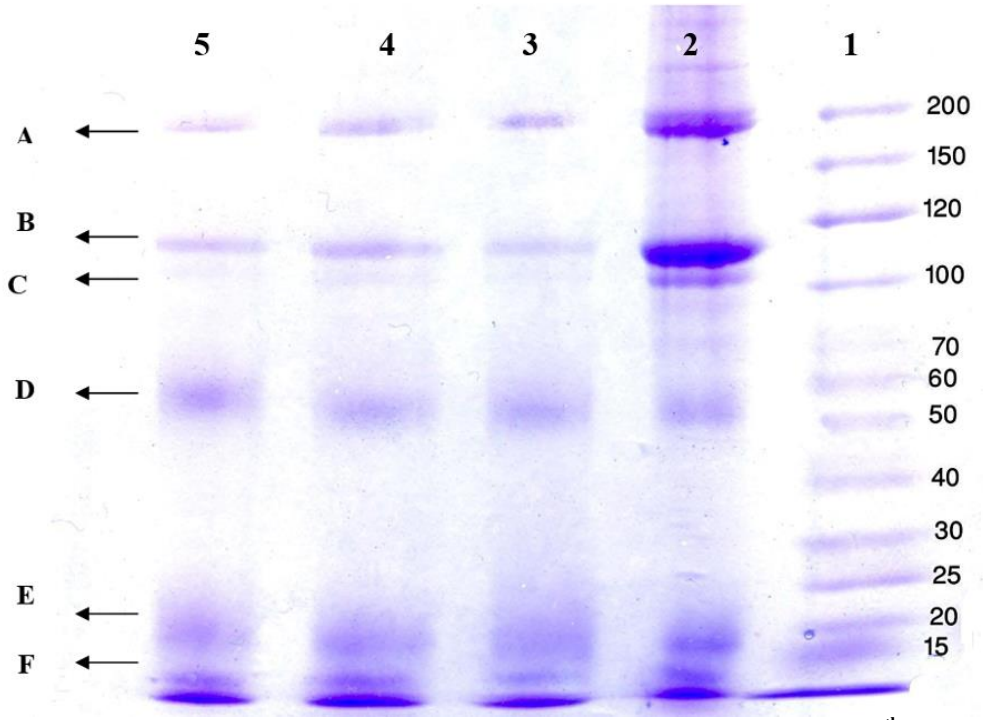


Figure 4: SDS-PAGE patterns of lyophilized raw surimi and fish burger at 0 and 90th day of frozen storage. Column 1: marker, column 2: raw surimi, column 3: Surimi burger at 0 day of storage, column 4: Surimi burger after 24 hours storage and column 5: Surimi burger after 90 days of storage. A=Myosin heavy chain (MHC), B=C-protein, C=α-actinin, D=Actin, E=β-tropomyosin, F=Myosin light chain (MLC).

Sensory evaluation

Changes in scoring of sensory parameters (odor, texture, color, flavor and overall acceptability) of fish during frozen storage on 0 and 90 days are presented in Table 3.

Results of changes in scoring of sensory properties in fish burger showed that the difference between 0 and 90 days of frozen storage was not significant (p>0.05). Furthermore, there was no significant difference between scoring of color, odor, texture, flavor and overall acceptability properties of fish burger during frozen storage (p>0.05).

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Table 3: Scoring of sensory attributes of fish burger during 90 days of frozen storage.

Sensory evaluation	Storage period (days)	Fish burger
Odor	0	2.78 ± 0.94 [a]
	90	2.6 ± 0.92 [a]
Texture	0	2.61 ± 0.92 [a]
	90	2.61 ± 0.78 [a]
Color	0	3.33 ± 0.77 [a]
	90	3.21 ± 0.81 [a]
Flavor	0	2.83 ± 0.86 [a]
	90	2.72 ± 0.83 [a]
Overall acceptability	0	2.72± 0.89 [a]
	90	2.67 ± 0.91 [a]

Values are mean ± SD (n= 3). Different lowercase letters for each parameter display significant ($p< 0.05$) difference between two periods.

Discussion

In this study, fish burger was prepared from *S. Commersonnianus* surimi. Physicochemical properties of fish burger were investigated during frozen storage. Results showed that moisture value in raw surimi was much higher than that in fish burger ($p<0.05$). This can be due to the fact that fish burger is a mixture of surimi (60%) and other ingredients (such as oil, starch, soy protein, spices, etc.). Additives (i.e., fillers and binders) have lower water content compared to raw surimi. Moreover, they can absorb water and decrease the moisture content of fish burger (Park, 2005). Ingredients in fish burger had lower protein content compared to those in raw surimi due to the fact that only 60% of fish burger formulation constituted of surimi, the rest included non-protein compounds. Results in Table 1 indicate that fat content in raw surimi was significantly lower than that in fish burger; this is due to the use of margarine in fish burger. Higher ash content of fish burger was due to the use of additives. Therefore, the difference between proximate composition of surimi and fish burger resulted in a significant difference in pH of samples.

Cooking loss and shrinkage of fish burgers was lower than those of beef burgers. There is a possible relation between decrease of cooking loss and higher fat retention in burgers (Hartmann *et al.*, 2020). Keeping fat into the matrix of meat products during processing is necessary for ensuring sensory quality and acceptability (Moghtadaei *et al.*, 2018). There is a positive relationship between fat content and cooking loss in burgers after cooking (Ueda *et al.*, 2007). During heating burgers firstly, fat melts and then collagen, which is major part of the connective tissue, pressing fat out of the cell (Andersson and Tornberg, 2000; Lucas-González *et al.*, 2020).

Serdaroglu and Degirmencioglu (2004) reported that fat content affect hamburger patty shrinkage and reducing fat content from 20% to 5%

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significantly decrease the shrinkage. In addition, they showed that meat balls tend to shrink during cooking process, due to denaturation of meat proteins which lose water and fat contributing to the shrinkage process.

Tokur *et al.* (2004) showed that there is an increasing trend in FFA content of fresh fish burger produced from Tilapia during 8 months of frozen storage. Our study also showed that FFA increased during frozen storage. Nutritional components (mainly proteins and PUFAs) in this fish and other seafoods are very susceptible to degradation and putrefaction during storage (Khoshnoudi-Nia and Moosavi-Nasab, 2019a). However, FFA content of surimi burger was much lower than that of beef burger. The amount of fat in fish flesh was lower than that in beef samples and this low fat also is reduced during surimi production. Therefore, FFA value of surimi burger was significantly lower than that of beef burger during storage (Yousefi and Moosavi-nasab, 2014).

Lipid oxidation is another important factor indicating spoilage in frozen fish and meat products (Khoshnoudi-Nia and Moosavi-Nasab, 2019c). The increasing trend of PV value during storage time could be due to increase in free heme and/or other prooxidants in myofibrils of fish muscle after death (Nanditha and Prabhasankar, 2008; Khoshnoudi-Nia and Moosavi-Nasab, 2019b). In agreement with our finding, Bavitha *et al.* (2016) on fish burger produced from catla (*Catla catla*) showed that PV increased to 4.98 meq/kg fat after 17 days storage at 4±1°C. In this study, PV and FFA values of surimi burgers were in the standard range during storage. Therefore, rancid odor did not develop in the fish burger during 90 days of frozen storage and desired quality was maintained.

Using SDS-PAGE, raw surimi showed characteristic bands with MWs of 194.6, 112.2, 109.6, 51.3 and 14.6-18.1 KDa which were related to MHC, c-protein, α-actinin, actin, and MLC proteins, respectively. All these specific bands were observed in fish burger, but with a less intensity due to the use of only 60% raw surimi to prepare fish burger. Moreover, SDS-PAGE analysis showed that the intensity of protein bands in fish burger did not change during frozen storage confirming that protein subunits were relatively stable in fish burger within 90 days of frozen storage. The results were in agreement with those reported by Moosavi-Nasab *et al.* (2019) about SDS-PAGE of fish nugget during 90 days of frozen storage. Inhibition of myofibrillar proteins denaturation during frozen storage can be related to the cryoprotective effect of other additives (filler and binder) in fish burger formulation. Cryoprotectant substances are effective in preventing denaturation of myofibrillar proteins during frozen storage. Matsumoto (1980) hypothesized a different effect that the cryoprotectant molecules of low weight carbohydrate may bind or associate with protein molecules at one of the functional groups either by ionic bands

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or by hydrogen bands. Thus, each protein molecule is coated with cryoprotectants. Moosavi-Nasab (2003) on Alaska Pollock surimi with flaxseed, whey protein and soy protein cryoprotectants showed that intensity of myofibrillar protein subunits were quite stable during frozen storage at -20°C for 2 years. The similar observation in SDS-PAGE was found in some related previous studies (Panpipat *et al.*, 2010; Van Phu *et al.*, 2010; Priyadarshini *et al.*, 2017).

In this study, fish burger was produced from sarm (*S. commersonnianus*) surimi and other ingredients. Physicochemical and sensory properties were compared with beef burger as a popular product. Cooking loss and shrinkage of fish burger was significantly lower than those of beef burger. However, PV value and FFA content of fish burger increased during storage, but these values were in the standard range. Data showed that frozen sarm fish burger maintained its quality and showed relatively acceptable physicochemical properties up to 90 days of frozen storage. Good sensory properties were a positive point for commercialization of surimi burger and related products. Thus, surimi and fish burger can be suitable and safe substitute for beef burger in meat industry for human consumption and it can be a good example of producing value-added products from relatively low cost fish.

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