

INFLUENCE OF WASHING AND FROZEN STORAGE ON THE MYOFIBRILLAR PROTEIN FRACTION IN SARDINE MINCE FLESH.

Influencia del lavado y almacenamiento congelado en la fracción de las proteínas miofibrilares de la pulpa de sardina.

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ABSTRACT

Frozen storage of fish species, such as sardine, result in detrimental changes in functional properties that determine storage life. Sardine meat is characterized by high fat content, dark meat, and sarcoplasmic proteins that inhibit gel formation. Washing mince flesh with solutions such as sodium bicarbonate is very effective for removing undesirable components. The objective of this research was to study the effects of frozen storage at -30°C in the myofibrillar protein fraction of sardine mince flesh washed with 0.5% sodium bicarbonate solution. Samples of sardine-minced flesh were washed three times with a 0.5% of sodium bicarbonate solution and centrifuged at 3000 rpm for 15 minutes. These samples were divided in lots of 100 g. packed in plastic bags and stored at -30°C, and analyzed every 30 days for 150 days. The myofibrillar proteins were extracted using a phosphate buffer (tris HCl, KCl, EDTA, pH 7.6), and evaluated by SDS-PAGE. The bands were analyzed and digitalized with a Gel Doc 2000 and Quality One 4.1.1 by Bio-Rad. The main bands of myofibrillar protein were identified by comparison of these against a prestained molecular weight standard. After 60 days there was deterioration of the myofibrillar protein fraction with apparent molecular weight between 220 and 65KD, and the formation of molecular aggregates at high molecular weight occurred. After 120 days due to myofibrillar protein deterioration, protein and peptides with low molecular weight were formed and increasing throughout frozen storage. Understanding the mechanism involved in the deterioration of the mince flesh during frozen storage we would enable to help the establishment of quality parameters and ability to predict storage life for that product.

Key words: Sardine, frozen storage, myofibrillar protein, sodium bicarbonate, washing.

RESUMEN

El almacenamiento congelado de especies pesqueras, como la sardina, resulta en cambios significativos en sus propiedades funcionales las cuales determinan su tiempo de vida en almacenamiento. La pulpa de sardina se caracteriza por un alto contenido de grasa, músculo oscuro, y proteínas sarcoplasmáticas que inhiben la formación de geles a base de esta pulpa. Aplicando tratamiento de lavado a la pulpa de sardina se remueven compuestos indeseables para la preparación de productos a base de esta pulpa y a la vez aumentando su tiempo de vida en anaquel. El objetivo del presente estudio fue evaluar el efecto del almacenamiento en congelación a -30°C sobre la fracción de las proteínas miofibrilares de la pulpa de sardina tratada con soluciones al 0,5% de bicarbonato de sodio. Lotes de pulpa de sardina se le aplicó tratamiento de lavado con una solución de bicarbonato de sodio al 0,5% y luego centrifugadas a 300 rpm por 15 min. para la eliminación del agua remanente. Lotes de 100 gr. fueron empacados en bolsas de polipropileno y almacenadas a -30°C y analizadas cada 30 días durante 150 días. Las proteínas miofibrilares fueron extraídas con buffer fosfato (tris HCl, KCl, EDTA, pH 7,6), y evaluadas por la técnica de electroforesis, SDS-PAGE. Las bandas de las diferentes proteínas y sus productos de degradación fueron analizadas y digitalizadas utilizando un Gel Doc 2000 y un programa Quality One 4.1.1 de Bio-Rad. Las principales bandas y sus productos de degradación fueron identificados por comparación de estos contra un estándar de peso molecular. A los 60 días se observó el comienzo del deterioro de las proteínas miofibrilares con pesos moleculares aparentes entre 220 y 65KD, y la formación de agregados moleculares de alto peso molecular. A los 120 días este deterioro se hace más pronunciado apareciendo gran cantidad de bandas de bajo peso molecular, péptidos, los cuales incrementan a medida que transcurre el tiempo de almacenamiento congela-

do. Sin embargo, estos cambios son menos severos que los observados en la pulpa de sardina sin tratamiento (control). La evaluación de los cambios que envuelven el deterioro de la pulpa de sardina en congelación podría ayudar a establecer parámetros de calidad y permitir predecir el tiempo de vida útil de los productos a base de estas pulpas.

Palabras clave: Sardina, almacenamiento congelado, proteínas miofibrilares, tratamiento con bicarbonato de sodio.

INTRODUCTION

The sardine (*Sardinella aurita*) is a very important low cost fish resource in Venezuela. The annual catch is about 110,000 metric tons [14] with large amount of this catch used for food and canned products and a large amount of this catch is used for animal food and canned products. The consumption of fresh sardine or its frozen sardine products is not well accepted by the consumer because of the high fat content, large percentage of dark muscle, and high concentration of sarcoplasmic proteins. One alternative to increase sardine consumption could be the production of sardine mince flesh. Sardine mince flesh production is a relatively simple process in which muscle is separated from bones yielding a dark flesh meat. The process of producing mince flesh combines muscle components such as lipids, sarcoplasmic proteins, and digestive enzymes, inorganic salts, and low molecular weight organic substances that induce myofibrillar protein denaturation. Myofibrillar proteins are the most important muscle component since they are responsible for the texture attributes and functional properties of muscle in foods [4, 5, 15].

Washing treatment on fish mince flesh helps remove those components that produce denaturation of myofibrillar protein and help to increase gel formation and myofibrillar protein concentration for further mince flesh based product production. The importance of washing treatment is to remove pro-oxidants and components susceptible to lipid oxidation. Several studies have been conducted using washing treatment solutions such as sodium chloride, sodium bicarbonate; sodium phosphate and water to enhance the quality of fish mince flesh [4, 5, 10, 12, 16, 19, 20]. These studies stated that treatment of washing on the fish mince flesh significantly reduces soluble proteins, pro-oxidative enzymes, lipids, and increased gel-forming ability and improved color properties of the final product.

Frozen storage of fish mince flesh has been largely used for preservation of food by decreasing microbial. Conversely, during frozen storage fish mince flesh become unstable and undergoes a number of alterations that determine the end of its storage life. Frozen storage induces protein aggregation, causing hardening of the muscle. Myofibrillar proteins undergo denaturation and aggregation when the water and associated solutes in the tissue are lost due to dehydration by freezing. This

process produces an undesirable texture for the products elaborated from this raw material. Hydrophobic interactions have been identified as a cause of lower extractability and reduction of the functionality of the myofibrillar protein. Similarly, during frozen storage formaldehyde increases its interaction with myofibrillar proteins accelerating their denaturation and aggregation [1, 3, 7, 8, 9, 13, 17]. Moreover, several researchers have concluded that washing, fish mince, will decrease the stability of its products when frozen due to the removal of oxidative compounds and the increased polarity of the residual lipids [10, 12, 20].

For a better understanding of the effects of storage and the subsequent deterioration of the mince flesh during frozen storage, and to help establish quality parameters that would be used to predict storage life for products made with sardine mince flesh the present study evaluated the effects of frozen storage at -30°C for 150 days on the myofibrillar protein fraction of sardine flesh washed with 0.5% sodium bicarbonate solution.

MATERIALS AND METHODS

Material

Sardines were caught from Sucre State, Venezuela, and transported in insulated boxes with ice to the Food Science Technology Institute in Caracas. After reaching the laboratory, the fish were deheaded, gutted and treated with 0.5% sodium bicarbonate (NaHCO_3) solution (1:5 mince flesh:water) (FIG. 1) following the procedure stated by Barrero and Bello [5]. Mince flesh from sardines treated with NaHCO_3 0.5% solution and a control (sardines mince flesh that were not washed) were divided into 100 g lots, packed, frozen at -30°C and stored at -30°C for 150 days until analysis.

Total protein extractable: Total protein content was determined by micro-Kjeldhal method A.O.A.C. [2]. Total extractable protein in saline solution was determined according to the method of Arai [1], with the following modifications: 10g of mince flesh was homogenized with buffer saline (0.45M KCl, 3.38 mM K_2PO_4 and 15.5 Na_2HPO_4 ; I= 0.5, pH 7.5). After 24 hr the supernatant was collected and protein content was determined by micro-Kjeldhal method A.O.A.C. [2].

SDS-PAGE: Sodium dodecylsulphate-polyacrylamide gel electrophoresis (SDS-PAGE) was performed according to Hashimoto *et al.* [11]. Protein extraction was performed following the procedure stated by Ashie *et al.* [3]; 5 g of mince flesh was homogenized with buffer (tris HCl, KCl, EDTA, pH 7.6). Extracted protein was adjusted to 80 $\mu\text{g}/\mu\text{l}$ following method stated by Lowry *et al.* [16] and subjected to electrophoresis in 12% polyacrylamide. Protein molecular weight standard markers ranging from 14.300 to 200.000 DA were purchased from Gibco BRL MA7405. After electrophoresis, the gels were stained with Coomassie Blue R-250 for 20 minutes and destained with 10% Acetic acid, 10% methanol and 80% distilled

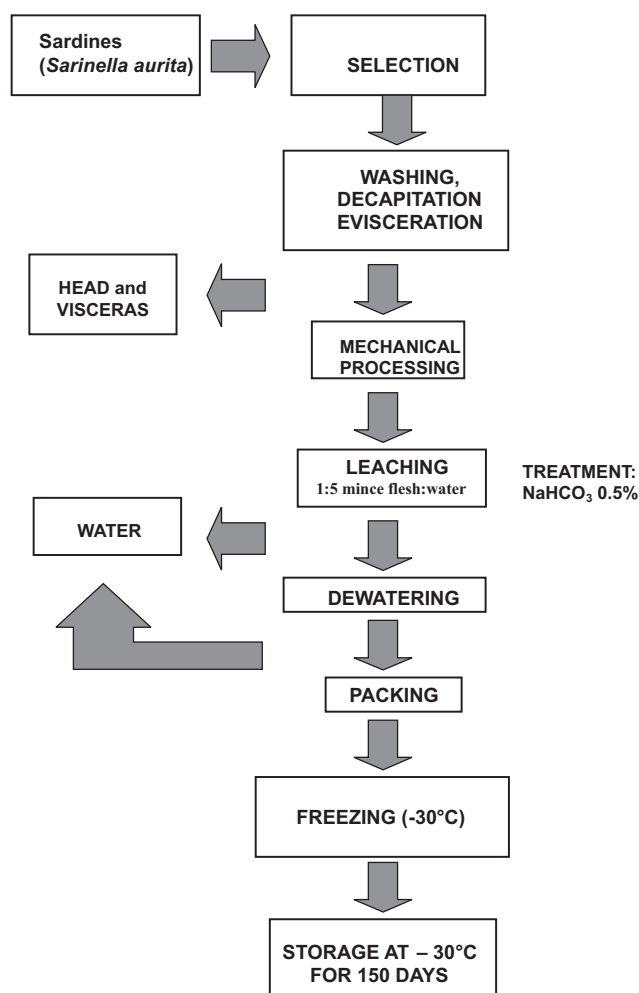


FIGURE 1. SARDINE MINCE FLESH MANUFACTURING STEPS/ DIAGRAMA DE FLUJO PARA LA ELABORACION DE PULPA DE SARDINA.

water solution for 24 hr. The bands of proteins were digitized and their optic density obtained using Gel Doc 2000 Bio-Rad and analyzed by Quantity One 4.1.1 Bio-Rad software.

Statistic analysis: All data were analyzed using Stat Graphic 6.0 (Manugistics, Inc., Rockville MD, USA). The total extractable protein was evaluated using ANOVA at a significant level of 95%. The dependent variable was the concentration for each days evaluated.

RESULTS AND DISCUSSION

Total extractable protein

The initial amount of protein extractable in saline solution was significantly ($P < 0.05$) higher for sardine mince flesh control (7.79%) compared to sardine mince flesh treated with 0.5% NaHCO₃ solution (6.83%) (TABLE I). Total extractable protein decreased from 6.22% to 3.67% for the control after 150 days of frozen storage, representing 41% of the total extractable protein. The most drastic change from 7.91% to 3.67% (53%)

was between 120 and 150 days of storage at -30°C . Conversely, sardine mince flesh treated with 0.5% NaHCO₃ solution decreased drastically from 6.83% to 2.81% representing 58% of the total extractable protein after 30 days of storage at -30°C ; thereafter the protein extractable decreased 46% after 150 days of the frozen storage. Lack of protein solubility during frozen storage was due to interactions responsible for aggregation of the myofibrillar proteins Benjakul *et al.*, [6] stated that these interactions included disulfide bridges as well as formaldehyde formation. They evaluated physicochemical changes of some tropical fish muscle proteins during frozen storage and found that formaldehyde is an effective cross-linker that induces aggregation of protein thereby decreasing protein solubilization. They also noted a decrease in saline protein solubilization due to the exposure of reactive sulfhydryl groups that induce oxidation or disulfide exchange. Moreover, formaldehyde is responsible for oxidation of sulfhydryl groups inducing protein aggregation. Similarly, Careche *et al.* [8] stated that the myosin heavy chain is the most involved protein in aggregate formation. They evaluated the influence of frozen storage temperature to the type of aggregation of miofibrillar proteins in cod (*Gadus morhua*) fillets concluding myosin was more involved than actin in the aggregates at -30°C .

The difference in protein extractability between sardine mince flesh treated with 0.5% NaHCO₃ solution and the control could be due the lack of protection effect of the myofibrillar protein by components such as lipids that are removed during washing treatment resulting in protein aggregation at the beginning of frozen storage. Montero *et al.* and Tejada *et al.* [18, 19] stated the protective effect during frozen storage is due to the lipids contents. They reported that the washing process and cryoprotectants could modify the organization of the myofibrillar protein favoring aggregation during frozen storage.

TABLE I
TOTAL EXTRACTABLE PROTEIN (g/100g $\pm$ SE) FOR SARDINE (*Sardinella aurita*) TREATED WITH 0.5% NaHCO₃ SOLUTION AND CONTROL, STORED AT -30°C FOR 150 DAYS/ PROTEINA TOTAL EXTRAIBLE (g/100g $\pm$ SE) PARA SARDINA (*Sardinella aurita*) ACONDICIONADA CON UNA SOLUCIÓN DE NaHCO₃ AL 0,5% Y ALMACENADA A -30°C POR 150 DÍAS

Storage time (days)	Treatment	
	Control	NaHCO ₃ 0.5%
0	7.79 ^a $\pm$ 1.13	6.83 ^b $\pm$ 1.95
30	6.22 ^a $\pm$ 0.81	2.81 ^b $\pm$ 0.89
60	6.94 ^a $\pm$ 0.60	3.19 ^b $\pm$ 1.09
90	7.91 ^a $\pm$ 1.25	4.34 ^b $\pm$ 1.07
120	4.53 ^a $\pm$ 0.25	2.16 ^b $\pm$ 0.64
150	3.67 ^a $\pm$ 0.08	1.52 ^b $\pm$ 0.20

Result from 4 replications. ANOVA statistical analysis. Assay performed in three replications. a,b- means not followed by the same letter within row differ ($P < 0.05$).

SDS-PAGE

The electrophoresis pattern of myofibrillar protein for sardine mince flesh control and mince flesh treated with 0.5% NaHCO₃ solution during frozen storage at -30°C varied between treatments (FIGS. 2 and 3, TABLES II and III). The most important myofibrillar protein bands, 200 KDa, 41 KDa, 35 KDa and 31 KDa, were correlated to each standard molecular weight marker. Optic density (OD) of myofibrillar proteins increased intensity of the band and band number during frozen storage. As frozen storage advanced, the protein extracted with saline solution increased for low molecular weight products (LMWP) 30 days and after 60 days after initiation of frozen storage for the control and sardine mince flesh treated with 0.5% NaHCO₃ solution respectively. This could be attributed to the higher proteolytic enzyme activity, high lipid content being oxidized, and trimethylamine (TMA) content that produced LMWP in the control samples. Low molecular weight proteins were responsible for the high protein extractable values obtained for the control during frozen storage. Conversely, sardine mince flesh treated with 0.5% NaHCO₃ solution had lower of LMWP at the beginning of frozen storage due to the washing treatment, which eliminated low molecular weight proteins, sarcoplasmic proteins and low molecular weight compounds that can affect degradation during frozen storage. However, sardine mince flesh treated with 0.5% NaHCO₃ solution contained a higher proportion of high molecu-

lar weight products (HMWP) throughout frozen storage. These high proportions of HMWP could be due to the production of proteins aggregations which increased the intensity of the bands between 200 to 45 KDa regions. Since myosin and HMWP are responsible for hydrophobicity, extractable protein from sardine mince flesh treated with 0.5% NaHCO₃ solution decreased during frozen storage. The decrease in protein extraction during frozen storage has been reported elsewhere. Tejada *et al.* [19] concluded that myofibrillar proteins decreased significantly as frozen storage advanced due to the gradual change of salt-extracted proteins in the protein composition. They also stated that during frozen storage there was an increase in high molecular weight band, which did not enter the gel. Futher, Montero *et al.* [17] evaluated chemical and functional properties of sardine (*Sardina pilchardus W.*) dark and light muscle proteins during frozen storage and the effect of washing on mince quality. They stated that the decrease in soluble protein in the treated mince was due in part to the production of high molecular weight polymers through the increase of disulfide bonds. Also, the loss of Ca-ATPase activity due to oxidation of SH-groups on the actomyosin indicated aggregation or denaturation and this loss of activity increased considerably in the first month of storage. After 60 days of frozen storage in 0.5% NaHCO₃ solution, the LMWP increased in number of eletrophoretic bands until the end of storage.

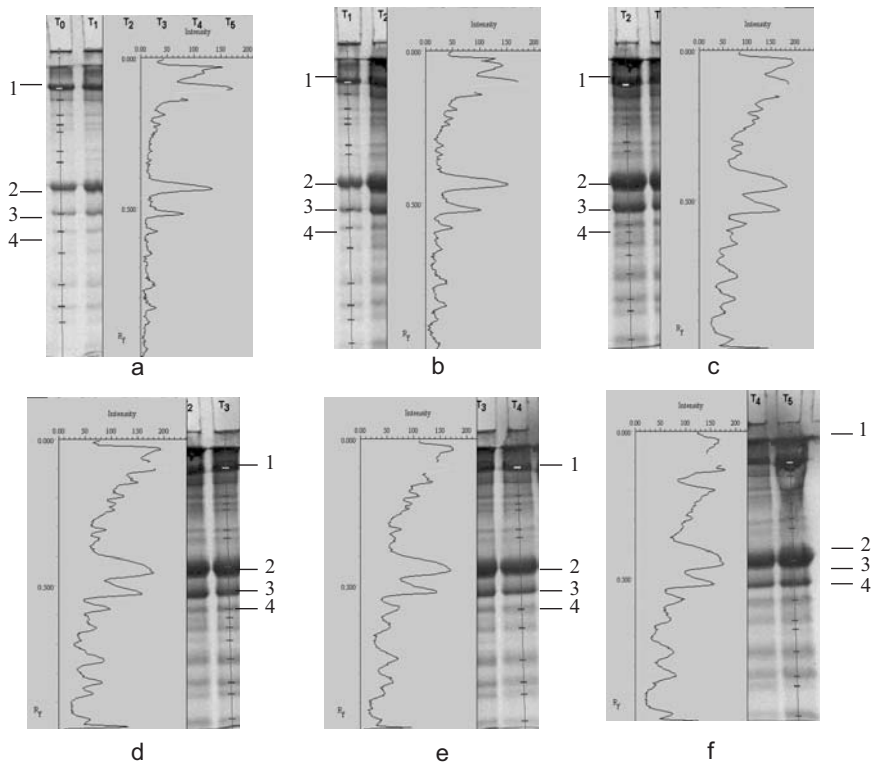


FIGURE 2. SDS-PAGE AND OPTIC DENSITY OF PROTEIN EXTRACTED FROM SARDINE MINCE FLESH (*Sardinella aurita*) STORED AT - 30°C. A- 0 B- 30 C- 60 D-A- 90 E- 120 F- 150 DAYS. 1- 200 KDA, 2- 41 KDA, 3- 35 KDA, 4-31 KDA./
SDS-PAGE Y DENSIDAD OPTICA DE PROTEINAS EXTRAIDAS DE LA PULPA DE SARDINA (*Sardinella aurita*) ALMACENADA A - 30°C. A- 0 B- 30 C- 60 D-A- 90 E- 120 F- 150 DIAS. 1- 200 KDA, 2- 41 KDA, 3- 35 KDA, 4-31 KDA.

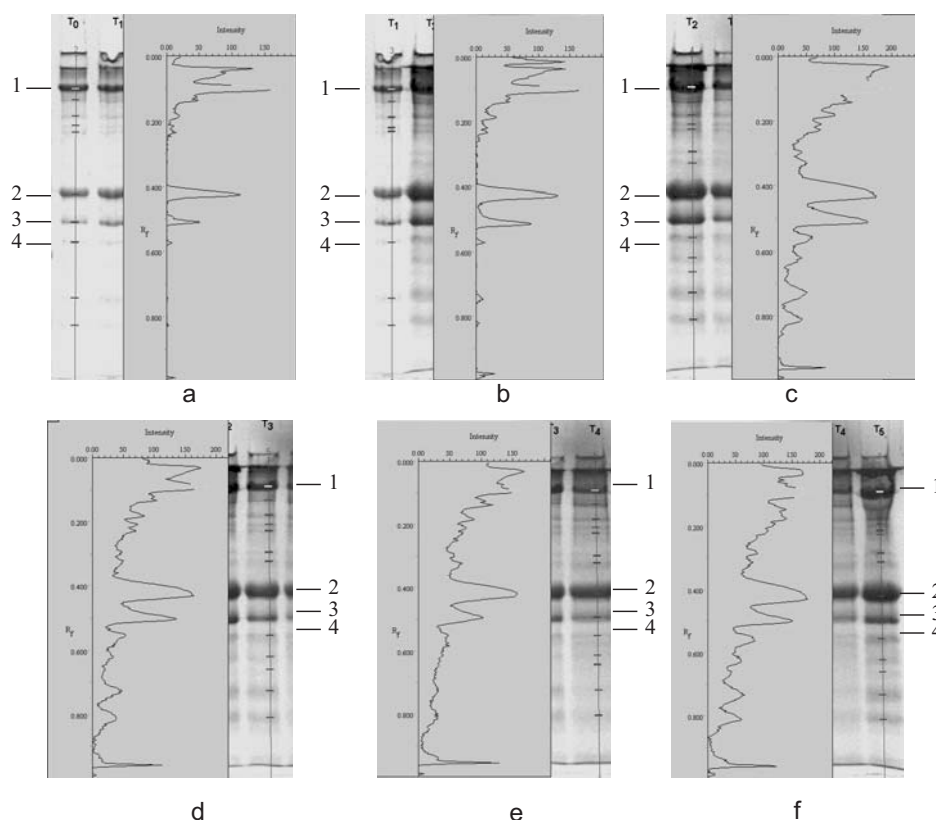


FIGURE 3. SDS-PAGE AND OPTIC DENSITY OF PROTEIN EXTRACTED FROM SARDINE MINCE FLESH (*Sardinella aurita*) TREATED WITH 0.5% NaHCO_3 AND STORED AT -30°C . A- 0 B- 30 C- 60 D- 90 E- 120 F- 150 DAYS. 1- 200 KDA, 2- 41 KDA, 3- 35 KDA, 4-31 KDA/ SDS-PAGE Y DENSIDAD OPTICA DE LAS PROTEINAS EXTRAIDAS DE LA PULPA DE SARDINA (*Sardinella aurita*) ACONDICIONADA CON NaHCO_3 0.5% Y ALMACENADA A -30°C . A- 0 B- 30 C- 60 D- 90 E- 120 F- 150 DAYS. 1- 200 KDA, 2- 41 KDA, 3- 35 KDA, 4-31 KDA.

TABLE II
PROTEIN MOLECULAR WEIGHT (KDA) OBTAINED BY SDS-PAGE AND ANALYZED BY OPTIC DENSITY OF SARDINE MINCE FLESH (CONTROL) DURING FROZEN CONDITIONS AT -30°C . / PESO MOLECULAR DE LAS PROTEINAS OBTENIDAS POR SDS-PAGE Y ANALIZADAS POR DENSIDAD OPTICA DE LA PULPA DE SARDINA (CONTROL) DURANTE EL ALMACENAMIENTO CONGELADO A -30°C

Line #	Standard	0 days	30 days	60 days	90 days	120 days	150 days
1	220.950	166.729	166.032	152.806	171.829	171.480	0.000
2	96.740	128.481	127.745	117.477	124.082	123.709	0.000
3	71.770	93.622	94.344	91.787	0.000	123.709	89.725
4	45.470	81.660	82.223	80.970	0.000	92.261	83.147
5	28.680	73.932	76.281	74.167	75.586	82.331	74.172
6	19.740	59.257	59.998	60.376	59.489	75.353	61.933
7	14.530	53.182	54.798	0.000	54.787	59.865	55.969
8		41.491	41.287	41.650	41.680	55.120	41.238
9		35.505	35.496	34.606	34.985	41.813	35.373
10		31.766	31.737	31.633	0.000	35.478	31.934
11		0.000	27.916	0.000	0.000	31.678	27.873
12		21.909	21.695	0.000	28.109	27.991	0.000
13		18.777	18.577	0.000	0.000	22.117	0.000
14		0.000	16.919	22.444	22.226	18.779	18.434
15			14.558	18.718	18.637	17.265	17.278
16				17.327	17.252	14.486	14.153
				14.393	14.653		

TABLE III
PROTEIN MOLECULAR WEIGHT (KDA) OBTAINED BY SDS-PAGE AND ANALYZED BY OPTIC DENSITY OF SARDINE MINCE FLESH (CONTROL) DURING FROZEN CONDITIONS AT - 30°C/ PESO MOLECULAR DE LAS PROTEINAS (KDA) OBTENIDAS POR SDS-PAGE Y ANALIZADAS POR DENSIDAD OPTICA DE LA PULPA DE SARDINA (CONTROL) DURANTE EL ALMACENAMIENTO CONGELADO A - 30°C

Line #	Standard	0 days	30 days	60 days	90 days	120 days	150 days
1	220.950	189.347	189.767	198.198	207.003	202.960	202.960
2	96.740	145.767	143.058	139.982	149.413	146.633	131.575
3	71.770	100.630	98.866	103.258	105.527	101.445	108.259
4	45.470	88.031	86.245	89.268	90.299	89.485	95.848
5	28.680	81.213	82.373	84.287	83.325	83.544	88.466
6	19.740	43.896	43.733	65.509	65.509	64.500	83.544
7	14.530	36.344	35.995	58.712	59.794	59.971	87.459
8		31.701	31.613	44.018	44.305	44.715	67.504
9		22.857	22.708	36.703	37.182	37.789	61.631
10		19.631	19.479	32.656	33.082	33.201	44.426
11				28.384	28.532	28.795	37.303
12				26.259	26.533	27.321	32.774
13				23.426	23.548	23.637	28.329
14				20.154	20.259	20.450	26.486
15							23.273
16							20.239

CONCLUSION

A remarkable difference between the control and washing treatment with 0.5% NaHCO₃ solution during frozen storage is that the washing treatment with 0.5% NaHCO₃ solution decreased protein denaturation (decrease solubilization of protein) keeping protein on stable conditions for further utilization. Washing treatment with 0.5% NaHCO₃ resulted enhance sardine mince flesh and could be recommended to decreased protein denaturation, increase storage life of further products made from sardine mince flesh. Further investigations are needed using other washing treatments such as sodium chloride, water or their combination, all of what could increase storage life of sardine mince flesh.

ACKNOWLEDGMENTS

This study was supported by Consejo de Desarrollo Científico y Humanístico, Universidad Central de Venezuela, project PI 03-32-3843-2000.

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