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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Effects of different cooking methods on the proximate and fatty acid composition of Atlantic salmon (*Salmo salar*)

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Abstract: It is essential for human health to maintain a diet rich in unsaturated fatty acids, particularly polyunsaturated (PUFA), composed of omega-3. Atlantic salmon (*Salmo salar*), an important source of omega 3 long chain PUFAs, has a sizeable amount in international seafood trade because it is an abundant source of omega-3 long-chain PUFAs. Despite the fact that cooking fish to high temperatures alters its fat, protein, vitamin, and mineral content, cooked fish is preferred by consumers. The purpose of this research was to compare nutritional, physical and sensory properties of Atlantic salmon cooked in the oven, steamed and also a combination of the two cooking methods. Farmed Atlantic salmon was used to make steaks that were defrosted in the fridge the night before. Cooking methods applied were baking in the oven, steaming, and a combination of oven-baking and steaming. The results showed that the crude protein level of oven-baked salmon meat was greatest among all cooking methods. Heat treatment affected the fatty acid composition of Atlantic salmon flesh, as shown that the total saturated fatty acids of cooked fish groups were higher than those of raw salmon. It was determined that oven baking was the most effective heat treatment for maintaining all lipid characteristics of the meat, including the PUFA concentration and n-3/n-6 ratio. When EPA and DHA values of all cooking groups were compared, combination cooking group has lowest value than other cooking groups.

Keywords: Heat treatment, Atlantic salmon, omega-3, oven-baking, steaming

INTRODUCTION

Individual diet has critical situation at prophylaxis and treatment processes, especially due to preventative medicine. Unsaturated fatty acids (UFA), which the body cannot synthesize on its own, are among the required dietary components for the human body but must be received through diet. The fatty acids, especially omega 3 and omega 6 polyunsaturated fatty acids (PUFA), were mentioned many studies on effects of them on health, and relationships between them and risk factors of the health. American Heart Association (AHA) has recommended enhancing consumption of omega-3 fatty acids for risk reduction of patients with cardiovascular diseases (CVD) (Smith Jr et al., 2011). Also, different studies have given countenance to consumption of PUFAs for the risk reduction in CVD (Wang, 2018; Jackson et al., 2019). Polyunsaturated fatty acids, especially omega 3, can protect against not only CVD also inflammatory diseases, cancer, obesity, diabetes (Gu et al., 2015; Nabavi et al., 2015; Saini and Keum, 2018), Alzheimer's disease (Song et al., 2016), kidney function (Xu et al., 2016) and major depressive disorder (Bigornia et al., 2016; Husted and Bouzinova, 2016). Alpha-Linolenic acid (ALA) (C18:3n3), Eicosapentaenoic acid (EPA) (C20:5) and Docosahexaenoic acid (DHA) (C22:6) are acceptable important omega 3 fatty acids.

One of the major sources of PUFAs is oily fish and/or fish oil. Naturally, fish and seafood consumption tend to increase a few decades. Global fisheries production has totally reached 177.8 million tonnes in 2019. Atlantic salmon (*Salmo salar*), that is a rich omega 3 long chain PUFAs resource, has a special place in the international seafood trade because of its 2.615 million tonnes production from aquaculture and 17.1 billion USD nominal value (FAO, 2021).

Fish meat is obtained by removing head, viscera, frame, fin, gill, and bone from fish. Consumers generally prefer cooked fish meat except non-heat treatment processed products for example pickled, dried and/or salted fish or some ethno-traditional products like sashimi. However, a high temperature has the potential to reduce the number of PUFAs in the flesh, particularly EPA and DHA, by destroying carbon double bonds. Additionally, the application of heat treatment results in a shift in the proportions of total fat, total protein, vitamins, and minerals found in fish meat. Fish cooking uses different techniques such as oven-baking, microwaving, frying (pan- or deep-), poaching, boiling, and grilling etc. These techniques are usually used as domestic cooking. During Covid19 pandemics, most of governments all on the world introduced restrictions for preventing spread of the disease such as closing up restaurants, diners, snack bars etc. Due to the influence of social media, many people have experimented with different culinary methods at home.

Oven-baking, which is a dry-heat cooking technique (Moradi et al., 2011; Sampels, 2015), is one of most used of them. Recent studies have reported that oven baking was best method for nutritional quality and PUFAs of cooked fish (Şengör et al., 2013; Hosseini et al., 2014; Vikøren et al., 2017). In addition, Erdem and Dinçer (2019) have informed that oven baking was optimal cooking technique for nutritional properties of flesh in their study.

Already, mild- and moist-heat treatments like steaming (Moradi et al., 2011; Sampels, 2015) are also popular in household. There are several studies reported that nutritional values of steamed fish meat have been closest those of raw fish meat (Choo et al., 2018; Cano-Estrada et al., 2018; Dong et al., 2018). Oven-baking and steaming are two cooking techniques with different characteristics. The study's objective is to examine the nutritional, sensory, and occasionally physical characteristics of oven-baked, steam-cooked and also combination these methods on Atlantic salmon (*Salmo salar*). In the experimental plan, two different cooking methods were used in combination in order to identify changes in the fatty acid composition and lipid index values of fish meat.

MATERIALS AND METHODS

Fish samples

Salmon steaks from farmed Atlantic salmon (*Salmo salar*) that were shipped from Norway as frozen were acquired from a global supplier and totalled 61 pieces each of 113.89±3.31 g. 10 pieces were used as raw material for proximate composition, fatty acids composition, lipid quality indices and colour measurement. Before cooking, each sample was defrosted overnight in a refrigerator at 4°C.

Cooking methods

The cooking time of 18 minutes was determined based on the salmon meat's ability to maintain a consistent internal temperature of 63°C during the steaming process (USDA, 2023). Three different techniques were used. First batch used 17 Atlantic salmon pieces was cooked by using oven, second batch used 17 Atlantic salmon pieces was cooked by using water vapour and the last process used 17 Atlantic salmon pieces was the combination of both two cooking techniques. For oven baking, 18 minutes heating at 180°C were used within a conventional oven as preheated (Öztiryakiler Industrial Conventional Oven GN 1/1 Model, Turkey). The final internal temperature of oven-baked salmon meat was recorded at 70.8°C. For steaming, water (250 ml) was boiled in cooking pot (diameter: 20 cm; height: 12 cm) and a stainless-steel mesh strainer was placed in same pot. During steaming, salmon meat did not touch water just the vapour was used. Steaming occurred for 18 minutes at 100°C. For the combination method, steaming was firstly applied for 9 minutes, and then oven baking was performed for 9 minutes.

Proximate composition

Atlantic salmon were homogenised using an electric chopper (Arzum AR1021, Turkey). Moisture and ash analyses were gravimetrically performed salmon pieces by placing into a glass petri dish at 105°C and a porcelain crucible at 550°C, respectively (Ludorf and Meyer, 1973). Sample and reagent for crude oil analysis (chloroform / methanol; 2/1) were mixed with a homogeniser, then solvents in permeate was evaporated (Bligh and Dyer, 1959). Crude oil percentage was calculated gravimetrically. Kjeldahl method was utilised for crude protein analysis (N×6.25) via Gerhardt Vapodest 40 according to A.O.A.C. (1984) official method.

Fatty acids analysis

Atlantic salmon steak oil that had been extracted from raw and cooked salmon steak was analysed using gas chromatography (GC) (Shimadzu Corp., Kyoto, Japan) to ascertain its fatty acids composition (FAC). Methyl esters were prepared by dissolving 10 mg of extracted oil in 2 mL of n-hexane and then adding 4 mL of (2 mol/L) KOH to methanol, as described by Ichihara et al. (1996). After centrifugation at 1792g, the N-hexane layer was separated out (Özogul and Özogul, 2007). Capillary column GC (HP-88; 100 m 0.25 mm i.d., 0.20 m film thickness; Agilent Technologies International Japan, Tokyo, Japan) equipped with a flame ionisation detector was used to identify fatty acid methyl esters. First, the column was heated from 120 to 170 °C at a rate of 10 °C/min, then it was heated to 250 °C at a rate of 4 °C/min, and finally it was maintained at 250 °C for 5 minutes. The flame ionisation detector was heated to a comfortable 260°C. A 1L sample was divided and injected at a 1:50 ratio. The concentration was determined by comparing the peak area of the samples to that of the mix standard. The average percentage of the overall FAME area was used to express the results of the three replicate GC analyses.

Lipid quality

The atherogenic and thrombogenic indices (AI and TI, respectively) were derived using Ulbricht and Southgate equations (1991) to assess the likelihood that cooked samples would cause coronary heart disease. However, it is important to prioritise health while choosing a cooking method. Hypocholesterolemic/Hypercholesterolemic ratio (h/H) was calculated according to Santos-Silva et al. (2002). Flesh lipid quality index is calculated by relating the levels of the principal polyunsaturated fatty acids (PUFAs) n-3 eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the flesh to the overall lipid content of the flesh as a percentage (Abrami et al., 1992; Senso et al., 2007).

Cooking loss

Using an equation inspired by Gluchowski et al. (2020), cooking loss was determined as a percentage from the difference in weights of the Atlantic salmon flesh before and after cooking.

Colour measurement

The colour measurement method reported by Schubring (2003) was used. *L**(lightness), *a** (redness) and *b** (yellowness) values of CIElab colour space, were determined with measuring 10 times from the raw and cooked Atlantic salmon placed into a glass petri dish, after steaks mixed homogeneously by a chopper.

Sensory evaluation

Seven assessors with experience in the sensory evaluation of fish products used a methodology described by Carbonell et al. (2002). Odour, appearance, flavour, texture, and general acceptance were all rated as sensory criteria. The evaluation of attributes ranged from 1 (weak) to 5 (intense).

Statistical analysis

The data was displayed as mean standard deviation. One-way ANOVA analysis was used to describe the variations in means. To examine for significant differences between the mean values of the various outcomes, the SPSS 25 program's Tukey test was utilised. P<0.05 was used as the significance level for all groups.

RESULTS AND DISCUSSION

Results of proximate analyses

Proximate compositional effects of different cooking techniques on salmon meat can be seen at Table 1.

Table 1. Proximate composition results (g/100 g)

Proximate composition	Raw salmon	Oven baking	Steaming	Combination cooking
Crude protein	19.33±0.44[a]	19.90±0.76[ab]	22.53±0.20[b]	23.14±1.97[b]
Crude fat	14.52±0.13[a]	26.38±1.87[b]	20.52±0.72[c]	19.38±0.38[c]
Moisture	63.00±0.42[a]	51.26±0.54[b]	53.74±0.60[c]	54.53±0.59[c]
Ash	1.24±0.17[a]	1.14±0.01[a]	1.24±0.08[a]	1.08±0.02[a]

At the level of P<0.05 significances, the same letter of meaning on the same line do not differ in any appreciable ways

In the study, the untreated group is defined as the raw salmon group (control group) to be used in comparisons to determine the effects of cooking techniques. As shown in Table 1 raw salmon steaks have the lowest crude fat percentage than those of cooked salmon groups (Table 1). The cooked groups demonstrated a significant increase in crude fat percentages as a result of water extraction in salmon meat, as anticipated due to the use of heat treatment. This situation depends on cooking time and temperature as mentioned before (Bastias et al., 2017). The findings indicate that the oven-baked salmon group exhibits the highest crude fat percentage, which aligns with the findings of previous studies (Şengör et al., 2013; Hosseini et al., 2014; Nieva-Echevarría et al., 2018). Oven-baking as a dry-heat cooking method may accelerates evaporation from salmon meat.

The moisture percentage of raw salmon is 1.23, 1.17 and 1.15 times more than oven-baking, steaming and combination cooking, respectively. Crude fat contents of oven-baking, steaming and combination cooking groups, are respectively approximately 1.82, 1.41 and 1.33 times more than uncooked salmon's. Although all cooking groups were used the same time (18 minutes), temperature used in oven-baking affected moisture and crude fat percentage. Therefore, crude fat and moisture contents of oven baking salmon meat have showed statistically significance (P<0.05). This result can be explained as the low amount of moisture in the oven environment and the high amount of evaporated water. There are studies informed that oven baked salmon meat has higher lipid percentage than steamed salmon meat vice versa moisture percentage (Larsen et al., 2010; Şengör et al., 2013; Fomena Temgoua et al., 2022). There was no statistically significant difference observed in the ash contents among all groups (P<0.05).

Cooked salmon steaks by a combination method of steaming and oven baking has shown highest crude protein content. Although, crude protein values of oven-baked salmon is higher than those of steamed salmon in recent studies (Bastias et al., 2017; Gluchowski et al., 2020; Fomena Temgoua et al., 2022), steamed salmon's protein percentage is higher than that of oven-baked salmon in the present study. There was no statistically significant difference among the groups of cooked salmon in terms of crude protein content (P>0.05). Oven-baked salmon meat has shown the lowest protein value in all cooked groups. Protein denaturalization may be discussed for oven-baked salmon meat; as a consequence, it was exposed to higher temperatures for a longer time than the others.

Fatty acids composition

Table 2 shows how different cooking techniques affect the fatty acid composition of Atlantic salmon meat. As a consequence of heat treatment, total saturated fatty acids (∑SFA) of cooked salmon groups increased according to initial value of raw salmon in Table 2. While comparing the three prepared groups, it was observed that the steamed group had the lowest increase in ∑SFA. However, it was noted that the level of palmitic acid (C16:0) in the steamed salmon meat increased, but it reduced in both the oven-baked group and the combination cooking group. There was no statistically significant difference (P<0.05) observed in the value of C16:0 between steaming salmon meat and raw salmon. Although stearic acid (C18:0) was no in raw salmon meat, was seen in both oven-baked and combination cooked salmon meat groups.

The application of the oven temperature of 180°C has the potential to induce lipid oxidation and lipid hydrolysis in crude fats of salmon meat. The oven-baking group has the lowest values of both total monounsaturated fatty acids (∑MUFA) at 47.12 and oleic acid (C18:1n9c) at 38.44%. Linoleic acid (C18:2n6c) has shown reductions for oven-baked and combination cooked salmon in comparison with the initial value because of probably high temperature and dry heating from the oven. The statistical analysis of eicosapentaenoic acid (EPA) (C20:5) and docosahexaenoic acid (DHA) (C22:6) levels in salmon meat indicates that there is a significant difference (P<0.05) between the steaming and combination cooking methods (oven baking and steaming) compared to the raw and oven baking methods. The combination cooking of salmon meat has been found to yield a statistically significant difference (P<0.05) in the α-linolenic acid (ALA) (C18:3n3) content, with the lowest value seen compared to the other groups. The EPA and ALA values of all cooked salmon groups exhibited a decrease as a result of heat treatment. Nevertheless, the cooked groups, excluding oven baking, exhibited a decrease in DHA value.

Table 2. Fatty acid composition results of groups (g/100 g of total fatty acids)

Fatty acids	Raw salmon	Oven baking	Steaming	Combination cooking
C4:0	0.04±0.00^{a}	0.04±0.00^{a}	0.04±0.01^{a}	0.05±0.00^{a}
C8:0	0.01±0.00^{a}	0.0±0.0^{a}	0.02±0.00^{b}	0.02±0.00^{b}
C10:0	0.00±0.00^{a}	0.00±0.00^{b}	0.01±0.00^{c}	0.01±0.00^{ac}
C12:0	0.04±0.01^{a}	0.03±0.00^{a}	0.04±0.00^{a}	0.03±0.00^{a}
C13:0	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}
C14:0	1.89±0.02^{a}	1.85±0.02^{a}	1.99±0.02^{b}	1.88±0.01^{a}
C15:0	0.16±0.00^{a}	0.16±0.00^{a}	0.18±0.00^{b}	0.16±0.00^{a}
C16:0	10.25±0.04^{a}	9.67±0.07^{b}	10.36±0.05^{a}	9.91±0.02^{c}
C17:0	0.17±0.00^{a}	0.16±0.00^{b}	0.18±0.00^{c}	0.17±0.00^{a}
C18:0	0.0±0.0^{a}	3.09±0.02^{b}	0.0±0.0^{a}	3.20±0.01^{c}
C20:0	0.55±0.01^{a}	0.55±0.05^{a}	0.59±0.03^{a}	0.55±0.00^{a}
C21:0	0.02±0.00^{a}	0.0±0.0^{b}	0.0±0.0^{b}	0.02±0.00^{c}
C22:0	0.24±0.00^{a}	0.24±0.03^{a}	0.25±0.03^{a}	0.24±0.00^{a}
C23:0	0.28±0.03^{a}	0.30±0.02^{a}	0.27±0.03^{a}	0.27±0.01^{a}
C24:0	0.14±0.01^{a}	0.11±0.01^{b}	0.0±0.0^{a}	0.11±0.00^{c}
∑SFA	13.80	16.21	13.94	16.63
C14:1	0.01±0.00^{a}	0.02±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{a}
C16:1	2.27±0.02^{a}	2.09±0.02^{b}	2.14±0.01^{c}	2.12±0.01^{bc}
C18:1n9t	0.05±0.01^{a}	0.0±0.0^{b}	0.05±0.00^{a}	0.05±0.00^{a}
C18:1n9c	39.60±0.03^{ac}	38.44±0.41^{b}	40.13±0.14^{a}	39.08±0.04^{c}
C20:1	5.43±0.04^{a}	5.39±0.06^{a}	5.78±0.02^{b}	5.56±0.01^{c}
C22:1n9	0.85±0.03^{a}	0.82±0.04^{a}	0.87±0.01^{a}	0.84±0.01^{a}
C24:1	0.47±0.02^{a}	0.40±0.0^{b}	0.47±0.02^{a}	0.42±0.00^{b}
∑MUFA	48.68	47.12	49.45	48.08
C18:2n6c	16.70±0.03^{a}	16.14±0.14^{b}	16.84±0.07^{a}	16.14±0.01^{b}
C18:3n6	0.10±0.01^{ac}	0.13±0.01^{b}	0.10±0.00^{a}	0.11±0.00^{c}
C18:3n3	10.40±0.02^{a}	10.07±0.06^{b}	10.07±0.03^{b}	9.70±0.01^{c}
C20:2	1.72±0.01^{a}	1.63±0.10^{a}	1.72±0.03^{a}	1.64±0.01^{a}
C20:3n6	0.21±0.00^{a}	0.29±0.01^{b}	0.22±0.02^{a}	0.25±0.01^{c}
C20:3n3	1.01±0.00^{a}	1.03±0.02^{a}	1.06±0.10^{a}	1.00±0.01^{a}
C22:2	0.18±0.04^{a}	0.14±0.01^{a}	0.15±0.04^{a}	0.12±0.03^{a}
C20:5	2.82±0.04^{a}	2.68±0.03^{b}	2.47±0.05^{c}	2.42±0.01^{c}
C22:6	4.37±0.03^{a}	4.53±0.06^{b}	3.97±0.03^{c}	3.89±0.01^{c}
∑PUFA	37.51	36.64	36.60	35.27
PUFA/SFA	2.71	2.26	2.62	2.12
Σn6	17.02±0.03^{a}	16.55±0.15^{b}	17.17±0.07^{a}	16.50±0.01^{b}
Σn3	18.61±0.05^{a}	18.30±0.16^{a}	17.57±0.15^{b}	17.01±0.04^{b}
Σn3/Σn6	1.09	1.10	1.02	1.03
DHA/EPA	1.55	1.69	1.60	1.61

At the level of P<0.05 significances, the same letter of meaning on the same line do not differ in any appreciable ways

The samples were analysed using a combination cooking method to find the lowest values for several parameters, including total polyunsaturated fatty acids (∑PUFA), the ratio of polyunsaturated fatty acids to saturated fatty acids (PUFA/SFA), total omega 6 fatty acids (∑n6), and total omega 3 fatty acids (∑n3). The group that undergoes oven baking exhibits the highest value for the ratios of ∑n3/∑n6 and DHA/EPA when compared to all other groups. Even though ∑n6 values for the steamed group were found to be higher than that of the uncooked samples, ∑n6 values fell after cooking the salmon meat groups using oven-baking and combination cooking methods, as seen in Table 2. However, these differences have no statistically meaning (P<0.05). DHA/EPA was seen to be lower in raw salmon compared to the three other groups, although PUFA/SFA ratio of raw salmon was the highest value.

Oven baking, out of all the thermo-processes examined, was shown to be the most efficient heat treatment for preserving all lipid attributes of the meat, such as the PUFA content and n-3/n-6 ratio (Table 2). The effects shown in previous studies exhibit variation contingent upon the cooking manner employed and the impact of heat (Garcia-Arias et al., 2003; Gladyshev et al., 2006; Sioen et al., 2006; Schneedorferova et al., 2015). The consumption of foods that are abundant in omega-3 polyunsaturated fatty acids (PUFAs) is associated with numerous advantages, primarily attributed to their good impact on human well-being. However, the thermal treatments had a significant impact on the most widely recognised EPA and ∑PUFA, observed across all groups, with the combination cooking group exhibiting the lowest levels of these substances. A same movement was likewise detected in ALA. The three main types of n-3 polyunsaturated fatty acids, namely ALA, DHA and EPA, are predominantly obtained from seafood and are effectively utilised by the human body (Ng, 2006). According to Grosso et al. (2014), the primary omega-3 FA, ALA, can be converted into long-chain PUFA as well as DHA and EPA. The aforementioned results provide further support for the argument that ALA remains a viable precursor for the synthesis of EPA and DHA, primarily due to its limited influence during the thermal processing. The effects of various cooking techniques on the fatty acid content of different fish species have been the subject of numerous research.

According to a study conducted by Koubaa et al. (2012), the effects of steaming and oven-baking on the fatty acid profiles of cooked fish species were found to have minimal affect. Similarly, Moradi et al. (2009), indicated that the oven-baking technique resulted in little alterations in both the fat content and fatty acid composition of the fillets of *Parastromateus niager*. Furthermore, the utilisation of the oven baking technique resulted in an enhancement in the quantity of EPA and DHA in grams within the meat of New Zealand king salmon (Larsen et al., 2010). The ratio of n3/n6 fatty acids in the oven-baked salmon was found to be higher in comparison to the steamed salmon (Şengör et al., 2013). On the other hand, a previous study conducted by Fomena Temgoua et al. (2022), has reported that the concentration of n-3/n-6 and EPA+DHA in steamed salmon is significantly higher ($p < 0.05$) compared to the oven-baking treatment. The preservation of EPA and DHA content in rainbow trout is maximised through the process of steaming (Cano-Estrada et al., 2018). The findings in the present study indicate that oven-baking had a higher positive impact on the content of n3/n6, EPA, DHA, and ∑PUFA in salmon meat compared to steaming. The observed variations in outcomes among same cooking processes, as previously discussed, may be attributed to factors such as the application method, cooking duration, or temperature.

Values of lipid quality indexes

Lipid quality indices' results can be seen in Table 3. Lower values of both AI and TI indicate superior nutritional quality of fatty acids. Consequently, diets characterised by low AI and TI values have the potential to mitigate the risk of developing coronary heart disease (CHD). Higher values of the h/H ratio are beneficial when considering the specific effects of fatty acids on cholesterol metabolism. h/H ratio possesses the capacity to offer a more accurate evaluation of the influence of fatty acid composition on cardiovascular disease (Karimian-Khosroshahi et al., 2016; Chen and Liu, 2020). FLQ index can be regarded as an adjunct to EPA + DHA, given that the absolute quantity of EPA and DHA holds greater significance (Senso et al., 2007; Chen and Liu, 2020). Oven-baked salmon flesh has lowest value of AI and highest value of FLQ and h/H. However, steamed salmon flesh has highest value of AI and, lowest value of FLQ, TI and h/H. For AI, determined raw salmon value has no statistically difference (P>0.05) when compared with oven baking and combination cooking groups, separately. Highest value of TI is 0.17 was determined in combination cooking groups. h/H ratios of raw and combination cooking salmon showed no statistically significance (P>0.05) but statistical differences were determined in oven baking and steaming groups.

Table 3. Results of lipid quality indexes (%)

Lipid Quality Indexes	Raw salmon	Oven baking	Steaming	Combination cooking
AI (%)	0.21±0.0^{ac}	0.20±0.0^{a}	0.22±0.0^{b}	0.21±0.0^{c}
TI (%)	0.14±0.0^{a}	0.15±0.02^{ab}	0.14±0.0^{a}	0.17±0.0^{b}
FLQ (%)	7.19±0.07^{a}	7.21±0.09^{a}	6.32±0.02^{b}	6.43±0.06^{b}
h/H (%)	5.75±0.02^{a}	5.88±0.04^{b}	5.65±0.03^{c}	5.74±0.02^{a}

At the level of P<0.05 significances, the same letter of meaning on the same line do not differ in any appreciable ways. AI: Atherogenic Index. TI: Thrombogenic Index. FLQ: Flesh Lipid Quality Index. h/H: Hypocholesterolemic/ Hypercholesterolemic ratio

Cooking loss results

Heat treatment effects on cooking loss values on salmon flesh can be seen at Table 4.

Table 4. Initial and cooked weights (g) and cooking loss percentages of salmon steaks

	Oven baking	Steaming	Combination cooking
Initial weight (g)	114.21±2.30^{a}	115.22±4.27^{a}	113.29±4.15^{a}
Cooked weight (g)	100.30±1.86^{a}	102.37±3.83^{a}	101.11±3.71^{a}
Cooking loss (%)	12.17±0.15^{a}	12.24±0.07^{a}	9,63±0.12^{b}

At the level of P<0.05 significances, the same letter of meaning on the same line does not differ in any appreciable ways

Water and volatiles within salmon meat retires with increase of heat and temperature. This leads to a loss at total weight. Cooking loss percentages for three cooking methods were given at Table 4. Steamed salmon steaks showed highest percentage of cooking loss. Salmon steaks by cooking combination methods had the lowest cooking loss value. Between the oven baking and steaming techniques no statistical difference was determined. However, significant differences were seen when compared with these two techniques with the combination cooking techniques. The combination method's water holding capacity was greater than that of the other procedures, as shown in Table 4. This may be the reason of heat treatment techniques and time. Combination method first treatment was steaming (9 min) this process may keep the moisture of the salmon meat later oven baking (9 min) treatment decrease the moisture of the salmon meat (evaporation). But the process time of the heat treatments were 50% lower than each techniques, this was the reason of determining higher water holding capacity (lower Cooking loss). Similar results were also determined in previous studies in Szlinder-Richert and Malesa-Ciecwierz, 2018. Although cooking loss value depends on cooking method and fish species (Szlinder-Richert and Malesa-Ciecwierz, 2018), the results of oven baked and steamed salmon steaks have nearly given the same values. However, 11.6% value of cooking loss of salmon fillet by steamed similarly above-mentioned method (Gluchowski et al., 2020) was not statistically differed the present steamed salmon steaks' value. Steaming, a relatively mild heating process, is expected reducing cooking losses (Wang et al., 2020).

Colour measurements

Following the cooking process, the lightness parameters (*L**) of the salmon steaks exhibited an increase (Table 5). Statistically significance (P<0.05) between *L** results of cooked salmon meat groups and raw salmon meat was determined. Salmon meat cooked by combination method of oven baking and steaming has highest *L** value, but lowest *a** (redness) and *b** (yellowness) value. *a** value of oven baked salmon meat increased while the others decreased after cooking and differed statistically significance (P<0.05) from other cooked salmon meat groups.

Table 5. Colour measurements

	Raw salmon	Oven baking	Steaming	Combination cooking
L*	63.42±3.71^{a}	72.40±6.30^{b}	76.44±7.90^{b}	76.55±4.17^{b}
a*	13.63±0.85^{a}	13.97±0.53^{a}	11.01±0.97^{b}	10.86±0.75^{b}
b*	21.87±1.73^{a}	20.82±2.39^{a}	20.12±1.66^{ab}	18.35±1.59^{b}

At the level of P<0.05 significances, the same letter of meaning on the same line do not differ in any appreciable ways

The observed increases in *L** values among the cooked salmon meat groups may be attributed to the denaturation of proteins and subsequent whitening of the meat that occurs during the heating process (Wan et al., 2019). Wang et al. (2020) reported the natural pink colour of the whitefish (*Coregonus peled*) muscle rapidly transitions to a pale whitish colour during the process of steam cooking. This change is accompanied by an increase in the *L** value, reaching a high reading at a specific time point. The observed rise in *L** value during the initial phase of steaming can be attributed to the progressive denaturation of myosin and the oxidation of haemoglobin and myoglobin. As the myosin underwent incremental modifications, the pigmentation of the fish progressively transitioned to a white colour (Wan et al., 2019; Wang et al., 2020). In the context of combination cooking, the L* value exhibited a modest increase compared to that of steamed salmon meat. This might perhaps be attributed to the occurrence of browning events on involving proteins, or amines, as well as protein-lipid reactions. The changes in the *a** values of steamed and combination cooked samples were impacted by the oxidation of haemoglobin that takes place during the cooking process, which may lead to a reduction in the *a** values (Thanonkaew et al., 2006; Wan et al., 2019).

Sensory evaluation

Sensorial panel results of the groups can be seen at Figure 1. Oven-baked salmon showed highest scores in appearance, odour and flavour. Steamed salmon has given lowest results for all criteria except odour. Odour scores of oven baked, steamed and combination-cooked salmon was respectively presented 4.14±0.69, 3.42±0.78 and 3.28±0.75. No statistical differences were found in all criteria ($P<0.05$).

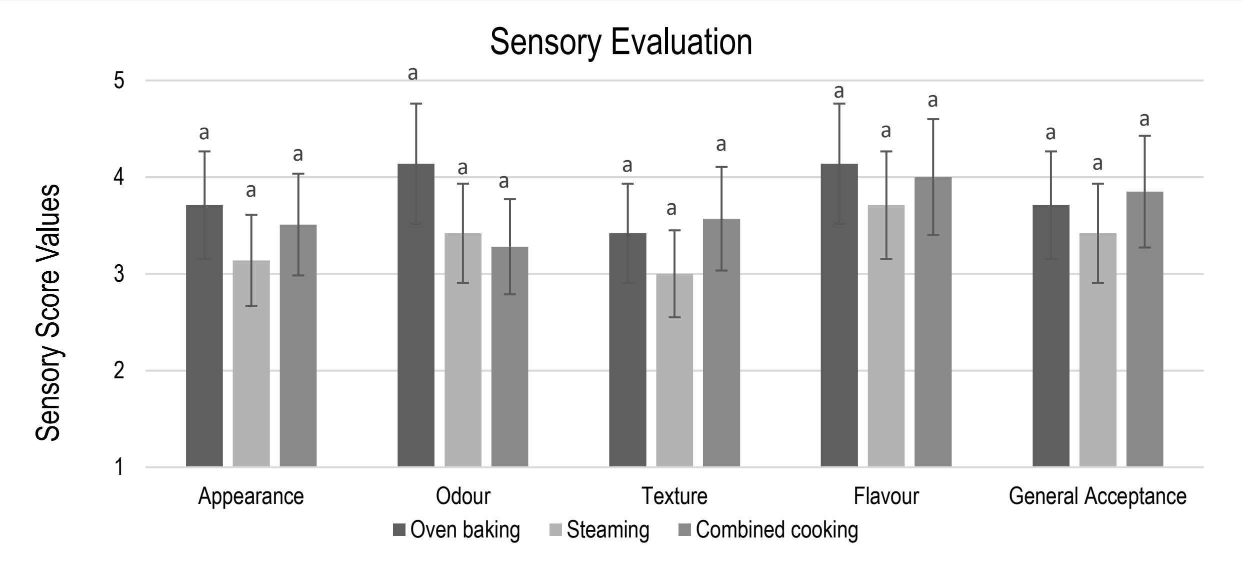

Figure 1. Sensory evaluation results of cooked salmons

Due to the results preferences in parameter of general acceptance are given as follows; Combination cooking> Oven baking>steaming. A comprehensive assessment of sensory criteria has been conducted by Larsen et al. (2011), revealing that the oven-baking procedure resulted in an enhanced preference for salmon meat. In the sensory evaluation of king salmon subjected to various heat treatments, it was observed that oven-baking was preferred above alternative methods such as steaming. In the sensory evaluation, oven-baked king salmon received the highest ratings in terms of colour, texture, and scent criteria, indicating its superior quality. Conversely, steamed king salmon was found to be less attractive in comparison (Larsen et al., 2011). The firm and chewy texture of oven-baked salmon meat is a result of the dehydration process that takes place during preparation, which reduces its moisture content. The high temperatures can also enhance the formation of corresponding smells, tastes, and flavours. In a study conducted by Alexi et al. (2019), it was shown that both steam-cooking and oven-cooking methods yielded comparable sensory profiles for meagre and gilthead seabream. The varying impact of culinary techniques on the lipid and sensory attributes of meagre and gilthead seabream suggests that a universal guideline cannot be used. Instead, the selection of a specific preparation method should be contingent upon the fish species and their corresponding fat composition.

CONCLUSION

The primary objective of this study was to investigate the effects of combining oven baking and steaming techniques on the nutritional characteristics, fatty acid content, and lipid indices of Atlantic salmon. While heat treatments of salmon meat decreased Σn3 values, oven baking salmon meat was affected at least. The Atlantic Salmon exhibited an elevation in Σn6 fatty acid content during the steaming procedure. The study findings indicate that the combination cooking method yields the most favourable value in terms of PUFA/SFA ratio. Based on the analysis of Σn3/Σn6 and DHA/EPA values, it can be concluded that oven-baking is marginally more efficient compared to other heat treatments.

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AUTHOR CONTRIBUTIONS

Ömer Alper Erdem: Performed heat treatment processes, proximate analyses, cook loss, colour measurements, sensory evaluation, statistical analyses, writing- original draft. Mehmet Tolga Dinçer: Performed supplies frozen Atlantic salmon steaks, heat treatment processes, cook loss, sensory evaluation, fatty acids composition, statistical analyses, writing-original draft.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest or competing interests.

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ETHICS APPROVAL

No specific ethical approval was necessary for the study.

DATA AVAILABILITY

For any questions, the corresponding author should be contacted.

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