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Divergences of Biochemical Features of Three Reared Trouts; Brook Trout (*Salvelinus fontinalis*, Mitchill 1814), Rainbow Trout (*Oncorhynchus mykiss* Walbaum, 1972), and Black Sea Trout (*Salmo trutta labrax* Pallas 1811)

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ABSTRACT

The objective of this present study is to signify biochemical features of three reared trouts (brook trout, rainbow trout, Black Sea trout) that are economically consequential and reared fish species in the Eastern Black Sea region. The rainbow trout has been reared successfully for a long period of time. However, brook trout and the Black Sea trout have been two new species to be reared in the region with a high potential contribution to the economy. Therefore, there is a strong need to determine and report the differences between the fish (especially the two new species), levels of carbohydrates, energy, carotenes (Vitamin A), fatty acid, and proximate composition (protein, lipid, moisture, and ash). In addition, the lipid indices [Atherogenic Index (AI), Thrombogenic Index (TI), and polyene index (PI)] were also measured and reported for the trouts. Moreover, the color of the fillets of the fish was also measured. The results of this present study show that the average levels of moisture and protein varied while the average levels of lipid and ash were close to each other. The highest levels of carbohydrates, energy, and carotenes were determined in the muscle of brook trout in this study. The highest meat yield was also obtained from brook trout followed by Black Sea trout and rainbow trout. A total of 19 fatty acids were determined for Black Sea trout and brook trout and 17 fatty acids for rainbow trout in the present study. The omega-3 levels of the all trout used for the present study were roughly twice as much as that of the omega-6, except for rainbow trout.

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Yetiştiriciği Yapılan Üç Tür Alabalığın; Kaynak Alabalığı (*Salvelinus fontinalis*, Mitchill 1814), Gökkuşağı Alabalığı (*Oncorhynchus mykiss* Walbaum, 1972) ve Karadeniz Alasının (*Salmo trutta labrax* Pallas 1811) Biyokimyasal Özelliklerinin Farklılıkları

ÖZET

Bu çalışmanın amacı, Doğu Karadeniz Bölgesi'nde ekonomik olarak önemli ve yetiştirilen üç alabalık (kaynak alabalığı, gökkuşağı alabalığı ve Karadeniz alabalığı) türünün bazı biyokimyasal özelliklerini belirlemektir. Gökkuşağı alabalığı uzun süredir başarıyla yetiştirilmektedir. Ancak kaynak alabalığı ve Karadeniz alabalığı bölgede yetiştirilmeye başlanan ve ekonomiye katkısı yüksek iki yeni tür olmuştur. Bu nedenle, balıklar (özellikle iki yeni tür) arasındaki karbonhidrat, enerji, karoten (A Vitamini) ve yağ asidi ve besin bileşenleri (protein, lipit, nem ve kül) seviyelerindeki farklılıkları belirlemeye ve raporlamaya güçlü bir ihtiyaç vardır. Ayrıca, balıkların lipit indeksleri [Aterojenik Indeks (AI), Trombojenik Indeks (TI) ve polien indeksi (PI)] de hesaplanmıştır. Ek olarak, bu çalışmada balıkların fileto renkleri de ölçülmüştür. Balıklarda ortalama nem ve protein seviyeleri farklılık gösterirken, lipit ve kül seviyeleri birbirine yakın bulunmuştur. Bu çalışmada en yüksek karbonhidrat, enerji ve karoten seviyeleri kaynak alabalığında belirlenmiştir. En yüksek et verimi yine kaynak alabalığından elde edilmiştir, bunu Karadeniz alası ve gökkuşağı alabalığı izlemiştir. Çalışma için Karadeniz alası ve

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Anahtar Kelimeler
Besin bileşenleri
Alabalık
Karoten (A vitamini)
Fileto rengi
Yağ asitleri

kaynak alabalığında toplam 19 yağ asidi ve gökkuşağı alabalığı için 17 yağ asidi belirlenmiştir. Çalışmada kullanılan tüm alabalıkların yaklaşık omega-3 seviyelerinin, gökkuşağı alabalığı hariç, omega-6 seviyelerine oranları kabaca iki katı olduğu belirlenmiştir.

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INTRODUCTION

Brook trout, rainbow trout, and Black Sea trout are three reared fish species in the Eastern Black Sea region. These fish have their places on the counters in fish markets, and they compete with each other to get the attention of the customers. The brook trout and Black Sea trout species have challenges in the rearing field comparing the rainbow trout, which is relatively easy to rear. Although rainbow trout have many advantages in rearing conditions, the brook trout and Black Sea trout seem to be one step ahead in marketing prices. Recently, the brook trout, Black Sea trout, and rainbow trout are all subjected to many scientific studies not only in Turkey but also in many other countries such as the USA, Canada, Sweden, Ukraine, and China (Memiş et al., 2020; Çankiriligil & Berik, 2020; Latiu et al., 2020; Martling et al., 2020; Závorka et al., 2020; Zhang et al., 2021; Turan &Aksu, 2021; Barylo et al., 2021; Bayar et al., 2021; İspir et al., 2021; Baesu et al., 2022).

Fish and fish-related dishes nearly come first as a preferred food in diets for a variety of reasons. The taste and lipid content of the fish that make it a healthy food are among the many reasons. Consumption of fish provides some health benefits because fish contains bioactive constituents that improve nutritional quality (Li et al., 2020; Tacon et al., 2020; Chen et al., 2021). Department of health in many countries encourages fish consumption to develop a healthy population of people.

The main parts in muscle of fish are generally known to provide moisture, protein, lipid, and ash which are known proximate components and may vary from species to species (Öksüz & Özyılmaz, 2010; Kayım et al. 2011; Şahin et al., 2011; Öksüz, 2012; Yeşilayer & Genc, 2013; Ozyilmaz, 2019; Çankiriligil & Berik, 2020; Memiş et al., 2021). Fish consumption may give us an opportunity to get health benefits Individuals should consume fish regularly to get the benefits out of it.

Choosing the right fish for individual consumption, therefore, could be a crucial decision to obtain all beneficial ingredients available in the fish. The aim of this present study is to investigate the amounts of ingredients such as protein, lipid, ash, moisture, meat yield, carbohydrate, energy, carotene (Vitamin A), and fatty acids, and their lipid indices (Atherogenic Index, Thrombogenic Index, Polyene Index) available in three different salmonids (Brook trout, rainbow trout, Black Sea trout) in order for us to evaluate the similarities and differences. The fillet colors of these three reared trouts were also determined instrumentally to measure the color changes. The present study provides data on the biochemical attributes of these three fish species, specifically on fatty acid, protein, lipid, moisture, and ash of reared fish, providing unique knowledge to decide what type of fish should be included in an individual's diet.

MATERIALS and METHODS

Fish Materials

Brook trout (*Salvelinus fontinalis*, Mitchill 1814), rainbow trout (*Oncorhynchus mykiss*, Walbaum, 1972), and Black Sea trout (*Salmo trutta labrax*, Pallas 1811) have a growing importance in the Eastern Black Sea region. The fish used in the present study were purchased after regular harvesting times whenever they were ready for sale by the owner of the fish rearing unit. We did not interfere with any prior steps of our purchase of the fish samples however we asked the sellers of the fish about their life history of the fish and recorded the information in detail. Because we observed three different trouts that were reared in a commercial fish rearing unit in Trabzon/Turkey in this research, we present the information that we gathered in the following section.

The fish were grown from eggs to harvest in the commencal fish rearing units and fed with commercial feed. More specifically, the fish were fed with a meal called "range, nurse-s fish hatchery diet" until fish was 1 g in weight. Later on, the fish were fed with another type of feed (Sürsan, Aquamax, extruded fish meal, Muğla, Turkey) for the trouts from 1 g to harvesting. The fish meals were ordinary fish meals that were regularly used in rearing units in the region. The fish used in this current study was an average of 18-20 months old. The spring water was generally used by the units however the river water was also used whenever the spring water was not adequate.

A total of 14, 18, and 22 fish out of approximately 3000 kg capacity units were randomly selected for brook trout, rainbow trout, and Black Sea trout, respectively for the present study. The trouts were harvested late in March, in the middle of April, and early in May, which are the three months when the fish were sold frequently in the markets. Fish in ice boxes were transported to the laboratory. Their measurements (length and weight) were taken before filleting the fish. Only dorsal parts of the fish were used for the chemical analysis. The inside of the fillets was used for color measurements. The skinless fillets were finely chopped, gathered in a container, and mixed for the biochemical analysis.

Methods

The official methods were performed for the proximate compositions (the crude moisture, ash, protein, and lipid) which were given in detail in Öksüz (2012). The calculations used for carbohydrate contents and energy values were provided by Güner et al. (1998).

Determination of Total Levels of Carotene (vitamin A)

The spectrophotometric determination method described in TS, 1987 (Turkish Standard, number: 5036) and Morello et al. (2004) method were used to determine total carotene levels for all three fish species. A total of 7.5 g muscle lipid of Brook trout, rainbow trout, and Black Sea trout was weighed and dissolved with cyclohexane in a 25 mL volumetric flask. The mixture was made up to 25 mL volume with cyclohexane. The absorbance was read at 470 nm with a spectrophotometer (Shimadzu Hitachi U-1900 model). Its absorbance was measured with a spectrophotometer (Morella et al., 2004). The following equation was used for calculations.

Amount of carotenoids (mg carotenoids/kg lipid) = (A470 × 106)/(2000 × 100 × L)

A = Absorbance

L = Light path (cell thickness, mm)

Color measurements

A chroma meter (CR-400, Minolta, Osaka, Japan) was used to measure the color of the fillets of all three fish specimens. Inside of the fillets, places of the anterior, posterior, and caudal locations, were used for colorimetric analysis which was explained in Öksüz (2012).

Fatty Acid Methyl Esters

After obtaining lipids from all three fillets of the trouts, fatty acid methyl esters were carried out by using the lipid. GC-MS (Gas Chromatography-Mass Spectrometry) was used to determine the fatty acids of the lipids for all three fish muscles. Preparation, conversion, and separation of the fatty acid methyl esters were described in Öksüz and Özyılmaz (2010). The instrument and column conditions were also detailed in the same study, except for the column.

Lipid quality indexes

The data obtained from the fatty acid composition were used to calculate the Atherogenicity Index (AI), and Thrombogenicity Index (TI). The following equations reported by Ulbricht & Southgate (1991) were used to calculate Lipid Quality Indexes (AI and TI).

AI=[(4xC14:0)+C12:0+C16:0]/[(ΣPUFA-n6+ΣPUFA-n3)+ΣMUFA]

IT=[(C14:0+C16:0+C18:0)/(0.5xMUFA+0.5xPUFA-n6+3xPUFA-n3+PUFA-n3/PUFA-n6)]

Additionally, the following equation was used the calculate polyene index (PI), which evaluates the PUFAs damage (Lubis & Buckle, 1990).

(PI) = (C20:5 + C22:6)/C16:0

Statistical analysis

Statistical analysis was performed with SPSS (22.0). Significance was established at $P<0.05$. The data obtained from this study regarding three different trout species were subjected to a one-way analysis of variance (ANOVA), and a mean comparison was carried out by using Duncan's Multiple Range test to see if there are any statistically significant differences between groups. The homogeneity of variances was tested before ANOVA analysis was performed.

RESULTS and DISCUSSION

In this study, the length and the total weight of the brook trout, rainbow trout, and Black Sea trout were tabulated in Table 1. The average lengths were measured in the range of 25.82±2.12 -27.93±1.01 cm for the trouts. The highest weight obtained from rainbow trout was followed by brook trout and Black Sea trout. The highest length was also obtained from rainbow trout.

Table 1. Total length and total weight of the brook trout, rainbow trout, and Black Sea trout

Çizelge 1. Kaynak alabalığı, gökkuşağı alabalığı ve Karadeniz alasının boy ve ağırlığı

Fish species	Length (cm)	Total Weight (g)
Brook Trout	25.82±2.12	232.93±43.01
Rainbow Trout	27.93±1.01	272.61±13.86
Black Sea Trout	25.89±1.07	199.77±10.41

n=14 brook trout, n=18 rainbow trout, and n=22 Black Sea trout

The proximate composition, meat yield, carbohydrate, energy, and carotenes levels of the brook trout, rainbow trout, and Black Sea trout were shown in Table 2. The meat yield diverged in trout species. This divergence was measured to be statistically significant (P<0.05). The highest meat yield was obtained from brook trout followed by Black Sea and rainbow trout in this study. Şahin et al. (2011) study reported that the meat yield of brook trout was higher than that of Black Sea trout. The present study obtained similar results regarding meat yield. Additionally, Özyılmaz (2019) reported the meat yield of rainbow trout as 66.23±0.71% which was higher than that of the rainbow trout in the present study.

Table 2. The proximate composition, meat yield, carbohydrate, energy, and carotene (Vitamin A) levels of the brook trout, rainbow trout, and Black Sea trout

Çizelge 2. Kaynak alabalığı, gökkuşağı alabalığı ve Karadeniz alasının besin bileşenleri, et verimi, karbonhidrat, enerji ve karoten (A vitamini) düzeyleri

Fish species Components	Brook Trout	Rainbow Trout	Black Sea Trout
Moisture (%)	73.92±0.68[a]	76.19±0.88[b]	77.630±99[b]
Lipid (%)	1.14±0.08[a]	1.31±0.05[b]	0.81±0.04[c]
Ash (%)	1.15±0.02[a]	1.37±0.05[b]	1.51±0.06[c]
Protein (%)	22.29±0.83[a]	19.92±0.56[b]	18.67 ±0.34[c]
Meat yield (%)	56±0.02[a]	48±0.03[b]	50±0.01[c]
Carbohydrate (%)	1.50±0.54[a]	1.21±1.03[a]	1.38±0.77[a]
Energy	445.12±11.46[a]	406.58±13.93[b]	369.30±14.84[c]
Total carotenes (μg 100 g^{-1})	94.22±7.90[a]	36.00±0.88[b]	79.72±1.34[c]

n=3 for the chemical analysis
[a,b,c] Values within same row with different superscripts diverge significantly at P<0.05

The average moisture levels were calculated in the following order; brook trout<rainbow trout<Black Sea trout (Table 2). Only the amount of moisture in brook trout was statistically different from the two others (P<0.05). The brook trout in this study has got the least moisture levels. Additionally, while the findings relating mean moisture levels of Black Sea trout were found to be higher than that of wild brown trout (74.8±1.1%) and reared rainbow trout (75.6±1.2%) (Yeşilayer & Genc., 2013), they were found to be very closer to the that of wild brown trout (77.80±0.3%) (Kayım et al., 2011).

Ranges of the average lipid levels of the trouts were calculated to be 0.81±0.04-1.31±0.05%. The lipid levels of the trouts varied only in a small amount. Although small changes were observed among the lipid levels in trouts, it was evaluated to be statistically significant (P<0.05). Given that all trout species have less than 2% lipid level, they were all defined as lean fish. The fish were harvested after the spawning period. The reason for having less lipid level could be the result of the period. One other reason could be their diet. Another reason could be the environmental effects. The wild Black Sea trout came from two different places, cultured Black Sea trout came from three different fish farming units, and three filial generations were measured in the range of 6.13±0.18% - 8.11±0.21% in the study of Çankırılıgil & Berik (2020). Lipid levels of the trouts in the present study were found lower than that stated in this previous study (Çankırılıgil & Berik, 2020). On the other hand, Ateş et al. (2013) measured the levels of the lipid in wild brown trout in winter as 1.48%, which was close to the levels of lipids in Black Sea trout in this current study. According to Özyılmaz (2019), the lipid of rainbow trout was 10.61±0.05%, which was higher than that of the rainbow trout, brook trout, and Black Sea trout in the present study. The differences in lipid levels of the trouts in the present study and that in the previous studies can be attributed to the changes in the feed and farm conditions.

The highest ash levels were measured in the Black Sea trout, followed by rainbow trout and brook trout. The ash levels among trouts differed from each other. Differences in ash content were found to be statistically significant (P<0.05). According to the study of Çakmak et al. (2018), the ash level of the fifth generation of Black Sea trout was 1.51±0.12%, the results very similar to the one reported in the present study.

The protein levels of the brook trout were the highest among all three trouts in the present study. Similarly, Barylo et al. (2021) reported the protein levels of three salmonids namely brown trout, rainbow trout, and brook trout. Accordingly, the brook trout was the highest one as to their protein levels. Additionally, the protein levels of the brook trout were measured to be 22.29±0.83% which was higher than that of rainbow trout, and Black Sea trout. Moreover, Çakmak et al. (2018) reported that the protein level of the fifth generation of Black Sea trout as 15.22±0.48% which was lower than that of Black Sea trout as well as all other trouts used in the present study. The protein levels of wild Black Sea trout from two different rivers (Altındere River and Çağlayan River), three different rearing units, and three different filial generations were found to be in the range of 17.94±0.10-17.52±0.18% (Çankırılıgil & Berik, 2020). These values of protein in wild Black Sea trout, reared Black Sea trout, and filial generation of the Black Sea trout in study of Çankırılıgil & Berik (2020) were lower than those of protein in reared Black Sea trout which was 18.67±0.34% in the present study.

The carbohydrate amounts, energy value, and total carotene levels of the brook trout, rainbow trout, and Black Sea trout were shown in Table 2. The carbohydrate amounts of all trouts used in this current study were in the range of 1.21±1.03-1.50±0.54 %. Çakmak et al. (2018) reported the carbohydrate level of the fifth generation of Black Sea trout as 0.89±0.02%. The findings of the carbohydrate level of Black Sea trout as well as the other two salmonids in this study are higher than those of previously published findings (Çakmak et al., 2018). The brook trout also got the highest percentage of energy value compared to the two other salmonids. Similar energy values were measured for three freshwater fish species while lower carbohydrate levels were stated for those three freshwater fish species (Ozyilmaz et al., 2016). The total carotene levels are statistically significant from each other in the present study ($P<0.05$).

The average levels of the total carotene (vitamin A) in the brook trout were almost three times higher than those of the total carotene in the rainbow trout. The mean amount of the total carotene in the liver oil of guitarfish, string ray, and eagle ray (249.72±69.6 µg $100g^{-1}$, 401.49±4.06 µg 100 g^{-1}, and 104.53±2.10 µg 100 g^{-1}, respectively) were reported to be higher than that of carotene in all trouts under investigation in the present whereas that of carotene levels in bignose shark (29.26±2.83 µg 100g $^{-1}$) were lower (Özyılmaz & Öksüz, 2015). The amounts of total carotenes in the livers of the smooth-hound and cownose ray were reported to be 83.78±3.53 µg 100 g^{-1} and 73.22±0.35 µg 100 g^{-1}, respectively. Findings of total carotenes in the livers of these two different cartilaginous fish species were in the range of carotene levels of all trouts in this present study (Özyılmaz & Öksüz, 2015).

The color of the muscle in the fishery sector can be considered a crucial issue to many customers as well as retailers. That is why the color of the fish fillets was measured for the present study. We aimed at figuring out whether the flesh color of these three salmonids can be a distinctive character to distinguish the trouts from each other. Although these three salmonids in this study belonging to the same family, their color of the muscle are different from each other visually and instrumentally. The color measurements of fillets' brook trout, rainbow trout, and Black Sea trout were tabulated in Table 3.

Table 3. Color measurements of fillets' brook trout, rainbow trout, and Black Sea trout
Çizelge 3. Kaynak alabalığı, gökkuşağı alabalığı ve Karadeniz alası filetolarının renk ölçümleri

		Lx (Lightness)	C (Chroma)	H (Hue)
Anterior,	Brook Trout	47.31±1.05	10.85±0.26	50.53±0.56
	Rainbow Trout	56.86±0.35	6.07±0.19	66.42±0.44
	Black Sea Trout	45.41±1.15	3.85±0.18	77.38±1.02
Posterior	Brook Trout	48.59±0.89	10.31±0.33	78.52±0.64
	Rainbow Trout	48.75±0.57	4.57±0.34	71.15±1.01
	Black Sea Trout	39.46±0.65	6.80±0.41	47.69±0.64
Caudal	Brook Trout	61.64±0.49	23.78±0.30	73.46±0.51
	Rainbow Trout	48.53±0.77	7.45±0.46	62.08±1.08
	Black Sea Trout	47.65±0.70	5.55±0.43	66.72±0.63

The average means and standard deviations for measurements of fillets (n=3)

The lightness (L^*) values in the trouts generally differed in the anterior, posterior, and caudal parts of the muscle, except for, a few minor similarities. Only the average chroma (C) values in the anterior and posterior parts of the brook trout were similar. Other than that all chroma values divert in fillets of the brook trout, rainbow trout, and Black Sea trout. Like the chroma values, Hue (H) values also varied in different parts (anterior, posterior, and caudal) of the same fillets for each fish species. The highest lightness and chroma levels were measured in caudal parts of the brook trout fillet whereas the highest hue values were determined in the fillets of anterior parts of the Black sea trout and posterior parts of the brook trout. All three salmonid species had different fillet colors in anterior, posterior, and caudal parts which can be evaluated to be some possible identifiers for the processed fish fillets in the present study.

According to Erikson & Misimi (2008), there are different factors (e.g., perimortem handling stress, rigor mortis, ice storage) that affect skin and fillet color changes in Atlantic salmon. while healthy wild and reared Mediterranean amberjacks were measured to be similar with regard to their fillet colors (Öksüz, 2012), three salmonid species in the present study were not similar in their fillet colors.

A total of 19 fatty acids were determined for Black Sea trout and brook trout, and a total of 17 fatty acids were determined for rainbow trout in the present study. The fatty acid components of the brook trout, rainbow trout, and Black Sea trout were tabulated in Table 4. All of the trouts have less than 24% of total saturated fatty acid and have higher than 26% total monounsaturated fatty acids. Their total monounsaturated fatty acids were determined in the range of 48.18-50.84%. The lowest total saturated fatty acids were measured in rainbow trout. Palmitic acid (C16:0) was the highest fatty acid in total saturated fatty acid followed by stearic acid (C18:0) and myristic acid (C14:0) in the present study. Additionally, Pentadecylic acid (C15:0) and Arachidic acid (C20:0) were not found or found in lower amounts than detection limits in the muscle of rainbow trout.

The mean amount of C16:0 in brook trout and Black Sea trout was found to be different however these differences were not statistically significant (P>0.05). The amount of C16:0 in the muscle of rainbow trout was found to be significantly lower than that of C16:0 in the muscle of brook trout and Black Sea trout (P<0.05). In addition, the average levels of C16:0 in brook trout and Black Sea trout in the present study were found to be higher than those of C16:0 in brook trout and Black Sea trout as reported in the study of Şahin et al. (2011). These differences for the same fish species in two different studies could be attributed to the differences in the environmental conditions of the fish species.

Among monounsaturated fatty acids; palmitoleic acid (C16:1n9), oleic acid (C18:1n9), vaccenic acid (C18:1n7), and eicosenoic acid (C20:1n9) were determined in the muscle of brook trout, rainbow trout, and Black Sea trout in this study. The levels of C18:1n9 in the flesh of all trouts were the highest fatty acid in total monounsaturated fatty acids. The percentages of C18:1n9 out of all monounsaturated fatty acids determined in the present study were calculated to be 70.71%, 77.53%, and 79.20% in the muscle of brook trout, rainbow trout, and Black Sea trout, respectively.

The amount of C18:1n9 in brook trout was found to be similar to that of C18:1n9 in Black Sea trout (P>0.05) whereas the mean level of the same fatty acid was higher in rainbow trout (P<0.05). The average level of C18:1n9 in rainbow trout was found to be 22.44±0.25% which was higher than that of C18:1n9 in wild caught rainbow (18.83±1.91%) and lower than that of cage reared rainbow (26.56±1.21%) and pond reared rainbow (24.29±2.82%) (Ural et al., 2017). The mean amounts of C18:1n9 in brook trout and Black Sea trout in this study were found to be lower than those of C18:1n9 in male and female brook trout and Black Sea trout and their hybrids (Şahin et al., 2011). The difference can be attributed to diet differences.

We have separated polyunsaturated fatty acids in two groups in Table 4 (omega-6 and omega-3). Linoleic acid (LA, C18:2n6), eicosadienoic acid (C20:2n6), and arachidonic acid (ARA, C20:4n6) have been classified as omega-6 fatty acids. The linolenic acid (ALA, C18:3n3), stearidonic acid (C18:4n3), eicosatrienoic acid (C20:3n3), eicosatetraenoic acid (C20:4n3), eicosapentaenoic acid (EPA, C20:5n3), docosapentaenoic acid (DPA, C22:5n3), and docosahexaenoic acid (DHA, C22:6n3) have been classified as omega-3 fatty acids in all trouts investigated for this study. Therefore, a total of three omega-6 fatty acids and six omega-3 fatty acids were determined in polyunsaturated fatty acids.

The mean levels of DHA in the muscles of brook trout and Black Sea trout were found to be the highest in all polyunsaturated fatty acids. DHA is considered a health promoted fatty acid for consumers (Zhang et al., 2021). On the other hand, the greatest amount of fatty acid for rainbow trout in all polyunsaturated fatty acids were seem to be the LA in the study. The average levels of ALA were higher than that of EPA for all trouts.

The average amounts of LA in the muscle of brook trout and Black Sea trout were found to be the greatest in all omega 6 groups and second greatest in all polyunsaturated fatty acids. On the other hand, rainbow trout had the highest amount of LA followed by DHA and ALA. Studies related to reared fish fatty acid simply showed that LA amounts in reared fish tended to be higher depending on the fish feeding ingredients (Öksüz, 2012; Yeşilayer & Genç, 2013; Yeşilayer et al., 2014; Dernekbaşı et al., 2015; Dernekbaşı et al., 2017; Özyılmaz, 2019; Dernekbaşı & Karatas, 2020; Dernekbaşı & Karayücel, 2021).

Fatty acid related lipid indices namely atherogenic index (AI), thrombogenic index (TI), and polyene index (PI) of the brook trout, rainbow trout, and Black Sea trout showed some differences. Some of these differences were found to be statistically significant (P<0.05). The differences between brook trout and Black Sea trout related to the values of AI, TI, and PI were always statically significant (P<0.05) whereas that of rainbow trout did not (P>0.05). The AI, TI, and PI point out the quality of the lipid for their health benefits. The amounts of AI, TI, and PI in the lipid of the brook trout, rainbow trout, and Black Sea trout investigated in this present study varied from species to species in the same salmonid family. Küçükgülmez et al. (2018) reported that values of AI, TI, and PI for golden grey mullet and gold band goatfish differed from season to season.

Table 4. The fatty acid components (% of total fatty acid) and related lipid indices [Atherogenic Index (AI), Thrombogenic Index (TI), and Polyene Index (PI)] of the brook trout, rainbow trout, and Black Sea trout

Çizelge 4. Kaynak alabalığı, gökkuşağı alabalığı ve Karadeniz alasının yağ asidi bileşenleri (toplam yağ asidinin yüzdesi) ve lipit indeksleri [aterojenik indeks (AI), trombojenik indeks (TI) ve polien indeksi (PI)]

Fatty Acids	Brook Trout	Rainbow Trout	Black Sea Trout
C14:0	1.83±0.23[a]	1.76±0.01[a]	1.18±0.01[b]
C15:0	0.89±0.27[a]	ND	0.84±0.16[a]
C16:0	17.26±1.36[a]	13.68±0.04[b]	16.22±0.33[a]
C18:0	3.60±0.25[a]	4.11±0.06[b]	3.96±0.08[b]
C20:0	0.32±0.03[a]	ND	1.82±0.51[b]
∑SFA	**23.90[a]**	**19.54[a]**	**24.02[b]**
C16:1n9	2.92±0.43[a]	2.62±0.01[a]	1.76±0.03[b]
C18:1n9	20.45±1.37[a]	22.44±0.25[b]	20.60±0.39[a]
C18:1n7	2.26±0.26[a]	1.90±0.10[b]	2.51±0.12[a]
C20:1n9	3.30±0.65[a]	1.98±0.03[b]	1.14±0.18[b]
∑MUFA	**28.92[a]**	**28.94[a]**	**26.01[a]**
C18:2n6	12.49±1.38[a]	21.78±0.15[b]	13.78±0.37[a]
C20:2n6	0.94±0.13[a]	0.79±0.03[a]	0.91±0.04[a]
C20:4n6	0.85±0.02[a]	0.81±0.03[a]	1.11±0.18[b]
n6	**14.28[a]**	**23.38[b]**	**15.80[a]**
C18:3n3	5.69±0.54[a]	6.80±0.08[b]	5.22±0.07[a]
C18:4n3	1.51±0.16[a]	1.34±0.03[a]	0.81±0.07[b]
C20:3n3	1.03±0.16[a]	0.91±0.03[a]	0.59±0.24[a]
C20:4n3	0.66±0.13[a]	0.52±0.03[a]	1.19±0.27[b]
C20:5n3	4.64±0.96[a]	2.94±0.06[b]	3.13±0.04[b]
C22:5n3	1.44±0.17[a]	1.11±0.04[a]	2.06±0.46[b]
C22:6n3	16.93±1.55[a]	13.83±0.23[b]	21.24±0.67[c]
n3	**31.90[a]**	**27.46[b]**	**34.23[c]**
∑PUFA	**46.18[a]**	**50.84[b]**	**50.03[c]**
AI	0.33±0.02[a]	0.26±0.00[b]	0.28±0.01[b]
TI	0.19±0.01[a]	0.18±0.00[ab]	0.17±0.00[b]
PI	1.25±0.06[a]	1.23±0.02[a]	1.50±0.02[b]
SFA	**23.90[a]**	**19.54[a]**	**24.02[b]**
MUFA	**28.92[a]**	**28.94[a]**	**26.01[a]**
PUFA	**46.18[a]**	**50.84[b]**	**50.03[c]**
n6	**14.28[a]**	**23.38[b]**	**15.80[a]**
n3	**31.90[a]**	**27.46[b]**	**34.23[c]**
n3/n6	**2.23[a]**	**1.17[b]**	**2.17[a]**
n6/n3	**0.45[a]**	**0.85[b]**	**0.46[a]**
EPA	**4.64[a]**	**2.94[b]**	**3.13[b]**
DHA	**16.93[a]**	**13.83[b]**	**21.24[c]**
EPA/DHA	**0.27**	**0.21**	**0.15**
DHA/EPA	**3.65**	**4.70**	**6.79**
PUFA/SFA	**1.93**	**2.60**	**2.08**
EPA+DHA	**21.57**	**16.77**	**24.36**

[a,b,c] Values within same row with different superscripts diverge significantly at $P<0.05$
AI (Atherogenic Index), TI (Thrombogenic Index), and PI (Polyene Index)]

CONCLUSIONS

The highest average moisture and ash level were found in the flesh of rainbow trout. In addition, all three fish have lower lipid levels and higher amounts of protein and carotene (vitamin A) which are considered very important for a healthy diet. Palmitic acid (C16:0) and oleic acid (C18:1n9) were the highest level of fatty acids in saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA), respectively. Docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) in polyunsaturated fatty acids (PUFA) were found to be different from each other ($P<0.05$). Although the levels of EPA and DHA in fish flesh are different from each other, they are good for health. All trouts in the present study seem suitable for consumption, and they should be added to diets in order to take full benefits.

Statement of Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical statement

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed by the authors.

Authorship Contribution Statement

The contribution of the authors is equal

REFERENCES

Ateş, M., Çakıroğulları, G. Ç., Kocabaş, M., Kayım, M., Can, E., & Kızak, V. (2013). Seasonal Variations of Proximate and Total Fatty Acid Composition of Wild Brown Trout in Munzur River, Tunceli-Turkey. *Turkish Journal of Fisheries and Aquatic Sciences 13*(4), 613-619.

Baesu, A., Audet, C., & Bayen, S. (2022). Evaluation of Different Extractions for the Metabolite Identification of Malachite Green in Brook Trout and Shrimp. *Food Chemistry 369*, 130567.

Barylo, Y., Loboiko, Y., Barylo, B., Keznine, M., & Benaissa, H. (2021). Condition Factor and Identification of Amino Acid Composition of Three Trout Species in the Western Region of Ukraine. *Egyptian Journal of Aquatic Biology & Fisheries 25*(4), 539-548.

Bayar, İ. , İnci, A., Ünübol Aypak, S. & Bildik, A. (2021). Büyük Menderes Nehri'nde (Aydın) Yaşayan İki Tatlı Su Balığı Türünün Kas Dokularındaki Total Yağ Asidi Kompozisyonunun Araştırılması. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 24*(2), 260-266. DOI: 10.18016/ksutarimdoga.vi.723089

Çakmak, E., Çankırılıgil, E. C., & Özel, O. T. (2018). The fifth culture generation of Black Sea Trout (Salmo trutta labrax): Culture characteristics, meat yield and proximate composition. *Su Ürünleri Dergisi 35*(1), 103-110.

Çankiriligil, E. C. & Berik, N. (2020). Chemical Composition of the Black Sea trout (Salmo labrax Pallas, 1814): A Comparative Study. *Aquatic Research 3*(4), 208-219.

Chen, J., Jayachandran, M., Bai, W., & Xu, B. (2021). A Critical Review on the Health Benefits of Fish Consumption and Its Bioactive Constituents. *Food Chemistry 369*, 130874.

Dernekbaşı,, S. & Karayücel, İ. (2021). Effect of Alternate Feeding with Fish Oil-and Peanut Oil-Based Diets on the Growth and Fatty Acid Compositions of European seabass fingerlings (Dicentrarchus labrax) in the Recirculated Systems. *Aquaculture Research 52*(7), 3137-3147.

Dernekbaşı, S., Kerim, M., & Alagil, F. (2015). Effect of Dietary Safflower and Canola Oil on Growth Performance, Body, and Fatty Acid Composition of rainbow trout (Oncorhynchus mykiss). *Journal of Aquatic Food Product Technology 24*(2), 131-142.

Dernekbasi, S. & Karatas, E., (2020). Effect of cycled feeding by diets including vegetable and fish oil on growth performances and fatty acid profiles of rainbow trout (Oncorhynchus mykiss Walbaum, 1792). *Pakistan Journal of Zoology 52*(4), 1471-1482.

Dernekbaşı, S., Karayücel, I., & Akyüz, A. P. (2017). Effect of diets containing laurel seed oil on growth and fatty acid composition of rainbow trout, Oncorhynchus mykiss. *Aquaculture Nutrition 23*(2): 219-227.

Erikson, U. & Misimi, E. (2008). Atlantic salmon skin and fillet color changes effected by perimortem handling stress, rigor mortis, and ice storage. *Journal of food science 73*(2), C50-C59.

Güner, S., Dincer, B., Alemdag, N., Colak, A., & Tüfekci, M. (1998). Proximate composition and selected mineral content of commercially important fish species from the Black Sea. *Journal of the Science of Food and Agriculture 78*(3), 337-342.

İspir, Ü. , Özcan, M. & Kırıcı, M. (2021). Fatty Acid Composition in Yersinia ruckeri Strains Isolated from Rainbow Trout Farms. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 24*(6), 1208-1212. DOI: 10.18016/ksutarimdoga.vi.838056

Kayim, M., Oksuz, A., Ozyilmaz, A., Kocabas, M., Can, E., Kizak, V., & Ates, M. (2011). Proximate composition, fatty acid profile and mineral content of wild brown trout (Salmo trutta sp.) from Munzur River in Tunceli, Turkey. *Asian Journal of Chemistry 23*(8), 3533-3537.

Küçükgülmez, A., Yanar, Y., Çelik, M., & Ersor, B. (2018). Fatty acids profile, atherogenic, thrombogenic, and polyene lipid indices in golden grey mullet (Liza aurata) and gold band goatfish (Upeneus moluccensis) from Mediterranean Sea. *Journal of Aquatic Food Product Technology 27*(8), 912-918.

Lațiu, C., Cocan, D., Uiuiu, P., Ihuț, A., Nicula, S. A., Constantinescu, R., & Mireșan, V. (2020). The Black Sea Trout, Salmo labrax Pallas, 1814 (Pisces: Salmonidae) in Romanian Waters. Bulletin UASVM *Animal Science and Biotechnologies 77*(2), 10-19.

Li, N., Wu, X., Zhuang, W., Xia, L., Chen, Y., Wu, C., Rao, Z., Du, L., Zhao, R., Yi, M., Wan, Q., & Zhou, Y. (2020). Fish Consumption and Multiple Health Outcomes: Umbrella Review. *Trends in Food Science & Technology 99*, 273-283.

Lubis, Z. & Buckle, K. A. (1990). Rancidity and lipid oxidation of dried-salted sardines. *Int. J. Food Sci. Technol. 25*(3), 295–303.

Martling, S., Simpson, G., Kientz, J. L., Rosburg, A. J., & Barnes, M. E. (2020). Brown Trout Spawn Timing, Redd Locations, and Stream Characteristics in Spearfish Creek within Spearfish, South Dakota, USA. *Open Journal of Ecology 10*(4), 177-188.

Memiş, D., Yamaner, G., Tosun, D. D., Tunçelli, G., & Tinkir, M. (2020). Current Status of Economically Important Diadromous Fish Species of Turkey; European eel, Black Sea trout and Sturgeon Species. *Aquatic Research 3*(4), 188-196.

Morelló, J. R., Motilva, M. J., Tovar, M.J., &Romero, M. P. (2004). Changes in Commercial Virgin Olive Oil (cv Arbequina) during Storage, with Special Emphasis on the Phenolic Fraction. *Food Chemistry 85*(3), 357-364.

Öksüz, A. (2012). Comparison of meat yield, flesh colour, fatty acid, and mineral composition of wild and cultured Mediterranean amberjack (Seriola dumerili, Risso 1810). *Journal of FisheriesSciences 6*(2), 164-175.

Öksüz, A. & Özyılmaz, A. (2010). Changes in fatty acid compositions of Black Sea anchovy (Engraulis encrasicolus L. 1758) during catching season. *Turkish Journal of Fisheries and Aquatic Sciences 10*(3), 381-385.

Özyılmaz, A. (2019). Differences in Nutrition Value and Fatty Acid Profiles of Cultured Fish Consumed in Turkey (Türkiye'de Tüketilen Kültür Balıklarında Besin Değeri ve Yağ Asidi Bakımından Farklılıklar). *Gıda-Journal of Food 44*(1), 50-59.

Özyılmaz, A. & Öksüz, A. (2015). Determination of the biochemical properties of liver oil from selected cartilaginous fish living in the northeastern Mediterranean. *Journal of Animal and Plant Sciences 25*, 160-167.

Ozyilmaz, A., Erguden Alagoz, S., Erguden, D., Ozeren, A., & Nadir Semerci, R. S. (2016). The proximate compositions, carbohydrate contents and energy values of three freshwater fish from Seyhan River in Adana/Turkey. *Journal of Entomology and Zoology Studies 4*(4), 1153-1155.

Şahin, Ş. A., Başçınar, N., Kocabaş, M., Tufan, B., Köse, S., & Okumuş, İ. (2011). Evaluation of meat yield, proximate composition and fatty acid profile of cultured brook trout (Salvelinus fontinalis Mitchill, 1814) and Black Sea Trout (Salmo trutta labrax Pallas, 1811) in comparison with their hybrid. *Turkish Journal of Fisheries and Aquatic Sciences 11*(2), 261-271.

Tacon,, A. G., Lemos, D., & Metian, M. (2020). Fish for Health: Improved Nutritional Quality of Cultured Fish for Human Consumption. *Reviews in Fisheries Science & Aquaculture 28*(4), 449-458.

Turan, D. & Aksu, S. (2021). A New Trout Species from Southern Marmara Sea Drainages (Teleostei: Salmonidae). *Journal of Anatolian Environmental and Animal Sciences 6*(2), 232-239.

Ulbricht, T. L. V. & Southgate, D. A. T. (1991). Coronary heart disease: seven dietary factors. *The lancet 338*(8773), 985-992.

Ural, M. S., Çalta, M., & Parlak, A. E. (2017). The comparison of fatty acids, fat-soluble vitamins and cholesterol in the muscle of wild caught, cage and pond reared rainbow trout (Oncorhynchus mykiss W., 1792). *Iranian Journal of Fisheries Science 16*(1), 431-440.

Yeşilayer, N. & Genç, N. (2013). Comparison of proximate and fatty acid compositions of wild brown trout and farmed rainbow trout. *South African Journal of Animal Science 43*(1), 89-97.

Yeşilayer, N., Elmastaş, M., Akın, Ş,, Genç, N., & Akşit, H. (2014). Farklı Düzeylerde α- tokoferol asetat ve Defne Ekstratı İçeren Antioksidantlı Yemlerin Gökkuşağı Alabalığının (Oncorhynchus mykiss) Büyüme Parametreleri ve Fileto Yağ Asitlerine Etkileri. *Journal of Agricultural Faculty of Gaziosmanpasa University 31*(1), 73-84.

Závorka, L., Larranaga, N., Lovén Wallerius, M., Näslund, J., Koeck, B., Wengström, N., Cucherousset, J., & Johnsson, J. I. (2020). Within-stream Phenotypic Divergence in Head Shape of Brown Trout Associated with Invasive Brook Trout. *Biological Journal of the Linnean Society 129*(2), 347-355.

Zhang, Q., Chen, Y., Xu, W., & Zhang, Y. (2021). Effects of Dietary Carbohydrate Level on Growth Performance, Innate Immunity, Antioxidant Ability and Hypoxia Resistant of Brook Trout Salvelinus fontinalis. *Aquaculture Nutrition 27*(1), 297-311.