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The Effect of Cold Marination on Some Physical Properties and Nutritional Composition of Sardine (*Sardina pilchardus*)

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Abstract: In the current study it was aimed to determine the effect of cold marination on the physical properties and nutritional quality of sardines. For this purpose, pH, colour, crude protein, crude oil, crude ash, moisture, fatty acid composition, amino acid, and mineral analyses were made in both raw and marinated sardine (marinated in 4% alcohol vinegar, 9% salt, and 0.3% citric acid at +4 °C for 36 hours). The *L** brightness value of sardine increased after marination. The crude ash content of the product was affected by marination, and the amount of crude protein and crude lipid increased ($p<0.05$). Glutamic acid, aspartic acid, alanine, and glycine contents of raw sardines increased after marination. In addition, there was an increase in the amounts of all essential amino acids except histidine. Palmitic acid was found to be the most abundant saturated fatty acid in sardines. The oleic acid content of the marinade increased with the marination process. It was determined that the Cd and Pb contents of raw and marinated sardines were below the limit values, and the Hg content of raw sardine was high. According to the results of the study, the marination process increased the brightness of the product, the amount of sweet and bitter amino acids, but it caused a decrease in omega 3 fatty acids.

Keywords: Sardine, marination, colour, fatty acids, amino acid, mineral

Soğuk Marinasyonun Sardalya'nin (*Sardina pilchardus*) Bazı Fiziksel Özellikleri ve Besin Bileşimi Üzerine Etkisi

Öz: Bu çalışmada soğuk marinasyonun sardalyanın fiziksel özellikleri ve besin bileşimi üzerine etkisinin belirlenmesi amaçlanmıştır. Bu amaçla hem çiğ hem de marine sardalyada (%4 alkol sirkesi, %9 tuz ve %0.3 sitrik asitte +4°C'de 36 saat marine edilmiştir) pH, renk, ham protein, ham yağ, ham kül, nem, yağ asiti kompozisyonu, amino asit ve mineral madde analizleri yapılmıştır. Marinasyondan sonra sardalyanın L* parlaklık değeri artmıştır. Ürünün kuru madde içeriği marinasyondan etkilenmiş, ham protein ve yağ miktarı artmıştır ($P<0.05$). Marinasyon sonrası çiğ sardalyanın glutamik asit, aspartik asit, alanin ve glisin içerikleri artmıştır. Ayrıca, histidin hariç tüm esansiyel amino asit miktarlarında artış olmuştur. Sardalyada en çok bulunan doymuş yağ asidi palmitik asit olarak tespit edilmiştir. Marinasyon işlemi ile marinatın oleik asit içeriği artış göstermiştir. Çiğ ve marine edilmiş sardalyaların Cd ve Pb içeriklerinin limit değerlerinin altında, çiğ sardalyanın Hg içeriğinin ise yüksek olduğu belirlenmiştir. Çalışma sonuçlarına göre marinasyon işleminin ürünün parlaklığını, tatlı ve acı aminoasit miktarını etkilediği buna karşın omega 3 yağ asitlerinde azalmaya neden olduğu tespit edilmiştir.

Anahtar Kelimeler: Sardalya, marinasyon, renk, yağ asitleri, amino asit, mineral

1. Introduction

Seafood is one of the most nutritious foods consumed around the world. It is recommended to consume seafood product with its high protein amounts, quality fatty acids, essential amino acids, minerals in the daily diet. However, when the population of Turkey is taken into consideration, the per capita consumption of seafood remains very low. Fish caught from the sea in a large part of Turkey is being consumed in the domestic market, the rest of the fish is sent to the fish meal and oil fabric and processing plants. For the last ten years, per capita consumption of seafood has not exceeded 7.1 kg in Turkey (TUIK 2021). While the average annual per capita consumption of seafood worldwide increased slightly from 19.9 kilograms to 20.5 kilograms between 2014 and 2019 (STATISTA 2021), these values could not be reached in Turkey. Considering the species obtained by caught, sardine is one of the first fish in Turkey. Considering the fish caught from Turkish seas in 2020, with 21265 tons, sardines are the 4th most caught fish after anchovy, sprat, and bonito (TUIK 2021).

Marination, which is one the seafood processing methods, is based on the interaction of acid and salt, giving flavour and aroma to the product, and extending its shelf life. With salting, which is one of the oldest processing methods, is tried to prevent spoilage by reducing the water content of the food. The pH of the

food is lowered by the acid added in marination and an edible product is obtained in a shorter time compared to salting. The method called marination has been tried in different ways in many kinds of seafood. The aim is not only to prevent microorganism growth but also it is used to tenderize or to change the taste, textural structural properties of raw materials (Gökoğlu et al. 2004). Studies on the use of marination technology in the processing of seafood are available in the literature (Gökoğlu et al. 2004; Kılınç & Çaklı 2004; Kılınç & Çaklı 2005; Kaba et al. 2014; Moreno et al.2017; Turan et al. 2017; Keskin et al. 2018; Kocatepe et al. 2019; Testa et al. 2019; Çorapcı et al. 2020; Szymczak et al. 2020; Çorapcı et al. 2021). The researchers studied the effects of marination under refrigerator conditions at different salt and acid concentrations in different fish species. 10% salt+4% (Turan et al. 2017; Keskin et al. 2018; Kocatepe et al. 2019) or 2% (Testa et al. 2019) acid for anchovy, 11% salt+ 4% acid (Çorapcı et al. 2020) or sea bream, 6% salt+ 5% acid (Szymczak et al. 2020) for Atlantic herring were used as a marination solution. In studies studied on sardines, 14% salt and 2%/4%/7% acid ratios were investigated by different researchers (Gökoğlu et al. 2004; Kılınç & Çaklı 2004; Kılınç & Çaklı 2005). In the present study, considering the previous studies, 4% alcohol vinegar+9% salt+0.3% citric acid was used for the sardine marination process. The study aims to determine the pH and colour changes observed in the product obtained by cold marination from frozen sardines and to determine the effect of marination on the proximate composition, fatty acids, amino acids, and mineral content of the product.

2. Material and Methods

2.1. Material

In the present study, 12 kg frozen sardines (*Sardina pilchardus*, Walbaum 1792) with average lengths of 13.25±0.20 cm and average weights of 19.64±0.93 were used as raw material for the marination process. Frozen sardines were purchased from a private company and brought to the laboratory within one hour under cold storage conditions. The study was carried out in November 2018.

Cold marination process

Frozen sardines were thawed under running water. The internal organs and heads of sardines were removed and cleaned. 2 kg of sardines were reserved for analysis before marination. After these processes, other sardines were marinated for 36 hours in marination solution (4% alcohol vinegar+9% salt+0.3% citric acid) with a fish: solution ratio of 1:1 at +4°C. After the marination, marinated sardines were removed from the solution and drained, and were make prepared for analysis.

2.2. Methods

Physical and proximate analysis were carried out in 2 replications and 3 parallels at Sinop University Fisheries Faculty, Fisheries Processing and Quality Control Laboratory. Fatty acids, amino acid, and mineral analyses were performed in 3 parallels at Sinop University Scientific and Technological Research Centre.

pH analysis

pH analysis was carried out using a pH meter. A 5 g of homogenized sample was transferred to the sample bottle. The measurement was carried out by immersing the pH meter probe into the sample.

Colour analysis

Konica Minolta (CRA-33a) colour measuring equipment was used for colour analyses. *L**, *a**, and *b** values were measured according to the International Commission on Illumination (CIE 1976).

Proximate analysis

The proximate composition (crude protein 984.13, crude lipid 960.39, crude ash 942.05), carbohydrates, and moisture contents were performed according to the AOAC official method (AOAC 1995; AOAC 2006). The energy value was calculated according to the method of Falch et al. (2010).

Amino acid analysis

Amino acid analyses were carried out using liquid chromatography (LC-MS/MS-Agilent Technology-6460 Triple Quad LC/MS) (Anonymous 1998). Ionization Modes: Electrospray ESI (- +), Atmospheric Pressure Chemical Ionization APCI (- +), Primary and Secondary Gases: Nitrogen (purity; 97%> and purity: 99.999%), Mass Filter and Detector: Triple Quadrupole, Dual mode (9 order), Liquid Chromatography Unit: Agilent Infinity 1260 HPLC, Nitrogen Gas Generator: Peak Scientific Instruments, NM32LA. JASEM quantitative amino acid LC-MS/MS analysis kit was used as a standard. Total sweet amino acids (Σ sweet AA) including glycine, alanine, and serine; and total bitter amino acids (Σ bitter AA) including isoleucine, arginine, phenylalanine, valine, tyrosine, leucine, methionine, and histidine, according to Dewi et al. (2016). The results were given in mg/100g protein.

Fatty acid analysis

Fatty acid compositions of raw and marinated sardine were analysed by GC/MS (Thermo Scientific/ Trace 1310 Gas Chromatography/ ISQ Single Quadrupole GC-MS) equipped with an auto sampler (AI-AS 1310 Series) (Gases Used: Nitrogen, Helium, Hydrogen, Dry Air. (99.999% purity), Available Detectors: GC-FID and GC-MS). A FAME mix (Supelco, 37 comp., Art No: CL40.13093, Bellefonte, PA, USA) was used to provide standards for comparison. The results were given in %.

Mineral analysis

Milestone (2018) method was used for the mineral analysis of samples. The acid (1 ml H_2O_2 30%, N 7 ml of HNO_3 65%) digestion of the sample in a closed vessel device using temperature control microwave (Ethos D, Milestone Inc. Sorisole, Italy) heating for the metal determination by spectroscopic methods. Analyses of elements were conducted using Agilent Technologies/7700X ICP-MS Systems. Analytical quality control was done using Agilent reference materials; std. 1: Agilent 8500-6940 2A (10 mg/kg-1 in 5% HNO3) was used for Li, Be, Na, Mg, K, Ca, Rb, Sr, Cs, Ba, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Al, Ga, As, Se, Tl, Pb; std. 2 Agilent 8500 - 6940 Hg (10 mg/kg-1 in 5% HNO3) was used for Hg analysis. The results were given in mg kg^{-1} in the wet weight.

Statistical analysis

A one-way analysis of variance was used to determine the differences in data's using MINITAB 21.1.0. software program (Minitab Inc., State College, PA, USA). Differences between means was determined by Tukey's test (a level of $p<0.05$ was used to establish significant differences among means).

3. Results and Discussion

3.1. pH values and colour analyses results of raw and marinated sardines

The pH values of raw and marinated sardine are shown in Table 1. Ludorf and Meyer (1973) reported the pH value was between 6.00–6.50 in raw fish. Due to an increase in compounds such as ammonia in fish meat during the deterioration of the fish, the pH value also increases. An increase in pH value is an indicator, used in spoiling the raw fish. With the effect of the acids used in the marination process, the pH decreased and the desired ratio in the marinated products was achieved. In the present study, the pH value of raw sardines was found to be 6.28. Gökoğlu et al. (2004), Kocatepe et al. (2019), and Gökoğlu (2002) had been reported that the pH values of marinated fish should be ranged between 4.00-4.50. The pH of the marinated sardines obtained in the study (4.28) was similar to these studies.

Küçükgülmez (2012) reported the pH value of marinated sardine was 4.5. Besides, the pH value of sardines, marinated with a solution containing 7% acetic acid and 14% salt, was reported as 4.23 after the marination processing. Kılınç and Çaklı (2004) and Çorapcı et al. (2020) determined that the pH value of marine sea bream ranged between 4.04-4.28.

*L**, *a**, *b** values of raw sardine fillets were reported as 47.19, 4.44, and 2.86, respectively by Kılınç and Çaklı (2005). In our study, the *L** value was lower than Kılınç and Çaklı (2005), this may be due to the freshness of the sardine. Küçükgülmez (2012) reported *L**, *a** and, *b** values of marinated sardines (3% acetic acid+ 10% salt) to be 62.91, 1.79, and 12.54, respectively. The *L** value, which is an indicator of brightness, was higher in the present study, the reason for this may be the higher rate of vinegar and citric acid use in our study compared to the literature. Similarly, Szymczak et al. (2020) stated that the *L** and values of raw Baltic herring decreased after the marination process (5% acetic acid+ 6%salt).

Table 1. pH values and colour analyses result of raw and marinated Sardine

Çizelge 1. *Çiğ ve marine sardalyanın pH ve renk analizi sonuçları*

		Raw Sardine	Marinated Sardine
pH		*6.28±0.01*^{a}	*4.28±0.01*^{b}
Colour	***L****	39.39±0.19^{a}	71.26±0.33^{b}
	a*	4.13±1.24^{a}	-0.6±0.13^{b}
	b*	3.6±1.25^{a}	14.97±0.83^{b}

Mean (n=6) ± st. error

a, b,: The difference between groups with different letters is significant ($p\leq0.05$)

3.2. Proximate composition of raw and marinated sardines

Moisture content analysis showed that with the marination process, water emerged from the fish tissue ($p<0.05$). The crude ash and carbohydrate contents of the sardine did not change statistically with the marination process ($p>0.05$). With the marination process, the dry matter content of the product was affected, and the crude protein and the crude lipid amount increased ($p>0.05$) (Figure 1). Kılınç and Çaklı (2004) found the moisture, crude protein, crude lipid, and ash contents of frozen sardines as 73.70, 15.4, 4.44, and 6.17%, respectively. Similar to the present study, there was also an increase in crude protein, crude ash, and crude oil content with marination in the literature (Kılınç & Çaklı 2004; Czerner et al. 2015). The

diffusion of salt into fish meat caused an increase in crude ash. Similar results have been reported for marinated fish (Czerner et al. 2015; Cabrer et al. 2002; Özden 2005; Bilgin et al. 2011; Zhelyazkov et al. 2015). Marination also caused an increase in the energy content of the product ($p<0.05$). While the previous energy content of sardine was 98.56 kcal/100g, this value increased by about 62% in the marinated sardine (156.84 kcal/100g).

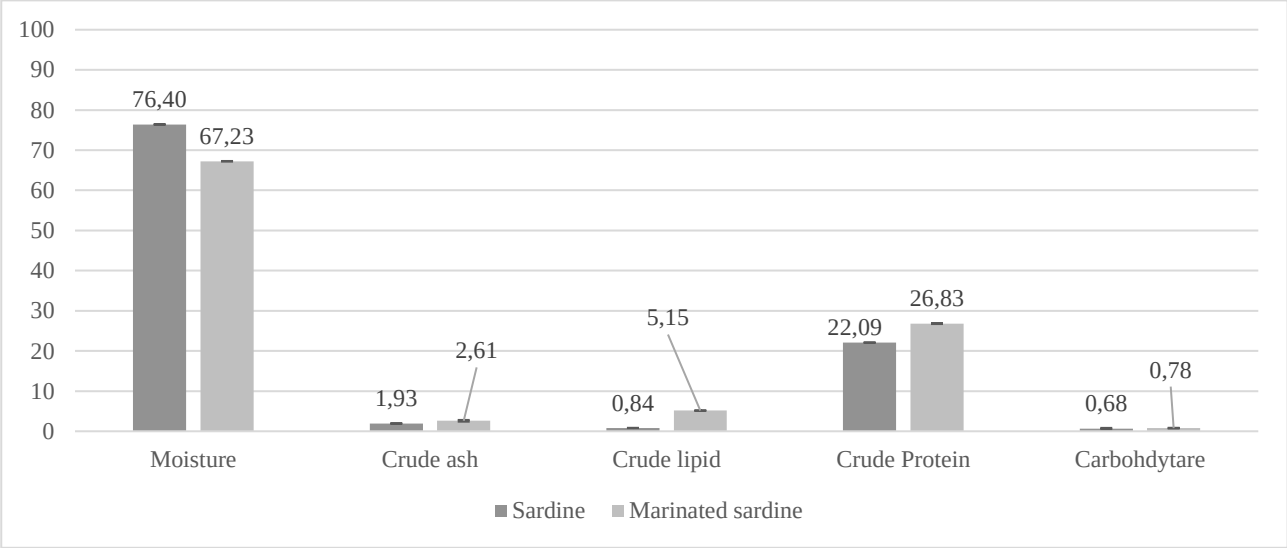

Figure 1. Proximate composition of raw and marinated sardine (%) (n=6)
Şekil 1. *Çiğ ve marine sardalyanın besin kompozisyonu*

3.3. Amino acid compositions of raw and marinated sardines

The amino acid compositions of raw and marinated sardines are shown in Table 2. Glutamic acid, aspartic acid, alanine, and glycine are responsible for flavour and taste. Özden (2005) reported that these amino acids are important by reason of they give marinated fish their characteristic taste and flavour. In the present study, glutamic acid, aspartic acid, alanine, and glycine contents of raw sardine increased after the cold marination process. The main essential amino acid in raw sardine was lysine. The lysine content of sardine increased with the marination process too ($p<0.05$). There was an increase in the amount of all essential amino acids except the histidine in the fish. ($p<0.05$). Similar results were reported by Kılınç and Çaklı (2004) and Özden (2005) about histidine contents of marinated sardine. The reason for this had been reported as the pH of marinades were not only total organic acid content but also the contents of basic and acidic amino acids such as histidine, glutamic acid, and aspartic acid: a decrease of histidine and an increase in glutamic and aspartic acid contents, presumably contribute to lowering pH of the marinade (Kılınç & Çaklı 2005).

The glutamic acid content, which plays an active role in the umami flavour, was high in raw sardine and marinated sardine.

Table 2. Amino acid compositions of raw and marinated Sardines (mg/100g protein)
Çizelge 2. *Çiğ ve marine sardalyanın amino asit kompozisyonu*

	Raw Sardine	Marinated Sardine
*Histidine**	0.62±0.02^a	0.45±0.03^b
Threonine	1.19±0.00^b	1.42±0.04^a
Valine	1.23±0.01^b	1.42±0.01^a
Methionine	0.72±0.01^b	0.90±0.00^a
Phenylalanine	1.10±0.01^b	1.22±0.01^a
Isoleucine	0.86±0.01^b	1.01±0.01^a
Leucine	1.70±0.06^b	2.14±0.00^a
Lysine	2.88±0.02^b	3.34±0.04^a
*Arginine**	1.44±0.00^b	1.71±0.06^a
Total Essential amino acid	11.74	13.61
Alanine	1.40±0.00^a	1.61±0.06^a
Aspartic Acid	2.26±0.05^a	2.73±0.14^a
Cysteine	0.27±0.00^a	0.32±0.02^a
Glutamic Acid	3.20±0.04^b	3.78±0.09^a
Glycine	0.92±0.04^b	1.13±0.02^a
Ornithine	0.06±0.01^a	0.06±0.00^a
Proline	0.94±0.00^b	1.03±0.01^a
Serine	1.15±0.01^b	1.33±0.02^a
Tyrosine	0.83±0.02^b	1.02±0.01^a
Taurine	0.39±0.00^a	0.21±0.01^b
Total Non-essential amino acids	11.42	13.22
Total amino acids	23.16	26.83
Sweet amino acids	3.47	4.07
Bitter amino acids	7.65	8.86

*: Conditionally essential amino acids.
Mean (n=3) ± st. error
a, b,: The difference between groups with different letters is significant ($p\leq0.05$)

It also had a high content of aspartic acid, one of the non-essential amino acids. Histidine and taurine content decreased with the marination process ($p<0.05$).

3.4. Fatty acid compositions of raw and marinated sardines

Fish is a high source of unsaturated fatty acids. The fatty acid compositions of raw sardine and cold marinated sardines are shown in Table 3. The most abundant saturated fatty acid in sardine was palmitic acid and present result was parallel with the literature (Karakoltsidis et al. 1995; Saglık and Imre 2001; Zlatanos & Laskaridis, 2007). Linoleic acid, docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA) were the highest percentages of fatty acids in raw sardines. Fish had low saturated fatty and high unsaturated fatty acid content. Fatty fishes such as mackerel, brook trout, herring, sardines, tuna, and salmon, etc. contain significant amounts of two important types of omega 3 fatty acids (DHA and EPA) (Turan et al. 2013). In present study, according to the results, sardine had high EPA and DHA contents. Also, the results show remarkable changes in the sardines with the marination process ($p<0.05$). Especially, butyric acid, palmitic acid, and DHA contents of sardines decreased after marination ($p<0.05$). The oleic acid content, which is an n-9 fatty acid, was increased by the marination process ($p<0.05$). As shown in Figure 1 and Table 3, raw sardines have a high protein, PUFAs (about 2.64 g/100g), and low-crude lipid content. This PUF content was higher than that of many protein foods listed by INFOODS (2021).

Sardine is the richest search for omega 3 fatty acids (Zlatanos & Laskaridis, 2007). Consumption of foods with high omega 3 content is important for the diet. Fast-food consumption habits have increased omega 6 intakes. The high levels of omega 3 fatty acids (above 30%) in *Sardine pilchardus* have also been reported by Zlatanos and Sagredos (1993). Similar results were found in present research. The recommended omega 3/omega 6 ratio to be taken daily is a minimum of 1. In present study, the omega 3/omega 6 ratio of sardines was above 1. After the marination process, this rate decreased but it did not fall below 1 value. ($p<0.05$). It is suggested that the omega 3/omega 6 ratio should be kept high, and this ratio should be 1:1 or 2:1 (Candela et al. 2011). Czerner et al. (2015) reported that the processing methods affected the omega 3/omega 6 ratios.

Table 3. Fatty acid compositions of raw and marinated sardines (%)

Çizelge 3. *Çiğ ve marine sardalyanın yağ asitleri kompozisyonu*

Fatty Acids%	Raw Sardine	Marinated Sardine
Butyric acid	7.32±0.13^a	4.30±0.25^b
Caproic acid	0.01±0.00^a	0.00±0.00^b
Caprylic acid	0.00±0.00^b	0.01±0.00^a
Capric acid	0.02±0.00^a	0.03±0.00^a
Undecanoic acid	0.01±0.00^a	0.01±0.00^a
Lauric acid	0.06±0.00^b	0.12±0.01^a
Tridecanoic acid	0.08±0.00^b	0.12±0.00^a
Myristic acid	4.25±0.04^b	5.42±0.29^a
Pentadecanoic acid	1.06±0.01^b	1.47±0.05^a
Palmitic acid	20.49±0.17^a	14.27±0.79^b
Heptadecanoic acid	1.30±0.01^b	1.49±0.05^a
Stearic acid	0.01±0.00^a	0.01±0.00^a
Arachidic acid	0.13±0.00^b	0.23±0.01^a
Heneicosanoic acid	0.06±0.01^a	0.08±0.00^a
Behenic acid	2.44±0.02^a	2.19±0.16^a
Tricosanoic acid	0.15±0.00^b	0.34±0.01^a
Lignoceric acid	0.37±0.01^b	0.55±0.00^a
Total SFA	37.76±0.07^a	30.63±1.65^b
Myristoleic acid	0.24±0.00^b	0.370±0.01^a
Pentadecanoic acid	0.14±0.00^b	0.19±0.01^a
Palmitoleic acid	0.33±0.01^b	0.68±0.02^a
Heptadecanoic acid	0.36±0.01^b	0.47±0.00^a
Oleic acid	3.65±0.00^b	21.12±1.29^a
Elaidic acid	0.21±0.00^b	5.33±0.40^a
Eicosenoic acid	1.71±0.01^b	2.21±0.13^a
Erucic acid	1.65±0.00^a	1.48±0.08^a
Nervonic acid	2.69±0.02^a	1.86±0.10^b
Total MUFA	10.99±0.05^b	33.72±2.02^a
Linolelaidic acid	0.16±0.00^a	0.01±0.00^b
Linoleic acid	8.22±0.04^a	9.25±5.36^a
Alpha-linolenic acid	0.64±0.00^b	1.67±0.09^a
Gamma-linolenic acid	1.24±0.01^b	1.99±0.12^a
Eicosadienoic acid	0.55±0.00^b	0.83±0.05^a
Arachidonic acid	2.44±0.022^a	2.19±0.16^a
Eicosatrienoic acid	0.30±0.02	0.35±0.02
Eicosapentaenoic acid (EPA)	8.82±0.02^a	7.29±0.45^b
Docosadienoic acid	0.15±0.00^b	0.34±0.01^a
Docosahexaenoic acid (DHA)	28.73±0.14^a	11.72±0.79^b
Total PUFA	51.25±0.10^a	35.63±7.06^b
omega 3	38.49±0.16^a	21.03±1.36^b
omega 6	12.76±0.07^a	14.61±5.02^a
omega 3/ omega 6	3.02	1.89
Total fatty acids	100.00±0.01^a	99.99±0.01^a

Mean (n=3) ± st. error

a, b,: The difference between groups with different letters is significant ($p\leq0.05$)

3.5. Mineral contents of raw and marinated sardines

Mineral contents of samples are shown in Table 4. The Be, Ag, Sb, Ga, and Tl contents of the samples are not shown in the table because they are <0.01 mg kg^{-1}. The major macro elements in sardine were K (4781.91 mg kg^{-1}) (Table 4). The recommended daily intake of K by the EGVM (2003) is 3500 mg K/day for adults. The macro element content of sardine had decreased after the marination process except for Na. The recommended

Na/K ratio for the prevention of heart diseases is less than 1 (Bu et al. 2012). In present study, the Na/K ratios of the raw sardine were determined as 0.38. The Na content of the sardine marinade was over the maximum measured value. The main reason for the increase in Na content of sardine marinade was the Na-containing salt used in marination process.

The determined dominant trace elements of sardine in present study were Zn, Fe, and As. The RDA for Zn 8-11mg/day for women and men (Dickinson 2000). The Zn content of sardine was quite high. Selenium is also a very valuable element for the immune system. The RDA of selenium is 55 µg/day for adults (Dickinson 2000). According to the Codex, the maximum Pb, Cd, and Hg levels permitted from the fish were 0.30, 0.10 (for sardines), and 0.50 mg/kg^{-1} (wet weight) (TGK 2021). Cd and Pb contents were lower than the limit values, but Hg level of sardine was high.

Table 4. Minerals contents of raw and marinated sardines (mg kg^{-1}) (wet weight)
Çizelge 4. *Çiğ ve marine sardalyanın mineral içeriği*

	Sardine	Marinated sardine
Ca	1199.77±26.94^{a}	639.68±3.36^{b}
Na	1839.52±43.00	*
Mg	595.47±15.39^{a}	250.75±1.71^{b}
K	4781.91±102.75^{a}	971.67±1.78^{b}
Li	0.21±0.00^{a}	0.17±0.01^{a}
Al	2.06±0.10^{b}	3.84±0.11^{a}
V	0.07±0.00^{a}	0.08±0.00^{a}
Cr	0.02±0.00^{b}	0.05±0.00^{a}
Mn	1.10±0.02^{a}	0.61±0.01^{b}
Fe	20.15±0.08^{a}	16.01±0.10^{b}
Co	0.03±0.00^{a}	0.02±0.00^{a}
Ni	0.11±0.00^{a}	0.09±0.00^{b}
Cu	1.12±0.00^{b}	1.83±0.02^{a}
Zn	27.52±0.11^{a}	12.18±0.19^{b}
As	13.11±0.05^{a}	2.79±0.00^{b}
Se	1.74±0.06^{a}	0.94±0.01^{b}
Rb	0.94±0.02^{a}	0.24±0.00^{b}
Sr	3.42±0.05^{a}	2.92±0.02^{b}
Cs	0.04±0.00^{b}	0.01±0.00^{a}
Ba	0.23±0.00^{a}	0.18±0.00^{b}
Pb	0.05±0.02^{a}	0.04±0.00^{b}
Cd	0.02±0.00^{a}	0.01±0.00^{b}
Hg	0.74±0.01^{a}	0.39±0.00^{b}

Mean (n=3) ± st. error, *over the maximum measured value.
a, b,: The difference between groups with different letters is significant ($p \leq 0.05$)

4. Conclusion

In the study, pH, colour values and nutritional composition of raw and marinated sardines were investigated. As an expected result of the marination process, the pH of the product decreased, the brightness (L^*) and yellowness (b^*) value increased, while the redness (a^*) decreased below zero. A product with high crude protein and crude lipid content was obtained due to water exit from the marinated tissue. Marinated sardines were high in essential amino acids. As with many processed products, a decrease in EPA, DHA, and total omega 3 fatty acids of marinated sardines was observed with the effect of processing. The mercury content of both raw sardines was higher than the limit values in the Turkish Food Codex. However, it is recommended to limit the consumption of sardines by children and pregnant.

References

Anonymous (1998). Amino acid analyser LC 3000 operation manual (AAAOM) sample preparation for physiological fluids (Tissue Extract). In: Manual version 4.1. of Eppendorf Biotronik Co., pp. 65–81.

AOAC (1995). Official Methods of Analysis, Association of Official Analytical Chemists.

AOAC (2006). Official methods of analysis Proximate Analysis and Calculations (17th edition), Association of Analytical Communities, Gaithersburg, MD,

Bilgin S, Çetinkaya S & Bolat Y (2011). Changes on the nutritional compositions of the sand smelt (*Atherina boyeri* Risso, 1810) marinade during storage. *African Journal of Biotechnology* 10(16): 3197-3203. https://doi.org/10.5897/AJB10.2067

Bu SY, Kang MH, Kim EJ & Choi MK (2012). Dietary intake ratios of calcium-to-phosphorus and sodium-to-potassium are associated with serum lipid levels in healthy Korean adults. *Preventive Nutrition and Food Science* 17(2): 93. https://doi.org/10.3746/pnf.2012.17.2.093

Cabrer AI, Casales MR, Yeannes MI (2002). Physical and chemical changes in anchovy (*Engraulis anchoita*) flesh during marination. *Journal of Aquatic Food Product Technology* 11(1): 19-30. https://doi.org/10.1300/J030v11n01_03

Candela CG, López LB & Kohen VL (2011). Importance of a balanced omega 6/omega 3 ratio for the maintenance of health. Nutritional recommendations. *Nutrición Hospitalaria* 26(2): 323-329. https://doi.org/10.3305/nh.2011.26.2.5117

CIE (1976). Commission International de L'Eclairage Colorimetry (Vol. 15). Vienna: Bureau Central de la CIE.

Çorapcı B, Köstekli B, Eyüboğlu A & Kocatepe D (2020). The effect of different application methods of sumac (*Rhus coriaria*) and tarragon (*Artemisia dracunculus*) on some quality properties of marinated sea bream (*Sparus aurata* L., 1758). *Journal of Food Processing and Preservation* 44(10): 1-15. https://doi.org/10.1111/jfpp.14751

Çorapcı B, Köstekli B, Eyüboğlu A & Kocatepe D (2021). The effect of different application methods of sumac (*Rhus coriaria*) and tarragon (*Artemisia dracunculus*) on nutritional composition, fatty acids and TBARS values of marinated sea bream (*Sparus aurata* L., 1758). *Journal of Food Processing and Preservation* 45(2): e15102. https://doi.org/10.1111/jfpp.15102

Czerner M, Agustinell SP, Guccione S & Yeannes MI (2015). Effect of different preservation processes on chemical composition and fatty acid profile of anchovy (*Engraulis anchoita*). *International Journal of Food Sciences and Nutrition* 66(8): 887-894. https://doi.org/10.3109/09637486.2015.1110687

Dewi EN, Amalia U & Mel M (2016). The effect of different treatments to the amino acid contents of micro algae Spirulina sp. *Aquatic Procedia* 7: 59-65. https://doi.org/10.1016/j.aqpro.2016.07.008

Dickinson A (2000). Recommended intakes of vitamins and essential minerals. CRN (Council for responsible Nutrition). The benefits of Nutritional Supplements.

EGVM (2003). Expert Group on Vitamins and Minerals. *Safe upper levels for vitamins and minerals*. Food Standards Agency. pp. 360. ISBN:1-904026-11-7.2003

Falch E, Overrien I, Solberg C & Slizyte R (2010). *Composition and calories*. In: Nollet L. M. L. & Toldrá F. (Eds.), Seafood and seafood product analysis, Part III (Chapter 16), 257–288 CRC Press, New York.

Gökoğlu N (2002). *Su Ürünleri İşleme Teknolojisi*. Su Vakfı Yayınları. Bilge Yayıncılık, Istanbul, Turkey.

Gökoğlu N, Cengiz E & Yerlikaya P (2004). Determination of the shelf life of marinated sardine (*Sardina pilchardus*) stored at 4°C. *Food Control* 15(1): 1-4. https://doi.org/10.1016/S0956-7135(02)00149-4

INFOODS (2021). International Network of Food Data Systems. *Latin American Food Composition Tables*. http://www.fao.org/infoods/infoods/tablas-y-bases-de-datos/america-latina/es/

Kaba N, Çorapcı B & Eryaşar K (2014). Determination of some quality properties and nutritional composition of Turkish raw meat ball produced with marinated Atlantic bonito. *The Journal of Food* 39(2): 63-70. https://doi.org/10.5505/gida.79188

Karakoltsidis PA, Zotos A & Constantinides SM (1995). Composition of the commercially important Mediterranean finfish, crustaceans, and molluscs. *Journal of Food Composition and Analysis* 8(3): 258-273. https://doi.org/10.1006/jfca.1995.1019

Keskin İ, Kocatepe D, Turan H, Altan CO, Köstekli B, Ceylan A & Candan C (2018). Marinasyon işlemi sirasinda hamside (*Engraulis encrasicolus* L. 1758) meydana gelen renk değişiminin ve bazi kimyasal parametrelerin belirlenmesi. *The Journal of Food* 43(4): 655-662. https://doi.org/10.15237/gida.GD18051

Kılınç B & Çaklı Ş (2004). Chemical, microbiological, and sensory changes in thawed frozen fillets of sardine (*Sardina pilchardus*) during marination. *Food Chemistry* 88(2): 275-280. https://doi.org/10.1016/j.foodchem.2004.01.044

Kılınç B, & Çaklı Ş (2005). Chemical, enzymatically, and textural changes during marination and storage period of sardine (*Sardina pilchardus*) marinades. *European Food Research and Technology* 221(6): 821-827. https://doi.org/10.1007/s00217-005-0114-y

Kocatepe D, Turan H, Altan CO, Keskin I, Ceylan A, Köstekli, B & Candan C (2019). Influence of different essential oils on marinated anchovy (*Engraulis encrasicolus* L. 1758) during refrigerated storage. *Food Science and Technology* 39: 255-260. https://doi.org/10.1590/fst.01318

Küçükgülmez A (2012). Effects of chitosan on the shelf life of marinated sardine (*Sardina pilchardus*) fillets during refrigerated storage. *Italian Journal of Animal Science* 11(3): e48. https://doi.org/10.4081/ijas.2012.e48

Ludorf W & Meyer V (1973). Fishe und fisherzeuge (pp. 209-210). Berlin:Verlag Paul Parey.

Milestone (2018). Milestone SK-10 High Pressure Rotor Application notes.

Moreno O, Gil À, Atarés L & Chiralt A (2017). Active starch-gelatine films for shelf-life extension of marinated salmon. *LWT-Food Science and Technology* 84: 189-195. https://doi.org/10.1016/j.lwt.2017.05.005

Özden Ö (2005). Changes in amino acid and fatty acid composition during shelf-life of marinated fish. *Journal of the Science of Food and Agriculture* 85(12): 2015-2020. https://doi.org/10.1002/jsfa.2207

Saglık S & Imre S (2001). ω3-Fatty Acids in Some Fish Species from Turkey. *Journal of Food Science* 66(2): 210-212. https://doi.org/10.1111/j.1365-2621.2001.tb11318.x

STATISTA (2021). Average annual per capita consumption of seafood worldwide from 2014 to 2020. https://www.statista.com/statistics/820953/per-capita-consumption-of-seafood-worldwide/

Szymczak M, Kamiński P, Felisiak K, Szymczak B, Dmytrów I, & Sawicki T (2020). Effect of constant and fluctuating temperatures during frozen storage on quality of marinated fillets from Atlantic and Baltic herrings (*Clupea harengus*). *LWT- Food Science and Technology* 133: 109961. https://doi.org/10.1016/j.lwt.2020.109961

Testa B, Lombardi SJ, Macciola E, Succi M, Tremonte P & Lorizzo M (2019). Efficacy of olive leaf extract (*Olea europaea* L. cv Gentile di Larino) in marinated anchovies (*Engraulis encrasicolus*, L.) process. *Heliyon* 5(5): e01727. https://doi.org/10.1016/j.heliyon.2019.e01727

TGK (2021). Türk Gıda Kodeksi/Turkish Food Codex. Gıdada bulaşanların maksimum limitleri. https://www.resmigazete.gov.tr/eskiler/2011/12/20111229M3-8.htm

TUIK (2021). Turkey Fisheries Statistics. https://www.tarimorman.gov.tr/SGB/Belgeler/SagMenuVeriler/BSGM.pdf

Turan H, Erkoyuncu İ & Kocatepe D (2013). Omega-6, omega-3 yağ asitleri ve balık. *Yunus Araştırma Bülteni* 2: 45-50. https://doi.org/10.17693/yunusae.v2013i21905.235422

Turan H, Kocatepe D, Keskin İ, Altan CO, Köstekli B, Candan C & Ceylan A (2017). Interaction between rancidity and organoleptic parameters of anchovy marinade (*Engraulis encrasicolus* L. 1758) include essential oils. *Journal of Food Science and Technology* 54(10): 3036-3043. https://doi.org/10.1007/s13197-017-2605-9

Zhelyazkov G, Popova T & Stratev D (2015). Chemical composition and fatty acid profile of marinated mackerel (*Scomber scombrus*) during processing and storage. *Macedonian Journal of Animal Science* 5(2): 75-80.

Zlatanos S & Laskaridis K (2007). Seasonal variation in the fatty acid composition of three Mediterranean fish–sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and pickarel (*Spicara smaris*). *Food Chemistry* 103(3): 725-728. https://doi.org/10.1016/j.foodchem.2006.09.013

Zlatanos S, & Sagredos A N (1993). The fatty acids composition of some important Mediterranean fish species. *Lipid / Fett* 95(2): 66-69. https://doi.org/10.1002/lipi.19930950207