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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

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Abstract

Meat yield, biochemical composition, and fatty acid profile of farmed brook trout (*Salvelinus fontinalis*), Black Sea trout (*Salmo trutta labrax*) and their hybrids were compared. Hybrids contained significantly higher carcass and meat yield values than brook and Black Sea trout. Although the weight percent head and bone (brook trout as 13.14, 1.66 %, Black Sea trout as 13.52, 1.22 % and their hybrids as 13.92, 1.44 %) of the species were similar, fin, carcass, gonad, liver, internal organs and meat yield of the species were significantly different from each other ($P<0.05$). Significant variation also occurred in their protein, fat ($P<0.001$) and ash contents ($P<0.05$) with the highest protein and fat contents in Black Sea trout. Although some variations occurred ($P<0.05$) between sexes for total saturated fatty acids (ΣSFA), there were no significant differences in the overall values among trout samples. Highest SFA was found for Black Sea trout as 22.04%. Hybrid samples contained lowest total monounsaturated fatty acids (MUFA) as 27.14% and significantly differed from brook trout. The highest polyunsaturated values were found in the hybrid samples as 39.41%. The values of eicosapentaenoic acid (EPA, 20:5 n-3), docosahexanoic acid (DHA 22:6 n-3), Σn3 for hybrids were significantly higher compared to others ($P<0.05$) and accounted for 4.27, 18.48 and 24.98%, respectively. The n3/n6 ratio significantly varied among the samples (1.41-1.89) with the highest value found in hybrids. Hybrid samples showed better meat yield and fatty acid profile compared to brook trout and Black Sea trout. Therefore, aquaculturing hybrid of *Salvelinus fontinalis* x *Salmo trutta labrax* is beneficial for fish farming and may present higher economical value.

Keywords: Black Sea trout, brook trout, hybrid, fatty acid profile, meat yield.

Kaynak Alabalığı (*Salvelinus fontinalis* Mitchill, 1814) ve Karadeniz Alabalığı'nın (*Salmo trutta labrax* Pallas, 1811) Et Verimi, Biyokimyasal Kompozisyonu ve Yağ Asidi Profilinin Hibritleriyle Karşılaştırılarak Değerlendirilmesi

Özet

Çalışmada, kültür şartlarında yetiştirilen kaynak alabalığı (*Salvelinus fontinalis*), Karadeniz alabalığı (*Salmo trutta labrax*) ve hibritlerinin et verimi, biyokimyasal ve yağ asidi kompozisyonları karşılaştırılmıştır. Hibrit balıkların karkas ve et verimi değerleri, kaynak ve Karadeniz alabalıklarından önemli oranda yüksektir. Balıklarda, baş ve kemik ağırlıklarının yüzdeleri (kaynak alabalığı: 13,14, %1,66, Karadeniz Alabalığı: 13,52, %1,22 ve hibrit: 13,92, %1,44) benzer olmasına rağmen yüzgeç, karkas, gonad, karaciğer, iç organlar ve et verimi birbirlerinden önemli oranda farklıdır ($P<0,05$). En yüksek protein ve yağ içeriği Karadeniz alabalığında bulunmasıyla birlikte; protein, yağ ($P<0,001$) ve kül miktarları ($P<0,05$) arasında önemli varyasyon gözlenmiştir. Cinsiyetler arasında toplam doymuş yağ asitleri (ΣDYA) açısından bazı varyasyonlar meydana gelmesine ($P<0,05$) rağmen, alabalık örnekleri arasında tüm değerler içerisinde önemli bir farklılık yoktur. En yüksek DYA %22,04 olarak Karadeniz alabalığında bulunmuştur. Hibrit örnekler %27,14 ile en düşük toplam tekli doymamış yağ asidi (ΣTDYA) içermektedir ve kaynak alabalığından önemli derecede farklıdır. En yüksek çoklu doymamış yağ asidi değerleri hibrit bireylerde %39,41 olarak bulunmuştur. Hibritlerin, eikosapentaenoik asit, (EPA, 20:5 n-3), dokosahekzaenoik Asit (DHA 22:6 n-3) ve Σn3 değerleri diğerleriyle karşılaştırıldığında istatistiksel olarak önemli oranda yüksek bulunmuştur ve miktarları sırasıyla %4,27, 18,48 ve 24,98 şeklindedir. n3/n6 oranı en yüksek hibritlerde bulunmasıyla birlikte örnekler arasında önemli değişimler (1.41-1.89) sergilemiştir. Hibrit örnekler, kaynak alabalığı ve Karadeniz alabalığı ile karşılaştırıldığında daha iyi et verimi ve yağ asidi profili sergilemektedir. Bu nedenle *Salvelinus fontinalis* x *Salmo trutta labrax* hibritlerinin kültüre alınması yetiştiricilik açısından faydalı olacak ve daha yüksek ekonomik değer sunacaktır.

Anahtar Kelimeler: Karadeniz alabalığı, kaynak alabalığı, hibrit, yağ asidi profili, et verimi.

Introduction

Aquaculture is rapidly gaining great importance in Turkey as in many countries of the world. It started with the culture of rainbow trout in the 1970s, but substantial commercial status was not achieved until 1990s. The development of a sustainable industry requires species diversification and application of appropriate management procedures. The culturing of more than one salmonid species in farms may provide one viable alternative. In this respect, species of genus *Salvelinus* has drawn considerable attention in recent years (Jobling, 1995; Okumuş and Başçınar, 2002).

Brook trout (*Salvelinus fontinalis*, Mitchill, 1814) is not a native species of Turkey. It has been introduced from Europe for aquaculture purposes (Okumuş *et al*., 1998). Today the species is reared in some rainbow trout farms in eastern Black Sea region, but there is no commercial production. We have conducted a series of studies to evaluate the aquaculture potential of the species with the ultimate aim of increasing species diversity in Turkish aquaculture (Okumuş and Başçınar, 2005).

The sea trout is an anadromous salmonid species of high ecological and commercial value, which is widely distributed in Europe, including the north-eastern Black Sea coast of Turkey and the Black, Azov and Caspian Sea basins. It occurs in rivers flowing from Turkey and other coastal states into the Black Sea. Therefore, it has been called the "Black Sea trout" by Turkish authorities and "Black Sea salmon" in other Black Sea countries (Okumuş *et al*., 2007).

There has been evidence that fish lipids are beneficial for human health, and polyunsaturated fatty acids (PUFA) especially omega 3 fatty acids (n-3 FAs) have been recognized to be essential components of human diet, prevent several diseases and have a vital role in health promotion. These fatty acids, particularly eicosapentaenoic, 20:5n3 (EPA) and docosahexaenoic, 22:6n3 (DHA) have been reported to prevent cardiovascular, depressions and some other diseases like cancer, inflammatory and autoimmune disorders, inflammation and arrhythmias rheumatoid arthritis (Kinsella, 1986; Kinsella, 1987; Lees and Karel, 1990; Simopoulos *et al*., 1991; Horrocks and Yeo, 1999; Mori *et al*., 1999; Babcock *et al*., 2000; Schmidt *et al*., 2006; Munakata *et al*., 2009). Since these fatty acids only occur in high amounts in seafood, it is necessary to determine the fatty acid compositions and total lipid contents of various seafoods in order to recommend a suitable preventive diet for several human diseases. Considering the high benefits of consumption of marine oils in human health, the Nutrition Committee of the American Heart Association recommends eating fish of any type 2 or 3 times a week (Kris-Etherton *et al*., 2003; Mnari *et al*., 2007). However, lipid content and fatty acid profile of fish are known to vary within species (Haliloğlu, 2001; Haliloğlu *et al*., 2002).

There have been several studies regarding carcass ratio, meat yield and biochemical composition of brook (Çelikkale *et al*., 1998) and Black Sea trout (Çakmak *et al*., 2008). Limited studies also exist on fatty acid composition of Black sea trout (Aras *et al*., 2003a) and brook trout (Atchison, 1975; Boccigone *et al*., 1985; Guillou *et al*., 1995; Guillou *et al*., 1996). However, studies on hybrid trout concentrated on its life cycle, growth and development (Blanc and Chevassus, 1986; Scheerer *et al*., 1987; McKay *et al*., 1992a, McKay *et al*., 1992b). Therefore no study exists about carcass ratio, meat yield, biochemical composition and fatty acid profile of hybrid trout in literature. The meat yield of the species in aquaculture affects the cultivation practices of these species (Cibert *et al*., 1999). It is also important to evaluate proximate composition as well as fatty acid profile of cultured species in terms of nutritional value which will directly affect their economical value. Therefore our objectives were to determine the carcass ratio, meat yield, biochemical composition and fatty acid profile of hybrid trout, which is aquacultured for the first time in Turkey, and to compare it with its originating species of Black Sea trout and brook trout.

Materials and Method

The investigation took place in Karadeniz Technical University Sürmene Marine Sciences Faculty Prof.Dr. İbrahim Okumuş Aquaculture Research Unit. Brook trout (*Salvelinus fontinalis*), was a domesticated fish species in this unit, F_1 (obtained from wild stock) Black Sea trout (*Salmo trutta labrax*) was grown from egg to harvest weight, parents were caught in wild, and hybrid fish was obtained by crossing female Black Sea trout and male brook trout broods. The fish was grown in circular fibreglass tanks; with diameters ranging from 50 cm to 3 m depending on fish size, in freshwater (supplied by a nearby spring by 200 m of pipeline). The fish, size 150-300 g, were fed commercial 4-8 mm extruded trout feed (Black Sea Feed, Sibal Co. Sinop, Turkey) in the same tank, i.e. polyculture. Table 1 shows the fatty acid profile of both pellet feed types used in this study. Samples were chosen from fish size ranging between 172.2-346.3 g (mean 267.9±57.16; n=10) for brook trout, 155.7-343.8 g (mean 257.8±57.04; n=10) for Black Sea trout, and 153.9-335.1 g (mean 243.7±65.17; n=10) for hybrid.

Carcass Ratio and Meat Yield

Ten fish were chosen randomly from each of the three species in July, at the age of 1.5 years. Except for hybrids, samples were represented by half males and half females for each species. Fish were dried with a towel before they were weighed, their length and weight measured and they were cut. First the fins and then head were separated together with gills, then

Table 1. Fatty acid profile (% total FAME) of two types of feed pellet used for feeding of trout species and their hybrids

Fatty acid type	Pellet No. 4 (n= 3)		Pellet No. 8 (n= 3)	
	Mean	SD	Mean	SD
C4:0	0.50	0.10	1.44	0.45
C8:0	0.28	0.01	-	-
C14:0	3.66	0.15	3.33	0.09
C15:0	0.31	0.00	0.30	0.00
C16:0	12.48	0.05	11.32	0,30
C16:1	3.94	0.01	3.74	0.11
C17:0	0.27	0.00	0.29	0.07
C17:1	0.32	0.02	0.31	0.01
C18:0	2.98	0.05	2.78	0.06
C18:1n9t	2.74	0.06	2.60	0.07
C18:1n9	12.51	0.16	11.19	0.17
C18:2n6	0.46	0.06	2.55	0.04
C18:3n6	7.06	0.80	6.99	0.07
C20:1	0.87	0.05	0.63	0.04
C22:1n9	0.82	0.04	1.16	0.01
C20:4n6	0.33	0.02	-	-
C22:2	1.00	0.10	0.85	0.06
C20:5n3	5.04	0.01	4.65	0.00
C24:1	0.58	0.08	0.45	0.06
C22:6n3	6.01	0.01	5.56	0.10

the ventral part was sheared, livers, gonads, heads and fins were weighed separately. The rest was recorded as carcass weight. The flesh was boiled in water until separated from the bone. Bones were cleaned so that there would be no flesh on them and evaluated as bone weight (TSE, 1982). Weight was measured using en electronic digital balance (± 0.1 g) (XB4200C, Presica, Switzerland). The following equation was used in calculating the weights of viscera and deadweight of meat:

Viscera weight = Total weight – (Head Weight + Carcass Weight + Fin Weight) (1)

Biochemical Analysis

Tissues of fish (flesh) samples were homogenized by using a kitchen food processor (Arçelik, K-1631 P Valso Plus, 2.2 L capacity, Turkey) for analysis of body weight properties (dry matter, total protein, total fat and ash contents). All the analyses were carried out in triplicate for such parameters. Dry matter was determined after drying at 100-105ºC for 24 h (AOAC, 1995, Method 985.14) and ash after combustion at 550ºC for 12 h according to the AOAC (1980) Method 7.009. Moisture content was determined by oven drying of 5 g of fish muscle and gonad at 105°C until a constant weight was obtained. Fat content was determined using a solvent extractor Velp SER 148/6 (Velp Scientifica, Milano, Italy) with petroleum ether (130°C), and protein content was determined by AOAC (1980) Method 2.507 using the Kjeldahl nitrogen (coefficient = 6.25) in an automated distillation unit (Buchi 339, Flawil, Switzerland). All analyses were conducted in triplicate.

Fatty Acid Analysis

Fatty acid analysis was carried out separately for each sex of brook trout and Black Sea trout. Since hybrids represent no sex, they were not differentiated for sex for the analysis. The edible part of fish from each species was removed, cut into pieces and homogenized. Sampling was also done in July with 1.5 years old fish. Analysis was carried out immediately after sampling from the fish aquaculture unit. Total lipid extraction of the samples was carried out in triplicate according to Bligh and Dyer (1959) method, using chloroform: methanol (2:1, v/v) solvent system. Results were calculated as g lipids per 100 g wet muscle. Methyl esters were prepared by transmethylation using 2 M potassium hydroxide in methanol and n-hexane according to the method described by Ichihara *et al.* (1996) with minor modification; 10 mg of extracted oil was dissolved in 2 ml hexane, followed by 4 ml of 2 M methanolic KOH. The tube was then vortexed for 2 min at room temperature. After centrifugation at 4000 rpm and at 4ºC for 10 min, the hexane layer was taken for GC analyses.

The determination of fatty acids was conducted using a Shimadzu 2010 gas chromatograph with autosampler (Shimadzu, JAPAN), equipped with split injector (ratio 1:20), a flame ionization detector (FID) and a 100 m SUPELCO (model SP™-2380, USA) fused silica capillary column (film thickness 0.20 µm, diameter 0.25 mm). The temperature of the injector port and the detector was held at 260°C. The injected volume was 1 µl. The temperature of column was held at 140°C for 5 min, raised to 240°C at 5ºC/min, held at 240ºC for 30 min. Fatty acids were identified by comparing the retention times of FAME with Supelco™ 37 component FAME mixture (Cat. No. 47885-U). Three replicate GC analyses were performed and the results were expressed in GC area % as mean values ± standard deviation.

The mean and standard deviation (±SD) were calculated for parameters in each group and one-way analysis of variance (ANOVA) was used to test for differences between groups and where significant differences ($P<0.05$ or $P<0.01$) were found a multiple comparison test (Tukey) was used to determine the different group(s). Data analyses were carried out using the Minitab 13.0 software (MINITAB Inc., USA) and JMP 5.0.1 package version (SAS Institute, Inc., Cary, NC, USA) statistical programs.

Results and Discussion

Figure 1 displays the differences in the ratios of different parts of three different trout samples as well as their meat yield. The carcass ratio to total body weight of hybrid was found as 69.83%, higher than book trout and Black Sea trout, which were 67.28 and 65.39%, respectively. Head and fin ratios of hybrid samples were also higher than those of other trout samples, while gonad and liver ratios were lower than others. The head, fin, gonad and liver ratios of hybrid were 13.92, 3.32, 0.23 and 1.68%. For brook trout they were 13.14, 2.39, 3.86 and 2.76%, and for Black Sea trout 13.52, 2.67, 5.19 and 1.87%. Bone ratios were highest for brook trout (1.66%) and lowest for Black Sea trout (1.22%). Hybrid trout bone ratio was 1.44%. The lowest viscera ratio was found for hybrid (12.92%) and highest for Black Sea trout (18.43%). The ratio of brook trout was close to Black Sea trout (17.19%). Meat yields of brook trout, Black Sea trout and hybrid were 65.62, 64.18 and 68.40%, respectively.

Black Sea trout showed similar features with brook trout and hybrids in terms of carcass ratio. However, hybrids and brook trout exhibit statistical differences ($P<0.01$). Although no significant differences were observed between Black Sea trout and brook trout in terms of gonad and viscera ratios, significant variation in the ratio of these organs occurred between two species and their hybrids ($P<0.01$). While Black Sea trout had similar meat yield value with other trout types, hybrid samples showed statistical differences with brook trout in terms of meat yield ($P<0.01$).

The meat yield value observed for cultured brown trout (*Salmo trutta forma fario)* in river water was 63.73% and ranged between 59.54-69.32% (Erdem, 2006). In the same study, meat yield for natural species obtained from the same rivers was found as 67.85 % with a range of 65.53-70.10% showing similarities with brook and Black Sea trout samples. Okumuş (2000) indicated that since cultured fish grow rapidly, their head, fins and viscera have greater ratios. For this reason, as the growth and growth rate increase, carcass ratio decreases. However; according to the result of the study of Kim (1988) on *Salmo gaidneri*, carcass ratio tended to increase significantly ($P<0.05$) with increasing body weight (Kim, 1988). Macías *et al.* (2004) found the carcass yield as 85.5% for 200 g rainbow trout which was lower than the yield of 300 g samples (88%). In the same study, meat yield constituted 53.14% of total weight and 55.25% of carcass weight. In our study, the carcass ratio of brook trout was found to be lower than the results of Macías *et al*. (2004) but higher than the result of Çelikkale *et al.* (1998) observed for brook trout. Çakmak *et al.* (2008) observed significant variation for the body weight ratios between male and female samples. They found the average carcass ratio as 69.5% and edible meat ratio as 60.4% for cultured Black Sea trout weighing between 159.78-2,596.27 g and ages between 2 and 5. On the other hand,

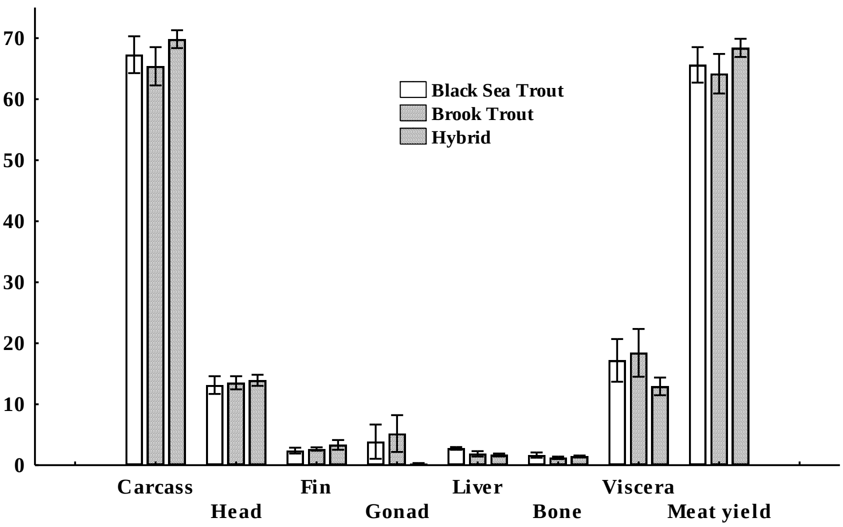

Figure 1. Percentage of carcass, head, fin, gonad, liver, bone, viscera and meat yield.

Okumuş (2000) and Kim (1988) observed that there was no change in carcass and edible meat ratio with the increase of fish weight. In our study, the carcass ratio was 67.28% for Black Sea trout which was close to the carcass results of Çakmak *et al.* (2008), but higher in meat yield. Çakmak *et al.* (2008) also reported lower head ratio for Black Sea trout as 12.2% compared to our results for the same species. However, Çelikkale *et al.* (1998) reported higher head ratio for brook trout as 14.88%. Since there has been no study about hybrids which originated from brook and Black Sea trout species, no comparisons were possible.

Regarding meat yield comparison among these three species; the difference between brook trout and hybrid was found as significant (P<0.01). Black Sea trout tended to show similarities with the other two species according to their meat yield. Linear relationship (y = a+bx) was detected between live weight (x) and their ratio for carcass, head, fin, gonad, liver, bone and viscera (y) of brook, Black Sea and hybrid trout (Table 2).

Table 3 represents proximate composition of three different trout species. No significant differences were observed for dry matter content amongst them, however, significant differences were observed for crude protein, crude fat and ash contents (P<0.01). The highest protein and fat contents were observed with Black Sea trout as 73.82% (DWB) and 11.02%, respectively, while hybrid samples contained highest ash value. Çelikkale *et al.* (1998) reported higher protein and dry matter content and lower ash and fat content for brook trout. Erdem (2006) reported no significant differences for protein content between cultured and natural brown trout obtained from rivers in Black Sea region of Turkey. However, significant variation was observed amongst the months, and protein content decreased significantly during spawning seasons for both cultured and natural samples.

The fatty acid profile (% of total FAs) of flesh lipids of both sexes for brook trout and Black Sea trout are listed in Table 4. Table 5 demonstrates overall mean values of FA profile of these species in comparison with their hybrid samples. Palmitic acid (16:0) was the major saturated fatty acid (SFA) in

Table 2. Relationship between total weight (x) of brook Trout (BT), Black Sea trout (BST), hybrid (H) with carcass, head, fin, gonad, liver, bone, viscera weights (y) (all models y = a + b x)

	Species	a	b	R^2	F	P
Carcass	BT	-10.6087	0.69487	0.901	72.88	0.00
	BST	7.28104	0.64223	0.942	130.76	0.00
	H	1.11908	0.69334	0.987	622.83	0.00
Head	BT	-1.35265	0.14018	0.775	27.52	0.00
	BST	6.99202	0.10295	0.584	11.23	0.01
	H	1.94435	0.13093	0.848	44.56	0.00
Fin	BT	0.94053	0.02293	0.581	11.09	0.01
	BST	0.53861	0.02171	0.245	3.92	0.08
	H	-4.32751	0.05225	0.616	12.85	0.01
Gonad	BT	-3.82845	0.06748	0.091	0.80	0.40
	BST	-8.61216	0.07374	0.066	1.64	0.24
	TT	-0.70899	0.00546	0.431	6.05	0.04
Liver	BT	1.96028	0.01110	0.117	1.06	0.33
	BST	0.75851	0.02449	0.783	28.84	0.00
	H	1.05853	0.01211	0.524	8.79	0.02
Bone	BT	2.31777	0.00313	0.079	0.68	0.43
	BST	1.99267	0.00839	0.129	1.18	0.31
	H	1.38159	0.00836	0.558	10.08	0.01
Viscera	BT	11.0208	0.14202	0.195	1.94	0.20
	BST	-14.8117	0.23312	0.638	14.15	0.01
	H	1.26407	0.12347	0.721	20.72	0.00

P= the significance level (P<0.05, P<0.01). n= 10 fish were used for each species.

Table 3. Biochemical composition (%) in dry matter of brook trout, Black Sea trout and their hybrid

	Brook trout	Black Sea trout	Hybrid	P
Dry matter	23.46±0.15[a]	23.26±0.36[a]	23.31±0.57[a]	P>0.05
Protein*	69.51±0.37 [b]	73.82±0.09 [a]	72.63±0.24 [c]	P<0.01
Fat*	9.92±0.07 [b]	11.02±0.02 [a]	9.68±0.10 [c]	P<0.01
Ash*	8.05±0.18 [a]	8.10±0.03[a]	8.46±0.13[b]	P<0.05

Values in the same line followed by different letter are significantly different (P<0.05, P<0.01).
*Calculated from dry weight basis. n= 3 for each species for each type of analysis.

Table 4. Fatty acid profile (% of total FAME) of male and female samples for brook trout and Black Sea trout

Fatty Acid type	Brook trout		Black Sea trout	
	♂	♀	♂	♀
C4:0	0.04±0.02[a]	0.53±0.05[b]	0.13±0.05[a]	0.12±0.00[a]
C6:0	0.01±0.00[a]	0.07±0.00[a]	0.01±0.00[a]	0.01±0.00[a]
C8:0	0.01±0.01[a]	0.01±0.00[a]	0.67±0.08[a]	0.65±0.00[b]
C10:0	0.01±0.00[a]	0.09±0.00[a]	0.03±0.00[a]	0.01±0.00[a]
C12:0	0.03±0.00[a]	0.05±0.01[a]	0.03±0.00[a]	0.03±0.00[a]
C13:0	0.02±0.00[a]	0.02±0.00[a]	0.02±0.00[a]	0.02±0.01[a]
C14:0	3.31±0.07[a]	3.14±0.01[a]	3.31±0.16[a]	2.73±0.01[b]
C15:0	0.03±0.01[a]	0.06±0.01[a]	0.02±0.01[a]	0.02±0.00[a]
C16:0	13.34±0.36[a]	12.94±0.08[a]	14.29±0.48[a]	12.79±0.09[b]
C17:0	0.06±0.00[a]	0.05±0.02[a]	0.06±0.01[a]	0.07±0.03[a]
C18:0	2.79±0.08[a]	3.10±0.16[a]	3.30±0.09[a]	2.92±0.05[b]
C20:0	0.06±0.01[a]	0.07±0.00[a]	0.08±0.02[a]	0.06±0.01[a]
C21:0	0.71±0.02[a]	0.73±0.04[a]	0.66±0.02[a]	0.67±0.08[a]
C22:0	0.62±0.04[a]	0.75±0.03[a]	0.79±0.00[a]	0.83±0.04[a]
C23:0	0.36±0.01[a]	0.17±0.00[b]	0.20±0.00[a]	0.19±0.01[a]
C24:0	0.02±0.00[a]	0.02±0.00[a]	0.04±0.02[a]	0.03±0.01[a]
ΣSFA	21.36±0.55[a]	21.78±0.38[a]	23.64±0.53[a]	20.44±0.33[b]
C14:1	0.02±0.00[a]	0.02±0.00[a]	0.02±0.00[a]	0.01±0.00[a]
C15:1	0.07±0.01[a]	0.07±0.01[a]	0.07±0.01[a]	0.07±0.02[a]
C16:1	4.93±0.04[a]	6.24±0.12[b]	4.41±0.15[a]	4.11±0.07[a]
C17:1	0.23±0.02[a]	0.25±0.04[a]	0.26±0.05[a]	0.21±0.02[a]
C18:1n9t	0.17±0.01[a]	0.23±0.04[a]	0.15±0.01[a]	0.20±0.00[b]
C18:1n9	23.92±0.39[a]	26.57±0.08[b]	24.26±0.22[a]	24.35±0.03[a]
C20:1	0.17±0.02[a]	0.16±0.01[a]	0.16±0.00[a]	0.20±0.01[b]
C22:1n9	0.33±0.04[a]	0.33±0.02[a]	0.34±0.02[a]	0.35±0.02[a]
C24:1	0.17±0.03[a]	0.10±0.00[b]	0.10±0.00[a]	0.12±0.01[a]
ΣMUFA	30.00±0.29[a]	33.89±0.24[b]	29.76±0.31[a]	29.43±0.17[a]
C18:2n6t	0.20±0.00[a]	0.22±0.01[a]	0.10±0.01[a]	0.12±0.03[a]
C18:2n6	13.22±1.35[a]	13.20±0.08[a]	13.67±0.06[a]	15.08±0.07[b]
C18:3n3	2.08±0.09[a]	2.04±0.02[a]	2.07±0.10[a]	2.34±0.02[a]
C18:3n6	0.52±0.06[a]	0.45±0.04[a]	0.48±0.02[a]	0.51±0.06[a]
C20:2	1.09±0.01[a]	0.90±0.05[b]	0.91±0.09[a]	0.96±0.06[a]
C20:3n3	0.10±0.01[a]	0.08±0.00[a]	0.10±0.01[a]	0.17±0.08[a]
C20:4n6	0.03±0.00[a]	0.03±0.01[a]	0.02±0.00[a]	0.04±0.02[a]
C20:5n3	4.23±0.10[a]	3.80±0.08[b]	3.19±0.42[a]	2.95±0.02[a]
C22:2	0.02±0.00[a]	0.02±0.00[a]	0.03±0.00[a]	0.02±0.00[a]
C22:6n3	15.50±0.02[a]	13.79±0.04[b]	14.25±0.66[a]	17.39±0.34[b]
ΣPUFA	37.97±1.45[a]	34.52±0.08[b]	34.97±0.61[a]	39.56±0.70[b]
EPA+DHA	19.73±0.08[a]	17.59±0.11[b]	17.44±0.24[a]	20.34±0.37[b]
Σn3	21.91±0.02[a]	19.70±0.09[b]	19.62±0.35[a]	22.85±0.46[b]
Σn6	13.96±1.42[a]	13.90±0.05[a]	14.28±0.56[a]	15.73±0.17[b]
Σn3/Σn6	1.58±0.10[a]	1.42±0.01[b]	1.37±0.03[a]	1.45±0.01[a]
Σn6/Σn3	0.63±0.06[a]	0.70±0.00[a]	0.73±0.01[a]	0.68±0.00[b]

Values in the same line followed by different letter are significantly different ($P<0.05$), n= 3 for each species.

muscle of both sexes for both species as well as their hybrids. Other studies also reported that 16:0 was the most abundant SFA in different trout species that are either wild or cultured (Suzuki *et al*., 1986; Tanakol *et al*., 1999; Kiessling *et al*., 2001; Aras *et al*., 2003a, 2003b; Erdem, 2006; Akpinar *et al*., 2009) as well as different marine or freshwater species (Tanakol *et al*., 1999; Şengör *et al*., 2003; Luzia *et al*., 2003; Özyurt *et al*., 2005; Güler *et al*., 2007). The variation in individual SFA between sexes were higher for Black Sea trout than brook trout ($P<0.05$). The variation in overall mean ΣSFA values amongst trout species and their hybrids were not significant despite few individual variations ($P<0.05$), and the values ranged from 21.57 to 22.04%. The highest SFA was observed for Black Sea trout. Aras *et al.* (2003a) observed 37.21% SFA for freshwater wild Black Sea trout which was higher than our levels. Akpinar *et al.* (2009) found also higher SFA levels at 28.5 and 29.4% for females and males of *Salmo trutta macrostigma*, respectively. Erdem (2006) demonstrated that SFA can vary throughout the year from 21.56 to 30% for wild and 21.64 to 27.87% for farmed cultured brown trout obtained from Black Sea rivers.

Oleic acid (18:1n9) was the main MUFA for all the samples analysed which was also supported by other studies in literature for trout species as well as other fish species (Tanakol *et al*., 1999; Alaşalvar *et al*., 2002; Aras *et al*., 2003a, 2003b; Erdem, 2006;

Table 5. Comparison of mean values for fatty acid profile (% of total FAME) of hybrid trout, brook trout and Black Sea trout

Fatty Acid Type	Hybrid	Brook trout	Black Sea trout
C4:0	0.14±0.04^{a}	0.29±0.03^{b}	0.08±0.02^{a}
C6:0	0.01±0.00^{a}	0.04±0.00^{a}	0.01±0.00^{a}
C8:0	0.04±0.06^{a}	0.01±0.00^{a}	0.34±0.04^{b}
C10:0	0.02±0.00^{a}	0.05±0.00^{a}	0.02±0.00^{a}
C12:0	0.03±0.01^{a}	0.04±0.01^{a}	0.03±0.00^{a}
C13:0	0.02±0.00^{a}	0.02±0.00^{a}	0.02±0.00^{a}
C14:0	3.32±0.38^{a}	3.22±0.04^{a}	3.02±0.07^{a}
C15:0	0.03±0.01^{a}	0.04±0.00^{a}	0.02±0.01^{a}
C16:0	13.90±0.19^{a}	13.14±0.22^{a}	13.54±0.19^{a}
C17:0	0.06±0.01^{a}	0.06±0.01^{a}	0.07±0.01^{a}
C18:0	2.78±0.02^{a}	2.95±0.12^{a}	3.11±0.07^{a}
C20:0	0.10±0.03^{a}	0.07±0.01^{a}	0.07±0.00^{a}
C21:0	0.68±0.03^{a}	0.72±0.03^{a}	0.67±0.03^{a}
C22:0	0.61±0.03^{a}	0.68±0.03^{a}	0.81±0.02^{b}
C23:0	0.17±0.00^{a}	0.23±0.01^{b}	0.20±0.00^{ab}
C24:0	0.03±0.01^{a}	0.02±0.00^{a}	0.04±0.01^{a}
ΣSFA	21.95±1.56^{a}	21.57±0.46^{a}	22.04±0.09^{a}
C14:1	0.02±0.00^{a}	0.02±0.00^{a}	0.01±0.00^{a}
C15:1	0.08±0.01^{a}	0.07±0.01^{a}	0.07±0.01^{a}
C16:1	4.48±0.42^{a}	5.59±0.04^{b}	4.26±0.11^{a}
C17:1	0.26±0.04^{a}	0.24±0.03^{a}	0.24±0.01^{a}
C18:1n9t	0.03±0.01^{a}	0.20±0.01^{b}	0.08±0.01^{c}
C18:1n9	21.77±0.71^{a}	25.24±0.23^{b}	24.31±0.13^{b}
C20:1	0.13±0.02^{a}	0.17±0.01^{a}	0.18±0.00^{a}
C22:1n9	0.31±0.01^{a}	0.33±0.03^{a}	0.35±0.00^{a}
C24:1	0.06±0.01^{a}	0.09±0.01^{ab}	0.11±0.00^{b}
ΣMUFA	27.14±1.24^{a}	31.94±0.26^{b}	29.60±0.24^{ab}
C18:2n6t	0.11±0.01^{a}	0.21±0.00^{b}	0.11±0.01^{a}
C18:2n6	12.52±0.65^{a}	13.21±0.64^{ab}	14.37±0.33^{b}
C18:3n3	2.14±0.42^{a}	2.06±0.04^{a}	2.21±0.06^{a}
C18:3n6	0.53±0.00^{a}	0.48±0.05^{a}	0.50±0.02^{a}
C20:2	1.25±0.18^{a}	1.00±0.03^{a}	0.93±0.02^{a}
C20:3n3	0.09±0.00^{a}	0.09±0.01^{a}	0.13±0.04^{a}
C20:4n6	0.02±0.00^{a}	0.03±0.00^{a}	0.03±0.01^{a}
C20:5n3	4.27±0.17^{a}	4.01±0.01^{a}	3.07±0.20^{b}
C22:2	0.01±0.00^{a}	0.02±0.00^{a}	0.22±0.01^{b}
C22:6n3	18.48±0.70^{a}	14.65±0.62^{b}	15.82±0.60^{b}
ΣPUFA	39.41±0.32^{a}	36.24±0.06^{b}	37.26±0.65^{b}
ΣPUFA/ ΣSFA	1.80 ±0.02^{a}	1.68±0.01^{b}	1.69±0.01^{b}
EPA+DHA	22.75±0.29^{a}	18.66±0.01^{b}	18.89±0.30^{b}
Σn3	24.98±0.26^{a}	20.85±0.06^{b}	21.23±0.41^{b}
Σn6	13.16±0.62^{a}	14.42±0.02^{b}	15.00±0.37^{b}
Σn3/Σn6	1.89±0.04^{a}	1.44±0.01^{b}	1.41±0.01^{b}
Σn6/Σn3	0.53±0.01^{a}	0.69±0.01^{b}	0.70±0.01^{b}

Values in the same line followed by different letter are significantly different (P<0.05).

Zlatanos *et al*., 2007). The highest MUFA value was represented by brook trout as 31.94% which was significantly different from hybrids (P<0.05). The variation between sexes for ∑MUFA was only significant for brook trout (P<0.05). Significant variation (P<0.05) between hybrids and other samples were found for C16:1, C18:1n9t, C18:1n9c and C24:1. Some variation was also observed between sexes, especially for brook trout (P<0.05). Aras *et al.* (2003a) observed 26.76% MUFA for wild freshwater Black Sea trout, which was lower than our results for cultured samples of the same species.

DHA was the primary PUFA in all analysed samples closely followed by linoleic acid (18:2n-6). ∑PUFA values of hybrids significantly differed from two trout species (P<0.05) showing the highest value amongst others as 39.41%. Significant differences were also found between sexes for both species (P<0.05). Justi *et al.* (2003) reported that the lipids of freshwater feeds are characterized by linoleic, α-linolenic (C18:3n3) and EPA. Hence, the fatty acid composition of freshwater fish is characterized by high contents of n-6 PUFA and mainly of linoleic and arachidonic (AA, C20:4n6) acids. In our study, although high levels of linoleic acid were observed as 12.52-14.37%, only trace levels of AA were detected in both trout species as well as their hybrids. The levels of C18:3n-3 ranged from 2.06-2.21% without a significant difference between two species and their hybrids. Aras *et al.* (2003a) observed lower linoleic acid content as 2.69% and higher AA values as 1.61% for wild Black Sea trout. Guillou *et al.* (1996) reported lower values of C18:2n6 and C18:3n3 for brook trout.

It has been reported that there is a strong relationship between the fish lipid composition and the diets of fish (Guillou *et al*., 1995; Grigorakis *et al*., 2002; Mnari *et al*., 2007). Mnari *et al*. (2007) observed that the fatty acid profile of gilthead seabream reflected the fatty acid composition of feed used. Erdem (2006) demonstrated that both 18:2n-6 and DHA levels in the muscle of brown trout were lower in wild samples than cultured trout with a great variation between months. Moreover, Haliloğlu *et al.* (2004) demonstrated that there were no significant differences in the levels of C18:2n-6 and AA for rainbow trout (*O. mykiss*) reared in both sea and freshwater cages. Therefore, our study indicates that such fatty acids were most probably influenced by the feeding regime.

Osman *et al.* (2001) reported that arachidonic acid is a precursor for prostaglandin and thromboxan which will influence the blood clot and its attachment to the endothelial tissue during wound healing. Apart from that, the acid also plays a role in growth. They also indicated that the contents of AA in marine fishes were lower than freshwater fishes. Linolenic acid is known as the metabolic precursor of the PUFAs-n3, also in humans (Vaccaro *et al*., 2005). Our results were higher than those obtained for hybrid sturgeon for C18:3n3 levels but lower for AA levels (Vaccaro *et al*., 2005).

The percentages of total saturated fatty acids (∑SFA) were found as the lowest and total polyunsaturated fatty acids (∑PUFA) as the highest in all analyzed trout samples indicating the health benefit of these species and their hybrids in terms of PUFA level. DHA and EPA had been shown to have preventive effects on human coronary artery disease. Therefore, fish have been suggested as a key component for a healthy diet in humans (Zuraini *et al*., 2006). In this study, The highest DHA level was found as 18.48% for hybrid samples and significantly differed from both brook and Black Sea trouts ($P<0.05$). Significant differences also occurred between sexes for both species ($P<0.05$). The highest EPA was also observed with hybrid samples as 4.27% and except with male samples of brook trout, the differences was found significant from others ($P<0.05$). The difference between sexes were only found for brook trout ($P<0.05$).

Numerous researchers have reported that DHA constitutes the majority of the PUFA in most marine fish (Tanakol *et al*., 1999; Grigorakis *et al*., 2002; Özyurt *et al*., 2005). Aras *et al.* (2003a) observed 21.42% DHA and 1.63% EPA. The great variation between wild and cultured Black Sea trout may be related to low levels of DHA in our feeds as seen in Table 1. EPA and DHA levels obtained for farmed brook trout by Guiliou *et al.* (1996) was lower than our findings. However, they reported higher levels of EPA in farmed brook trout with a diet supplemented by different vegetable oils indicating that brook trout have a capacity to elongate linoleic acid (18:2n-6) (Guillou *et al*., 1995). Therefore, low levels of EPA in our study may be related to low levels of linoleic acid in the diet for this study (Table 1).

Erdem (2006) observed lower DHA levels for wild *Salmo trutta forma fario* samples with a range of 4.07-12.02% compared to cultured samples as 9.65-13.43%. Opposite trend was reported for EPA levels as 3.99-7.92% and 2.23-2.97% for wild and cultured samples, respectively. Tanakol *et al.* (1999) reported 2.4% EPA and 17.1% DHA for wild freshwater *O. mykiss*. Akpinar *et al.* (2009) found between 6.45-7.88% EPA and 8.42-7.38% DHA for male and female samples of *Salmo trutta macrostigma*, respectively. Aras *et al.* (2003b) observed higher levels of EPA as 12.95 % and DHA as 16.07% for the same species indicating the regional effect in the same species in terms of EPA and DHA levels. Our results demonstrated higher levels of DHA and EPA from those of other trout samples reported by above literature except for wild brown trout, for EPA reported by Erdem (2006). Haliloğlu *et al.* (2004) demonstrated that significant variation occurred in EPA and DHA levels of the muscle tissues of rainbow trout reared in sea and freshwater cages. They observed higher DHA and lower EPA levels in the samples obtained from freshwater cages compared to sea cages. It is well known that fatty acid composition in fish muscle varies greatly depending on the species, diet composition and feeding regimes, husbandry practices and environmental conditions (Justi *et al*., 2003; Palmeri *et al*., 2007).

The n3/n6 ratio has been suggested as a useful indicator for comparing relative nutritional values of fish oils. It was suggested that a ratio of 1/1–1:5 would constitute a healthy human diet (Osman *et al*., 2001). Different recommendations also occur in the literature for different countries as low as 0.2 (Ben Smida *et al*., 2009). The n3/n6 ratios of all analysed samples were within the recommended value, and hybrid showed the highest ratio as 1.89 with a significant variation from others. The n3/n6 ratios observed in this study indicate that hybrid may be healthier to consume than its originated species. This ratio for hybrids were close to values observed by Haliloğlu *et al.* (2004) for cultured rainbow trout at seawater and freshwater and lower than the values of Aras *et al.* (2003b) and Akpinar *et al.* (2009) observed for wild *S. trutta macrostigma*. Aras *et al.* (2003a) observed much higher n3/n6 ratio for wild Black Sea trout as 6.27. Therefore, such value can change according to feeding regime or feed content of the species and different species.

The addition of n3 PUFA to diet could improve the nutritional value and protect against diseases (Özogul and Özogul, 2007). A minimum value of PUFA/SFA ratio recommended is 0.45 (HMSO, 1994). The PUFA/SFA levels in all types of analysed samples were well above the recommended level with a range 1.68-1.80, with the highest value found for hybrids. This level was higher than several marine species such as grey mullet, sardine, horse mackerel, turbot, common sole and red scorpion fish (Şengör *et al.*, 2003; Özogul and Özogul, 2007). Aras *et al.* (2003a) found lower PUFA/SFA level as 0.88 for wild Black Sea trout compared to our study.

The level of n6/n3 ratio is also important. The UK Department of Health recommends an ideal ratio of n6/n3 of 4.0 at maximum (HMSO, 1994) and higher values are suggested to be harmful to health and may promote cardiovascular diseases (Özogul and Özogul, 2007). In this study, this ratio was found to be lower than ideal ratio indicating the beneficial side of these species and their hybrid. The values ranged from 0.53-0.70, the highest value observed with Black Sea trout and the lowest with hybrid samples.

Conclusion

Since hybrids do not form gonad, they have higher carcass and meat yield values than brook and Black Sea trout. However; similar trend did not occur in the biochemical values despite the significant variation for protein, fat and ash contents. Hybrid samples showed better nutritional values compared to brook trout and Black Sea trout in terms of essential fatty acids such as EPA and DHA, total PUFA and n3/n6 ratio. Therefore, this study demonstrates that aquaculturing hybrid of *Salvelinus fontinalis* x *Salmo trutta labrax* is beneficial for future fish farming and may present higher economical value.

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