Turkish Journal of Fisheries and Aquatic Sciences 7: 65-70 (2007)

Storage Properties of Three Types of Fried Whiting Balls at Refrigerated Temperatures

Muhammet Boran[1,]*, Sevim Köse[1]
[1] Karadeniz Technical University, Faculty of Marine Science, 61530, Çamburnu, Trabzon, Turkey.

* Corresponding Author: Tel: +90. 462 7465495; Fax: +90. 462 7464046;
E-mail: mboran@ktu.edu.tr; muboran@yahoo.com

Received 24 December 2006
Accepted 10 April 2007

Abstract

In this study three types of fried fish balls from whiting (*Merlangius merlangus euxinus*, Nordmann, 1840) were assessed for sensory and chemical quality changes over a period of 15 days of refrigerated storage at 4ºC. The total volatile basic nitrogen (TVB-N) content, thiobarbituric acid (TBA) and trimethylamine (TMA) values increased significantly ($p<0.01$), while sensory attributes decreased during storage. TVB-N and TBA results for products remained under the limit for edibility. However, the TMA values of fried fish balls made from both plain mince and surimi reached the upper acceptability limit on the 10th day of storage. Sensory values showed that fish balls from plain mince had the shortest shelf life of 9 days, while the products originating from pre-cooked mince showed the longest shelf life, 11 days. Use of different types of mince in the fish balls had a significant effect on the quality of the products during the storage period ($p<0.05$).

Key words: whiting, fish balls, TMA, TVB-N, TBA, sensory, fish mince, shelf life.

Introduction

Fish, in comparison to other meat types, has several important nutritional characteristics in its favor, as well as certain health benefits-principally, that it is low in cholesterol, high in good-quality protein, and it contains unsaturated fatty acids, including the omega-3 type, which are reported to help prevent several human illnesses (Baker *et al.*, 1977; Kinsella, 1987; Nettleton, 1992).

Fish paste products, such as fish balls and fish cakes, are believed to have originally come from China with fresh fish used as the raw material. Fish paste products are now widely consumed in the Asian region. The fish ball-cake industry has been reported to be growing since the early 1980s in countries such as Singapore, Malaysia, China and Thailand. Manufacturers are also looking at the export market, especially for frozen fish balls and cuttlefish balls, to Australia, Japan, and the United States. Several manufacturers in Singapore have also invested overseas and have established fish ball-fish cake factories in Malaysia and China (Morrissey and Tan, 2000). FAO reports also show that fish balls are marketed and consumed around the world (FAO, 2003).

Several fish species around the world such as threadfin bream and bigeye snapper have been used or studied for making fish balls. The main method of producing fish balls is called surimi, and some countries use automated lines for production of fish balls from surimi (Morrissey and Tan, 2000). Surimi technology originated in Japan, and is commonly produced from Alaskan pollack as well as from whiting (Sonu, 1986). It is usually produced from white-muscled fish species, especially those of the *Gadidae* family, due to their white color and ability to produce a good gel. Although traditional surimi-based products are not well known in Turkey, they are consumed regularly in other parts of the world, including Japan and the USA.

The traditional method for producing fish mince in Turkey is either plain mincing or mince production after recovery from boiled fish (Metin *et al.*, 2002; Akkuş *et al.*, 2004). Therefore, it is important to know the shelf life and quality changes of different types of fish balls produced by different mincing methods. This can make contribution to seafood industry in selecting appropriate methods for producing ready-made seafood such as fish balls.

Gadoid fishes, such as hake, cod, haddock, and blue whiting constitute a large group of lean species commercialized both fresh and frozen in Europe (Rey-Mansilla *et al.*, 1999). Pacific whiting has been used widely in surimi production since 1990 after the use of protease inhibitors solved the problem of muscle protease in the myofibrillar flesh rapidly breaking down myofibrillar proteins, preventing the formation of a surimi gel (Morrissey and Tan, 2000). Whiting has been also suggested to be a good raw material for surimi production and has been investigated by several researchers (Aguilar *et al.*, 1989; Lee *et al.*, 1990; Hastings *et al.*, 1990; Park, 2000).

Whiting (*Merlangius merlangus*) has been reported to be a common fish in the North Sea and in parts of the Atlantic Ocean. The smallest subspecies is called *M. merlangus euxinus,* N. 1840 and has a maximum length of about 20 cm. This species is found off European shores from the Barents Sea and Iceland to Gibraltar, and in the western parts of the Baltic, Black, and Mediterranean Seas (Bristow, 1992). This species was reported in 2000 to be the fourth most commonly caught and consumed type of fish in Turkey, with a production total of 18,000 mt (DIE, 2003). However, whiting is not processed for domestic consumption in Turkey, as it is only consumed fresh throughout the year, mainly in coastal areas.

There is a growing interest in producing ready made seafood products in Turkey such as fish balls, and several studies have been conducted to investigate the quality changes of such products. One of these was performed by Akkuş *et al*. (2004) on fish balls that were prepared using boiled and raw anchovy. They determined that the shelf-life of the fish balls was 9 days at 4±1ºC. Gökoğlu (1994) used sensory, physical, chemical, and microbiological analyses to study fish balls made from mackerel that were prepared using the boiling (pre-cooking) method and stored at refrigerated temperature. In that study a shelf life of up to 8 days and spoilage after 10 days were reported for fish balls stored in refrigeration. Metin *et al.* (2002) found that trout burgers wrapped in gas barrier film had a shelf life of 21 days in cold storage. Baygar *et al*. (2002) conducted a study on stuffed trout under cold storage conditions and reported a shelf life of 5 days. Some studies were also carried out in other countries on either similar or different fish species. Baker *et al.* (1977) investigated the effect of mince from different fish species (mullet, cod, pollock and flounder) on acceptability to consumers.

There is insufficient data on the quality changes of whiting balls stored under refrigerated conditions and the effect of processing methods on the products shelf-life. Borderias *et al*. (1980) conducted an investigation on the storage properties of blue whiting after mincing by different methods. They advised using the cutter method for those fish species that could be filleted industrially, and reported that this allowed the addition of chilled water and other additives during the preparation of the minced fish, resulting in a fine texture. Our earlier study showed that each type of whiting mince prepared by using the surimi, plain mincing, and a pre-cooking method had 7 days of storage life according to sensory results (Köse *et al*., 2006). However, the products were not tested for their quality changes when different ingredients were added to the mince prior to storage under the same conditions.

Therefore, this study aims to investigate the quality changes of fried whiting balls made from mince that is produced by three different methods and stored under refrigerated conditions.

Materials and Methods

Fish Samples and Ingredients

Whiting (*Merlangius merlangus euxinus*, N. 1840) was caught daily from cost of south-eastern Black Sea using research vessel and gill net. The fish were iced on board. They were brought to the laboratory as soon as landed. Fish size varied between 11.0 and 16.2 cm, and average weight was 18.9 g. Other ingredients used were vegetables (garlic, parsley and onions), herbs (mint, red and black peppers), eggs and salt. They were provided from local markets.

Preparation of Products

Three types of fish balls were produced and their shelf lives under refrigerated condition were compared to each other. Each type of fish ball contained whiting mince produced using a different mincing technique. One of the methods was the surimi technique, which is commonly used in the USA and Japan. The surimi technique involves washing and dehydrating steps before addition of other ingredients and the product is known as "surimi fish balls." The second type of product is made by adding ingredients to the plain whiting mince without washing steps. This method is currently used in Turkey for other fish balls that are marketed. In both methods, mincing was carried out in this study using a kitchen food processor with a pore size of 5 mm. The third method was taken from a rarely known Turkish fish dish recipe that is not marketed commercially. This technique involves pre-cooking of the fish in boiling water for 1–5 minutes or more, depending on the fish size and the amount of fish placed in the water. After the heading and gutting fish were boiled, they were taken out of the water and left to cool. It was then easy to separate the flesh from the bones manually, with some of the fish separating by themselves after cooking. The procedures of the three techniques are shown in Figure 1.

After separating the flesh from the headed and gutted fish by either mincing or pre-cooking, other ingredients were added and mixed. The products contained about 77% of fish, 13.2% flour, 3.6% onions, 2% parsley, 1.8% garlic, 0.7% hot pepper, 0.6% red pepper, and 1.1% salt. Eggs were used in these mixtures only to bind the pre-cooked products. When eggs were added to pre-cooked products, less flour was used. The amount of flour for plain minced products was slightly higher with reduced amounts of onions and parsley in these products. After addition of the ingredients and mixing, the products were shaped into fish balls weighing approximately 25 g each. They were fried in small amount of vegetable oil until slightly brown and removed as they turned brown. All

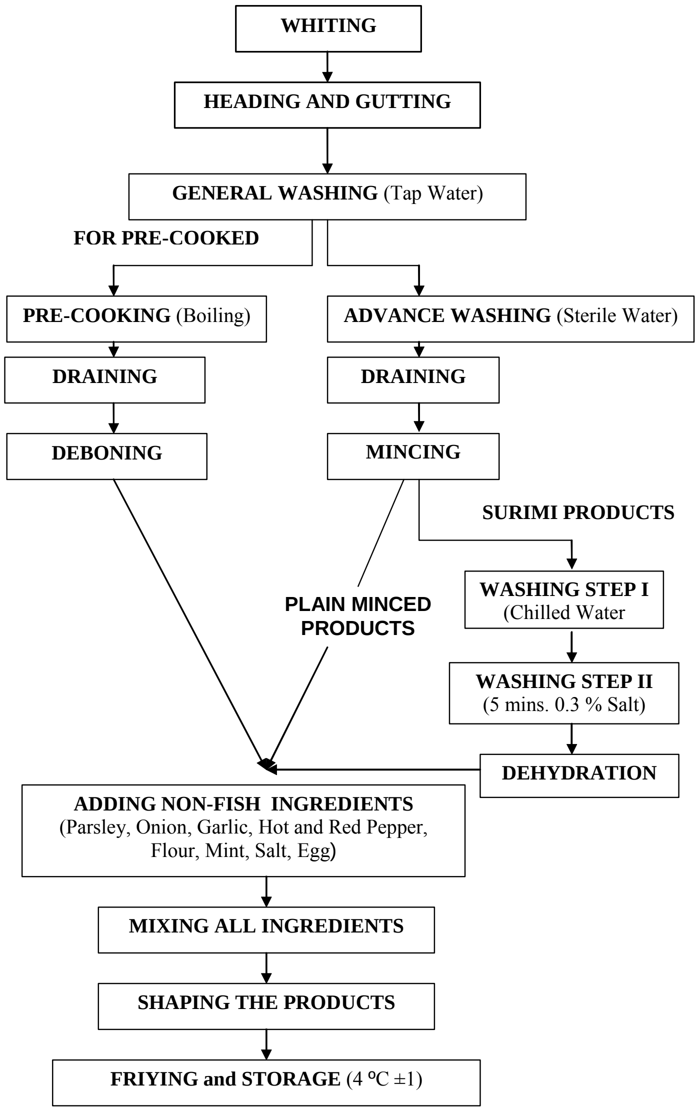

Figure 1. Processing outline of the products.

of the fried products were stored under refrigeration at 4±1ºC and analyzed for sensory and chemical quality during the storage.

Analytical Methods

Total volatile basic nitrogen (TVB-N) content was determined according to the method of Lücke and Geidel (İnal, 1992). Thiobarbituric acid (TBA) values, expressed as mg malonaldehyde/kg, were estimated using the method described by Smith *et al*. (1992). Trimethylamine analysis was carried out following the method proposed by Dyer (AOAC, 1990). All analyses were carried out in triplicate.

Eight trained assessors judged the overall acceptability of the samples on a five-point quality scale according to a modified technique of Pedrosa-Menabrito and Regenstein (1990). The scale points were; excellent, 5; good, 4; moderately good (acceptable), 3; poor, 2; very poor, 1. The biting attributes of each product were tested using the ashi test, utilizing a 10 point scale with higher point values indicating higher quality (Sonu, 1986). The data obtained were analyzed using analysis of variance (ANOVA) and when significant differences were found, comparisons among means were carried out by using the Tukey test (Sokal and Rolf, 1987).

Results and Discussion

Results for sensory analyses and the ashi test are presented in Table 1. The fish ball containing pre-cooked mince was found to be the best-liked product and had the longest shelf life (11 days) in refrigerated storage compared to the others. Taste panel results showed that fish balls containing surimi had the lowest scores. In our earlier study, we found 7 days of shelf life for all types of mince under refrigerated

Table 1. Results (Mean±SD) for sensory analyses and ashi test

Test Type	Plain Mince	Surumi	Pre-cooked
Ashi Test (10 points)	9±0.5 (8.6-9.4)*	9±0.3 (8.7-9.3)	8±0.2 (7.8-8.2)
Taste (5 points)	4.5±0.3 (4.2-4.8)	4±0.2 (3.8-4.2)	5±0.2 (4.8-5.2)
Shelf life-refrigerated (days)	9	10	11

* 95% confidence limit

conditions according to sensory values (Köse *et al.*, 2006). The current study showed an extended shelf life for each type of fish ball originating from the same type of mince used in the earlier study. It was also found that ashi test results were higher for fried fish balls, compared to the results obtained for the three different whiting mince samples used in our earlier study. The weakest product was fish ball prepared from pre-cooked mince, which received 8 points on the ashi test. Akkuş *et al.* (2004) found 11 days of shelf life for fish balls produced from boiled and raw anchovy mince, according to sensory values under refrigerated conditions. Their results support the sensory values we observed with whiting balls prepared from pre-cooked mince.

The changes in TMA-N, TVB-N and TBA for fried fish balls from plain, surimi and precooked mince during the 15-day storage period under refrigeration at 4±1°C are shown in Table 2. TMA-N, TVB-N and TBA levels of these products increased significantly over time ($p<0.01$).

TMAO is generally present in marine fish and it is the most commonly used chemical method for assessing fish quality (Magnusson and Martinsdóttir, 1995). TMA is produced by the decomposition of TMAO due to bacterial spoilage and enzymatic activity (Serdaroğlu and Deniz, 2001). It is reported that 10–15 mg TMA-N/100 g is generally regarded as the limit of acceptability for human consumption (Huss, 1988).

In this study, TMA content ranged from 2.32 to 21.80 mg N/100 g for fried fish balls made from plain mince, 3.68–20.01 mg N/100 g for surimi, and 2.97–16.94 mg N/100 g for precooked mince during the 15-day period of storage. The highest TMA value for each product type was recorded on day 15. TMA level for samples containing plain mince and surimi reached 16.23 and 15.25 mg N/100 g, respectively, on the 10th day, whereas the samples containing pre-cooked mince reached 16.94 mg N/100 g on the15th day. Based on TMA fried fish balls made from both plain mince and surimi were not consumable by the 10th day, while the products made from pre-cooked mince were consumable up to the 14th day of storage.

The values presented here are higher than those reported by others in several fish species, such as blue whiting and trout, stored at chilled temperatures (Rey-Mansilla *et al.*, 1999; Chytiri *et al.*, 2004). Similarly, other researchers observed lower TMA values with fish balls made from different fish species such as mackerel and anchovy (Gökoğlu, 1994; Akkuş *et al.*, 2004). Rey-Mansilla *et al.* (1999) claimed that unlike other fish species groups, Gadoids possess as a distinguishing feature the ability to break TMAO down enzymatically into dimethylamine (DMA) and formaldehyde (FA). Although they observed lower TMAOase activity with blue whiting, they reported that higher values with other Gadoids by different researchers. It was claimed that the reason for differences was due to high intraspecific variability in TMAOase activity. Varlık (1994) found that sardine stored at 4°C lost its consumable properties after 7 days due to higher TMA level.

The concentration of TVB in freshly caught fish is typically reported to vary between 5 and 20 mg N/100 g, whereas levels of 30–35 mg N/100g flesh are generally regarded as the limit of acceptability for cold water fish stored on ice (Kyrana *et al.*, 1997). TVB-N levels in our present study were low at the beginning of the storage period since all of the products were prepared from fresh fish. The TVB-N contents of the fried fish balls containing plain mince ranged from 8.13 to 32.21 mg N/100 g, 9.54 to 26.53 mg N/100 g for surimi, and 4.24 to 28.02 mg N/100 g for pre-cooked mince during the 15-day period of storage at 4°C (Table 2). The values for the three types of products remained within acceptable limits throughout the storage period. The TVB-N results for surimi and plain mince samples used in our earlier study (Köse *et al.*, 2006) were very high compared to those obtained for fish balls made from the same type of mince in our present work. However, slightly lower results were observed in the pre-cooked mince in the previous study. Therefore, it can be concluded that frying may affect the TVB-N development in the products. Köse and Erdem (2001) observed that fresh whiting had 4 days of consumable quality based on TVB-N values taken at refrigerated temperatures, suggesting that processing whiting into fried fish balls can improve its shelf life under refrigerated temperatures. Akkuş *et al.* (2004) obtained higher values for the TVB-N of anchovy balls, and found that the shelf-life of fish balls was 9 days at 4ºC, evaluating the results of the sensory, physical and chemical analyses. Gökoğlu (1994) studied the quality changes of fish balls made from mackerel at refrigerated temperatures and obtained TVB-N values of 36.4 mg N/100 g on the 10th day, indicating unacceptable quality.

TBA is widely used for the assessment of the degree of lipid oxidation. TBA levels of fish balls made from plain mince, surimi, and pre-cooked mince increased throughout the entire 15-day storage period and ranged from 0.19 to 1.89, 0.22–1.00, and 0.20–

Table 2. Changes in TMA-N (mg N/100 g), TVB-N (mg N/100 g) and TBA (mg malonaldehyde/kg) values of three types of fried whiting balls stored at refrigerated conditions (Number in parentheses represent (±) standard deviation) (p<0.01).

Days	Plain Mince			Surimi			Precooked		
	TMA-N	TVB-N	TBA	TMA-N	TVB-N	TBA	TMA-N	TVB-N	TBA
0	2.32^{a} (0.02)	8.13^{a} (0.03)	0.19^{a} (0.01)	3.68^{a} (0.02)	9.54^{a} (0.04)	0.22^{a} (0.01)	2.97^{a} (0.01)	4.24^{a} (0.02)	0.20^{a} (0.01)
1	3.21^{b} (0.01)	9.31^{b} (0.03)	0.27^{a} (0.01)	5.10^{b} (0.04)	10.57^{b} (0.04)	0.24^{a} (0.01)	4.11^{b} (0.02)	5.28^{b} (0.02)	0.22^{ab} (0.01)
2	3.97^{c} (0.02)	9.71^{c} (0.02)	0.36^{ab} (0.01)	6.32^{c} (0.05)	12.05^{c} (0.03)	0.32^{b} (0.02)	5.10^{c} (0.02)	6.02^{c} (0.03)	0.26^{b} (0.01)
3	4.12^{d} (0.02)	10.30^{d} (0.03)	0.37^{b} (0.02)	6.54^{d} (0.02)	11.98^{c} (0.04)	0.48^{c} (0.02)	5.27^{d} (0.03)	7.13^{d} (0.02)	0.30^{c} (0.01)
4	5.16^{e} (0.01)	11.02^{e} (0.03)	0.40^{b} (0.01)	8.31^{e} (0.02)	13.25^{d} (0.04)	0.51^{c} (0.01)	5.69^{e} (0.02)	8.02^{e} (0.02)	0.39^{d} (0.02)
5	6.56^{f} (0.03)	11.88^{f} (0.02)	0.45^{b} (0.01)	10.56^{f} (0.04)	15.77^{e} (0.05)	0.54^{c} (0.03)	6.13^{f} (0.03)	9.70^{f} (0.03)	0.51^{e} (0.02)
6	7.12^{g} (0.02)	12.65^{g} (0.03)	0.48^{b} (0.01)	11.30^{g} (0.03)	16.09^{f} (0.04)	0.59^{d} (0.02)	6.96^{g} (0.02)	9.89^{g} (0.03)	0.56^{f} (0.01)
7	7.96^{h} (0.02)	13.86^{h} (0.03)	0.54^{bc} (0.01)	12.62^{h} (0.03)	17.65^{g} (0.04)	0.60^{d} (0.02)	7.59^{h} (0.02)	10.70^{h} (0.03)	0.56^{f} (0.02)
8	9.46^{k} (0.03)	13.80^{h} (0.02)	0.64^{c} (0.01)	12.70^{h} (0.03)	17.46^{h} (0.03)	0.64^{d} (0.02)	9.51^{k} (0.03)	12.43^{k} (0.02)	0.60^{g} (0.02)
9	10.71^{l} (0.03)	14.34^{k} (0.03)	0.66^{c} (0.01)	14.54^{k} (0.02)	21.01^{k} (0.03)	0.78^{e} (0.02)	10.71^{l} (0.03)	15.12^{l} (0.03)	0.73^{h} (0.02)
10	16.23^{m} (0.02)	16.80^{l} (0.02)	1.01^{d} (0.01)	15.25^{l} (0.02)	22.71^{l} (0.02)	0.90^{f} (0.02)	12.23^{m} (0.03)	21.81^{m} (0.04)	0.77^{hkl} (0.02)
11	16.24^{m} (0.01)	17.36^{m} (0.02)	1.06^{d} (0.01)	15.45^{m} (0.01)	22.86^{m} (0.02)	0.90^{f} (0.01)	13.66^{n} (0.01)	22.96^{n} (0.09)	0.78^{kl} (0.04)
12	16.86^{n} (0.01)	19.21^{n} (0.04)	1.13^{d} (0.01)	15.88^{n} (0.01)	22.960^{n} (0.02)	0.91^{f} (0.03)	13.95^{p} (0.02)	23.16^{p} (0.02)	0.80^{l} (0.01)
13	17.35^{p} (0.01)	21.80^{p} (0.02)	1.21^{d} (0.01)	16.34^{p} (0.01)	23.24^{p} (0.02)	0.95^{g} (0.01)	14.13^{r} (0.01)	23.79^{r} (0.01)	0.86^{m} (0.01)
14	18.08^{r} (0.03)	26.61^{r} (0.03)	1.40^{e} (0.01)	17.28^{r} (0.03)	24.25^{r} (0.04)	0.99^{g} (0.02)	14.89^{s} (0.03)	25.24^{s} (0.04)	0.97^{n} (0.03)
15	21.80^{s} (0.02)	32.21^{s} (0.02)	1.89^{f} (0.01)	20.01^{s} (0.02)	26.53^{s} (0.03)	1.00^{g} (0.01)	16.94^{t} (0.03)	28.02^{t} (0.05)	1.22^{p} (0.02)

Means with different letter within a column are significantly different

1.22 mg malonaldehyde/kg for plain mince surimi and pre-cooked products, respectively.

TBA values above 3–4 mg malonalydehyde/kg indicate quality loss in the fish products (Scott *et al.*, 1992). The results showed that oxidative rancidity remained relatively low in all samples throughout the storage period. Similarly, low TBA values have been reported for different types of species such as whole and filleted rainbow trout (Chytiri *et al.*, 2004) and farmed sea bream (Kyrana *et al.*, 1997), stored on ice. However, Köse and Erdem (2001) found higher TBA values for fresh whiting stored both at refrigerated and ambient temperatures. Their results showed that the products had unacceptable quality after 2 and 4 days at ambient and refrigerated temperatures, respectively.

Several methods exist to assess seafood quality and deterioration. However, there is much variation between species, as well as different products of the chemical, bacteriological, and sensory changes, depending on storage temperature and conditions, whether the product is fresh or processed, and the type of processing that is carried out. Therefore, the acceptable limits for each quality criteria may vary greatly for each type of product (Huss, 1988; Botta, 1995; Köse and Uzuncan, 2000).

In this study, the processing method affected all chemical parameters significantly (p<0.05). Significant differences occurred (p<0.05) between the product types for TBA, TVB-N and TMA values during the storage period. This study, thus demonstrated that mince produced by incorporating different mincing techniques into fish ball production affected their product quality as well as their shelf life at refrigerated conditions. The fish balls made from pre-cooked samples had higher consumer acceptability and shelf life. It was concluded that the shelf life of whiting can be increased when processed into fish balls or similar products. The type of mince used in ready-made fish products, such fish balls is important in relation to product quality and shelf life. Most studies on the shelf life of fish balls or burgers were carried out using products that were not fried before storage. Hence this study provides new information on the shelf life of fish balls at refrigerated conditions.

References

Aguilar, R.P., Crawford, D.L. and Lampila, L.E. 1989. Procedures for the efficient washing of minced whiting (*Merluccius productus*) flesh for surimi production. Journal of Food Science, 54: 248-252.

Akkuş, Ö., Varlık, C., Erkan, N. and Mol, S. 2004. Çiğ ve haşlanmış balık etinden yapılmış köftelerin bazı kalite parametrelerinin incelenmesi. Turkish Journal of Veterinary and Animal Sciences, 28: 79-85.

AOAC 1990. Official Methods of Analysis, 14th Edition. Association of Analytical Chemists. Washington DC.

Baker, R.C., Regenstein, J.M., Raccach, M. and Darfler, J.M. 1977. Frozen Minced Fish., Development of Products from Minced Fish: Booklet 3. NY Sea Grant Institute, NY. Albany, USA, 42 pp.

Baygar, T., Erkan, N., Metin, S., Özden, Ö. and Varlik, C. 2002. Soğukta depolanan alabalık dolmasının raf ömrünün belirlenmesi. Turkish Journal of Veterinary and Animal Sciences, 26: 577-580.

Borderias, A.J., Moral, A. and Matamoros, G.E. 1980. Storage properties of blue whiting after mincing by different methods. International Journal of Refrigeration, 12, 342-346.

Botta, J.R. 1995. Evaluation of Seafood Freshness Quality. VCH Publishers, Inc., New York, 180 pp.

Bristow, P. 1992. The İllustrated Encyclopedia of Fishes. Chancellor Press, London, 224 pp.

Chytiri, S., Chouliara, I., Savvaidis, I.N. and Kontominas, M.G. 2004. Microbiological, chemical and sensory assessment of iced whole and filleted aquacultured rainbow trout. Food Microbiology, 21: 157-165.

DIE 2003. State Fisheries Statistics, Turkey.

FAO 2003. Fisheries Statistics. http://www.fao.org /fi/statist/summtab/default.asp

Gökoğlu, N. 1994. Balık köftesinin soğukta depolanması. Gıda, 9: 217-222.

Hastings, R.J., Keay, J.N. and Young, K.W. 1990. The effect of particle size of mince, and mesh size of dewatering cloth, on the properties of washed whiting (*Merlangius merlangus*) mince. International Journal of Food Science and Technology, 25: 281-294.

Huss, H.H. 1988. Fresh Fish Quality and Quality Changes. FAO Fisheries Series No 29, Rome, 131 pp.

İnal, T. 1992. Besin Hijyeni, Hayvansal Gıdaların Sağlık Kontrolü, Final Ofset, İstanbul, 425 pp.

Kinsella, J.E. 1987. Seafoods and Fish Oils in Human Health and Disease. Markcel Decker Inc., New York, 398 pp.

Köse, S. and Erdem, M.E. 2001. Quality changes of whiting (*Merlangius merlangus euxinus* N., 1840) stored at ambient and refrigerated temperatures. Turkish Journal of Fisheries and Aquatic Sciences, 1: 59-67.

Köse, S. and Uzuncan, Y. 2000. Some quality changes of surimi produced from anchovy (*Engraulis encrasicholus*) during frozen storage –20ºC for five months. EU Su Ürünleri Dergisi. 17(3-4): 119-127 (in Turkish).

Köse, S., Boran, M. and Boran, G. 2006. Storage properties of refrigerated whiting mince after mincing by three different methods. Food Chemistry, 99: 129-135.

Kyrana, V.R., Lougovois, V.P. and Valsamis, D.S. 1997. Assessment of shelf-life of maricultured gilthead sea bream (*Sparus aurata*) stored in ice. International Journal of Food Science and Technology, 32: 339-347.

Lee, C.M.V., Lampila, L.E. and Crawford, D.L. 1990. Yield and composition of surimi from pacific whiting (*Merluccius productus*) and the effect of various protein additives on gel strength. Journal of Food Science, 55: 83-86.

Magnusson, H. and Martinsdóttir, E. 1995. Storage quality of fresh and frozen-thawed fish in ice. Journal of Food Science, 60: 273-278.

Metin, S., Erkan, E. and Varlık, C. 2002. The application of hypoxanthine activity as a quality indicator of cold stored fish burgers. Turkish Journal of Veterinary and Animal Sciences, 26: 363-367.

Morrissey, M.T. and Tan, S.M. 2000. World resources of surimi. In: J. Park (Ed.), Surimi and Surimi Seafood, Marckel Decker Inc., New York: 1-21.

Nettleton, J.A. 1992. Seafood nutrition in the 1990's issues for the consumer. Chapter 4. In: G. Bligh (Ed.), Seafood Science and Technology, Canadian Institute of Fish Tech.: 32-39.

Park, J. 2000. Surimi and surimi seafood. Marcell Dekker, New York, 500 pp.

Pedrosa-Menabrito, A.P. and Regenstein, J.M. 1990. Shelf-extension of fresh fish. A review Part III. Fish quality and methods of assessment. Journal of Food Quality, 13: 209-223.

Rey-Mansilla, M., Sotelo, C.G. and Gallardo, C.M. 1999. Decomposition of trimethylamine oxide during iced storage of blue whiting (*Micromesistius poutassou*). Zeitschrift für Lebensmittleunterszuchung und Forschung, 208: 267-269.

Scott, D.N., Fletcher, G.C., Charles, J.C. and Wong, R.J. 1992. Spoilage changes in deep water fish, smooth Oreo dory during storage in ice. International Journal of Food Science and Technology, 27 (5): 577-588.

Serdaroğlu, M. and Deniz, E.E. 2001. Balıklarda ve bazı su ürünlerinde trimetilamin ve dimetilamin oluşumunu etkileyen faktörler. EU Su Ürünleri Dergisi, 18: 575-581 (in Turkish).

Smith, G., Hole, M. and Hanson, S.W. 1992. Assessment of lipid oxidation in Indonesian salted-dried marine catfish (*Arius thalassinus*). Journal of the Science of Food and Agriculture, 51: 193-205.

Sokal, R.R. and Rohlf, F.J. 1987. Introduction to biostatistics. 2nd ed., *W.H.* Freeman and Company, New York, 349 pp.

Sonu, S.C. 1986. Surimi. National Marine Fisheries Service, NOAA, Technical Memorandum, NMFS, Terminal Island, Long Beach, California, 122 pp.

Varlık, C. 1994. Soğukta depolanan sardalyalarda histamin düzeyinin belirlenmesi. Gıda Teknolojisi, 19: 119-124.