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Effect of gelatin based edible coatings on quality of surimi from pearl mullet (*Alburnus tarichi,* Güldenstädt, 1814) during cold storage

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Abstract

A two-phase study was designed to investigate the effects of pH and salt concentration of washing solution on quality and yield of surimi from pearl mullet fillets and edible coatings on quality of the resultant surimi during cold storage. In the first phase, higher salt concentration increased gel strength of surimi and improved some other textural attributes. Surimi obtained by conventional method was found to be superior as higher yield, dry matter and protein contents were achieved. In the second phase of the study, surimi samples coated by 4 different coating formulations were stored at 4°C for 10 days along with fish mince and uncoated surimi as control. TVB-N values of coated samples were not significantly increased during storage while that of fish mince reached to 53.6 mg/100 g sample on the 7th day of storage. Acidity of all samples increased leading to lower ultimate pH values while ultimate pH of coated samples was not significantly different from that of control. In general, gelatin and chitosan based edible coatings were found not meaningfully effective in extending the shelf life of surimi under conditions studied and coating formulations used with while surimi itself showed prolonged shelf life compared to fish mince.

Keywords: cold storage; edible coating; pearl mullet; seafood quality; surimi.

Practical Application: An endemic fish species, pearl mullet, can be utilized in surimi production as an alternative value-added seafood. In addition, edible coatings may be utilized in cold preservation of surimi for extended shelf life and quality.

1 Introduction

Surimi is a popular product especially in some Asian and American countries, usually obtained from low fat fish meat (Tsuda et al., 2015). In surimi production, muscle proteins are aimed to be isolated while lipids, blood, enzymes and sarcoplasmic proteins are discarded to obtain a high-quality protein mixture, which is then frozen in the presence of cryoprotectants (Wu, 2016). Although about 60% of surimi is produced from haddock, this has recently diminished with successful use of other species (Park, 2000). Dry matter of surimi, which is a refined form of chopped fish, is mainly formed of muscle proteins. Surimi is used as a raw material in some imitated food products manufactured in various ways. These products such as shrimp, scallops and crab are imitated by surimi besides Japanese traditional food Kamaboko, which is also produced from surimi (Kolsarıcı & Ensoy, 1996). Surimi is a high-quality protein source and is naturally poor in lipids, cholesterol and calories (Şen et al., 2017). In addition, surimi may be used in production of antioxidant peptides and bioactive peptides by hydrolysis (Wang et al., 2020). In fact, washing water of surimi manufacturing, which is rich in proteins, may be utilized in fortification of food products in terms of their nutritional value (Oliveria et al., 2020).

Recently, health concerns related to food industry has gained tremendous attention both from consumers and scientists. Consumers prefer products that are not heat treated and free of food additives. Therefore, studies on processing techniques like non-thermal processing methods and new packaging materials have been on focus of recent researches from all over the globe. Edible films and coatings have been studied in terms of their potential in preserving the quality of seafood and extending their shelf life (Feng et al., 2016).

There are various polymers used as carrier in edible films and coatings, as well as many bioactive ingredients used for their useful effects like limitation of oxidation and microbial growth. Whey protein, for example, may be used in formulation of edible films and/or coatings, leading to superior mechanical properties in the presence of oligosaccharides (Fernandes et al., 2020). Corn starch is another polymer that can be used in active edible films, mechanical properties of which are greatly affected by mixing method and the level of added active ingredients (Santoso et al., 2019). Processing waste of various food manufacturing processes, like potato peel waste, may find a place in formation of edible films and coatings (Othman et al., 2017). Gelatin, on the other hand, is such a polymer widely used in studies on edible films and coatings, which is a hydrolyzed form of collagen, the major protein of connective tissue of animals (Calvarro et al., 2016). Gelatin is widely used in pharmaceuticals, foods and medical products, just to mention a few. Its films and coatings are edible and biodegradable that comes with no harm on environment and human health along with some technological advantages like low gas permeability, ease of application, low cost and widespread availability (Bahmanzadeh et al., 2018).

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Chitosan is de-acetylated form of chitin, which is the most common secondary polymer in the world derived from crustaceans such as shrimp and crab. Chitosan is a complex carbohydrate and a naturally derived ingredient, which has antimicrobial effects (Cisse et al., 2012; Feng et al., 2016). Pearl mullet (*Alburnus tarichi,* Güldenstädt, 1814) is an endemic fish species that lives in lakes and rivers of Van plateau, Turkey, and its annual harvest amount is approximately 13000 tons (Kılınççeker & Küçüköner, 2003).

In this study, pearl mullet fillets were used to get fish mince as starting material for surimi production obtained by altered washing solutions differing in pH levels and salt concentrations to investigate the effects of different pH and salt levels on product yield, gel strength, protein and dry matter content along with some textural features of the resultant surimi. After the determination of the process leading to the highest yield and quality, a follow-up study was carried out to determine the effects of gelatin based edible coatings in 4 different formulations fortified with rosemary extract or rosemary oil on the quality of surimi stored at 4°C for 10 days during cold storage.

2 Materials and methods

2.1 Materials

Pearl mullet (*Alburnus tarichi*, Güldenstädt, 1814), an endemic fish species to Lake Van Basin, Turkey, was obtained from a local fish market, immediately brought to the laboratory on ice, washed by cold tap water, beheaded, eviscerated and filleted manually. Fillets were used in surimi production after mincing by a Waring blender (Stamford CT, USA). Process flow scheme of surimi production is given in Figure 1.

In formulation of edible coatings, bovine hide edible gelatin (Gel) was used as carrier polymer; both sorbitol (Sor) and glycerol (Gly) as plasticizers; %90 deacetylated chitosan (Chi), rosemary extract (RE) and rosemary oil (RO) as antimicrobial and antioxidant agents, respectively. Abbreviations used for surimi groups and formulation of coating solutions applied are given below:

- SUR-C: No edible coating applied.
- SUR-1: 5% Gel, 0.5% Sor, 0.5% Gly, 0.5% Chi (Edible coating, EC).
- SUR-2: EC fortified with 1% RE (EC+1% RE).
- SUR-3: EC fortified with 2% RE (EC+2%RE).
- SUR-4: EC fortified with 2% RO (EC+2% RO).

All chemicals used in surimi production and analyses were of analytical grade and obtained from Sigma-Aldrich (Missouri, USA) and Merck (Darmstadt, Germany).

2.2 Experimental design

This study was carried out in two consequential stages, in the first of which surimi was produced from pearl mullet fillets by 10 different washing solutions in the second washing step to see the effects of pH and salt concentration on yield and quality of the resultant surimi. At the second, surimi considered to be the best according to the yield and quality was used for a storage trial in where the effect of edible coatings formulated with rosemary extract and rosemary oil was investigated during cold storage at 4°C for 10 days.

In the surimi production trial, 10 different surimi samples were obtained by different washing solutions in the second washing step as control that was just with distilled water (1), others were with solutions at 6 different pH levels of 4, 5, 6, 7, 8, and 10 as set by 0.1 or 1 N HCl and NaOH solutions appropriately (2-7) and at 3 different salt concentrations of 0.25, 0.5 and 1% NaCl (w/v) dissolved in distilled water (8-10) as treatments. Therefore, only difference among the samples was washing solution used in the second washing step differing in pH level and salt concentration, considered to be the treatment, which affects the precipitation of myofibrillar proteins according to pH of washing solution and isoelectric point of the target proteins, and salting out effect for the target proteins according to the salt concentration of washing solution, respectively.

Surimi with the highest yield and quality was then used for coating and cold storage trial in where 5 groups of surimi samples were used, uncoated as control (1) and others coated by gelatin based edible coatings with no further active ingredients (2), fortified with rosemary extracts at 2 different concentrations (3 and 4) and finally

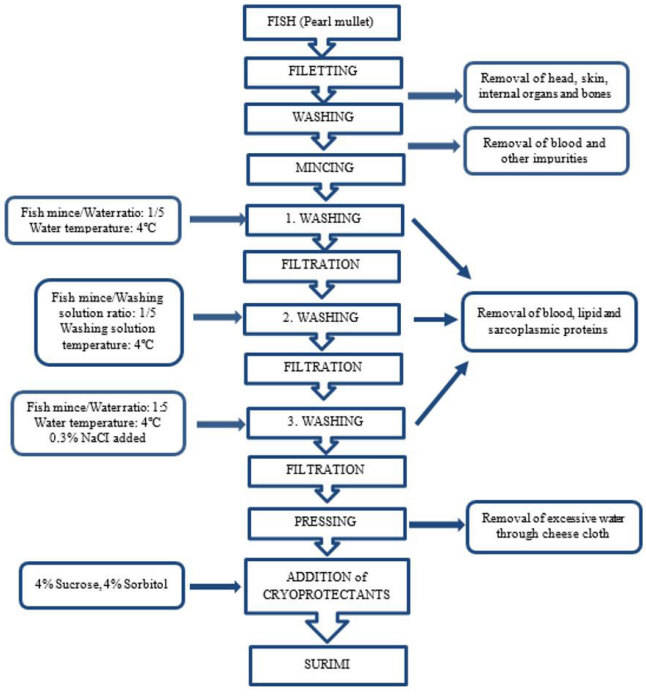

Figure 1. Process flow scheme for surimi production.

fortified with rosemary oil (5). After surimi samples were formed in ice cube trays and coated by spraying, the samples were placed in zipped refrigerator bags and stored at 4°C for 10 days (Figure 2). Surimi production was duplicated and all analyses were triplicated unless otherwise was stated. Storage study was a one-time trial and all measurements were at least triplicated.

2.3 Methods

Crude Nitrogen and Protein Content

Crude protein content of the samples was determined by Kjeldahl method (Horwitz, 2002, AOAC 954.01). 12 mL of sulfuric acid and 1 piece of Kjeldahl tablet as catalyzer were added on approximately 1 g of sample. After successful incineration, the tubes were cooled before distillation. After addition of both 75 mL of distilled water and %33 NaOH solution to each tube, distillation was carried out until about 150 mL distillate was collected onto 25 mL mixture of boric acid, methyl red and bromine cresol green indicator. After distillation, titration was performed by 0.1 N HCl.

Dry Matter and Crude Ash Content

Dry matter and crude ash content of the samples were analyzed according to the methods of AOAC International (Horwitz, 2002, AOAC 934.01 and AOAC 942.05, respectively). 5 g of fresh sample was dried at 105°C until constant weight typically within 8 hours. Similarly, previously dried samples were used for analysis of crude ash content by incineration in porcelain crucibles at 550°C until constant weight typically within 5 hours. Both dry matter and crude ash content were calculated based on weight loss of the initial samples.

Crude Fat Content

Crude fat content was determined by solvent extraction according to the method by AOAC International (Horwitz, 2002, AOAC 960.39), in which n-hexane was used as solvent. 5 g of sample was weighed into a paper cartridge and approximately 6 hours of extraction was carried out. Crude fat content was calculated based on gravimetrical difference.

pH Measurement

pH value of samples was measured according to the method reported by Soares et al. (2013). 2 g of samples was weighed and homogenized within 20 mL of distilled water. Homogenized samples were used for pH measurement carried out by a portable pH meter (SG7, Mettler Toledo, OH, USA) after successful calibration with buffer solutions of 4.00 and 7.00 before the measurements.

Analysis of Total Volatile Basic Nitrogen

Total volatile basic nitrogen (TVB-N) content was analyzed according to the method reported by Olgunoğlu (2007). 50 mL of distilled water was added to 10 g of sample in a beaker. Homogenized sample was transferred to a distillation tube along with 1 g of magnesium oxide. About 50 mL of distillate was collected into 10 mL of 3% boric acid. Distillate was titrated with 0.1 N HCl in the presence of methyl red as indicator.

Gel Strength and Texture Profile Analysis

Gel strength was measured as Bloom test (British Standards Institution, 1975) with slight modifications. Surimi gels prepared in a height of 20 mm were subjected to 8 mm penetration by using TA-XT2 texture analyzer (TA-XT II, Texture Technologies, MA, USA) and 12.7 mm diameter flat surface cylindrical probe. The force required for 8 mm penetration was given as gel strength in g. Similarly, texture profile analysis (TPA) was carried out by 2 times successive compression of surimi samples under a 50 mm in diameter flat surface cylindrical probe up to a 40% compression level, i.e. 8 mm compression for a sample 20 mm in height. The graph obtained was used for calculation of textural parameters such as hardness, adhesiveness, and springiness (Bourne, 2002).

Product Yield and Cooking Loss

Surimi yield was calculated based on the difference between the amount of surimi obtained and the initial amount of fish mince used for surimi production. Calculation was done according to the formula below:

$$Surimi\ yield\,(\%) = \frac{Weight\ of\ surimi}{Weight\ of\ \ fish\ mince} \times 100$$

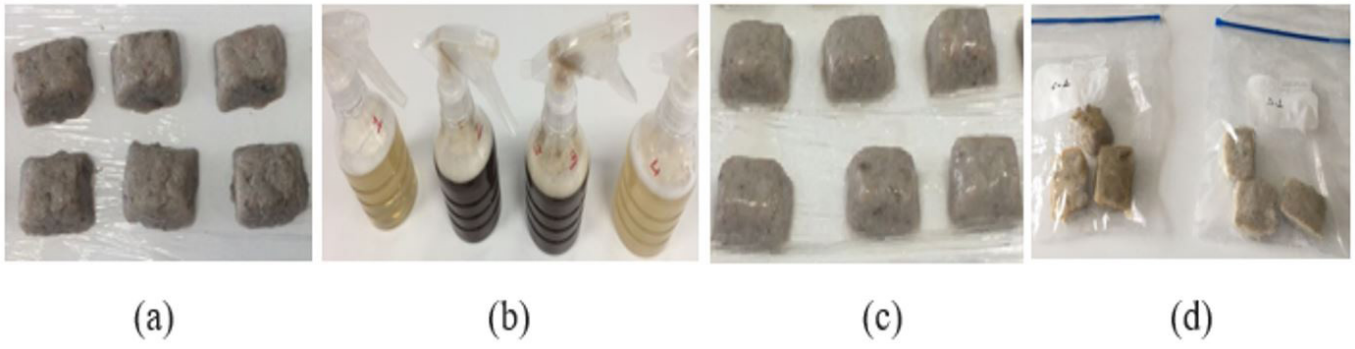

Figure 2. Formed surimi (a), coating solutions in sprayers (b), coated surimi samples (c), coated samples in zipped bags as stored (d).

For calculation of cooking loss, an electric grill was used to cook each sides of formed surimi samples for 3 min. After cooling the samples, cooking loss was calculated based on the difference between the weight of cooked surimi and its initial weight. The results were given according to the formula below:

$$Cooking\ loss(\%) = \frac{Initial\ weight\ of\ surimi - Weight\ of\ cooked\ surimi}{Initial\ weight\ of\ surimi} \times 100$$

Analysis of Color Difference

Color measurements were taken from at least five different points of surimi samples using a colorimeter (CSM5, PCE Instruments, Southampton Hampshire, UK). Difference in color of samples during storage was determined by total color difference (ΔE) value according to the formula given below (Chinnaswamy & Hanna, 1988).

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

Statistical Analysis

The data was statistically analyzed by one-way analysis of variance to determine if there was any significant difference among the pairs. Tukey-Kramer test was utilized in order to determine which pairs were significantly different at a significance level of 0.05 using JMP 8.0 (SAS, NC, USA).

3 Results and Discussion

3.1 Proximate composition of surimi

Proximate composition of fish mince and surimi from pearl mullet fillets is given in Table 1. Surimi had slightly lower protein content compared to that of fish mince due to loss of sarcoplasmic proteins and non-protein nitrogen. Both fat and mineral contents of surimi were also lower than that of fish mince due to loss of these components during several washing treatments of surimi production. On the other hand, moisture content of surimi was slightly higher compared to that of fish mince at a negligible level. In a previous study reported by Süle (2011), mince and surimi obtained from Prussian carp (*Carassius gibelio*, Bloch, 1782) were also compared for their proximate composition and similar results were reported as such surimi was lower in protein, mineral and fat content in comparison with the mince. Moisture content, on the other hand, was higher in mince, which may be due to species specific differences.

Table 1. Proximate composition of fish mince and resultant surimi from pearl mullet (%).

	Moisture	Crude protein	Crude fat	Mineral
Fish mince	77.6 ± 0.1	15.0 ± 0.1	4.1 ± 0.1	1.3 ± 0.1
Surimi (control)	78.8 ± 0.1	12.7 ± 0.4	1.4 ± 0.2	0.7 ± 0.1

Values are in mean ± standard deviation of triplicate measurements.

3.2 Yield and some quality parameters of surimi

Yield, gel strength, protein and dry matter content of surimi samples are given in Table 2. Surimi yield changed between 31.25 and 49.27% depending on pH level and salt concentration of solutions used in the second washing step. The highest yield was obtained in pH 4.0 considering all 10 samples, 1 as control, 3 different in salt concentrations and 6 different in pH levels. However, this level of yield was not significantly different from that of those surimi samples obtained as control and by different salt concentrations. On the other hand, the rise of pH from 4.0 led to significantly lower yield values, most probably due to limited hydrolysis and precipitation of proteins at higher pH values. Higher yield in pH 4.0 may be attributed to excessive hydrolysis of myofibrillar proteins at highly acidic conditions that resulted in higher amount of protein in surimi obtained, which is in part consistent with higher yield and dry matter content. It was also evident that the sample pH 10.0 resulted in the lowest yield and dry matter content, which was probably due to excessive wash out of proteins and other non-protein content of fish mince. Although there were significant differences among the samples considering yield and dry matter content, the values were in a quite narrow range except the sample pH 10.0. Similarly, there were significant differences among protein content of surimi samples although that was within a rather narrow gap framed within 10.39 and 12.67%.

Considering gel strength of surimi samples, it may be concluded that higher salt concentration resulted in higher gel strength, most probably due to potential role of salt ions as binding aid among protein structures. Lee et al. (2016) studied combined effect of pH and heating conditions on physical properties of surimi gels of Alaska Pollock. Surimi dough was prepared at different pH values (4.0-10.0) and a two-step heating was applied. Results concluded that deformability and gel strength were the highest at around pH 7.5-8.0. On the other hand, the lowest values of above-mentioned parameters were at pH 6.0, 6.5 and 10.0. In addition, two-step heating treatment increased the breaking force by 2 times compared to one-step fast heating. Priyadarshini et al. (2017) reported a study in where tilapia fish mince was washed according to either traditional method or an alternative method in where alkaline salt (single wash) solution was utilized. Their results concluded that alternative method by alkali salt washing led to higher gel strength. Tahergorabi et al. (2012) investigated the effect of salt and salt substitutes on instrumental quality of surimi. Their results showed that salt and salt substitutes improved gel texture in surimi even at higher levels in case of salt compared to salt substitutes, which is consistent with the results reported in the present study.

3.3 Textural attributes of surimi

Textural attributes of surimi samples calculated based on TPA graphs are given in Table 3. The lowest hardness value was observed in 0.25% NaCl sample although higher NaCl concentrations led to higher hardness values, consequently the highest in 1% NaCl sample. Likewise, the highest cohesion value was obtained in 1% NaCl surimi and the lowest in 0.25% NaCl. The highest adhesion, on the other hand, was in surimi obtained by pH 10.0 and the lowest was in pH 8.0. When it comes

Table 2. Physical and chemical features of surimi obtained by different washing solutions.

	Yield (%)	Dry matter (%)	Protein (%)	Gel strength (g)
Control	45.42 ± 1.11^{ABC}	21.18 ± 0.11^{CD}	12.67 ± 0.42^{A}	383.10 ± 9.73^{ABC}
pH 4	49.27 ± 1.04^{A}	25.24 ± 0.38^{A}	11.90 ± 0.51^{AB}	336.23 ± 33.76^{BCD}
pH 5	38.86 ± 0.95^{CDE}	21.68 ± 0.27^{C}	10.39 ± 0.34^{C}	332.28 ± 32.70^{CD}
pH 6	41.32 ± 4.66^{ABCD}	22.79 ± 0.23^{B}	12.08 ± 0.11^{AB}	263.81 ± 9.49^{D}
pH 7	34.90 ± 3.59^{DE}	22.57 ± 0.27^{B}	12.52 ± 0.57^{A}	295.83 ± 21.25^{CD}
pH 8	39.31 ± 2.29^{BCDE}	22.66 ± 0.25^{B}	11.97 ± 0.20^{C}	390.94 ± 13.81^{ABC}
pH 10	31.85 ± 5.00^{E}	18.92 ± 0.28^{E}	10.53 ± 0.25^{C}	399.85 ± 34.80^{AB}
NaCl 0.25%	48.30 ± 3.90^{AB}	20.60 ± 0.01^{D}	11.07 ± 0.07^{BC}	261.15 ± 2.80^{D}
NaCl 0.50%	47.78 ± 1.93^{ABC}	22.68 ± 0.41^{B}	10.59 ± 0.89^{C}	321.22 ± 17.27^{BCD}
NaCl 1%	42.73 ± 1.56^{ABCD}	21.46 ± 0.30^{C}	12.66 ± 0.36^{A}	519.01 ± 7.76^{A}

Values are in mean ± standard deviation of triplicate measurements. Different letters in the same column indicate significant difference among the samples at a significance level of 0.05.

Table 3. Textural attributes of surimi from pearl mullet obtained by different washing solutions.

	Hardness	Cohesion	Adhesiveness	Springiness	Gumminess	Chewiness
Control	339 ± 17DE	0.60 ± 0.05^{AB}	20.51 ± 11.50^{AB}	68.60 ± 4.24^{AB}	205.1 ± 27.9^{C}	141.1 ± 24.6^{D}
pH 4	425 ± 4^{BC}	0.64 ± 0.02^{A}	14.94 ± 3.06^{AB}	74.10 ± 1.45^{A}	270.5 ± 7.0^{B}	200.5 ± 9.1^{B}
pH 5	347 ± 32DE	0.62 ± 0.01^{AB}	19.49 ± 9.34^{AB}	71.91 ± 1.30^{AB}	214.1 ± 15.0^{C}	154.1 ± 13.2^{CD}
pH 6	458 ± 44^{B}	0.61 ± 0.03^{AB}	13.07 ± 3.04^{AB}	68.56 ± 2.63^{AB}	278.7 ± 15.5^{B}	190.8 ± 4.0^{BC}
pH 7	318 ± 6DE	0.63 ± 0.02^{AB}	25.72 ± 9.01^{AB}	71.23 ± 1.79^{AB}	201.01 ± 7.7^{C}	144.0 ± 9.1^{D}
pH 8	303 ± 9^{E}	0.64 ± 0.03^{A}	6.16 ± 1.21^{A}	71.10 ± 3.00^{AB}	193.8 ± 8.2^{C}	137.8 ± 9.5^{D}
pH 10	168 ± 16^{F}	0.58 ± 0.06^{AB}	45.64 ± 27.13^{B}	70.04 ± 10.06^{AB}	98.8 ± 19.2^{D}	70.5 ± 23.2^{E}
NaCl 0.25%	170 ± 14^{F}	0.54 ± 0.03^{B}	21.30 ± 7.30^{AB}	59.78 ± 6.19^{B}	91.6 ± 9.0^{D}	55.0 ± 9.5^{E}
NaCl 0.50%	373 ± 17^{C}	0.58 ± 0.03^{AB}	23.11 ± 7.16^{AB}	67.25 ± 2.54^{A}	215.6 ± 18.9^{C}	144.8 ± 9.7^{D}
NaCl 1%	519 ± 12^{A}	0.67 ± 0.03^{A}	16.91 ± 10.81^{AB}	74.97 ± 3.51^{A}	347.1 ± 14.7^{A}	260.3 ± 16.4^{A}

Values are in mean ± standard deviation of triplicate measurements. Different letters in the same column indicate significant difference among the samples at a significance level of 0.05.

to springiness, the highest value was in surimi sample obtained by 1% NaCl and the lowest was in 0.25% NaCl. Considering the chewiness, the highest value was in 1% NaCl surimi and significantly different from other samples (P<0.05). The lowest chewiness and gumminess values were in 0.25% NaCl surimi. Results showed that the concentration of NaCl in the second washing step significantly affected the textural attributes of surimi, as such the higher NaCl concentration, the greater textural attributes. In a study reported by Yu et al. (2017), surimi from silver carp was produced and compared with a commercial frozen surimi in the presence of different concentrations of different salts. They used NaCl at 1, 2 and 3%; KCI at 1.27, 2.55 and 3.82%; CaCl at 0.63, 1.27 and 1.89% (w/w) and examined the effect of salts and their concentrations on textural and physicochemical properties of surimi. It was determined that hardness, chewiness and adhesion increased with higher salt concentrations while springiness did not change significantly.

Overall results showed that differences in the second washing step did not lead to significant differences in general, while higher salt concentrations resulted in some improvements in textural attributes. Therefore, the method as control for surimi production was concluded to be the best considering the yield, protein content and gel strength achieved; and surimi obtained accordingly was further used for coating and cold storage trial.

3.4 Quality of coated surimi during cold storage

Change in Total Volatile Basic Nitrogen Content

TVB-N is produced upon protein decomposition by microbial and enzymatic activity. TVB-N value is an important indicator of the level of protein degradation (Kong et al., 2017). TVB-N value is expected to increase during storage of high protein animal foods. In the present study, changes in surimi samples were, in general, slight and not stable. On the other hand, fish mince showed significant (P<0.05) and steady increase during storage and reached to a level of 54 mg TVB-N/100 g sample at the 7th day of storage (Table 4).

TVB-N of all surimi samples were below 6 mg TVB-N/100 g sample during 10 days of cold storage (Table 4). Thaker et al.

(2015) reported that TVB-N content of Indian salmon stored at 6°C reached to a level of 35.11 mg/100 g on the 8th day of storage, which was consistent with our study, concluded a TVB-N value of 36.78 mg/100 g at the 7th day of storage.

Change in pH Value

Change in pH of surimi samples during cold storage at 4°C for 10 days is given in Table 5. Generally speaking, pH value of all samples significantly decreased beginning from the 2nd day of storage most probably due to increase in the concentration of organic acids upon microbial activity (P<0.05). Initial pH values of coated surimi samples were also slightly lower compared to that of control uncoated, most probably due to the ingredients used in the formulation of coatings. Eventually, all samples reached to the same ultimate pH level of about 4.7 except the control with 4.9, which was a negligible difference although significant (P<0.05) at the end of the 10 days of cold storage. In a study reported by Süle (2011), it was determined that initial pH value of fish mince increased upon addition of cryoprotectants. She

Table 4. Changes in TVB-N content (mg TVB-N/100 g sample) during cold storage.

	Initial	Day 1	Day 3	Day 5	Day 7	Day 10
FM	5.53 ± 0.04^{d}	7.90 ± 0.06^{d}	26.94 ± 1.95^{c}	36.78 ± 0.59^{b}	53.55 ± 2.14^{a}	ND
SUR-C	2.56 ± 0.03^{Bb}	2.71 ± 0.12^{Ab}	2.73 ± 0.09^{Bb}	5.30 ± 0.22^{Aa}	2.72 ± 0.03^{Ab}	5.11 ± 0.04^{Aa}
SUR-1	5.29 ± 0.43^{Aa}	2.77 ± 0.01^{Ab}	5.43 ± 0.08^{Aa}	2.69 ± 0.05^{Bb}	2.45 ± 0.05^{Ab}	2.66 ± 0.13^{Bb}
SUR-2	2.62 ± 0.04^{Ba}	2.74 ± 0.04^{Aa}	2.75 ± 0.05^{Ba}	2.57 ± 0.05^{Ba}	2.36 ± 0.36^{Aa}	2.73 ± 0.05^{Ba}
SUR-3	2.73 ± 0.03^{Bb}	2.69 ± 0.12^{Ab}	2.67 ± 0.09^{Bb}	2.74 ± 0.08^{Bb}	2.77 ± 0.01^{Ab}	5.25 ± 0.09^{Aa}
SUR-4	5.35 ± 0.04^{Aa}	2.69 ± 0.14^{Ac}	3.95 ± 1.67^{Aabc}	2.74 ± 0.07^{Bbc}	2.64 ± 0.10^{Ac}	5.13 ± 0.23^{Aab}

Values are in mean ± standard deviation of triplicate measurements. Different lowercase letters in the same row indicate significant difference during storage. Different uppercase letters in the same column indicate significant difference among surimi samples (P<0.05). FM: Fish Mince, SUR-C: Uncoated Surimi, SUR-1: EC, SUR-2: EC+%1 RE, SUR-3: EC+%2 RE, SUR-4: EC+%2 RO, ND: Not Determined.

Table 5. Changes in some quality indicators during cold storage of coated surimi.

Indicator	Samples	Initial	Day 1	Day 3	Day 5	Day 7	Day 10
pH	SUR-C	2.56 ± 0.03^{Bb}	2.71 ± 0.12^{Ab}	2.73 ± 0.09^{Bb}	5.30 ± 0.22^{Aa}	2.72 ± 0.03^{Ab}	5.11 ± 0.04^{Aa}
	SUR-1	5.29 ± 0.43^{Aa}	2.77 ± 0.01^{Ab}	5.43 ± 0.08^{Aa}	2.69 ± 0.05^{Bb}	2.45 ± 0.05^{Ab}	2.66 ± 0.13^{Bb}
	SUR-2	2.62 ± 0.04^{Ba}	2.74 ± 0.04^{Aa}	2.75 ± 0.05^{Ba}	2.57 ± 0.05^{Ba}	2.36 ± 0.36^{Aa}	2.73 ± 0.05^{Ba}
	SUR-3	2.73 ± 0.03^{Bb}	2.69 ± 0.12^{Ab}	2.67 ± 0.09^{Bb}	2.74 ± 0.08^{Bb}	2.77 ± 0.01^{Ab}	5.25 ± 0.09^{Aa}
	SUR-4	5.35 ± 0.04^{Aa}	2.69 ± 0.14^{Ac}	3.95 ± 1.67^{Aabc}	2.74 ± 0.07^{Bbc}	2.64 ± 0.10^{Ac}	5.13 ± 0.23^{Aab}
Storage Loss (%)	SUR-C	0.54 ± 0.14^{Bb}	1.64 ± 0.47^{Cb}	9.29 ± 1.94^{Aa}	12.39 ± 0.98^{Aa}	12.12 ± 1.64^{Aa}	0.54 ± 0.14^{Bb}
	SUR-1	1.23 ± 0.22^{Ad}	5.78 ± 0.10^{ABc}	10.38 ± 1.00^{Ab}	13.09 ± 0.56^{Aa}	13.33 ± 0.16^{Aa}	1.23 ± 0.22^{Ad}
	SUR-2	1.23 ± 0.06^{Ad}	6.22 ± 0.27^{Ac}	10.63 ± 0.30^{Ab}	13.17 ± 0.29^{Aa}	13.34 ± 0.62^{Aa}	1.23 ± 0.06^{Ad}
	SUR-3	1.51 ± 0.24^{Ad}	6.19 ± 0.31^{ABc}	10.58 ± 0.45^{Ab}	13.11 ± 0.06^{Aa}	13.33 ± 0.32^{Aa}	1.51 ± 0.24^{Ad}
	SUR-4	1.15 ± 0.11^{Ad}	5.24 ± 0.48^{Bc}	10.68 ± 0.41^{Ab}	13.26 ± 0.18^{Aa}	13.46 ± 0.31^{Aa}	1.15 ± 0.11^{Ad}
Cooking Loss (%)	SUR-C	56.41 ± 3.75^{Aab}	59.84 ± 3.56^{Aa}	41.11 ± 0.19^{ABc}	48.28 ± 0.36^{Abc}	56.26 ± 0.60^{Aab}	51.65 ± 0.37^{Aab}
	SUR-1	52.03 ± 0.85^{ABa}	40.87 ± 0.73^{Bb}	50.28 ± 0.29^{Aa}	52.87 ± 1.07^{Aa}	45.08 ± 3.17^{Bab}	45.57 ± 1.59^{ABa}
	SUR-2	58.66 ± 4.10^{Aa}	36.41 ± 4.66^{Bb}	47.16 ± 5.36^{Aab}	44.28 ± 7.98^{Aab}	46.64 ± 1.89^{Bab}	46.54 ± 0.74^{ABab}
	SUR-3	49.02 ± 3.03^{Aa}	36.96 ± 0.25^{Bc}	41.02 ± 0.02^{ABbc}	47.83 ± 0.70^{Aa}	41.64 ± 2.67^{Bbc}	45.33 ± 1.44^{ABab}
	SUR-4	45.00 ± 4.98^{Aa}	41.26 ± 7.17^{Ba}	34.80 ± 0.42^{Ba}	44.24 ± 1.06^{Aa}	41.08 ± 0.95^{Ba}	42.94 ± 0.81^{Ba}
ΔE Value	SUR-C	-	1.91 ± 0.37^{Ac}	10.09 ± 1.52^{Ab}	14.57 ± 3.08^{Bab}	16.73 ± 2.77^{Ba}	15.57 ± 2.63^{Bab}
	SUR-1	-	2.98 ± 1.82^{Aa}	7.76 ± 1.41^{Aa}	8.35 ± 1.56^{Ba}	7.16 ± 2.25^{Ba}	6.47 ± 4.05^{Ba}
	SUR-2	-	2.67 ± 1.18^{Aa}	6.05 ± 4.47^{Aa}	7.41 ± 1.27^{Aa}	2.34 ± 1.06^{Aa}	5.13 ± 1.98^{Aa}
	SUR-3	-	3.87 ± 3.01^{Aa}	6.11 ± 2.83^{Aa}	6.55 ± 1.81^{ABa}	7.24 ± 2.35^{Ba}	9.37 ± 7.30^{Ba}
	SUR-4	-	4.56 ± 3.03^{Aa}	1.54 ± 1.18^{Aa}	3.18 ± 1.55^{Ba}	7.73 ± 2.93^{Ba}	6.70 ± 4.27^{Ba}

Values are in mean ± standard deviation of triplicate measurements. Different lowercase letters in the same row indicate significant difference during storage while different uppercase letters in the same column indicate significant difference among surimi samples (P<0.05) separately for each parameter. FM: Fish Mince, SUR-C: Uncoated Surimi, SUR-1: EC, SUR-2: EC+%1 RE, SUR-3: EC+%2 RE, SUR-4: EC+%2 RO.

also determined that pH value increased with 90 days of storage, which was expected because of amine formation upon protein hydrolysis. In the present study, storage was not probably long enough to see that increase in pH. Turan & Sönmez (2010) produced 2 groups of surimi from stingray (*Raja clavata*) fish. The first group included 4% of sorbitol, 4% of sucrose and 0.3% of sodium tripolyphosphate, and the second group was with 8% of sorbitol and 0.3% of sodium tripolyphosphate. They stored surimi samples at -23.8 ± 2°C for 6 months and observed that pH of the first group was 7.34 while it was 6.98 in the second group, indicating that cryoprotectants and their levels are effective on pH of surimi significantly. pH of fish muscle is affected by many factors including initial microbial load and microflora, storage conditions, packaging and related measures, etc. An initial drop but later ultimate rise in pH was associated with microbial activity at first resulted in organic acids and further hydrolysis of proteins leading to volatile amines, respectively (Thaker et al., 2015).

Storage and Cooking Loss Values

Storage loss is an indicator of weight loss as vaporization and was observed in all samples during cold storage, which was significant but slightly in higher levels for coated samples, due to loss from coating itself. The difference between coated and uncoated samples was also significant ($P<0.05$). Weight loss in control reached to a level of 12% at the end of 10 days of cold storage while that was about 13% in uncoated samples. There was no significant difference among coated samples in terms of weight loss. It was observed that initial weight loss rate decreased after 5 days of cold storage (Table 5). The highest loss was found in SUR-4 with 13.36 ± 0.31 percent.

Cooking loss value, on the other hand, determines the amount of water lost during cooking. It is associated with water holding capacity of meat proteins. The greater water holding capacity leads to the lower cooking loss (Alakrash et al., 2016). Significant differences were observed in cooking loss value of the samples ($P<0.05$). Initially high values of cooking loss decreased at first with storage due to water loss but later increased significantly again with further storage. Generally speaking, it might be concluded that cooking loss came to an equilibrium level of 45% for coated samples while it was about 55% for uncoated control.

Change in Color

L value indicates brightness and increased in all surimi samples significantly ($P<0.05$) while differences between surimi samples were insignificant. A steady increase was observed in control reaching the highest L value among the other samples. Ramirez-Guerra et al. (2018) reported significant decrease in L value of uncoated and coated Pacific sierra fish during cold storage. The color of fish may be quite different from its surimi and might increase in L value during cold storage. Considering the value of a, it was slightly negative, indicating negligible greenness, and did not changed significantly during storage in all samples. When it comes the value of b, it was slightly positive, which indicates slight yellowness, but did not significantly differ among the samples during cold storage. Şen et al. (2017) measured color of surimi from sardines and haddock. It was reported that L value decreased by storage while the values of a and b increased. For better evaluation of color change in samples, color difference (ΔE) was calculated, which is given in Table 5. ΔE increased in uncoated surimi during cold storage, which was significant ($P<0.05$). However, changes in ΔE value of coated samples were not significant, indicating that all coating treatments were successful in limiting discoloration of surimi during cold storage.

4 Conclusions

Surimi from pearl mullet was studied for the first time. This study is also one of the few studies on use of edible coatings in seafood. It is concluded that gel strength and some textural attributes of surimi showed enhanced characteristics by increase in salt concentration of the second washing fluid in a limited manner. Nevertheless, alteration of pH and salt concentration of the second washing fluid did not lead to a superior surimi in terms of yield and quality. Gelatin based edible coatings formulated with rosemary extract and oil were effective, to some extent, on the quality of surimi during cold storage in spite of their own drawbacks. It is noteworthy that cooking loss and discoloration was limited in surimi samples by coating. It was also concluded that pearl mullet may be utilized in surimi production, providing a more durable seafood of pearl mullet and an alternative way of consumption. Further research is needed for optimization of formulation of edible films and coatings and their expected use for extension of shelf life of seafood products.

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