Textural and chemical attributes of sausages developed from Talang Queenfish *(Scomberoides commersonnianuus)*mince and surimi

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Abstract

Talang Queenfish (*Scomberoides commersonnianuus*) is relatively inexpensive fish with low consumption in Fars Province, South of Iran. In this research which was performed in 2011, sausages were produced from mince and surimi of this species and some physicochemical attributes of the products were investigated during 60 days of cold storage at 4 °C. According to the results, free fatty acid (FFA), peroxide and TBARS values of minced fish sausagewere significantly higher than thosefor surimi sausage ($p<.05$). It was found that minced fish sausage significantly had ($P<.05$) more breaking and gel strength compared to the surimi sausage at each time of preservation. There were significant differences ($P<.05$) in L*, a* and whiteness colorimetric parameters of the sausages. Scanning electron microscopy images demonstrated that the surface porosity increased during preservation. This study demonstrated that surimi sausage had better textural and chemical characteristics than minced fish sausage during cold storage.

Keywords: Minced fish, Surimi, Sausage, Colorimetry, Texture

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Introduction

Nowadays, demanding for meat products is high because they are safe, nutritious, varied and attractive in appearance and texture (Desmond, 2006; Kemi et al., 2006).Recently, manufacturing meat basis products like sausages from new kinds of meat sources such as fish and poultry has been developed (Farouk et al., 1999; Jimenez-Colmenero, 2000; Ruusunen and Puolanne, 2005). Some of the developments have been based on beneficial effects on health (Kantha, 1987). Fish stock encounters with a great threat due to increasing demand for traditional raw materials to obtain fish protein ingredients (Hultin, 2002). This matter has caused overfishing of some substantial species and has required governmental notice to prevent the shortage of important species (Hultin et al., 2005). One method to avoid overfishing problem is production of fish protein ingredients such as surimi, minced fish, and fish protein isolate using different methods or new fish species (Shaviklo, 2006). In general, surimi contains about 76% water, 15% protein, 6.85% carbohydrate, 0.9% fat and 0.03% cholesterol (Chaijan et al., 2004; Jin, 2007). Many studies have focused on the use of various functional ingredients in sausage formulations (Beggs et al., 1997; Shand, 2000; Ripoche et al., 2001). Suitable properties of surimi such as light colour, bland odour, low fat content and high in myofibrillar proteins as well as considerable functional characteristics due to the unique gelling property of its concentrated proteins, make surimi as a perfect functional ingredient to make up new food products (Han-Chingand and Leinot, 1993; Venugopal and Shahidi, 1995; Lanier, 2000). In brief, surimi is an inexpensive and healthy source of protein that can be used as a convenience meat sources in food product formulations such as burgers, noodles and sausages (Park, 2005).

Commonly, fresh meat products are kept at refrigerated temperatures in the range of 2-5 ºC (Gheisari, 2011). Hence, due to microbial growth and lipid oxidation at this storage condition, a lot of undesirable components could be formed (Raharjo et al., 1992). Rancidity is one of the significant changes which occur due to lipid oxidation (Gheisari, 2011). Texture plays an important role in acceptance of food products. There are several studies on textural properties of meat muscle and meat products especially sausage and ham. Tensile test has been carried out for determination of mechanical properties of meat and meat basis products (Willems and Purslow, 1996). Herrero et al. (2007) applied tensile tests to dry fermented sausages to determine their breaking strength. Laakkonen et al. (1970)reported that solubilization of connected tissue and denaturation of myofibrillar proteins lead to tenderization and toughening of meat during heating. Cured meat products contain myoglobin, oxymyoglobin, and metmyoglobin pigments. Varied methods are accessible to determine the colours objects of meat products (Uren and Babayigit, 1996). Cardoso et al.(2008) declared that the use of 5.2% (w/w) chicory root inulin and 2.6% (w/w) extra hake mince in fish sausage formulation results in an increase in gel strength and hardness values compared to the control fish sausage . Groninger et al. (1983) found that the fish

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sausage prepared from the muscle that was ground while thawed had an acceptable texture in comparision with the sausage prepared from muscle ground while frozen. Shaviklo (2007) studied some properties of fish sausages produced from mince fish and surimi of silver carp. He declared that the fish sausages made from silver carp minced fish have a distinct fishy smell and taste which are not acceptable by many of Iranian consumers.

The main objectives of this study were to produce fish and surimi sausages as novel meat basis products and eventually comparison of their physicochemical properties after 0, 14, 30, 45 and 60 day storage at 4±1 ºC.

Materials and methods

Talang Queenfish (approximately 65 kg) was purchased from local market in Fars province, (south of Iran) and transferred to the Department of Food Science and Technology of Shiraz University and kept chilled for 48 h at -18 °C and then was taken and refrigerated overnight at 4 °C for further processing. The fish were manually filleted or eviscerated and then deboned and washed prior to be minced by a meat grinder (Nasional Co., Iran) equipped with a die (Pore diameter = 4 mm). Then, approximately 20 kg of the minced fish was processed to surimi. The process involved three washing steps by cold water (25±1 °C) for removing water soluble proteins and then dewatered using cheese cloth filtration. In each step, the ratio of water to the minced meat was 4:1 (w/w). During each washing step, the mixture was stirred for 5 min. For more dewatering, at the third step, 0.2% NaCl was added to the mixture and during the dewatering period a 15 kg weight was placed on the cloth filter for 10 min (Moosavi-Nsab et al., 2005).

The chilled surimi and minced fish were reached to room temperature (approximately 25 °C) prior to be minced again to obtain a homogenous texture. Basic formulation of the sausages is shown in Table 1.

Table 1. Basic formulation for minced fish and surimi sausages production

Constituents	Amount (%)	Constituents	Amount (%)
Minced fish or Surimi	60.66	Corn starch	1.52
Crushed ice	14.20	Gluten	1.01
Sunflower oil	10.11	Textured soy protein	5.05
Nitrite	0.01	Casein	2.27
Na-3-Polyphosphate	0.20	Ascorbic acid	0.10
Salt	1.62	Spices	3.28

As Table 1 shows, with the exception of the used type of meat (surimi or minced fish), other constituents of the minced fish and surimi sausages were similar. The used meat materials were chopped in a mixer (Aleranderwerk, A.FW 140/83

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model,Germany) at low speed for approximately 1 min. Then salt, sodium tripolyphosphate (Merck Co, Germany) and half of crushed ice were added to the mixer and continuously chopped for 2 min at higher speed. Then textured soy protein, three quarters of the oil, ascorbic acid and the remained ice were added. Finally, remainde part of the oil as well as the spices were added to the mixture at low speed for 30 s. Eventually, the processed paste was stuffed into a standard collagen casing using a filler (Aleranderwerk, A.FW 45/78 model, Germany) and then sealed (12±2 cm length). The sealed sausages pasteurized at 78 ºC for 2.5 h before cooling at 4 ºC overnight. The produced fish and surimi sausages were evaluated for physicochemical properties after 0, 14, 30, 45 and 60 days of storage at 4±1 ºC.

In order to ensure that the pasteurization process of the products has been occurred as expected, microbial counts were performed. Plate count agar (PCA) and potato dextrose agar (PDA) were used as microbial culture media for total counts and mold-yeast counts of the products, respectively after 24 h incubation at 37 °C in an incubator according to the AOAC standard method (AOAC, 2006). After removing the casing at each storage time, chemical analysis tests were performed in triplicates on all samples. Moisture content was determined using an oven(Galenkamp, 1H-100 model, UK) according to the AOAC standard (AOAC, 2006). Total protein (Crude protein, N = 6.25) content was determined using the Kjeldahl method according to the AOAC standard methods (AOAC, 2006). Fat content was determined by the Soxhlet–Henkel method (AOCS, 2006). Ash content was determined by mineralisation at 550 ºC according to the AOAC standard methods (AOAC, 2006).

A STM-50 texture analyzer (Sanatam, IR-UK Ltd) with a 25 kg load cell was used to measure textural properties. The tensile test was performed to determine breaking strength of the samples during cold storage. Generally, at each storage time, three pieces of the samples was cut approximately 100 mm long, 10 mm wide and 5 mm thick. Two tensile clamps were used for the test in which one tensile clamp was installed to the textural analyzer base while the other one was attached to the load cell. The prepared samples were placed between the mentioned clamps on the texture analyzer. A cross-head speed of 2 mm/s was applied to the samples until rupture. The maximum force (N) required for breaking the samples was recorded using a programmed computer. To calculate breaking strength (N/cm^2) the maximum breaking force was divided into cross-sectional area (Thickness × Width) of the portions (Herrero et al., 2007; Herrero et al., 2008; Honikel, 1998).

Puncture test was conducted based on the method reported by Kim and Park (2000). A spherical ended probe with 6 mm diameter and crosshead speed of 2 mm/s was used for the test. For this reason, cylindrically shaped samples with lengths and diameters of 15 and 20 mm were cut into test specimens. The textural testes were carried out in triplicate.

The cylindrical shape of samples with 20 mm diameter and 10 mm length were prepared to evaluate L*, a* and b*colour parameters of Hunter Lab (strictly L*, a* and b*) colorimetric system. L* is lightness component in the range of 0 to 100 while a*

[DOR: 20.1001.1.15622916.2014.13.1.19.9]

(Redness parameter) and b* (Yellowness parameter) are two chromatic components without numerical limit (Afshari-Jouybari and Farahnaky, 2011). In this study, a* and b* value scales were reported from -44 to +44. The samples were placed in a box (50×50×60 cm) under homogenous light distribution condition (K = 6500). The images were obtained using a digital camera placed vertically at 35 cm distance from the samples. The angle between the axis of the lens and the sample was approximately 45 ° . The attained images with RGB format were converted to L*, a* and b* values of Hunter Lab color space using image processing toolbox of MATLAB (The Mathworks Inc., MA, United State) (Fernandez et al., 2005). Finally, whiteness index was calculated as described by Lanier et al. (1991) as follows:

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

At each sampling time (0, 14, 30, 45 and 60 days) 25 g of the products was used for lipid extraction using the AOCS method (2006). Acid value test was carried out to determine the quantity of free fatty acid (FFA) formed in the sausages during cold storage at 4 ºC. Titration is one of the methods that is widely used to measure FFA in a fat or extracted fat from a sample (Melton, 1983). Acid value was determined according to AOCS and reported as the number of milligrams of sodium hydroxide necessary to neutralize the FFA in 1 g of the oil. Peroxide value is a measure of the concentration of peroxide and hydroperoxide components formed during the initial stages of lipid oxidation (Salih et al., 1989). The AOCS standard method (2006) was applied to determine the peroxide value of the products. The peroxide value (POV) was calculated and expressed as milliequivalents peroxide per kg of the sausages samples. The extension of lipid oxidation at each sampling time was assessed by measuring thiobarbituric acid reacting substances (TBARS) according to the method described by Mei et al. (1998). The results expressed as mg malonaldehyde per 10 kg of the products specimens.

Thin layers of the samples were coated with gold using an ion sputter (Fisons Instruments, UK). The coated samples were viewed and photographed using the scanning electron microscope (SEM) (model 5526, Cambridge, UK) at 20 kV.

One-way analysis of variance (ANOVA) by SPSS 17 (SPSS Inc., Chicago, IL, USA) was performed for the analysis of the data. Duncan test at 95% confidence level was accomplished to determine the effect of different storage time on the physicochemical properties of the samples. Factorial test was carried out to indicate simultaneous effects of type of product (A factor) and storage time of the samples (B factor) (Moosavinasab and Yousefi, 2011). Data were presented as the mean of each result and the standard deviation (SD) of the mean.

Results

Figure 1 shows microbial counts of the products after 24 h of cooking (pasteurization) process. No significant difference was observed between microbial counts of the products ($p>.05$).

The results of the compositional analysis of the two products are represented in Table 2. As shown, the total protein, fat and ash

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contents of the surimi sausage samples were significantly lower ($p<.05$) than that of minced fish sausage samples at time zero ($p<.05$). Surimi sausage had significantly higher moisture content attributed to the high moisture content of the surimi used in its formulation ($p<.05$).

Table 2-Chemical composition of the products at time zero

Samples	%Moisture	%Total protein	%Fat (dry basis)	%Ash
Minced fish sausage	65.46^{c}±0.49	19.42^{a}±1.34	19.12^{a}±0.44	2.09^{b}±0.00
Surimi sausage	67.45^{b}±0.47	14.61^{c}±1.61	16.82^{b}±1.12	3.01^{a}±0.00
Surimi	76.13^{a}±1.13	15.14^{b}±0.43	1.09^{c}±0.16	1.40^{c}±0.01

* Data are the mean of three replicates± standard deviation

** Different letters within a column indicate significant differences (p<.05).

Breaking strength (BS) values of the produced sausages obtained from tensile test are shown in Table 3. Analysis of tensile test showed statistically difference ($p<.05$) indicating a great dispersion of BS between both studied samples during cold storage. There was a significant difference in 'product type × storage time' interaction ($p<.05$). Results showed that increasing storage time resulted in an increase of the products BS, thus, more tensile strength was needed to rupture.

Table 3–Changes in textural properties of sausages from mince and surimi during 60 days of storage at 4 °C

Storage time (d)	Breaking strength (N Cm $^{-2}$)		Gel strength (N Cm)	
	mince	Surimi	mince	Surimi
0	1.71^{e}±0.05	1.08^{e}±0.03	1.24^{e}±0.07	0.96^{e}±0.01
14	2.53^{d}±0.01	1.25^{d}±0.04	1.69^{d}±0.03	1.09^{d}±0.07
30	3.73^{c}±0.03	1.81^{c}±0.07	2.35^{c}±0.06	1.38^{c}±0.03
45	5.49^{b}±0.08	2.70^{b}±0.02	3.20^{b}±0.08	1.74^{b}±0.04
60	6.04^{a}±0.06	3.60^{a}±0.02	3.45^{a}±0.05	2.15^{a}±0.05

* Data are the mean of three replicates± standard deviation

** Different letters within a column indicate significant differences ($p<.05$).

Value of weight loss due to decrease in moisture content of the samples during storage is represented in Table 4. There was a positive correlation between the extent of decrease in moisture content of the samples and firmness values of those during storage (r=0.91).

[DOR: 20.1001.1.15622916.2014.13.1.19.9]

Table 4- Values of weight loss during storage

Storage time (d)	mince sausage (g)	Surimi sausage (g)
14	9.64^{d}±0.82	10.12^{d}±0.25
30	11.63^{c}±0.21	12.23^{c}±0.30
45	14.53^{b}±0.83	14.92^{b}±0.82
60	17.61^{a}±0.51	17.75^{a}±0.12

* Data are the mean of three replicates± standard deviation

** Different letters within a column indicate significant differences ($p<.05$).

RGB images of the samples were converted to Lab format using image processing Toolbox of MATLAB. The changes in Hunter Lab color parameters of the samples during storage are shown in Table 5. CIE L* values showed an overall significant decrease in lightness of both kinds of sausages over the storage period.

Table 5- Changes in hunter lab parameters during storage

Storage time (d)	Surimi sausage			Mince sausage		
	*L**	*a**	*b**	*L**	*a**	*b**
0	60.8^{a}±2.7	-0.3^{a}±0.4	5.4^{c}±0.9	55.6^{a}±0.9	1.6^{a}±0.8	5.9^{c}±0.3
14	57.2^{ab}±3.3	-0.3^{a}±0.5	5.6^{c}±0.6	53.8^{a}±1.9	$1.1a^{b}$±0.8	6.3^{c}±0.7
30	53.2^{bc}±2.9	-0.7^{ab}±0.1	6.8^{bc}±0.3	47.8^{b}±2.7	0.9^{ab}±0.2	8.1^{b}±0.4
45	52.8^{bc}±2.4	-1.1^{bc}±0.3	8.3^{ab}±0.8	44.3^{b}±2.9	0.3^{bc}±0.5	9.0^{a}±0.6
60	49.5^{c}±2.9	-1.6^{c}±0.4	9.5^{a}±2.2	44.9^{b}±0.7	-0.3^{c}±0.2	8.5^{ab}±0.8

* Data are the mean of three replicates± standard deviation

** Different letters within a column indicate significant differences ($p<.05$).

The results showed a significant difference for lightness value between the products at all times of storage. CIE a* value of the products decreased ($p<.05$) throughout the study, while b* value increased slightly. Comparison between a* parameter of two types of production indicated a significant difference due to using the washing steps during surimi production process. Eventually, calculation of whiteness parameters demonstrated that this index significantly was affected by both storage time and product type ($p<.05$).

Changes in acid value during refrigerated storage are shown in Fig. 3. Acid values increased significantly over the storage period in both surimi and minced fish sausages. The results indicated that lipolysis was augmented with increasing the storage time. As shown in Fig. 4, increasing storage period caused an increase in peroxide values. There was a positively correlation between the acid value and peroxide value (r=0.99) as expected. The extent of oxidative rancidity in a fat may also be determined by its TBA number. TBA

[DOR: 20.1001.1.15622916.2014.13.1.19.9]

values were found to be affected by the storage period ($p<.05$), which resulted in an increase of TBA values (Fig. 5). As indicated, the TBA values continuously increased up to 55.5 and 61.5 mg malonaldehyde per 10 kg of surimi and minced fish sausage, respectively for 60 days of storage. A significant positive correlation was found between TBA and acid values (r=0.96) as well as TBA and peroxide values (r=0.98) which demonstrated a suitable coincidence between these oxidation factors. Except for peroxide value for both TBA and acid values the 'product type × storage time' interactions were significantly different ($p<.05$). It was found that there was a significant difference between acid, peroxide and TBARS values of the products samples during preservation ($p<.05$).

Differences in microstructure of both samples were observed by scanning electron microscopy at times 0 and after 60 days of storage are shown in Fig. 6. As indicated in the images, for both kinds of the products void and open structure were observed after 60 days of storage (Fig 6-b and Fig 6-d in comparison with Fig 6-a and Fig 6-c).

Discussion

Maximum permissible counts for total bacteria and mold-yeast for sausages products according to the Iranian standard institute (Gheisari, 2011) are 1×10^5 and 1×10^2 CFU/g. As shown, the obtained total bacteria and mold-yeast counts of both products were in the permissible range indicating appropriate thermal process of the sausages.

The significant differences between the chemical compositions of the mince fish and surimi sausages were due to use of three washing steps to produce raw surimi in which high extent of sarcoplasmic proteins, fat and ionic materials are removed (Park and Morrisey, 2000).

Dehydration of cooked sausage during storage is one of the main reasons for increasing firmness value (Murphy et al., 2004). As shown, minced fish sausage exhibited a significant difference ($p<.05$) in BS compared to the surimi sausage (Table 3) during storage time due to the higher protein content. Filho et al. (2010) declared thatthe inclusion of the obtained minced fish from Nile tilapiafilleting wastein substitution to the fillet caused to increase in the softness of the produced sausages, represented by the decrease in the attained values for chewiness, cohesiveness and hardness. Cardoso et al.(2008) found that the use of 5.2% (w/w) chicory root inulin and 2.6% (w/w) extra hake mince in fish sausage formulation resulted in a increase in gel strength and hardness values. Ahhmed et al. (2007)reported that the breaking strength of chicken and beef sausages increased by addition of transglutaminase with the rise in temperature from 40 to 80 °C. Gel strength of minced fish sausage was significantly ($p<.05$) higher than that of surimi sausage. Aggregation of myofibrillar proteins result in forming gel structure in emulsion-type meat products like sausages (Park, 2005). Kim and Park (2000) stated that gel strength is not a suitable measure of gel's properties because this textural property is affected by quantity and quality of proteins. As a result, it was found that the higher amount of proteins in minced fish sausage (19.41 %) than surimi

[DOR: 20.1001.1.15622916.2014.13.1.19.9]

sausage (14.61 %) caused higher gel strength of minced fish sausage compared to surimi. According to the results, the author's findings are in agreement with Kim and Park(2000) data and their suggestion. In brief, for these products, the quantities of proteins showed more effect on the gel strength than their quality (Actomyosin or Sarcoplasmic). Herrero et al. (2008) reported that sausage formulation constituents play an important role in firmness of the products. They classified some cooked meat sausages into three groups based on BS and some texture profile analysis (TPA) parameters. Murphy et al. (2004) reported that increasing surimi and fat level together in pork-surimi sausage resulted in a decrease in hardness force values from 28.7 to 15.1 N.

Because of using three cyclic washing steps to produce raw surimi, considerable amounts of the pigments which naturally exist in fish flesh were eliminated. This matter caused an increase in the lightness value of surimi sausage compared to minced fish sausage. Due to oxidation of some color constituents especially myoglobin, the redness parameter a* of Hunter Lab color space consequently decreased. As shown in Fig. 2 for surimi sausage, whiteness value was higher than minced fish sausage at all of the storage times because of the especial color characteristics of the surimi used in surimi sausage formulation. Murphyet al. (2004) reported that the L* value in some recipes of surimi-pork sausage decreased significantly from 71.57 to 55.95 only 12 days after preservation, while for a* and b* values no significant changes were observed. Jo et al. (2000) reported that the L* value of irradiated pork sausage increased up to 71 during storage whereas for a* value this effect was decreasingly. According to the results, it is clear that the type of employed meat in sausage formulation has a remarkable impact on the changes of color parameters.

During storage, the level of free fatty acids in the products depends on the hydrolytic activity of lipase as well as oxidative reactions that change the free fatty acids released in lipolysis (Soriano et al., 2006). The amount of fat in fish flesh reduced during surimi production processfrom 2.9 to 1.1%, therefore, the acid values of surimi sausage were significantly lower than that of minced fish sausage during storage. Free fatty acid content is an index of the extent to which hydrolytic rancidity has occurred in a product. Free fatty acids content is used broadly as a conventional indication of the condition and edibility of pure oils and fats and the fat extracted from food products, including meat (Levermore, 2004). Toldra (1998) reported that a significant percentage of the generated free fatty acids in dry meat products had been due to phospholipid hydrolysis. Toldra (2006) related that lipids and phospholipids are hydrolyzed by lipase and phospholipase, yielding free fatty acids, which are oxidised into peroxides. As expected, by increasing period of storage the peroxide values consecutively increased due to more oxidation (Levermore, 2004). As mentioned before, because of higher content of fat in fish flesh than surimi, more oxidation products such as peroxides and malonaldehyde produced during the cold storage of the samples. Peroxide formation during storage

[DOR: 20.1001.1.15622916.2014.13.1.19.9]

was low at the first stages of oxidation because of induction period, the length of which will depend on the nature of the fat and the presence of antioxidants and then rapidly increased due to high rate of formation (Gotoh and Wada, 2006). High peroxide values are a definite measure of rancidity in fats (Levermore, 2004). There was a significant difference between the TBA value of surimi sausage compared to that of minced fish sausages because of those results that was noticed for acid and peroxide values, respectively. TBA values may represent the content of secondary lipid oxidation products. Increasing oxidation and proteolysis rates can increase secondary products, such as malondialdehyde and biogenic amine formation (Kurt and Zorba, 2009). The effects of storage period on TBA values were in accordance with the results of Bozkurt and Erkmen (2004) who reported that TBA values were significantly related to an increased storage period for sucuk (Turkish dry fermented sausage). As with peroxide value, a low TBA value is not exactly a measure of fat quality because aldehydes may have not yet formed or volatile aldehydes may have been lost during processing and storage (Tokur et al., 2006). The significant differences between FFA, peroxide and TBARS values of the samples were due to the higher fat content of minced fish sausage compared to surimi sausage, because susceptibility to lipid oxidation is closely related to fat level of the samples (Tang et al., 2001). The obtained results for TBA values of surimi sausage during the storage period was approximately similar to the Murphy et al. (2004) data for two sausage recipes of pork-surimi basis. This similarity was more specially after 14 days of storage, when the TBA value reached to 28.6 mg malonaldehyde per 10 kg of surimi sample. Raju et al. (2003) reported similar results for the produced sausages from threadfin bream fish flesh. They concluded that the amount of FFA and PV values consequently increased over storage time, but in the presence of 50 ppm nisin the changes were strongly low. Similar results were reported by Cardoso et al. (2008) for produced fish sausage from African hake (*Merluccius capensis*) during 83 days of storage at 2 °C.

Since the moisture content of the samples decreased during storage, this open form of structure indicated lower water retained in the network of the samples at 60 days of storage compared to time zero (Table 4) (Riebroy et al., 2005).

In this study two types of fish sausage consisting minced fish and surimi sausages were produced. Then, some physicochemical properties of the produced sausages during cold storage at 4 °C over 60 days were studied. As a result, surimi sausage whiteness value was higher than minced fish sausage at all times of storage because of the especial color characteristics of the surimi used in surimi sausage formulation. Because of higher content of fat in the fish flesh than surimi, more oxidation products such as peroxides and malonaldehyde produced during the cold storage of the samples. Analysis of tensile test showed statistically difference ($p<0.05$) indicating a great dispersion of BS between both studied samples during cold storage. The obtained images using SEM indicated more

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void and open structure of the sausages after 60 days of storage compared to time zero. This study demonstrated that surimi sausage had better physical and chemical attributes than minced fish sausage during cold storage at 4˚C.

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