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RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

Comparison on nutritional properties of wild and cultured brown trout and Atlantic salmon

Doğal ve kültür dere alabalığı ve Atlantik somonunun besinsel özelliklerinin karşılaştırılması

Ömer Alper Erdem[1] ● Başak Alkan[2]* ● Mehmet Tolga Dinçer[3]

[1] Ege University, Faculty of Fisheries, Department of Fish Capturing and Fish Processing Technology, Section of Fish Processing Technology, 35100 Bornova, Izmir, Turkey http://orcid.org/0000-0002-1745-1751
[2] Ege University, Faculty of Fisheries, Department of Fish Capturing and Fish Processing Technology, ection of Fish Processing Technology, 35100 Bornova, Izmir, Turkey http://orcid.org/0000-0002-2447-5823
[3] Ege University, Faculty of Fisheries, Department of Fish Capturing and Fish Processing Technology, Section of Fish Processing Technology, 35100 Bornova, Izmir, Turkey http://orcid.org/0000-0003-1867-4305

*Corresponding author: bas.alkan2@gmail.com
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Abstract: Brown trout is a fish species that both is caught and is cultured. This study has presented a comparison on proximate composition, fatty acids profile and lipid quality of wild- and cultured brown trout, and Atlantic salmon. Crude protein and crude oil of Atlantic salmon were found highest than wild and cultured brown trout and significantly differences (P<0.05). Although there is no significantly difference (P<0.05) between cultured brown trout and Atlantic salmon on eicosapentaenoic acid (EPA), there are significantly differences (P<0.05) between three fish samples on linoleic acid, linolenic acid and docosahexaenoic acid (DHA) values. Cultured brown trout has given lowest oleic acid (C18:1n9c) value and ΣMUFAs (Mono unsaturated fatty acids) with 28.05% and 35.43%. Atherogenic index and thrombogenic index of all groups were found low values. Although the highest value h/H was found in Atlantic salmon, the highest value of FLQ (Flesh lipid quality) was found in cultured brown trout.

***Keywords*:** Proximate composition, fatty acids, lipid quality, brown trout, Atlantic salmon

Öz: Dere alabalığı hem avlanan hem de yetiştiriciliği yapılan bir balık türüdür. Bu çalışmada, doğal ve kültür dere alabalığı ve Atlantik somonunun temel besinsel kompozisyonları, yağ ve yağ asitleri arasındaki farklılıklar araştırılmıştır. Ham protein ve ham yağ verileri açısından Atlantik somunununda daha yüksek ve istatistiki farklılık veren değerler bulunmuştur (P<0.05). Kültür dere alabalığı en düşük oleik asit (C18:1n9c) ve ΣTDYA değerini % 28.05ve % 35.43 ile vermiştir. Eikopentaenoikasit (EPA) açısından kültür dere alabalığı ve Atlantik somonarasında istatistiksel fark (P<0.05) bulunmazken, linoleik asit, linolenik asit ve dokasahekzaeoik asit (DHA) değerleri açısından üç balık örneğinde istatistiksel farklılıklar tespit edilmiştir (P<0.05). Aterojenik indeksve trombojenik indeks değerleri tüm gruplarda düşük olarak tespit edilmiştir. Her ne kadar en yüksek h/H değeri Atlantik somonda tespit edilmiş bile olsa en yüksek ELK (Et Lipit Kalite) değeri kültür dere alabalığında tespit edilmiştir (P<0.05).

Anahtar kelimeler: Besin madde bileşenleri, yağ asitleri, lipit kalitesi, dere alabalığı, Atlantik somon

INTRODUCTION

Nutritionists recommend that fish be eaten at least 2-3 times a week. In developed countries, the human fish consumption is usually higher than it is in developing countries (Lövkvist, 2014). Especially the Mediterranean diet based on a rich intake of fish. It is well known that fish lipids are rich in long-chain n-3 polyunsaturated fatty acids (n-3 PUFAs), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Fish oils are claimed to help prevent childhood asthma, cardio-vascular disease, hypertension, alzheimer's disease and mood disorders. In addition, fish is an important source of animal proteins (rich in essential amino acids). Proteins are important for development and growth of the human body and repairing of worn out tissues (Mohanty, 2015). Fish contains essential vitamins and minerals like selenium, iron, iodine, calcium, vitamin A, D and B12 (Wine et al, 2012). That vitamins and minerals are required for transporting oxygen to all parts of the body, for strong bones, normal vision and the nervous system. In addition, their deficiency is associated with anemia, poor learning ability. Protein content of fish varies from 15 to 20% of the body weight. Besides, fat content of fish varies 5-20% of the body weight (Mohanty, 2015). There are three types of fatty acids; saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs).

Fish with high n-3 content, like salmon, is a primary source of the long chain n-3 fatty acids EPA and DHA (Lövkvist, 2014) .One of the commercially important species among Salmonids is the Atlantic salmon, which inhabits riverine ecosystems at high latitudes.The main producer countries of Atlantic salmon (*Salmo salar*) are Norway, United Kingdom, Finland, Ireland, Russian Federation, Iceland, Denmark, Canada, United States of America, Chile and Australia. The major markets for farmed Atlantic salmon are Japan, the European Union and North America (FAO, 2019). In 2016, global aquaculture production value of Atlantic salmon was 2.247.759 tons. On the other hand, global capture production value was 2.319 tons in 2014 (FAO, 2019).

Brown trout is a close relative of the Atlantic salmon. Brown trout live in cold rivers and lakes, and spawn in rivers and streams with clean gravel beds. Migrating forms grow in lakes and the sea to a large size, but migrate upwards to spawn in rivers (FAO). Brown trout is one of the most preferred wild freshwater fish species in east Black Sea Region (Turkey) due to its nutritional value, palatable aroma and as well as being popular in sport fishing (Kaya and Erdem, 2009). For brown trout, global aquaculture value was 4.189 tons in 2016 (FAO, 2019). In Turkey, aquaculture production value of trout (*Salmo* sp.) was 980 tons for marine water and 1.944 tons for inland water in 2017 (TUİK, 2017).

The objective of this study is to investigate the potential of a new alternative species, which can be preferred by consumers, by comparing proximate composition, fatty acids profile and lipid quality of wild- and cultured brown trout (*Salmo trutta fario*) with those of Atlantic salmon (*Salmo salar*) known as a rich source of polyunsaturated fatty acids.

MATERIALS AND METHODS

Fish samples

In the current study, three fish fillet samples were used as materials; wild brown trout (*Salma trutta fario*), cultured brown trout (*Salmo trutta fario*) and cultured Atlantic salmon (*Salmo salar*). Ten individuals for each group were used during analyses. After fish were filleted, dorsal part of right fillet of fish was partitioned from ventral part and was used during analyses. Wild brown trout (*Salmo truttafario*) was purchased from a fish supplier in Izmir, Turkey. Cultured brown trout was taken from a fish farm in Giresun, Turkey. Cultured Atlantic salmon (*Salmo salar*) was bought from a fishery products' importer.

Proximate composition

Moisture value and crude fat analysis wererespectively reported by Ludorff and Meyer (1973) and Bligh and Dyer (1959), ash analysis and the protein assay were performedby a method of 935.47 AOAC(1984) and the Kjeldahl method of AOAC(1984), respectively. Carbohydrate value was determined by difference method (Atwater &Braynt, 1900). Energy value was calculated according to Merrill and Watt (1955).

Fatty Acids Analysis

Fatty acid compositions of fat extracted from the samples were determined by GC. Methyl esters were prepared by trans-methylation using 2 M KOH in methanol and n -heptane according to the method described by Ichihara et al. (1996). Moreover, HP - Agilent 6890 (Santa Clara, CA, USA) model gas chromatographer (GC) was used for the measurements. The GC analyses were performed in triplicate, and the results expressed as percentage of total FAME area as the mean value of a percentage.

Lipid quality indices

Using Ulbricht and Southgate equations (1991), the atherogenic and thrombogenic indices (AI and TI, respectively) were calculated to measure the risk of cooked samples to the incidence of coronary heart disease. On the other hand, to determine the healthiness priority of cooking technique.

$$Atherogenic index = \frac{[(12{:}0) + (4 \times 14{:}0) + (16{:}0)]}{[\sum MUFA + \sum PUFA(n-6) + (n-3)]}$$

$$Thrombogenic index = \frac{[(14{:}0) + (16{:}0) + (18{:}0)]}{\begin{bmatrix}(0.5 \times \sum MUFA) + (0.5 \times \sum PUFA(n-6)) + \\ (3 \times \sum PUFA(n-3)) + \left(\frac{n-3}{n-6}\right)\end{bmatrix}}$$

Flesh lipid quality indices the percentage relationship between the main PUFAs n-3 eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in flesh and total lipid in flesh (Abrami et al., 1992; Senso et al., 2007). Hypocholesterolemic/ Hypercholesterolemic ratio (h/H) was calculated according to Santos-Silva et al. (2002).

Statistical analysis

The results were presented as mean ± standard deviation. The differences between the means were described by using one-way ANOVA analysis. Tukey and Duncan tests on SPSS 20 program was used to look for significant differences between the mean values of the different outcomes. Significance level was determined as $P<0.05$ for all groups.

RESULTS AND DISCUSSION

Proximate composition

The proximate composition of wild brown trout, cultured brown trout and Atlantic salmon is shown in Table 1. Nostatistically significant difference ($P<0.05$) was determined between the parameters of protein, fat, ash and moisture between wild brown trout and cultured brown trout. The difference was determined in carbohydrate values of the samples ($P<0.05$).In the study performed by Antão-Geraldes et al (2018), all compositional parameters were found significantly different between wild and cultured brown trout. They found the highest crude protein content, lipid content and dry matter in cultured samples. In farmed rainbow trout, crude protein content was found significantly same in wild brown trout and crude lipid content was found the highest and significantly different in all groups (Antão-Geraldes et al., 2018). Barylo and Loboiko (2018) were found protein and lipid content higher in rainbow trout than brown trout in their study. But also inverse results can be seen in the literature, protein and lipid content were found lower in rainbow trout in the study of Cano-Estrada et al (2018). In another study, the highest protein was found in wild brown trout but there was not a significantly different (P<0.05) between wild and cultured samples. Lipid content of wild brown trout was found lower than cultured one (P<0.05) (Erdem, 2006). In another study performed by Tilami et al. (2018), their results showed that protein content was found to be higher and lipid content was lower than our brown trout samples. In another study, wild brown trout significantly higher than farmed trout (P<0.05) (Kaya et al, 2014). Average protein content was higher in wild one and lower in cultured one than this study. In the wild brown trout crude lipid content was higher than farmed brown trout (P<0.05) (Kaya et al, 2014).

In this study, crude fat and crude protein values were significantly different between brown trout samples and Atlantic salmon (P<0.05).The study showed that these two values (crude protein and crude oil) were higher in Atlantic salmon (P<0.05). Similar results were also determined by Bastias et al. (2017). Holland et al.(1993) also determined the proximate composition of Atlantic salmon. In their study, these researchers found lower protein content and higher fat content than our findings. In the study also calorie contents of the samples were calculated. Highest calorie was determined from Atlantic salmon samples with the value of 147.82 kcal g^{-1}. The lowest value was determined (129.27 kcal g^{-1}) from the wild brown trout samples. The maximum amount of carbohydrate content was observed in wild brown trout (3.6%). That content was found 2.76 and 2.05 for cultured brown trout and Atlantic salmon, respectively. Kaya et al. (2014) reported that maximum energy values for wild and cultured brown trout were found as 140 kcal/100g. The highest carbohydrate amount was 2.97(g/100g in cultured brown trout and 1.17 (g/100g) in wild brown trout. Tilami et al. (2018), they found energy value 148kcal/100g in brown trout. In another study, Holland et al.(1993) were found energy value 180g/100g in Atlantic salmon.

Table 1. Proximate composition results

	Wild Brown Trout	Cultured Brown Trout	Atlantic Salmon
Protein (%)	17.22±0.25^b	17.36±1.10^b	20.88±0.88^a
Fat (%)	5.21±0.44^b	6.42±1.38^b	9.29±1.21^a
Moisture (%)	72.84±0.23^a	72.34±0.76^a	66.65±0.12^b
Ash (%)	1.13±0.07^a	1.12±0.03^a	1.13±0.06^a
Carbohydrate (%)	3.6±0.03^a	2.76±0.01^b	2.05±0.04^c
Calorie (kcal/g)	129.27	137.57	147.82

* Means in the same row with the same letter do not different significantly at the level of P<0.05 significance.

Fatty acid composition

The fatty acid composition of wild brown trout, cultured brown trout and Atlantic salmon are shown in Table 2.Total saturated fatty acids (SFA) was found higher in the wild brown trout compared with cultured brown trout and Atlantic salmon. Total monounsaturated fatty acids (MFAs) and polyunsaturated fatty acids (PUFAs) were higher in the Atlantic salmon and cultured brown trout, respectively. Oleic acid (C18:1n9c) was the most common fatty acid in all fish groups in this study. In oleic acid, there were significantly difference (P<0.05) between all groups and the highest value was found in Atlantic salmon. In linoleic acid (C18:2n6c), the highest value was found in cultured brown trout and that value was significantly different (P<0.05) in all groups. Eicosapentaenoic Acid (EPA) in the both cultured and Atlantic salmon were found similar (P>0.05). The highest EPA was found in Atlantic salmon and the lowest value was found in wild brown trout. Significant differences in docasahexaenoic acid (DHA) content were observed in wild brown trout, cultured brown trout and Atlantic salmon. The highest and the lowest DHA was observed in cultured brown trout and wild brown trout, respectively. The highest DHA/EPA ratio was found in cultured brown trout and the highest n-3/n-6 ratio was found in Atlantic salmon. In the study of Antão-Geraldes et al. (2018), they found the highest oleic acid value in cultured brown trout between cultured brown, wild brown and rainbow trout. There were significantly difference (P<0.05) between all groups. In wild brown, our oleic acid result was higher than the above mentinoed study. In linoleic acid they found the highest value in rainbow trout and there was significantly difference (P<0.05) between all groups. In wild and cultured brown trout, linoleic acid content was lower than results of current study on the other hand n-6 values were lower than results of our study. In the current study DHA/EPA value was also higher than their study. In another study, oleic acid values were lower than our results of study in wild and cultured brown trout (Erdem, 2006). In linoleic acid, our result was higher in cultured brown trout and lower in wild brown trout than that study. The highest DHA-EPA ratio was found in cultured brown trout but our ratio was higher than that value (Erdem, 2006). Tilami et al. (2018) reported that oleic acid in brown trout was found 22.94% in total fatty acids. The value is lower than our results in wild and cultured brown trout.Inlinolec acid, their results substantially lower than our results and their n-6 value lower than our values (Tilami et al., 2018).

Total amount of n-3 acids in Atlantic salmon were higher than other samples. On the other hand, total amount of n-6 acids in Atlantic salmon were lower than other samples. Cultured brown trout had the highest content of n-6 acids. In another study that performed by Bastias et al. (2017), oleic acid and linoleic acid values were lower than results of our study in Atlantic salmon. Additionally, DHA/EPA ratio and n-3/n-6 ratio were lower than our results. The results of Lövkvist's (2014) study, the highest linoleic acid value was found lower than our salmon result. DHA/EPA ratio was found lower than our results. n-3 and n-6 results usually found lower than our study like other results. In another study, oleic acid value was found higher than our results but linoleic acid value was lower than our results in Atlantic salmon (Dadras, 2013). n-3/n-6 ratio was found same as our results but total n-3 and n-6 values were lower than our results.

Table 2. Fatty acids composition comparison of the samples

	Wild Brown Trout	Cultured Brown Trout	Atlantic Salmon
C4:0	0.07±0.00[a]	0.05±0.00[a]	0.04±0.00[a]
C8:0	0.08±0.01[a]	0.02±0.00[b]	0.01±0.00[b]
C12:0	0.03±0.00[a]	0.03±0.00[a]	0.03±0.00[a]
C13:0	0.01±0.00[b]	0.02±0.00[a]	0.01±0.00[b]
C14:0	1.91±0.01[a]	2.51±0.01[b]	1.84±0.01[c]
C15:0	0.21±0.01[b]	0.29±0.01[a]	0.16±0.00[c]
C16:0	17.98±0.04[a]	15.86±0.10[b]	10.53±0.05[c]
C17:0	0.25±0.00[b]	0.32±0.00[a]	0.17±0.00[c]
C18:0	0.00±0.00[b]	0.00±0.00[b]	3.24±0.02[a]
C20:0	0.28±0.01[b]	0.31±0.02[b]	0.48±0.02[a]
C21:0	0.03±0.01[a]	0.00±0.00[b]	0.00±0.00[b]
C22:0	0.25±0.01[a]	0.24±0.03[a]	0.21±0.00[a]
C23:0	0.56±0.00[b]	0.68±0.05[a]	0.33±0.00[c]
C24:0	0.09±0.01[a]	0.12±0.04[a]	0.11±0.01[a]
∑SFA	21.75	20.45	20.4
C14:1	0.02±0.00[a]	0.03±0.00[a]	0.00±0.00[b]
C16:1	3.48±0.02[b]	3.82±0.02[a]	2.03±0.01[c]
C18:1n9t	0.10±001[a]	0.09±0.01[a]	0.04±0.00[b]
C18:1n9c	34.78±0.15[b]	28.05±0.07[c]	37.78±0.18[a]
C20:1	1.96±0.03[b]	1.94±0.04[b]	5.11±0.04[a]
C22:1n9	0.23±0.00[b]	0.27±0.06[b]	0.78±0.02[a]
C24:1	0.29±0.01[b]	0.33±0.05[b]	0.45±0.02[a]
∑MFA	40.86	34.53	46.19
C18:2n6c	26.31±0.07[b]	27.60±0.12[a]	16.18±0.20[c]
C18:3n6	0.49±0.02[a]	0.39±0.02[b]	0.09±0.01[c]
C18:3n3	3.44±0.00[c]	3.50±0.01[b]	9.54±0.03[a]
C20:2	1.66±0.01[b]	1.62±0.04[b]	1.83±0.01[a]
C20:3n6	0.78±0.01[a]	0.71±0.02[a]	0.26±0.00[b]
C20:3n3	0.25±0.00[a]	0.27±0.03[a]	1.14±0.02[b]
C22:2	0.16±0.01[a]	0.15±0.02[a]	0.15±0.01[a]
C20:5	1.03±0.01[b]	2.44±0.07[a]	2.49±0.02[a]
C22:6	3.32±0.02[c]	8.35±0.06[a]	5.00±0.05[b]
∑PUFA	37.44	45.03	36.68
PUFA/SFA	1.72	2.20	1.80
Σn6	27.58±0.02	28.70±0.04	16.53±0.05
Σn3	8.03±0.01	14.56±0.04	18.17±0.03
Σn3/Σn6	0.29	0.51	1.1
DHA/EPA	3.22	3.42	2.01

* Means in the same row with the same letter do not different significantly at the level of P<0.05 significance

Lipid quality indices

It is important that AI and TI have lower values for lipid quality because of coronary diseases' indices of them. Although three fish group showed lower values, AI and TI of wild and cultured brown trouts were higher than that of Atlantic salmon (P<0.05).Secci et al. (2015) reported that AI and TI values for Atlantic salmon were respectively 0.22 and 0.13. The AI values were the same as current study. TI value of wild rainbow trout (0.20) was lower than cultured rainbowtrout (0.30) found by Fallah et al. (2011). However, there is no similar situation in the present study. h/H ratio provides effects of fatty acids being apprehensible on cholesterol metabolism. Thus, it is preferred that the ratio shows higher value (Santos et al., 2014; Pleadin et al., 2017). h/H was lower in wild and cultured brown trout than in Atlantic salmon (Table 3). Dal Basco et al. (2013) informed on h/H ratios of wild and cultured brown trout, 0.18 and 2.16, respectively. These values were quite lower than those of the present study. Although Atlantic salmon is known as a good n-3 fatty acids source, DHA value of cultured brown trout was found higher than Atlantic salmon in this study. As a consequence, FLQ related to EPA and DHA percentage in total lipids was highest in cultured brown trout (P<0.05).

Table 3. Lipid quality indices

	Wild Brown Trout	Cultured Brown Trout	Atlantic Salmon
AI	0.34±0.01[a]	0.33±0.02[a]	0.22±0.01[b]
TI	0.34±0.01[a]	0.24±0.02[b]	0.18±0.01[c]
FLQ	4.34±0.02[c]	10.79±0.06[a]	7.49±0.08[b]
h/H	3.46±0.15[c]	3.80±0.21[b]	5.74±0.03[a]

* Means in the same row with the same letter do not differ significantly at the level of P<0.05 significance

CONCLUSIONS

In this study, proximate composition, fatty acids and lipid quality indices results of wild and cultured of brown trout and Atlantic salmon were compared. The highest ΣMUFAs value was found in Atlantic salmon, and the lowest was found in cultured brown trout. Nevertheless, the highest ΣPUFAs value was found in cultured brown trout, and the lowest was found in Atlantic salmon. Unsurprisingly, Atlantic salmon showed a good performance for Σn3, Σ3/Σ6,and h/H. However, the highest values of PUFAs/SFAs, DHA/EPA and FLQ were found in cultured brown trout. These findings can give an alternative fish species, which can be preferred by consumers who also care about healthy diet.

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