Frontiers in Food, Drug and Natural Sciences (2023), 1: 30-35
An international peer-reviewed online journal
Avialable online: fd-science.com

Research Article

Changes of biogenic amines in silver carp (*Hypophthalmichthys molitrix*) fillet under different packaging conditions

Mohammadali Khanlar[a*], Nargess Anoosheh[b], Gholamreza Shahhosseini[c]

[a] *Department of Fisheries, University of Zabol, Zabol, Iran*
[b] *Department of Fisheries, University of Tehran, Karaj, Iran*
[c] *Agricultural, Medical & Industrial School, Atomic Energy Organization of Iran, Karaj, Iran*

ARTICLE INFO

This article was previously published in *Persian Journal of Seafood Science and Technology* (*2015, 1: 30-35*). However, the journal's name was changed to *Frontiers in Food, Drug and Natural Sciences* (*FDNS*). For the citation purposes and courtesy of the authors, this article is re-published in *FDNS*.

* Direct inquiries to author:
m.khanlar@gmail.com

ABSTRACT

A comparative study of the effects of different packaging on the formation of biogenic amines during storage of silver carp (*Hypophthalmichthys molitrix*) at 4 ºC was carried out. Silver carp fillet were stored in air, modified atmosphere packaging (MAP) and vacuum packaging (VP). Silver carp fillets were mmicrobiologically acceptable for up to 4 days in air, 12 days in MAP and 8 days in VP. The biogenic amine content generally increased in all treatments with increasing storage time. The concentrations of putrescine and/cadaverine in fish stored in air reached maximum levels of 132.18 mg 100 g^{-1} and 143.4 mg 100 g^{-1} after 16 days, respectively Significant differences were found ($p<0.05$) in the levels of cadaverine and putrescine among the three treatments. Spermidine and spermine levels increased slightly and did not change much throughout the storage period for all experimental conditions. The amine contents of silver carp were highest in silver carp stored in air, followed by VP and MAP. The use of MAP showed a with carbon dioxide to extension the shelf-life (approximately four days) of silver carp by inhibiting microbial growth compared to air and VP. Quality indices related to the contents of the major biogenic amines were calculated and they correlated well with microbiological indices.

Keywords: Biogenic amines; Fish quality; Food packaging; Storage.

1. Introduction

Biogenic amines (BA) have been studied extensively because of their role in foodborne disease. They are low molecular weight compounds, and the most important biogenic amines occurring in food are histamine (HIS), putrescine (PUT), cadaverine (CAD), spermidine (SPD), spermine (SPM), tyramine (TYR), tryptamine (TRY), 2-phenylethylamine (PHE), and agmatine (AGM), which are produced by decarboxylation of amino acids. Among the biogenic amines, histamine is potentially hazardous and the causative agent of histamine intoxication associated with the consumption of seafood (Morrow, Margolies, Rowland & Roberts, 1991). The other biogenic amines, such as putrescine and cadaverine, have been reported to enhance the toxicity of histamine (Stratton, Hutkins, & Taylor, 1991).

Seafood, including fish, is a rich source of high-quality protein, essential vitamins and healthful unsaturated fatty acids. The high content of proteins, on the other hand, represents a risk in the decomposition processes. The disintegration of proteins yields peptides and amino acids, which are susceptible to further decay, resulting in BAs, which can be widely distributed in proteinaceous foods (Křížek, Vácha, Vorlová, Lukášová, & Cupáková, 2004). Furthermore, fish is one of the most highly perishable food products and the shelf life of such products is limited in the presence of normal air by the chemical effects of atmospheric oxygen and the growth of aerobic spoilage microorganisms (Alak, Hisar, Hisar, & Genççelep, 2011; Özogul, Polat, & Özogul, 2004). Modification of the atmosphere within the package by decreasing the oxygen concentration, while increasing the content of carbon dioxide and/or nitrogen, has been shown to significantly prolong the shelf life of perishable food products at chill temperatures (Parry, 1993). Vacuum packaging (VP) is also

a type of MAP system because air is removed from the package. VP is normally placed in a pack of low oxygen permeability, air is evacuated and the package sealed (Church, 1998). MAP and vacuum-packaging (VP), along with refrigeration, have become increasingly popular preservation techniques, which have brought major changes in storage, distribution, and marketing of raw and processed products to meet consumer demands (Özogul et al., 2004).

BAs such as putrescine, cadaverine, spermidine, spermine, histamine and tyramine are non-volatile and low-molecular weight compounds and are generally produced by microbial decarboxylation of specific amino acids (Hwang, Lee, Huang, Lin, Shiau, Hwang, & Tsai, 2010; Kim, Mah, & Hwang, 2009;). The amount and type of formed BAs is related to initial quality of the raw material, the availability of free amino acids, the presence of bacterial biogenic amine decarboxylases and the temperature (Křížek et al., 2004). Determination of BAs in proteinaceous foodstuff is important because they can affect on human health and can be used as quality marker Hosseini, Hamzeh, Moslemi, Lashkan, & Iglesias, 2013). BAs play an important role in the degradation pathway of amino acids and since they are produced by spoilage bacteria toward the end of shelf life, their level can represent the quality of food (Rodríguez-Méndez, Gay, Apetrei, & De Saja, 2009).

BA formation in fish and fish products depends on the amino acid content of fish, the presence of bacterial biogenic amine decarboxylases and favorable environmental conditions. Accumulation of BAs leads to toxicological hazards. Hence, this could be used as an indicator for assessment of the quality of fish and fish products (Sivertsvik, Jeksrud, & Rosnes, 2002; Kříže et al., 2004).

The effects of MAP and VP on seafood have been reviewed extensively but little information exists regarding biogenic amine production in silver carp, a species of freshwater cyprinid fish and one the most popular fish in the Asian countries, stored in modified atmospheres and vacuum packs. Therefore, in the present investigation, a comparative study of the effect of modified atmosphere and VP on biogenic amine formation in silver carp (*Hypophthalmichthys molitrix*), with an emphasis on a potential quality index, was attempted.

2. Materials and Methods

2.1. Sample preparation

Forty-five individuals of silver carp (*H. molitrix*), representing the size range commercially available to customers (mean weight: 950±30 g) were collected randomly from a local fish farming (Karaj, Iran) in March 2015. Selected samples were transported to the laboratory in ~1 h and during transportation, all the samples were covered by ice. The fish to ice ratio was approximately 1:3 and thickness of ice layer was ~10 cm. In the laboratory, fish were washed with distilled water and then filleted manually. Afterward, all fillet divided into three lots. One lot was packed in air, and the remaining two lots, were packed in MAP and VP by a vacuum packaging machine (Guater Control Co., Tehran, Iran). Then all the samples were kept at refrigerator (Azemayesh Co., Iran) for 16 days and at each sampling time (0, 4, 8, 12 and 16 days), three randomly chosen fillet were removed from refrigerator and their microbial and biogenic amine content were determined.

2.2. Total viable count (TVC)

At each storage interval, surface of each sample was first cleaned with alcohol and then 10 g of flesh with both white and dark muscle was taken and transferred into 90 ml 0.1% peptone water, homogenized using a Stomacher Lab-Blender (Seward type 400, London, UK) for 1 min. From this dilution, other serial decimal dilutions were prepared. In this study, TVC were determined using plate count agar (Oxide Inc. London, UK), according to the standard American public health association method (Downes & Ito, 2001) by counting the colony forming units ($\log_{10}$ CFU g^{-1}) after incubating the plates at 30 °C for 48 h. Microbial analyses were performed in triplicate on three subsamples of each of the replicates.

2.3. Determination of biogenic amine (BA) content

All standard BAs and LC grade materials *i.e.*, methanol, chloroform, butanole, diethyl ether, and n-heptanewere were obtained from Merck Co.; double distilled and deionized Millipure water (Millipore, Mississauga, Canada) was used for dilution and chromatographic separation. A Waters 1525 HPLC (Waters Co., Milford, USA) equipped with a Waters 2487 UV-detector set at 254 nm was use for the BA analyses. The column was a reversed phase C18 Waters Spherisorb ODS-2 (250 x 4.60 mm; particle diameter, 5 µm) with a Waters Spherisorb pre-column cartridge (10 mm length) packed with the same material. The mobile phase was an isocratic mixture of methanol:water (62:38 by volume) and the flow rate was 1.1 ml min^{-1} at room temperature.

From each sample, 5 g of flesh was homogenized in a Waring blender (Waring, New Hartford, CT) for 1 min. The procedure for extraction, separation, and quantification described by Paleologos, Chytiri, Savvaidis and Kontominas (2003) was used and explained by Moini et al. (2012). According to this procedure a solution of BA is obtained after sample treatment with trichloroacetic acid (6% w/v) and centrifugation (6×130 g, 20 min, 4 °C; 236 HK, Hermle, German). BA were isolated after derivatization with benzoyl chloride and surfactant mediated cloud point extraction before HPLC separation and quantification. Results are reported as μg^{-1} fish muscle.

2.4. Quality index (QI) and Biogenic amines index (BAI)

Calculating of the quality index and biogenic amines index were done by the methods described by Veciana-

Nogués, Mariné-Font, & Vidal-Carou. (1997), respectively, as follow:

$$\text{Quality index} = (\text{HIS}+\text{PUT}+\text{CAD})/(1+\text{SPM}+\text{SPD})$$

$$\text{Biogenic amines index} = (\text{HIS} + \text{PUT} + \text{CAD} + \text{TYR})$$

2.5. Statistical analysis

All measurements were performed in triplicate for each lot, and the mean values±standard deviation were reported for each case. The one-way ANOVA and the Duncan's test was used for analysis and mean comparison using SPSS software (Version 16.0, Chicago, USA). Significance of differences was defined as $p<0.05$.

3. Results & Discussion

3.1. Biogenic amines analysis

The Changes in biogenic amines contents in the Silver carp stored in air, MAP and VP for 16 days at 4 °C are shown in Tables 1, respectively. The amount of cadaverine increased during the storage period and reached to 143.4±11.3 mg100 g^{-1} for air storage, 122±15.1 mg 100 g^{-1} for VP and 102±17.5 mg 100 $g^{-1}$for MAP. The increase of cadaverine samples in air was higher than in samples stored in VP and MAP throughout the time of storage, putrescine was also a lot of changes, reaching the levels of 132.18±9.36 mg 100 $g^{-1}$for air storage, 82.7±5.89 mg 100 g^{-1} for VP and 76.3±2.94 mg 100 g^{-1} for MAP. Large changes in the contents of putrescine and cadaverine were observed throughout the storage period of silver carp in MAP, VP and in air storage.

The concentration of putresine increased during the storage period of Silver carp held in air, VP and MAP, reaching maximum levels of the days 16. Significant differences were found ($p<0.05$) in the levels of cadaverine and putresine among the three treatments. Ababouch, Souibri, Rhaliby, Ouahdi, Battal and Busta (1996) found that cadaverine and putresine accumulated rapidly, reaching levels of 235 mg 100 g^{-1} and 30 mg 100 g^{-1}, respectively, after 24 h of storage at ambient temperature. In this experiment, these amine contents of silver carp were highest in silver carp stored in air, followed by VP and MAP. These findings were similar to work on herring stored in air and MAP at 2±2 °C. It was found that the concentrations of these amines in herring held at 2±2 °C increased more rapidly than in herring stored in MAP (Özogul, Taylor, Quantick, & Özogul, 2002; Özogul et al., 2004). Spermidine and spermine levels increased slightly and did not change much throughout the storage period for the three different conditions. Significant differences were observed in spermine and spermidine contents among the treatments ($p<0.05$). However, lower values were obtained for silver carp stored in MAP (Table 1). This is in agreement with findings for herring stored in MAP (Özogul et al., 2002).

Table 1

Changes in biogenic amines contents (mg 100 g^{-1}) of Silver carp (*Hypophthalmichthys molitrix*) stored in vacuum, modified atmosphere and air (control) condition

	PUT			CAD			SPM		
Day	MAP	VP	air	MAP	VP	air	MAP	VP	air
0	1.01±0.36	1.24±0.68	8.43±2.18	ND	4.76±0.95	13.2±4.69	9.69±1.67	8.52±0.63	9.08±1.85
4	3.14±0.89	7.39±1.41	13.6±2.36	5.96±0.97	8.35±1.76	36.5±11.41	7.68±1.79	8.79±1.86	10.4±2.36
8	11.4±2.45	18.8±3.35	46.7±4.28	16.5±4.02	41.3±5.38	62.4±9.30	8.41±1.52	8.68±1.58	12.5±1.79
12	43.9±1.36	35.2±3.61	96.6±11.01	42.7±6.25	63.4±8.68	116±14.58	12.5±2.41	13.2±2.79	16.1±1.58
16	76.3±2.94	82.7±5.89	132.2±9.36	102±17.47	122±15.10	143±11.31	13.0±1.53	12.1±2.69	15.0±1.31

Continue of table 1

	HIS			SPD			TYR		
Day	MAP	VP	air	MAP	VP	air	MAP	VP	air
0	ND	ND	ND	5.36±1.79	5.67±0.98	7.11±0.69	ND	ND	0.31±0.022
4	ND	ND	0.39±0.06	9.14±1.08	8.41±1.41	7.05±0.65	ND	ND	0.85±0.31
8	ND	ND	0.58±0.19	10.3±2.41	11.9±2.05	12.0±2.68	ND	ND	0.94±0.27
12	ND	0.41±0.095	0.54±0.08	9.08±2.53	11.5±203	12.6±2.23	0.63±0.09	1.05±0.63	1.62±0.79
16	0.37±0.06	0.49±0.074	0.71±0.15	11.3±1.07	12.1±1.38	12.8±2.50	1.05±0.41	1.94±0.41	2.01±0.31

Table 2
Quality and biogenic amine indices of Silver carp (*Hypophthalmichthys molitrix*) stored in vacuum, modified atmosphere and air (control)

	QI			BAI		
Day	MAP	VP	air	MAP	VP	air
0	0.06±0.01	0.40±0.01	1.26±0.11	1.01±0.47	6.01±1.03	22.0±2.61
4	0.51±0.04	0.87±0.47	2.74±0.43	9.10±1.04	15.8±3.11	51.4±6.42
8	1.41±0.31	2.79±0.65	4.30±0.86	27.9±2.21	60.1±8.19	111±11.81
12	3.83±0.17	3.16±0.49	7.17±1.03	87.2±6.41	99.8±13.4	215±19.51
16	7.07±1.04	8.16±1.05	9.60±1.21	180±8.68	208±9.79	278±16.05

Ababouch et al. (1996) reported that ice storage inhibited the formation of these two amines in sardine. However, at ambient temperature, spermine and spermidine levels reached 5 and 6 mg 100 g^{-1} after 24 h, respectively (. The amount of histamine increased during the storage period and reached 0.71 ± 0.15 mg 100 g^{-1} for air storage, 0.49 ± 0.074 mg 100 g^{-1} for VP
increased during the storage period and reached 0.71 ± 0.15 mg 100 g^{-1} for air storage, 0.49 ± 0.074 mg 100 g^{-1} for VP and 0.37 ± 0.06 mg 100 g^{-1} for MAP. Lowest histamine were obtained from silver cap stored under MAP, indicating that the presence of the CO_2 in the pack inhibited the growth of microorganisms, which resulted in preventing of spoilage and extending of shelf life of the fish. (Sato, Fujii, Masuda, & Okuzumi. (1994) reported that the histamine content of mackerel, stored at 5 ˚C, increased rapidly when the number of bacteria reached above 10^6 cells g^{-1}. Histamine forming bacterial species and strains differ considerably in amounts of histamine formation, and the type of spoilage bacteria present depends on an aquatic environment (López-Sabater, Rodriguez-Jerez, Hernández-Herrero, & Mora-Ventura, 1994; Silva, Ponte, & Dapkevicius, 1998).

The formation of high concentrations of histamine in fish products can be fairly rapid and depends on the number of microorganisms present (Ababouch, Afilal, Rhafiri, & Busta, 1991; Pacheco-Aguilar, Lugo-Sánchez, Villegas-Ozuna, & Robles-Burgueno, 1998). Tyramine concentration increased during the storage period, reaching the levels of 2.01 mg 100 g^{-1} for silver carp in air, 1.94 mg 100 g^{-1} for VP and 1.05 mg 100 g^{-1} for MAP at 16 days. Tyramine was not detected for silver carp in VP and MAP until eight days. There are no significant differences within the three storage conditions ($p>0.05$).

Table 2 shows biogenic amine quality and indices for silver carp stored in air, VP and MAP. There was an increase in the two indices with storage time, indicating that these two indices can be used to determine the spoilage of silver carp. However, the biogenic amine index gave values twice higher than the quality index. Mieltz and Karmas (1977) proposed the value of 10 as the limit of fish acceptability for the quality index (QI). This value was reached in samples after 16 days of storage for air, indicating that the quality index correlated well with mmicrobiological index of silver carp stored in air, MAP and VP. The biogenic amine index (BAI) proposed by Veciana-Nogues et al. (1997) also correlated with sensory acceptability of silver carp in air, MAP and VP since it increased with storage time. However, more studies on BAI are needed to set a limit of fish acceptability in MAP and VP.

3.2. Total viable count (TVC)

Figure 1 shows total viable counts in silver carp stored in air, in VP and in MAP at 4 °C. Bacteria grew most quickly in silver carp stored in air, followed by those in VP and the lowest counts were with MAP where the log phase was apparently extended. One of the major mechanisms of MAP and VP techniques is to change the level of oxygen in a food environment so as to have an effect on the growth of different groups of microorganisms. Consequently, fish in air exhibited higher biogenic amine values than in VP and MAP storage. The use of MAP with carbon dioxide has

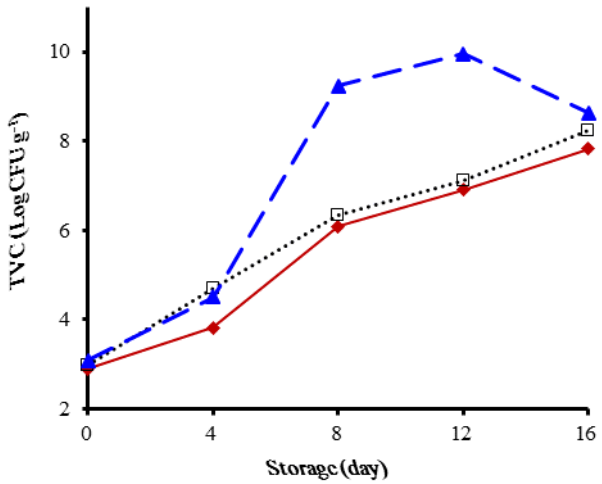

Figure 1
Total viable counts (CFU g^{-1}) in Silver carp (*Hypophthalmichthys molitrix*) stored in air (▲), in VP (□) and in MAP (♦) at 4 ˚C. Each point shown is the mean value of three determinations for each sampling. Standard deviation was not shown.

been shown to extend the shelf-life (approximately four days) of silver carp by inhibiting microbial growth compared to air and VP conditions better than the levels of biogenic amines, also showed total count. It can also be concluded that the biogenic amine index gave values twice as high as the quality index. The other significant conclusion is that the lowest concentrations of biogenic amines were obtained from silver carp stored in MAP because CO_2 inhibits the formation of biogenic amines. Also to sum up, the maximum levels of histamine and tyramine were less than the EU acceptable level and the recommendation, therefore all samples were considered as safe.

The microbial quality of fish flesh depends both on aquaculture and on sanitary conditions in the slaughterhouse. When fish are gutted, bacteria from gills, and especially from the gut, can contaminate edible muscles. Study of bacterial contamination of the carp flesh was complementary to biogenic amine determination. The removal of O_2 is more important than the inclusion of high CO_2 content in the pack, due to oxidation of fat. Aerobic microorganisms are generally sensitive to CO_2/N_2; therefore, MAP delays the spoilage of fish. Huss (1972) indicated that CO_2 decreases with an increase in temperature (Daniels, Krishnamurthi, & Rizvi, 1985). Pastoriza, Sampedro, Herrera and Cabo. (1996) reported that significant differences ($p<0.05$) were found between control (air) and MAP-stored samples in terms bacterial counts. In the present study, significant differences ($p<0.05$) were observed between samples kept in air and in MAP. When the aerobic plate count reaches 106 CFU (colony forming units) per gram or milliliter in a food product, it is assumed to be at, or near, spoilage level. Marrakchi, Bennour, Bouchriti, Hamama and Tagafait (1990) reported that initial TVC of iced sardines was 3.16×102 CFU g^{-1}, reaching the limit counts of 106-107 CFU g^{-1} at day 9, while the counts exceeded these limits within 24 h at ambient temperature. In this study, the limit of acceptability (106 CFU g^{-1}) in terms of total viable count was 4 days for silver carp stored in air, 8 days for VP, and 12 days for MAP. The result obtained from evaluation, after VP and MAP treatment, showed a longer shelf life when compared with microbiological assessment.

4. References

Ababouch, L., Afilal, M., Rhafiri, S., & Busta, F. (1991). Identification of histamine-producing bacteria isolated from sardine (*Sardina pilchardus*) stored in ice and at ambient temperature (25 °C). *Food Microbiology, 8*(2), 127-136 .

Ababouch, L., Souibri ,L., Rhaliby, K., Ouahdi, O., Battal, M., & Busta, F. (1996). Quality changes in sardines (*Sardina pilchardus*) stored in ice and at ambient temperature. *Food Microbiology, 13*(2), 123-132 .

Alak, G., Hisar, S.A., Hisar, O., & Genççelep, H. (2011). Biogenic amines formation in atlantic bonito (*Sarda sarda*) fillets packaged with modified atmosphere and vacuum, wrapped in chitosan and cling film at 4 c. *European Food Research and Technology, 232*(1), 23-28 .

Church, N. (1998). Map fish and crustaceans' sensory enhancement. *Food Science and Technology Today, 12*(2), 73-83 .

Daniels, J. A., Krishnamurthi, R., & Rizvi, S. S. (1985). A review of effects of carbon dioxide on microbial growth and food quality. *Journal of Food Protection, 48*(6), 532-537 .

Downes, F. P., & Ito, K. (2001). *Compendium of methods for the microbiological examination of foods* (4 ed). USA, Washington, DC. : American public health association.

Hosseini, S. V., Hamzeh, A., Moslemi, M., Lashkan, A. B., & Iglesias, A. (2013). Effect of delayed icing on biogenic amines formation and bacterial contribution of iced common carp (*Cyprinus carpio*). *Molecules, 18*(12), 15464-15473 .

Huss, H. (1972). Storage life of prepacked wet fish at 0° c: I. Plaice and haddock. *International Journal of Food Science & Technology, 7*(1), 19-3.

Hwang, C. C., Lee, Y. C., Huang, Y. R., Lin, C. M., Shiau, C. Y., Hwang, D. F., & Tsai, Y. H. (2010). Biogenic amines content, histamine-forming bacteria and adulteration of bonito in tuna candy products. *Food Control, 21*(6), 845-850 .

Kim, M. K., Mah, J. H., & Hwang, H. J. (2009). Biogenic amine formation and bacterial contribution in fish, squid and shellfish. *Food Chemistry, 116*(1), 87-95 .

Křížek, M., Vácha, F., Vorlová, L., Lukášová, J., & Cupáková, Š. (2004). Biogenic amines in vacuum-packed and non-vacuum-packed flesh of carp (*Cyprinus carpio*) stored at different temperatures. *Food Chemistry, 88*(2), 185-191 .

López-Sabater, E., Rodriguez-Jerez, J., Hernández-Herrero, M., & Mora-Ventura, M. (1994). Evaluation of histidine decarboxylase activity of bacteria isolated from sardine (*Sardina pilchardus*) by an enzymic method. *Letters in Applied Microbiology, 19*(2), 70-75 .

Marrakchi, A. E., Bennour, M., Bouchriti, N., Hamama, A., & Tagafait, H. (1990). Sensory, chemical, and microbiological assessments of Moroccan sardines (*Sardina pilchardus*) stored in ice. *Journal of Food Protection, 53*(7), 600-605 .

Mietz, J. L., & Karmas, E. (1977). Chemical quality index of canned tuna as determined by high-pressure liquid chromatography. *Journal of Food Science, 42*(1), 155-158 .

Moini, S., Sotoodeh, A. M., Haghoo, A., Moslemi, M., Hosseini, S. V., Regenstein, J. M., Feás Sanchez, X., Aflaki, F., & Yadollahi, F. (2012). Changes in biogenic amines and bacteria of tiger-toothed croaker (*Otolithes ruber*) during ice storage. *Journal of Aquatic Food Product Technology, 21*(2), 147-155 .

Morrow, J. D., Margolies, G. R., Rowland, J., & Roberts, L. J. (1991). Evidence that histamine is the causative toxin of scombroid-fish poisoning. *New England Journal of Medicine, 324*(11), 716-720 .

Nout, M. (1994). Fermented foods and food safety. *Food Research International, 27*(3), 291-298 .

Özogul, F., Gökbulut, C., Özogul, Y., & Özyurt, G. (2006). Biogenic amine production and nucleotide ratios in gutted wild sea bass (*Dicentrarchus labrax*) stored in ice, wrapped in aluminum foil and wrapped in cling film at 4 °C. *Food Chemistry, 98*(1), 76-84 .

Özogul, F., Polat, A., & Özogul, Y. (2004). The effects of modified atmosphere packaging and vacuum packaging on chemical, sensory and microbiological changes of sardines (*Sardina pilchardus*). *Food Chemistry,* 85(1), 49-57 .

Özogul, F., Taylor, K., Quantick, P., & Özogul, Y. (2002). Changes in biogenic amines in herring stored under modified atmosphere and vacuum pack. *Journal of Food Science, 67*(7), 2497-2501 .

Pacheco-Aguilar, R., Lugo-Sánchez, M., Villegas-Ozuna, R., & Robles-Burgueno, R. (1998). Histamine quantification in monterey sardine muscle and canned products from northwestern mexico. *Journal of Food Composition and Analysis, 11*(2), 188-195 .

Paleologos, E., Chytiri, S., Savvaidis, I., & Kontominas, M. (2003). Determination of biogenic amines as their benzoyl derivatives after cloud point extraction with micellar liquid chromatographic separation. *Journal of Chromatography A, 1010*(2), 217-224 .

Parry, R. (1993). *Principles and applications of modified atmosphere packaging of foods* (ed). London: Blackie Academic & Professional.

Pastoriza, L., Sampedro, G., Herrera, J.J., & Cabo, M.L. (1996). Effect of modified atmosphere packaging on shelf-life of iced fresh hake slices. *Journal of the Science of Food and Agriculture, 71*(4), 541-547 .

Rodríguez-Méndez, M., Gay, M., Apetrei, C., & De Saja, J. (2009). Biogenic amines and fish freshness assessment using a multisensor system based on voltammetric electrodes. Comparison between cpe and screen-printed electrodes. *Electrochimica Acta, 54*(27), 7033-7041 .

Sato, T., Fujii, T., Masuda, T., & Okuzumi, M. (1994). Changes in numbers of histamine-metabolic bacteria and histamine content during storage of common mackerel. *Fisheries Science, 60*(3), 299 -302.

Silva, C. C., Ponte, D. J., & Dapkevictus, M. L. E. (1998). Storage temperature effect on histamine formation in big eye tuna and skipjack. *Journal of Food Science, 63*(4), 644-647 .

Sivertsvik, M., Jeksrud, W. K., & Rosnes, J. T. (2002). A review of modified atmosphere packaging of fish and fishery products–significance of microbial growth, activities and safety. *International Journal of Food Science & Technology, 37*(2), 107-127 .

Stratton, J. E., Hutkins, R. W., & Taylor, S. L. (1991). Biogenic amines in cheese and other fermented foods: A review. *Journal of Food Protection, 54*(6), 460-470 .

Veciana-Nogues, M., Izquierdo-Pulido, M., & Vidal-Carou, M. (1997). Determination of ATP related compounds in fresh and canned tuna fish by HPLC. *Food Chemistry, 59*(3), 467-472 .

Veciana-Nogués, M., Mariné-Font, A., & Vidal-Carou, M. (1997). Biogenic amines as hygienic quality indicators of tuna. Relationships with microbial counts, ATP-related compounds, volatile amines, and organoleptic changes. *Journal of Agricultural and Food Chemistry, 45*(6), 2036-2041 .