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ORIGINAL ARTICLE

Effects of cooking methods and temperatures on nutritional and quality characteristics of anchovy (*Engraulis encrasicholus*)

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Abstract The aim of this study was to determine the nutritional and quality characteristics of anchovy after cooking. The fish were cooked by different methods (frying, baking and grilling) at two different temperatures (160 °C, 180 °C). Crude ash, crude protein and crude fat contents of cooked fish increased due to rise in dry matter contents. While cooking methods affected mineral content of anchovy, cooking temperature did not affect. The highest values of monounsaturated fatty acids were found in baked samples. Polyunsaturated fatty acids in baked samples were also high and similar in fried samples. Fried samples, which were the most preferred, lost its nutritional characteristics more than baked and grilled samples. Grilled and baked fish samples can be recommended for healthy consumption. However, grilled fish samples had hard texture due to more moisture loss than other methods. Therefore, it is concluded that baking is the best cooking method for anchovy.

Keywords Anchovy · Cooking · Quality · Nutrients

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Introduction

The anchovy (*Engraulis encrasicholus*) is a pelagic fish species belonging to the Engrauliadae family. Marine fishery is the most important segment within the fisheries sector in Turkey. Marine fisheries production was 61.1% of total production catch in 2009. Anchovy is the most important species accounting for 53.7% of total marine catch (Anonymous 2009). As a traditional product for many years, anchovies retain their popularity as the most common fish caught in Turkey. Its suitability for further processing (salting, marinating, canning and processing to fish oil etc.) has lead to industrialization. Also there many meals in which anchovies are very popular. Among these, fried anchovies, anchovy soup, anchovy pickles, anchovies in rice, anchovies in olive oil and anchovy composts are the most popular ones (Anonymous 2000; 2003).

Studies on the relation between food intake and health are based on data from raw food without consideration cooking and other processes that cause considerable alterations. Cooking of foods prior to consumption is important for healthy nutrition. Cooking methods and temperatures have important role on keeping nutrients. Methods for preparation and cooking of foods cause some changes in structures of food components (Ackurt 1991). Foods such as meat and fish become edible and more digestible when they are subjected to cooking. However, heat treatment can lead to undesirable modifications, such as the loss of the nutritional value of foods due mainly to lipid oxidation, and changes in some components of the protein fraction.

The aim of this study was to investigate the changes in nutritional and quality characteristics of anchovy after cooking by three different methods which are widely used.

Materials and methods

Fish

Research material anchovy (*Engraulis encrasicholus*) were purchased from the local fish market in Antalya (Turkey). The fishes were directly transferred to the laboratory in polystyrene boxes within an hour after purchase. They were eviscerated, filleted and washed and then cooked by frying, baking and grilling. In total 17 kg of fish with an average weight of 10.55±1.25 g was used. The fish were divided into three groups. All the fillets retained their skin.

Cooking treatments

The fish were cooked using by three methods, (frying, baking and grilling) and two temperatures (160 and 180 °C).

1- Frying: The fish were fried in a pan filled with sunflower oil at 160 and 180 °C.
2- Baking: The fish were baked in an electrically operated oven at 160 and 180 °C for 20 min.
3- Grilling: The grilling process was carried out using an electrically operated grill at 160 and 180 °C for 20 min.

Analyses

After cooling of cooked fish analyses were performed. Before analyses the fish in each lot were homogenized using blender. All assays were conducted on duplicate samples of the homogenates.

Proximate composition

The moisture content of anchovy was determined by drying the fish meat in an oven at 105 °C until a constant weight was obtained (AOAC 1990). Crude protein content was calculated by converting the nitrogen content determined by Kjeldahl's method (6.25 X N). Ash content was determined by dry ashing in a furnace oven at 525 °C for 24 h (AOAC 1990). Fat was extracted by the method described by the Bligh and Dyer (1959).

Mineral analyses

For mineral determination, the samples were digested in HNO3/HClO4 (Kacar 1972). The elements Na, K, Ca, Mg, Fe, Zn, Mn, Cu were measured by atomic absorption spectrophotometer (AAS) using a Varian Spectra atomic absorption spectrophotometer model A-400. Phosphorus (P) was measured by a spectrophotometer (Shimadzu UV 160 A) after color development the samples in Barton solution (Kacar and Kovanci 1982). The results were expressed as absorbance at 430 nm. Standard curves were used for the determination of the elements in question.

Peroxide value

The peroxide value (PV) was determined using the method described by the American Oil Chemists' Society (1990). The sample was dissolved in 30 ml glacial acetic acid–chloroform solution (3/2 v/v) and 1 ml KI solution (14 g KI/10 ml distilled water) was added. Distilled water (30 ml) was added after 1 min and the mixture was titrated with sodium thiosulfate (0.01 N) until the yellow color was lost. Then 5 ml starch indicator was added and the solution was titrated again with sodium thiosulfate until the blue color disappeared. The PV was calculated using the following formula:

$$(\mathrm{PVmEq/kg}) = (\mathrm{V} - \mathrm{B} \times \mathrm{Nf}/\mathrm{W}) \times 1000,$$

Where V is the volume of sodium thiosulfate consumed, B is the volume of normal sodium thiosulfate consumed during a blank titration, W is the weight of the sample (grams) and Nf is the normality of sodium thiosulfate multiplied by a factor.

Fatty acids composition

Lipid extraction was carried out by the method of Bligh and Dyer (1959). Extracted lipids were transferred to glass vials and esterified as described by Morrıson and Smith (1964). Fatty acids composition of anchovy lipids was determined using GC (Fisons Instruments HRGC MEGA 2). The GC was equipped with a SPB-17 fused slica column (30 m, 0.25 mm, 0.25 μm) and flame ionization detector. Fatty acids methyl esters (FAME) were eluted from the column with helium as the carrier gas. The oven temperature increased from 150 to 250 °C at 2 °C/min. The injector and detector temperatures were set at 220 and 275 °C respectively. Peaks were identified by comparing the retention times with those of a mixture of Standard methyl esters (SIGMA 18919). FAME concentrations were expressed as a percentage of the total of the identifiable fatty acids.

Color

A CR-400 Minolta chromometer instrument was used to measure the color of raw and cooked fillets. Color was determined in three zones on fish fillets. Triplicate measurements were taken at each zone using CIE Lab L* (lightness), a* (redness) and b* (yellowness) system.

Texture analysis

Penetrometer (Humboldt) equipped with a total of 45 g load weight was used to determine the hardness of fish fillets.

The needle of instrument was placed at the surface of filleted fish and the instrument was turned on for 10 s to produce a puncture the depth of puncture was measured in mm with greater depth indicating lower hardness. Penetration measurements were done in 4 different areas of the fillet surfaces. Data are means of four measurements.

pH measurement

The pH value was determined by dipping the pH electrode into homogenates of filleted fish in distilled water (1/1) (Manthey et al. 1988). All measurements were performed at room temperature using pH-meter (WTW Inolab, Weilhem, Germany).

Sensory analyses

Sensory analysis was performed by a panel of 5 panelists. The panelists were from the staff of Food Engineering Department who had experience evaluating seafood. After cooking, the samples were coded using letters and randomly presented to the panelists. All assessments took place in individual booths in a day light conditions. Panelists were asked to evaluate taste, color and odor of samples on a 7-point hedonic scale (Amerina et al. 1965). An overall quality score was calculated as the mean score of appearance, color and odor. The scale was defined as 7 "excellent", 6 "good", 5 "moderate", 4 "fair", 3 "slight poor", 2 "poor", 1 "very poor".

Statistical analysis

Two replications of the experiment were conducted at separate times and all analyses were performed in duplicates. Means and standard errors were calculated. Data were analyzed by a split plot design in a completely randomized system, with cooking methods (frying, baking, grilling) as a whole plot and cooking temperatures (160 and 180 °C) and cooking methods by cooking temperatures as a sub-plot (Gomez and Gomez 1985). Analysis was conducted using the SAS software (Statistical Analysis System, Cary, NC, USA). When main effects or interactions were significant, Duncan's Multiple Range test was used.

Results and discussion

Results of proximate composition analyses of raw fish were given in Table 1. After cooking process using three methods, dry matter, ash, fat and protein contents of fish significantly ($p<0.05$) increased. Cooking methods had significant effect ($p<0.05$) on dry matter content in fish. The lowest and the highest dry matter contents were found in fried and grilled samples respectively (Table 2). The lowest moisture loss has been found in hamburger cooked in frying pan (Rodrıgez-Estrada et al. 1997). Similar results were found in a previous study for rainbow trout (Gokoglu et al. 2004). The lowest ash content was also found in fried samples. Cooking methods significantly affected fat level of fish. The highest fat level was found in fried samples. Absorption of frying oil by the fish caused high fat levels in fish muscle. There were no differences ($p>0.05$) in fat levels between baked and grilled samples. Similar results related to fat levels in fish cooked by different methods have been reported (Steiner-Asiedu et al. 1991; Gokoglu et al. 2004; Salawu et al. 2005; Marimuthu et al. 2011). Although cooking temperatures had no significant influence on dry matter, ash and protein contents of anchovy temperatures affected the fat level of fish. Higher fat levels were observed in the samples cooked at 160 °C than those cooked at 180 °C. Increase in cooking temperature prevented more fat absorption. Flick et al. (1989) reported that fat content in battered fish portions decreased with increase in temperature.

Table 3 shows effect of cooking methods and cooking temperatures on mineral composition of anchovy. Cooking

Table 1 Compositions of proximate, mineral and fatty acids and values of peroxide, pH, penetrometer, color and sensory in raw anchovy[a]

	Proximate composition (%)				Mineral composition (mg/kg)								
RAW	Dry matter	Ash	Fat	Protein	Na	K	Ca	Mg	P	Fe	Zn	Mn	Cu
	28.2 (6.0)	1.2 (0.01)	8.7 (0.04)	18.6 (1.3)	781.9 (66.4)	883 (25.9)	1672.2 (25.3)	314.6 (38.8)	171.4 (30.5)	9.1 (4.4)	29.5 (0.4)	3.2 (0.7)	4.6 (1.0)
	Fatty acid composition (%)												
FISH	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{20:1}$	$C_{22:1}$	$C_{24:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:5}$	$C_{22:6}$			
	5.7 (0.4)	13.0 (1.2)	5.4 (2.0)	2.2 (0.4)	1.7 (0.6)	2.6 (0.8)	0.2 (0.0)	1.2 (0.03)	2.9 (0.2)	17.6 (3.4)			
	Peroxide value		pH		Penetrometer value			Color			Sensory		
								L*	a*	b*			
	4.71 (0.3)		6.42 (0.04)		42.8 (2.8)			32.37 (2.0)	1.20 (0.8)	1.16 (0.2)	7.0 (0)		

[a] All values reflect mean and (standard deviation) of duplicate samples of two experiment replicates

methods had significant effects on Na, Ca, Mg, Zn and Cu contents of fish. The lowest concentrations for Na, Ca, Mg, Zn and Cu were found in fried samples the highest ones were grilled samples. In the previous studies it was found that the processing and cooking methods had little or no effect on the elements (Gall et al. 1983; Steiner-Asiedu et al. 1991), but Ackurt (1991) reported that mineral levels in some fish samples were affected by cooking methods. Salawu et al. (2005) reported that cooking methods affected mineral concentrations in catfish. Gall et al. (1983) found that while mineral concentrations decrease in fatty fishes after cooking no difference was observed in low fat species. Marimuthu et al. (2011) indicated that mineral contents of snakehead fish were affected by cooking methods. Cooking temperatures had significant ($p<0.05$) influence on Ca, Zn and Cu concentrations in anchovy (Table 3). Higher Ca, Zn and Cu concentrations were found in the samples cooked at 160 °C than those cooked at 180 °C. There was no significant ($p>0.05$) effect of cooking temperatures on other minerals in fish.

Saturated fatty acids (SFA) identified in raw and cooked samples were palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids (Table 4). Cooking methods had significant ($p<0.05$) effect on SFA. While total SFA levels decreased in fried and grilled samples level did not change in baked samples. There was no difference in SFA levels of samples cooked at 160 °C and 180 °C (Table 4). Monounsaturated fatty acids (MUFA) identified in raw and cooked anchovy were oleic ($C_{18:1}$), eicosonoik ($C_{20:1}$), erusic ($C_{22:1}$) and nervonic ($C_{24:1}$) acids. After frying and baking MUFA level of anchovy significantly ($p<0.05$) increased. Whereas MUFA levels of grilled samples decreased. Cooking temperatures had no effect on MUFA level. Polyunsaturated fatty acids (PUFA) identified in raw and cooked anchovy were linoleic ($C_{18:2}$), linolenic ($C_{18:3}$), eicosapentaenoic ($C_{20:5}$) and docosahexaenoic ($C_{22:6}$) acids. While PUFA levels of fried and grilled samples decreased the level in baked samples increased. The highest PUFA level was found in baked samples. No differences were found in PUFA contents between the samples cooked at 160 °C and 180 °C statistically.

Fatty acid composition of sunflower oil that was used for frying was investigated. Palmitic ($C_{16:0}$), stearic ($C_{18:0}$), oleic ($C_{18:1}$) and linoleic ($C_{18:2}$) acids were identified in sunflower oil (Table 5). It was especially rich in oleic and linoleic acids. Concentrations of fatty acids in sunflower oil did not change significantly after frying process. It has been reported that fatty acid composition of fried fish was similar to culinary fat due to oil absorption during the frying process (Sanchez-Muniz et al. 1992; Ohgaki et al. 1994). The highest oleic acid content of fried samples in the present study agrees with the results reported by these researchers.

The peroxide value which indicates products of fat oxidation were determined in raw and cooked anchovy. The peroxide value permits the initial stage of the oxidative changes occurring to be defined. However, the high temperature accompanying culinary processes can speed up the breakdown of peroxides into their carbonyl components (Illow & Illow 2002). Relatively high peroxide value was found in raw anchovy (Table 1). After cooking process by all methods peroxide values significantly

Table 2 Effect of cooking methods and cooking temperature on proximate composition of anchovy[a]

Factors	Parameters			
	Dry matter (%)	Ash (%)	Fat (%)	Protein (%)
Cooking methods[b]				
Frying	42.8a	1.4a	21.5a	20.2a
Baking	50.0b	2.4b	13.8b	34.4b
Grilling	55.5c	2.2b	12.7b	44.4c
Standard error	1.1	0.08	1.0	0.4
Cooking Temperatures[c]				
160 °C	48.2a	2.1a	14.4a	32.2a
180 °C	50.7a	1.9a	17.6b	31.3a
Standard error	1.1	0.08	1.0	0.4

[a] Means within the same factor and the same column with different superscript letters are different ($p<0.05$). Means reflects of duplicate samples of two replicates

[b] Each number represents the average value of each parameter for all samples of the same treatment

[c] Each number represents the average value of each parameter for all samples with the same cooking temperature

Table 3 Effect of cooking methods and cooking temperatures on mineral composition (mg/kg) of anchovy[a]

Factors	Parameters								
	Na	K	Ca	Mg	P	Zn	Fe	Mn	Cu
Cooking methods[b]									
Frying	760.9a	1063.4a	1291.4a	354.61a	316.6a	29.5a	9.2a	3.6a	4.0a
Baking	1204.3b	1771.4a	2540.2b	526.03b	641.7a	47.1b	15.3a	5.0a	6.6b
Grilling	2354.4c	1491.5a	2432.0b	586.13b	860.7a	59.8c	14.7a	4.3a	5.3ab
Standard error	174.4	255.24	246.1	63.30	189.8	4.9	2.2	0.48	0.8
Cooking Temperatures[c]									
160 °C	1466.2a	1637.1a	2274.1a	511.9a	624a	50.6a	13.9a	4.7a	6.5a
180 °C	1433.3a	1247.1a	1901.7b	465.8a	588.8a	40.3b	12.3a	1.0a	4.1b
Standard error	6.6	196.4	164.1	22.9	52.5	4.05	0.8	0.3	1.0

[a] Means within the same factor and the same column with different superscript letters are different ($p<0.05$). Means reflects of duplicate samples of two replicates

[b] Each number represents the average value of each parameter for all samples of the same treatment

[c] Each number represents the average value of each parameter for all samples with the same cooking temperature

increased. The lowest peroxide values were found in grilled samples (Table 6). Higher values were obtained in fried and baked samples than grilled samples. Ferioli et al. (2008) stated that cooking catalyzed the formation of peroxides and heat proved to be a pro-oxidant factor. Al-Saghir et al. (2004) reported that a slight lipid oxidation effect due to the heating procedures applied in salmon fillets. There were no differences in peroxide values between fried and grilled samples.

Cooking temperature had significant effect on peroxide values in anchovy. Lower ($p<0.05$) values were found in the samples cooked at 160 °C than those at 180 °C. Peroxide value is a less effective parameter to evaluate lipid stability in cooked samples due to pro-oxidant effect of heating. Cooking methods and temperatures had no effect on pH value of anchovy.

Texture of raw and cooked samples was measured using penetrometer. Cooking methods affected texture of anchovy. While the highest penetrometer values were found in fried samples the lowest values were in grilled samples (Table 6). These results show that fried samples had softer texture than those baked and grilled samples. Fat absorption during frying

Table 4 Effect of cooking methods and cooking temperatures on fatty acid composition (%) of anchovy[a]

Factors	Parameters									
	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{20:1}$	$C_{22:1}$	$C_{24:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:5}$	$C_{22:6}$
Cooking methods[b]										
Frying	1.7a	4.8a	18.5a	1.3a	2.4a	2.6a	4.3a	0.04a	1.6a	10.4a
Baking	3.9b	14.8b	5.1b	5.3b	1.05b	9.01b	0.41b	2.8b	4.9b	21.24b
Grilling	1.8a	6.01a	1.5	0.2a	0.2b	0.5a	0.05b	0.6a	1.7a	6.8a
Standard error	0.3	1.8	2.3	0.8	0.3	1.2	0.6	0.4	0.7	2.6
Cooking Temperatures[c]										
160 °C	2.4a	9.1a	8.3a	1.1a	0.9a	2.9a	1.2a	0.8a	2.5a	11.5a
180 °C	2.5a	8.0a	8.5a	3.4b	1.5a	5.1a	1.9a	1.4a	3.0a	14.0a
Standard error	0.3	1.8	2.3	0.8	0.3	1,2	0.6	0.4	0.7	2,6

[a] Means within the same factor and the same column with different superscript letters are different ($p<0.05$). Means reflects of duplicate samples of two replicates

[b] Each number represents the average value of each parameter for all samples of the same treatment

[c] Each number represents the average value of each parameter for all samples with the same cooking temperature

Table 5 Fatty acid composition (%) of oil (sunflower oil) used for frying

	Before use	After use (one frying)
$C_{16:0}$	3.0	5.6
$C_{18:0}$	7.1	8.7
$C_{18:1}$	43.5	57.9
$C_{18:2}$	11.0	13.2

process and increase of fat concentration in fish muscle caused softer texture in fried samples. As known fats considerably affect the texture of foods and high fat foods have softer texture. Grilled samples had the hardest texture among the samples cooked by other methods. The reason of hardness in grilled samples is loss of water and fat during grilling process. Cooking temperatures had no influence on texture of anchovy. There was no difference in penetrometer values of samples cooked at 160 °C and 180 °C

L, a, b values were significantly affected by cooking methods. After cooking using three methods color values (L, a, b) significantly increased. The lowest L, a, b values were found in grilled samples (Table 6). There were no differences in L,a,b values between fried and baked samples.

The highest sensory scores were obtained for fried samples (Table 6). Lower scores were given for grilled samples by the panelists compared to fried and baked samples. Acceptability of grilled samples was low due to harder texture. Baked samples were evaluated as tasteless and flavorless by the panelists. Fat absorption of fish muscle during frying process enhanced texture and flavor and for this reason fried samples were the most preferred samples in terms of sensory characteristics.

Conclusion

It was concluded that cooking methods had influence on nutritional and quality characteristics of anchovy. Proximate and fatty acids compositions, peroxide value, color, texture and sensory properties of anchovy were affected by cooking methods. While some mineral concentrations changed after cooking some of them were not affected. Cooking temperatures had no influence on nutritional and quality characteristics of anchovy. Although panelist liked fried samples fat level increased due to absorption of frying oil by the fish. Moreover some minerals, SFA and PUFA levels of fried samples increased. Fat absorption of fish increases the energy value. Therefore, frying cannot be recommended for people who would like to limit their dietary intake of fat due to diet and health concerns. Health organizations all over the world have promoted lower intake of total dietary fat, saturated fatty acids and cholesterol as a means of preventing cardiovascular heart disease. Although baked and grilled samples were healthier than those fried samples baked anchovy can be recommended for healthy eating because of harder texture, lower PUFA content and lower sensorial acceptability of grilled samples.

Table 6 Effect of cooking methods and cooking temperatures on chemical, physical and sensory quality characteristics of anchovy[a]

Factors	Parameters						
	Peroxide value[b]	pH	Penetrometer value[c]	Color			Sensory scores
				L*	a*	b*	
Cooking methods[d]							
Frying	7.2a	6.5a	59.7a	58.6a	7.2a	6.5a	5.8a
Baking	7.3a	6.6a	41.9b	59.5a	7.3a	6.6a	5.5a
Grilling	5.7b	6.4a	22.6c	38.7b	5.7b	6.4a	4.2b
Standard error	0.2	0.03	0.1	1.7	0.2	0.03	0.07
Cooking Temperatures[e]							
160 °C	6.1a	6.5a	39.8a	51.6a	6.1a	6.5a	5.1a
180 °C	7.3b	6.5a	43.0a	53.0a	7.3b	6.5a	5.2a
Standard error	0.2	0.03	0.1	1.7	0.2	0.03	0.07

[a] Means within the same factor and the same column with different superscript letters are different ($p<0.05$). (Means of duplicate samples of two replicates for Peroxide value, pH and penetrometer values; of triplicate measurements for color and of five panelists for sensory)

[b] $meqO_2/kg$

[c] mm × 100

[d] Each number represents the average value of each parameter for all samples of the same treatment

[e] Each number represents the average value of each parameter for all samples with the same cooking temperature

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