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Full Length Research Paper

Changes on the nutritional compositions of the sand smelt (*Atherina Boyeri* Risso, 1810) marinade during storage

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This study was carried out to evaluate the chemical and sensory quality of sand smelt (*Atherina boyeri*) treated with marinating solution containing either 10% NaCl+2% acetic acid or 10% NaCl+3% acetic acid at 4°C for 120 days. The fish-to-marinating solution ratio was 1:1. According to the results of the chemical composition analysis of the fresh and marinated sand smelt, a significant increase (P<0.05) in ash and fat content and a decrease (P<0.05) in protein and moisture content were determined. In fatty acid analysis results, it was seen that there existed a decrease in unsaturated fatty acids in the marinated samples, and it was understood that the samples which had been marinated by using 2 and 3% acetic acid at the end of the storage period for 120 days were not spoilt according to the results obtained from the pH, thiobarbituric acid (TBA) and total volatile basic-nitrogen (TVB-N) analysis and sensory analysis. When comparing all parameters of group 2% with group 3%, the differences were statistically insignificant (P>0.05). However, it has been thought that only 3% acetic acid was suitable for marination of sand smelt because of the pH value of group 2%.

Key words: Sand smelt, *Atherina boyeri*, marinade, acetic acid, nutritional composition.

INTRODUCTION

The process of marination is to keep the fish by means of the brine consisting of salt and acetic acid (Erkan et al., 2000). Marinade is a canned product prepared with the solution of salt and vinegar, and it can also be made by adding tomato sauce, spices and different sauces into the fresh fish and the boiled or fried fish meats (Yapar, 1998; Çelik, 2004). The fish, like herring (*Clupea harengus*), sprat (*Sprattus sprattus*), sardine (*Sardina pilchardus*), ancho-vy (*Engraulis encrasicolus*) and cod (*Gadus morhua*), were used for marination (Erkan et al., 2000). Also, fresh, frozen or dry salted fish and parts of fish can be used for marination (Varlık et al., 1993).

The solutions which are used in marination can be of a wide-range. The one which is mostly used is the mixture of salt dissolved in water, acetic acid (vinegar) and spices (Dokuzlu, 1997). Many factors like salt, acetic acid, spices, the material and the preliminary process affect the marination process and the quality of product (Varlık et al., 1993).

Many studies have been done concerning the technology of marinade in fish and other sea food, although a study had been carried out on the shelf life of the marinated sardines (*S. pilchardus*) (Gökoğlu et al., 2004). In another study, the changes occurred during the production of anchovy (*E. encrasicolus*) in which marinade were examined (Aksu et al., 1997), while in some other researches, salmon (*Oncorhynchus mykiss*) (Erkan et al., 2000), anchovy (*E. encrasicholus*), horse mackerel (*Trachurus trachurus*), chup mackerel (*Scomber Japonicus*) and sardines (*S. pilchardus*) (Özden and Baygar, 2003), anchovy meatball (Varlik et al., 2000), shrimps (*Parapenaeus longirostris*) (Cadun et al., 2005), herring (*Clupea harengus membrans*) (Kolakowski and Bednarczyk, 2003), clam (*Tapes decussatus*) (Çelik, 2004), roach (*Rutilus rutilus*), white fish (*Coregenus sp.*)

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Abbreviations: PUFA, Polyunsaturated fatty acid; **DHA,** docosahexaenoic acid; **TVB-N,** total volatile basic nitrogen; **TBA,** thiobarbituric acid.

(Çolakoğlu, 2004), Atlantic bonito (*Sarda sarda*) and belone (*Belone belone euxini*) (Eke, 2007) were used as marinade material. Sand smelt (*A. boyeri*) was used for the first time in this study and it is a common fish in inland waters and sea of Turkey. Kalogeropoulos et al. (2004) reported that fresh *A. boyeri* contains 766.3 (g/kg) (76.63%) moisture, 21.1 (g/kg) (2.1%) fats and 172.1 (g/kg) (17.21%) proteins. In another study, fatty acid composition of 19 species of fish from the Black Sea and the Marmara Sea was determined and in this study, 37.3 ± 3.9% saturated fatty acid and 62.7 ± 3.9% unsaturated fatty acid were calculated for *A. boyeri* (Tanakol et al., 1999). Also, Tanakol et al. (1999) stated that *A. boyeri* is a low-fat fish (2 to 4%). In a study on the microbiological quality of a fresh and processed *A. boyeri*, coliform groups, fecal streptococcus and number of total aerobic bacteria were searched in samples belonging to fresh, frozen and frozen breaded products (Çolakoğlu et al., 2006).

Although *A. boyeri* exists commonly in many water sources in Turkey and is being exported to the foreign markets freshly, recently, the countries of European Union demanded that it should be exported in frozen and breaded form (Çolakoğlu et al., 2006).

The structure of the population and bio-ecology of *A. boyeri* have been extensively investigated in various parts of the world (Altun, 1991; Leonardos, 2001; Tomasini and Laugier, 2002; Bartulovic et al., 2004; Özeren, 2004; Sezen, 2005; Küçük et al., 2006; Onaran et al., 2006). As stated previously, no study has been found on the nutritional value of marinated sand smelt. Therefore, the present study was aimed at determining some nutritional characteristics of fish and marinated sand smelt and to enlarge the product range of the species as well as to present it to the market as an alternative food.

MATERIALS AND METHODS

Sample preparation

The sand smelts (*A. boyeri*) were caught in Eğirdir Lake by beach seine. They were brought to the Food Laboratory as early as possible in plastic cases by cooling. A total of 100 sand smelts were randomly selected from the captured fish and were used for the study. The average length and weight of fish were 7.40 ± 0.56 cm and 3.47 ± 0.61 g, respectively. After removing the fillet, the fish flesh were kept in the deep freezer (-18°C) for 3 days.

Marinating process and storage

Before processing of marination, the fillet fish were dissolved under tap water for a short time, and then they were placed in glass jars in two groups. The acetic acid (2 and 3%, 99% H_3COOH, EU Origin 16084) and salt (10%, ≥ 99.5% NaCl, Sigma-Aldrich, S7653) solutions were used to marinate *A. boyeri* and the ratio of fish, and were applied as 1:1 (w/v) (Cadun et al., 2005; Kolakowski and Bednarczyk, 2003). After marination, the fish were removed from the solution and kept at ambient temperature. The fish were placed in the glass jars again and sunflower oil was added (1:1 w/v). Consequently, they were kept in the refrigerator at 4±1°C for storage. The changes of nutritional composition, pH, total volatile basic-nitrogen (TVB-N), thiobarbituric acid (TBA) and sensory analysis were carried out during the storage.

Analytical procedures

Moisture analysis was performed by the automatic moisture indicating device (AND MX-50, Japan), while the pH was measured directly through meat (WTW mark 320 set, Germany) by the digital pH meter. The amount of protein was calculated according to Kjeldahl method (Nx6.25) (AOAC, Method no: 940.25) (AOAC, 2000), while the content of fat was calculated according to Lovell (1975) and the amount of ash was calculated in accordance with Lovell (1981). TVB-N analysis was carried out according to Nicholas (1992), while TBA analysis was performed in accordance with the method modified by Erkan and Özden (2008) from Weilmeier and Regenstein (2004) and Khan et al. (2006).

Fatty acid analysis

Determination of the fatty acid was performed by the use of gas chromatography (GC/MS- QP 5050 A) (Shimadzu, Japan) according to Izquierdo et al. (2002) and Tokusoglu et al. (2007). The operating conditions of the device was: injection block (240°C), injection volume (1 µL), detector (250°C), flow velocity [(psi) 10 detector, (Ms detector) 70eV], type of ionization (EI), gas (helium), Cp WAX 52 CB 50 m (Varian, USA) X 0.32 mm (1.2 µm) and program of temperature (after waiting for 4 min at 60°C, it was made to reach 175°C by an increase of 13°C in 1 min). After waiting for 27 min at 175°C, it was raised up to 215°C by an increase of 4°C in 1 min. Waiting at this temperature for 5 min, it was made to reach 240°C by an increase of 4°C, while waiting at this temperature for 15 min, 50 µL oil was derivatized in 5% sodium methoxide (CH_3ONa) within a night, and 1 ml of hexane was added to it. The hexane phase was injected into the system and was studied on the 14 items of fatty acid (Supelco™ 37 Component FAME Mix, Sigma, USA) which can provide the methyl esters.

Sensory analysis

Sensory evaluations were performed by using ten previously trained panellists, who were asked to evaluate color, appearance, odor, taste, flavor, hardness, salt, vinegar and texture via the modified method of Altuğ and Elmaci (2005). According to this evaluation, a score of between 10 and 8 was accepted as “very good”, between 8 and 6 as “good”, between 6 and 3 as “proper to consume” and under 3 as “inconsumable” for each sensorial characteristic.

Statistical analysis

The analysis of nutritional composition, pH, TVB-N and TBA were performed in triplicate. The results were analysed using the one-way analysis of variance (ANOVA), the Statistical Package for the Social Sciences (SPSS) 13.0 and the multiple comparison test (DUNCAN) for significance analysis at P = 0.05.

RESULTS AND DISCUSSION

A. boyeri is a common species in the Mediterranean and

has shown distribution from north-east Atlantic to north-west coast of Scotland. Also, this species lives in the Black Sea, Aegean Sea, Marmara Sea, Aral and Caspian Sea (Altun, 1999; Tomasini and Laugier, 2002; Bartulovic et al., 2004). *A. boyeri*, which is widespread in the water source of Turkey, has been reported for the first time in 2003 by Yeğen et al. (2006) in Lake Egirdir. In recent years, a lot of A. boyeri have been caught in Turkey. According to the results of the chemical composition analysis, an important amount of decrease in the content of moisture ($P<0.05$) in marinated fish samples was determined.The moisture content of the fish flesh which was marinated by the 2% acetic acid was found to be higher ($P<0.05$) than the moisture content of the fish which was marinated by the 3% acetic acid. While the moisture content of *A. boyeri*was reported as 76.63% (Kalogeropoulos et al., 2004), the value for *Atherina mochon* was reported as 66% in the fresh fish and as 66 and 4% in the headed and gutted samples, respectively (El-Sahn et al.,1990). The values given by Kalogeropoulos et al. (2004) and the study's moisture values have been determined as close to each other (Table 1). In similar studies (Erkan et al., 2000; Çelik, 2004; Cadun et al., 2005; Eke, 2007), a decrease was determined in the content of water after marination. The decrease in the content of moisture can be caused by the characteristic of the salt to absorb water thus the crude fat content of the marinade products significantly increased ($P<0.05$) after the marination process (Table 1). In another study with related sand smelt, the value of crude fat of raw samples was determined as 2.11% (Kalogeropoulos et al., 2004). Statistically, difference between the crude fat contents of raw and marinated products was found to be significant ($P<0.05$). Similar results have been obtained in other studies (Cadun et al.,2005; Eke, 2007; Sallam et al., 2007) and application of different acetic acid rates has not affected the fat con- tents. When the crude protein value of sand smelt samples was examined, the decrease in the protein content of the marinade made by using 2% acetic acid was considered not to be significant ($P>0.05$), but the decrease in the protein content of the marinade made by using 3% acetic acid was considered to be significant ($P<0.05$) (Table 1). In a study, *A. boyeri* was used as material, while the protein content was determined as 17.21% (Erkan and Özden, 2008).

This value is close to the protein results of the present study. A similar decrease in the value of crude protein was reported in other studies (Çelik, 2004; Eke, 2007). According to the content of crude ash of raw samples, it was understood that there existed a significant increase ($P<0.05$) in the value of percentage crude ash of the fish samples in the solution, including 2 and 3% acetic acid and 10% salt. Similar results have also been obtained in other studies concerning the subject (Eke, 2007; Kalogeropoulos et al., 2004). In addition, difference between the samples marinated by the 2 and 3% acetic acid was found to be non-significant ($P>0.05$) in terms of ash value. The fatty acid compositions of all the samples studied were greatly affected by marinating, though the major change was mainly the increase of oleic and linoleic acid. This situation is due to the addition of fat during marination. According to the results of fatty acid analysis, the highest rate of saturated fatty acid belongs to palmitic acid ($C_{16:0}$) (Table 2a). Tanakol et al. (1999) and Kalogeropoulos et al. (2004) found similar results in their studies with *A. boyeri*. In this study and in the other studies (Tanakol et al., 1999; Kalogeropoulos et al., 2004), it has been determined that the highest value of the polyunsaturated fatty acid (PUFA) analyzed is doco- sahexaenoic acid (DHA $C_{22:6\ \omega-3}$) (Table 2b). Docosahexa- enoic acid (DHA, $C_{22:6\ \omega-3}$) value of raw fish was found as12.14 ± 0.12 and after 2 and 3% acetic acid application, it significantly decreased to 6.75 ± 0.44 and 7.61 ± 0.41%, respectively. The difference between the acetic acid rates has statistically been considered to be non-significant, generally ($P>0.05$).

It has been remarked that a decrease in the polyunsaturated fatty acids generally existed both in this study and in previous studies (Özden, 2005; Kalogeropoulos et al., 2004). The reason for the decrease in the polyunsaturated fatty acids can be the characteristics of this type of fat, which easily get oxidized mostly in the fish. Fish contain high level of unsaturated fatty acids which causes the oxidation to speed up during storage. Oxidation of the fatty acids starts in the chain of carbon by a molecule of oxygen participating in the carbon hydrogen bond in order to give hydro peroxide. Hydroperoxides are the active oxidants, and they easily incline to react with the other molecules (Özden et al., 2001).

According to the sensory analysis results of sand smelt marinade, it is understood that the samples belonging to both groups have got good quality in terms of all the parameters used in the study (Table 3). Depending on the period of storage, a decrease has been seen in the points obtained from the panelists. It has been determined that there was no significant difference in general amongst the rates of acetic acid applied to fish in terms of all the sensory criteria ($P>0.05$). Sensory analyses are commonly used to evaluate the quality criteria of the products made recently. The results that were especially obtained by the experimental findings should be supported and strengthened by the sensory analyses of evaluation. Özden et al. (2001) reported that if a product is having an acceptable feature in terms of quality parameters, but has an unacceptable characteristic in terms of sensory features, this product cannot be consumed. Dokuzlu (1997), reports that the most important criterion affecting the quality of product, while storing the food, is the result of sensory analysis. However, a product whose sensory analysis results are not suitable can not be served to consumer.

According to the sensory analysis, it was determined that Oncorhynchus mykiss marinade has a shelf life of

Table 1. The results of the chemical composition analysis of the raw and marinated sand smelts (mean ± SE).

Sand smelt	Moisture (%)	Crude fat (%)	Crude protein (%)	Crude ash (%)
Raw	78.28±0.20^{a}	1.84±0.30^{b}	19.64±0.45^{a}	1.67±0.00^{b}
2%	72.58±0.48^{b}	3.32±0.17^{a}	18.84±0.80^{a}	4.14±0.45^{a}
3%	70.77±0.17^{c}	3.37±0.04^{a}	16.43±0.33^{b}	4.11±0.12^{a}

The difference amongst the values specified in the same column by the same letters is not significant (P>0.05).

Table 2a. Changes on the fatty acids of raw and marinated sand smelts during storage (mean ±SE).

Day	Sand smelt	C14:0	C15:0	C16:0	C17:0	C18:0	C16:1	C18:1 (ω -7)
0	Raw	1.70±0.01^{a}	1.65±0.03^{a}	23.74±0.25^{cdef}	1.72±0.01^{a}	7.08±0.0^{4c}	4.75±0.08^{a}	6.81±0.04^{a}
1	2%	0.85±0.04^{Bg}	0.72±0.04^{Bcde}	21.93±0.43^{Bh}	0.65±0.02^{Be}	7.07±0.31^{Bc}	2.09±0.15^{Bh}	4.90±0.34^{Ag}
	3%	0.98±0.02^{Afg}	0.91±0.01^{Abc}	24.57±0.30^{Abcde}	1.17±0.03^{Abcd}	8.93±0.67^{Aab}	2.55±0.01^{Ag}	5.81±0.08^{Acdef}
7	2%	1.22±0.03^{Abcde}	0.68±0.05^{Ade}	25.05±0.29^{Aabc}	1.23±0.03^{Abcd}	8.12±0.04^{Aabc}	3.20±0.01^{Acd}	6.14±0.05^{Abcd}
	3%	1.12±0.06^{Acdef}	0.88±0.08^{Abcd}	24.93±0.27^{Aabcd}	1.30±0.10^{Abc}	8.93±0.67^{Aa}	2.66±0.12^{Bfg}	6.05±0.23^{Acde}
14	2%	1.53±0.20^{Aa}	1.00±0.04^{Ab}	24.79±0.21^{Abcde}	1.28±0.55^{Abc}	7.89±0.51^{Aabc}	3.37±0.11^{Abc}	6.36±0.17^{Aabc}
	3%	1.09±0.01^{Acdef}	0.91±0.06^{Abc}	24.58±0.39^{Abcde}	1.26±0.09^{Abcd}	8.01±0.51^{Aabc}	2.83±0.05^{Bef}	5.81±0.13^{Acdef}
30	2%	1.07±0.05^{Adef}	0.91±0.04^{Abc}	23.62±0.92^{Adef}	1.20±0.05^{Abcd}	7.84±0.14^{Aabc}	2.81±0.13^{Aefg}	5.62±0.23^{Adef}
	3%	1.07±0.07^{Adef}	0.82±0.14^{Abcde}	22.94±0.42^{Afgh}	1.13±0.04^{Acd}	7.69±0.22^{Abc}	2.80±0.07^{Afg}	5.71±0.09^{Adef}
60	2%	1.11±0.01^{Acdef}	0.79±0.07^{Abcde}	23.50±0.29^{Aefg}	1.23±0.00^{Abcd}	8.04±0.10^{Aabc}	3.06±0.02^{Aef}	5.88±0.07^{Acde}
	3%	0.95±0.01^{Bfg}	0.65±0.03^{Ae}	22.15±0.29^{Bgh}	1.08±0.03^{Bd}	7.79±0.16^{Abc}	2.67±0.05^{Bfg}	5.29±0.06^{Bfg}
90	2%	1.02±0.04^{Befg}	0.71±0.09^{Acde}	23.38±0.75^{Aefg}	1.24±0.07^{Abcd}	8.55±0.60^{Aab}	2.71±0.04^{Bfg}	5.53±0.23^{Aef}
	3%	1.23±0.05^{Abcd}	0.97±0.05^{Ab}	23.38±0.45^{Aefg}	1.19±0.02^{Abcd}	7.28±0.12^{Ac}	3.20±0.13^{Acd}	5.73±0.13^{Adef}
120	2%	1.32±0.01^{Ab}	0.84±0.10^{Abcde}	25.85±0.58^{Aab}	1.26±0.08^{Abcd}	7.98±0.40^{Aabc}	3.57±0.08^{Ab}	6.45±0.22^{Aab}
	3%	1.29±0.01^{Abc}	0.93±0.06^{Abc}	26.28±0.68^{Aa}	1.34±0.08^{Ab}	8.10±0.52^{Aabc}	3.57±0.01^{Ab}	6.89±0.18^{Aa}

The capitals in the columns express the acetic acid values of 2 and 3%, while the lowercases express the difference between the days. The difference amongst the values specified by the same letters is not significant (P>0.05).

Table 2b. Changes on the fatty acids of raw and marinated sand smelts during storage (mean± SE)

		C18:1 (ω-9)	C18:2 (ω-6)	C18:3 (ω-6)	C20:4 (ω-6)	C20:5 (ω-3)	C22:5 (ω-3)	C22:6 (ω-3)
	Raw	8.52±0.16^{I}	4.00±0.38^{d}	1.48±0.08^{a}	5.05±0.03^{a}	9.93±0.19^{a}	3.96±0.08^{a}	12.14±0.12^{a}
1	2 %	16.18±0.55^{Aab}	23.92±1.06^{Aab}	0.94±0.10^{Ae}	2.82±0.40^{Aefg}	6.20±0.10^{Acde}	1.83±0.27^{Acd}	7.33±0.22^{Acdef}
	3 %	14.02±0.41^{Bcde}	18.97±0.93^{Babc}	1.05±0.00^{Acde}	3.47±0.07^{Acdef}	6.60±0.24^{Abcde}	1.88±0.13^{Acd}	7.10±0.52^{Acdef}
7	2 %	11.33±0.03^{Bh}	15.03±0.13^{Bc}	1.22±0.03^{Abc}	4.15±0.05^{Ab}	7.11±1.33^{Abcd}	2.55±0.09^{Acd}	9.40±0.12^{Ab}
	3 %	14.27±0.45^{Aabcde}	18.98±0.51^{Aabc}	1.11±0.03^{Abcde}	3.06±0.40^{Adefg}	6.34±0.59^{Acde}	2.11±0.50^{Abcd}	6.75±0.84^{Bcdef}
14	2 %	11.55±0.37^{Afg}	15.01±1.19^{Ac}	1.18±0.02^{Abcd}	3.81±0.07^{Abc}	8.18±0.24^{Ab}	2.67±0.09^{Ab}	8.21±0.95^{Abc}
	3 %	13.01±0.60^{Aefg}	17.43±0.85^{Aabc}	1.05±0.67^{Acde}	3.50±0.16^{Acde}	7.38±0.07^{Bbc}	2.27±0.21^{Abcd}	8.07±0.28^{Abc}
30	2 %	13.49±1.05^{Acdef}	19.30±1.46^{Aabc}	1.06±0.10^{Acde}	3.38±0.20^{Acdef}	7.03±0.50^{Abcd}	2.40±0.10^{Abcd}	6.90±0.52^{Acdef}
	3 %	14.47±1.42^{Aabcde}	19.39±1.63^{Aabc}	1.13±0.04^{Abcde}	3.45±0.25^{Acdef}	6.68±0.65^{Abcde}	1.82±0.48^{Acd}	7.44±0.79^{Acde}

Table 2b. cont.

60	2 %	13.32±0.07^{Bdefg}	19.55±0.89^{Babc}	1.15±0.04^{Abcd}	3.57±0.10^{Abcd}	6.80±0.46^{Abcde}	2.28±0.16^{Abcd}	7.63±0.21^{Acd}
	3 %	16.30±0.41^{Aa}	24.21±0.56^{Aa}	1.00±0.06^{Ade}	2.69±0.12^{Bg}	5.59±0.30^{Ade}	2.06±0.20^{Abcd}	6.02±0.31^{Bdef}
90	2 %	15.47±0.50^{Aabc}	23.23±0.63^{Aab}	0.94±0.06^{Ae}	2.85±0.06^{Aefg}	5.31±0.20^{Ae}	1.93±0.17^{Abcd}	5.69±0.25^{Af}
	3 %	15.22±1.24^{Aabcd}	21.80±0.30^{Aabc}	1.10±0.06^{Abcde}	2.79±0.25^{Afg}	5.81±0.47^{Acde}	1.83±0.14^{Acd}	5.92±0.42^{Aef}
120	2 %	14.11±1.08^{Abcde}	17.48±0.58^{Aabc}	1.16±0.06^{Abcd}	3.39±0.15^{Acdef}	6.64±0.35^{Abcde}	1.81±0.22^{Acd}	6.75±0.44^{Acdef}
	3 %	12.67±0.13^{Aefg}	16.42±0.14^{Abc}	1.29±0.00^{Ab}	3.33±0.23^{Acdefg}	6.81±0.32^{Abcde}	1.67±0.08^{Ac}	7.61±0.41^{Acd}

The capitals in the columns express the acetic acid values of 2 % and 3 %, and lowercases express the difference between the days, the difference amongst the values specified by the same letters is not important (P>0.05).

Table 3. The results of the sensory analysis of marinated sand smelts during storage (mean± SE).

Sensory feature	Sand smelt	1	15	30	60	90	120
Color	2%	7.20±0.36^{Aa}	7.40±0.58^{Aa}	7.10±0.72^{Aa}	6.40±0.45^{Aa}	5.70±0.79^{Aa}	6.10±0.48^{Aa}
	3%	7.00±0.42^{Aab}	7.40±0.56^{Aa}	7.10±0.60^{Aab}	6.00±0.37^{Aab}	4.10±0.86^{Ac}	5.40±0.54^{Abc}
Appearance	2%	7.00±0.35^{Aa}	7.30±0.63^{Aa}	7.10±0.89^{Aa}	6.30±0.56^{Aa}	4.90±0.74^{Aa}	5.80±0.53^{Aa}
	3%	6.80±0.47^{Aab}	7.30±0.50^{Aa}	7.00±0.73^{Aab}	6.50±0.56^{Aab}	4.00±0.91^{Ac}	5.10±0.57^{Abc}
Odor	2%	6.90±0.38^{Aa}	6.70±0.67^{Aa}	6.30±0.88^{Aa}	5.30±0.60^{Aa}	4.60±0.91^{Aa}	5.30±0.62^{Aa}
	3%	7.00±0.49^{Aa}	7.30±0.68^{Aa}	6.30±0.79^{Aab}	4.60±0.70^{Abc}	3.80±0.73^{Ac}	4.80±0.53^{Abc}
Taste	2%	6.80±0.65^{Aa}	6.90±0.59^{Aa}	6.30±0.94^{Aa}	--	--	--
	3%	7.00±0.58^{Aa}	6.90±0.72^{Aa}	6.30±0.88^{Aa}	--	--	--
Flavor	2%	6.70±0.54^{Aa}	6.90±0.55^{Aa}	6.30±0.94^{Aa}	--	--	--
	3%	7.10±0.57^{Aa}	6.90±0.72^{Aa}	6.30±0.88^{Aa}	--	--	--
Hardness	2%	7.50±0.67^{Aa}	6.10±0.80^{Aa}	6.50±0.65^{Aa}	5.80±0.55^{Aa}	4.40±0.65^{Aa}	6.10±0.50^{Aa}
	3%	7.30±0.54^{Aa}	6.40±0.54^{Aa}	6.40±0.83^{Aa}	5.90±0.67^{Aa}	3.60±0.87^{Ab}	5.10±0.71^{Aab}
Salt	2%	7.00±0.62^{Aa}	7.00±0.65^{Aa}	6.90±0.62^{Aa}	--	--	--
	3%	7.20±0.44^{Aa}	7.10±0.57^{Aa}	6.80±0.53^{Aa}	--	--	--
Vinegar	2%	7.00±0.65^{Aa}	7.00±0.67^{Aa}	5.70±0.65^{Aa}	--	--	--
	3%	6.50±0.64^{Aa}	7.40±0.73^{Aa}	5.90±0.80^{Aa}	--	--	--
Texture	2%	7.70±0.47^{Aa}	7.00±0.58^{Aa}	6.30±0.90^{Aa}	6.90±0.50^{Aa}	4.80±0.96^{Aa}	5.90±0.60^{Aa}
	3%	6.50±0.64^{Aa}	6.90±0.46^{Aa}	7.20±0.76^{Aa}	6.40±0.56^{Aa}	3.70±0.92^{Ab}	5.20±0.66^{Aab}

Results have been given as the average of the 10 different points obtained. In the columns, the capitals indicate the 2 and 3% acetic acid, while the small letters express the difference between the days in the lines. The difference between the values specified with the same values is not significant (P>0.05).

Table 4. The pH, TVB-N and TBA analysis results of the marinated sand smelt (mean± SE).

Day	pH		TVB-N (mg/100 g)		TBA (µg MDA/g)	
	2%	3%	2%	3%	2%	3%
Raw	6.16 ±0.00^{a}	6.16 ±0.00^{a}	16.07±0.22^{a}	16.07±0.22^{a}	0.52±0.01^{f}	0.52±0.01^{f}
1	4.53±0.00^{Ab}	4.25±0.00^{Ba}	5.86±0.26^{Ab}	6.43±0.08^{Aef}	4.68±0.04^{Abcd}	4.27±0.03^{Bde}
7	4.42±0.00^{Ae}	4.22±0.00^{Bb}	6.55±0.27^{Ag}	6.49±0.12^{Ae}	4.29±0.16^{Bde}	5.76±0.08^{Aa}
15	4.43±0.00^{Ade}	4.19±0.00^{Bc}	8.70±0.22^{Ad}	8.07±0.23^{Bd}	4.50±0.29^{Bcd}	6.00±0.00^{Aa}
30	4.44±0.00^{Ad}	4.16±0.01^{Be}	8.64±0.16^{Ade}	8.51±0.28^{Ad}	4.61±0.08^{Abcd}	4.50±0.29^{Acd}
60	4.44±0.00^{Ad}	4.20±0.00^{Bd}	10.56±0.10^{Ac}	10.14±0.05^{Ac}	4.08±0.07^{Be}	4.78±0.07^{Acb}

Table 4. cont.

90	4.46 ± 0.00^{Ac}	4.22 ± 0.00^{Bc}	13.28 ± 0.05^{Ab}	11.85 ± 0.05^{Bb}	4.28 ± 0.16^{Bde}	4.97 ± 0.06^{Ab}
120	4.45 ± 0.00^{Ac}	4.26 ± 0.00^{Bb}	7.46 ± 0.24^{Af}	6.18 ± 0.35^{Bef}	4.00 ± 0.00^{Bc}	4.52 ± 0.07^{Acd}

The difference between the values indicated with the same small letters in the columns and obtained depending on the time of storage is not significant (P>0.05). Likewise, the difference between the ones indicated with the same capitals of the values obtained from the different processes in the lines is not significant (P>0.05).

60 days, *E. encrasicolus* marinades for 90 days (Özden et al., 2001) and marinated *E. encrasicolus* meatball for 4 months (Varlik et al., 2000). As such, there was an important decrease in the pH value of sand smelt after marination (P<0.05). It has been determined that the difference between the 60th and 90th day pH values belonging to the samples marinated using 2 and 3% acetic acid was not significant (P>0.05), while it was significant on the other days (P<0.05) (Table 4). Also, it has been reported that the pH value in the products marinated must be between 4.1 and 4.5 (Varlik et al., 1993; Aksu et al., 1997). It is seen that the pH values obtained in the study is in the range of 4.53 ± 0.00 and 4.16 ± 0.01 (Table 4). A similar decrease in the value of pH was reported in the previous studies with *E. encrasicolus*, *S. pilchardus*, *O. mykiss*, *T. trachurus*, *Scomber japonicus* and *Belone belone euxini* species (Varlik et al., 1993; Aksu et al., 1997; Cadun et al., 2005; Özden et al., 2001). TVB-N is one of the spoilage parameters in fish and fish products. In the present study, an important decrease occurred in the values of TVB-N at the end of the 1st day (P<0.05), then important increases were seen during the storage period (P<0.05) (Table 4). Similar findings were obtained by Cadun et al. (2005). In another study, a low TVB-N value, which changed irregularly during storage, was determined (Özden and Baygar, 2003). Regarding the value of TVB-N, Dokuzlu (1997) reported the limit values as very good until 25 mg/100 g, good until 30 mg/100 g, marketable until 35 mg/100 g and spoilt more than 35 mg/100 g. It was obvious that marination decreased TVB-N values. Both groups were rated 'good quality' due to their TVB-N values. When comparing TVB-N value of group 2% with group 3%, no significant difference was determined (P>0.05) generally. TBA analysis is an important quality index, indicating fat oxidation. Oxidative rancidity is a complex spoilage, and especially occurs in fatty fishes (Connell, 1980). An important increase (P<0.05) occurred in the value of TBA in the beginning of storage. When comparing TBA values of group 2% with group 3%, a significant difference was determined according to the storage period except the 60th day of storage (Table 4). According to Schormuller (1968, 1969), TBA value should be less than 3 mg malonaldeyde/kg in perfect quality material and should not be more than 5 mg malon- aldeyde/kg in good quality material, consumption limits were from 7 to 8 mg malonaldeyde/kg (Cadun et al.,2005), and both groups were close to the acceptability limits for consumption. However, the highest TBA value (6.00 ± 0.00 µg MDA/g) that was obtained in the study is lower than the limit values given.

Conclusion

A few studies exist which have been performed on the management of *A. boyeri*. Marinade technology has been tried for the first time in this species. In the light of the findings of the present study, it is thought that sand smelt is a material which is rich in unsaturated fatty acids and suitable for marination. It has been understood that the marinated product obtained from sand smelt can be consumed tastefully, and that the product still had no spoilage at the pH, TVB-N and TBA analyses carried out during the 120 days period of storage. When comparing all parameters of group 2% with group 3%, no significant difference was determined (P > 0.05) generally. However, when the pH values of the products marinated with 2% acetic acid were examined, it was thought that only 3% acetic acid rate was suitable for the marination of sand smelt, since the available environment of reproduction has been provided for the protein microorganisms which are acid resistant, especially for the bacterium reproducing in the anaerobic conditions like *Clostridium botilinum*.

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