www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 17:1179-1187(2017) DOI: 10.4194/1303-2712-v17_6_11

RESEARCH PAPER

Comparison of Fatty Acid Compositions and ω3/ω6 Ratios of Wild Brown Trout and Cultured Rainbow Trout

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Received 14 February 2017
Accepted 10 April 2017

Abstract

Fish are a unique dietary source beneficial to human health. These valuable effects originate from ω3 polyunsaturated fatty acids, particularly the eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the fish oil. In this study, fatty acid composition of the muscle lipids of *Salmo trutta macrostigma* (wild brown trout) and *Oncorhynchus mykiss* (cultured rainbow trout) in Gezende Dam Lake were determined by gas chromatographic technique. In both species, palmitic acid (16.26-18.94%), oleic acid (17.88-20.49%) and DHA (14.08-18.49%) were identified as major saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA), respectively. Wild fish contained significantly more linolenic acid, arachidonic acid, eicosapentaenoic acid, docosapentaenoic acid, total ω3 fatty acids and has higher ω3/ω6 ratio than cultured fish. In conclusion, wild brown trout may have a higher nutritional value considering total ω3 fatty acids (35.52-27.43%) and ω3/ω6 ratio (3.84-1.56) compared to cultured rainbow trout.

Keywords: Fatty acid composition, *Salmo trutta macrostigma*, *Oncorhynchus mykiss*, wild, cultured, Gezende Dam Lake, Turkey.

Introduction

Fishes are the most important nutrients for human health. Benefits of fish or fish oil in human health may be related to PUFAs, especially ω3 PUFAs (Sidhu, 2003). ω3 PUFA also have beneficial effects on human health (Kinsella, Lokesh & Stone, 1990; Steffens, 1997). Because ω3 fatty acids are essential in growth and development along life, these fatty acids should be included in the diets (Simopoulos, 1991). SFAs speed up atherogenesis whereas MUFAs and PUFAs, generally reduce coronary artery disease (Kinsella, Lokesh & Stone, 1990). Humans need to increase the consumption of long chain ω3 PUFAs and decrease intake of SFAs (Lunn & Theobald, 2006). Decreasing SFAs and increasing MUFAs in the diet decrease diastolic blood pressure. The replacement of SFA with MUFA and ω3-linolenic acids seems to stimulate beneficial health effects in humans with cardiovascular disease (Rasmussen et al., 2006). Unlike SFAs, which have been shown to have negative health problems, ω3 fatty acids have been associated with many health benefits (Freeman, 2000). There is convincing evidence that replacing SFA with PUFA decreases the risk of coronary heart disease (FAO, 2010). Fish oils contain long chain PUFAs especially ω3 PUFAs, such as eicosapentaenoic acid (EPA; C 20:5 ω3) and docosahexaenoic acid (DHA; C 22:6 ω3). These long chain polyunsaturated fatty acids have been reported to have beneficial effects on human health (Ackman, 2001; Sidhu, 2003). ω3 fatty acids are healthy nutrients for growth and development of the human organism and these fatty acids are beneficial to retina and brain development (Simopoulos, 1991). ω3 fatty acids are essential for human development in utero and in infancy (Connor, 2000). EPA and DHA have beneficial characteristic for the prevention of human coronary artery disease (Leaf & Weber, 1988). DHA plays an important role for brain and eye development in infants (Holub, 2001). Arachidonic acid and EPA are the parent compounds for the production of eicosanoids (Simopoulos, 2002). Many studies demonstrates that low consumption of ω3 polyunsaturated fatty acids is related to the incidence of coronary heart disease (Hu & Willett, 2002; Lee & Lip, 2003). Consumption of fish and fish oils appears to reduce the risk of coronary heart disease (Kris-Etherton, Harris, & Appel, 2002). In addition, these ω3 fatty acids are important to prevent of cancer, hypertension, diabetes, depression, allergy and some other disease (Connor, 2000; Coste, Gerbi, Vague,

Pieroni, & Raccah, 2003; Gottrand, 2008; Hibbeln, 1998; Holm et al., 2001; Hu, Cho, Rexrode, Albert, & Manson, 2003; Pike, 1999; Rose, 1997; Simopoulos, 2004). An increase in the ω3/ω6 fatty acid ratio in diet is benefical to prevent coronary heart disease by reducing plasma lipids in humans (Kinsella, Lokesh & Stone, 1990).

The fatty acid composition of fish lipids is influenced by diet, reproductive cycle, species, salinity, season, water temperature, individual-specific behaviors, spawning, geographical location and sex (Akpinar, Görgün, & Akpinar, 2009; Bayır et al., 2010; Çelik, Diler, & Küçükgülmez, 2005; Guler, Aktumsek, Cakmak, Zengin, & Citil, 2011; Haliloğlu, Bayır, Sirkecioğlu, Aras, & Atamanalp, 2004; Henderson & Tocher, 1987; Sardenne et al., 2017; Shirai, Suzuki, Tokairin, Ehara, & Wada, 2002; Sushchik, Rudchenko, & Gladyshev, 2017; Uysal, Yerlikaya, Aksoylar, Yöntem, & Ulupinar, 2006). Another important factor affecting fatty acid composition is whether the fish is wild or cultured. Wild fish contain more ω3 fatty acids than cultured fish (Ozogul, Yavuzer, Ozogul, & Kuley, 2013). In addition, wild fish living in lakes are better sources of DHA than cultured fish reared in polyculture (Łuczyńska, Tońska, Krejszeff, & Żarski, 2016).

Gezende Dam is constructed on Ermenek River. The body of the dam, which is a concrete arch-type, has a volume of 98 dam³, a height from the riverbed is 75 m, a volume of lake is 91,90 hm³, and a lake area is 3,97 square kilometers (DSİ, 2013). The species of trout used in the research are Salmonid species. Most economically important members of this family are in the forefront of artificial cultured fish (Geldiay & Balık, 1996). The wild brown trout which is naturally grown in Ermenek River is *Salmo trutta macrostigma* (Dumeril, 1858) and the cultured rainbow trout is grown in cages from local fish farm is *Oncorhynchus mykiss (Walbaum, 1792)*.

No reports have been published about the fatty acid composition of wild brown trout and cultured rainbow trout in Gezende Dam Lake. Therefore, the aim of this work is to compare of the wild brown trout and cultured rainbow trout in terms of their fatty acid composition.

Materials and Methods

Sample Collection

Trout in inland water has the highest production rate in cultured aquaculture fish with 53,1 % (TÜİK, 2011). Trout is preferred by consumers due to its good taste. Trout production is about 60% of the total fish production and trouts are the main cultured freshwater fish in Turkey (Harlioğlu, 2012). *Salmo trutta* L. (wild brown trout) are native to North America, Europe, West and North Asia (Geldiay & Balık, 1996). Brown trout can be considered as an important fish species in Turkey. It is highly accepted in Turkey and the local market value is higher than rainbow trout (Arslan, Sirkecioglu, Bayir, Arslan, & Aras 2012). Europe and Turkey are the natural distribution area of brown trout (Yeşilayer & Genç, 2013). Rainbow trout is primarily raised in inland waters and trout production has increased recently (Balcı Akova, 2015). Rainbow trout is the most important cultivated fish species in Turkey (Akpinar, Akpinar, Gorgun & Akpinar, 2015). This species is one of the most widely cultured species throughout the world (Kalyoncu, Yaman & Aktumsek, 2010).

Trout species used in this study have been obtained from Gezende Dam Lake, Mut, Turkey. The fishes used in this study are presented in Figure 1 and Figure 2. All fish used in this study are almost at the same size and age (over 2 years old). Total weight and

Figure 1. Salmo trutta macrostigma (wild brown trout).

Figure 2. *Oncorhynchus mykiss* (cultured rainbow trout).

average length are about 250-300 g and 150-170 mm, respectively. Fish were transported to the laboratory in about four hours in ice cooler box and 10 g dorsal muscle tissues were taken as the samples. The samples were frozen at -26 ºC until analyzed. At the beginning of analysis, the samples were allowed to equilibrate to room temperature.

Fatty Acid Analysis

Total lipids of fish have been extracted with chloroform/methanol (2:1 v/v) according to the Folch, Lees, & Sloane-Stanley (1957). The fatty acids in the total lipid have been esterified into methyl esters by saponification with 0.5 N methanolic NaOH and transesterified with 14% BF_3 (v/v) in methanol (IUPAC, 1979).

Fatty acid methyl esters (FAMEs) have been analyzed on a HP (Hewlett Packard) Agilent 6890N model gas chromatograph (GC), equipped with a flame ionization detector (FID) and fitted with a HP-88 capillary column (100 m, 0.25 mm i.d. and 0.2 µm). Injector and detector temperatures have been 240 and 250 ºC, respectively. The oven was programmed at 160 ºC initial temperature and 2 min initial time. Thereafter the temperature was increased to 185 ºC at 4 ºC/min, then increased to 200 ºC at 1 ºC/min and held at 200 ºC for 46.75 min. Total run time was 70 min. Carrier gas used was helium (1 mL/min).

Identification of fatty acids has been carried out by comparing sample FAME peak relative retention times with those obtained for Alltech, Nu-Check Prep. Inc. USA and Accu standards. Results have been expressed as FID response area relative percentages. Each reported result is the average value of three GC analyses. The results are offered as mean ± SD in Table 1.

Statistical analyses were performed using SPSS 15.0. Differences among the mean values of the fish species were compared by *t*-test at a 0.05 significance level.

Results and Discussion

Fatty acid composition of wild brown trout and cultured rainbow trout is presented in Table 1. Thirty eight fatty acids were identified from the muscle of both species. Generally, palmitic acid (C 16:0) (16.26-18.94%), oleic acid (C 18:1 ω9) (17.88-20.49%) and DHA (C 22:6 ω3) (14.08-18.89) were the most abundant fatty acids in both species. These results were similar to those reported by Akpinar, Görgün, & Akpinar (2009), Haliloğlu, Bayir, Sirkecioğlu, & Aras (2005) and Ateş et al. (2013) for *S. trutta macrostigma*, Haliloğlu, Bayır, Sirkecioğlu, Aras, & Atamanalp, (2004) and Chávez-Mendoza et al. (2014) for *O. mykiss*. Wild brown trout had a large amount of palmitic acid (18.94%) while cultured rainbow trout had more oleic acid (20.49%) and DHA (18.89%). Environmental factors affect the fatty acid content in fish (Henderson & Tocher, 1987; Haliloglu et al., 2004).

In the present study, palmitic acid was identified as the major SFA in wild brown trout and cultured rainbow trout. Other predominant SFAs were stearic acid in both species. Similar results also obtained from for *S. trutta macrostigma* (Akpinar, Görgün, & Akpinar, 2009; Ateş et al., 2013; Haliloğlu, Bayir, Sirkecioğlu, & Aras, 2005) and *O. mykiss* (Chávez-Mendoza et al., 2014; Kalyoncu, Yaman, & Aktumsek, 2010; Sabetian, Delshad, Moini, Islami, & Motalebi, 2012). Kaya & Erdem (2009) also reported that palmitic and stearic acid were major SFA in wild

Table 1. Fatty acid compositions of muscle of wild brown trout and cultured rainbow trout in Gezende Dam Lake (%) *

FATTY ACIDS	Wild brown trout	Cultured rainbow trout
C 8:0	0.03 ± 0.03 ***, a	0.01 ± 0,01 a
C 10:0	0.02 ± 0.02 a	0.01 ± 0,01 a
C 11:0	0.03 ± 0.03 a	0.01 ± 0,00 b
C 12:0	0.68 ± 0.45 a	0.04 ± 0.01 b
C 13:0	0.02 ± 0.01 a	0.02 ± 0.01 a
C 14:0	2.21 ± 0.19 b	3.38 ± 0.54 a
C 15:0	0.22 ± 0.04 b	0.32 ± 0.03 a
C 16:0	18.94 ± 1.22 a	16.26 ± 0.50 b
C 17:0	0.41 ± 0.09 b	0.56 ± 0.02 a
C 18:0	4.27 ± 0.50 a	4.19 ± 0.45 a
C 19:0	0.17 ± 0.06 a	0.12 ± 0.03 a
C 20:0	0.32 ± 0.07 a	0.07 ± 0.01 b
C 21:0	1.04 ± 0.30 a	0.77 ± 0.22 b
C 22:0	0.01 ± 0.00 a	0.01 ± 0.00 a
C 24:0	0.01 ± 0.01 a	0.03 ± 0.02 a
∑ SFA **	28.38 ± 1.51 a	25.80 ± 0.62 b
C 14:1 ω5	0.17 ± 0.07 a	0.13 ± 0.03 a
C 15:1 ω5	0.03 ± 0.02 a	0.01 ± 0.00 b
C 16:1 ω7	7.24 ± 0.96 a	3.74 ± 0.69 b
C 17:1 ω8	1.19 ± 0.17 a	0.41 ± 0.07 b
C 18:1 ω9	17.88 ± 1.69 b	20.49 ± 0.52 a
C 18:1 ω7	0.03 ± 0.01 a	0.02 ± 0.01 a
C 20:1 ω9	0.20 ± 0.10 b	4.35 ± 0.70 a
C 22:1 ω9	0.07 ± 0.03 a	0.03 ± 0.01 b
C 24:1 ω9	0.03 ± 0.02 a	0.02 ± 0.01 b
∑ MUFA **	26.84 ± 1.98 b	29.20 ± 1.56 a
C 18:2 ω6	5.64 ± 1.10 b	15.33 ± 0.75 a
C 18:3 ω6	0.13 ± 0.02 a	0.16 ± 0.05 a
C 18:3 ω3	7.07 ± 1.55 a	2.40 ± 0.12 b
C 20:2 ω6	0.55 ± 0.46 a	0.80 ± 0.22 a
C 20:3 ω6	0.23 ± 0.06 a	0.28 ± 0.04 a
C 20:3 ω3	0.01 ± 0.01 a	0.01 ± 0.01 a
C 20:4 ω6	2.22 ± 0.35 a	0.51 ± 0.09 b
C 20:5 ω3	9.73 ± 0.57 a	4.37 ± 0.37 b
C 22:2 ω6	0.02 ± 0.01 a	0.01 ± 0.01 a
C 22:3 ω3	0.02 ± 0.01 a	0.01 ± 0.00 b
C 22:4 ω6	0.23 ± 0.15 a	0.22 ± 0.04 a
C 22:5 ω6	0.23 ± 0.07 a	0.27 ± 0.08 a
C 22:5 ω3	4.61 ± 0.71 a	1.75 ± 0.07 b
C 22:6 ω3	14.08 ± 1.12 b	18.89 ± 1.69 a
∑ PUFA **	44.77 ± 0.88 a	45.01 ± 1.75 a
∑ω3	35.52 ± 1.62 a	27.43 ± 1.56 b
∑ω6	9.25 ± 1.56 b	17.58 ± 0.93 a
∑ω3/ω6	3.84 a	1.56 b

* The data are presented as average values from three analyzed lots (means± SD).
** SFA: Saturated fatty acid MUFA: Monounsaturated fatty acid PUFA: Polyunsaturated fatty acid.
*** a, b values for sample with different letters in the same fraction are significantly dif

and farmed trout. Similar results have also been reported in farmed rainbow trout (Harlioğlu, 2012). In our study, wild brown trout contained more these fatty acids compared to cultured rainbow trout. Yeşilayer & Genç (2013) also reported similar results for wild brown trout and farmed rainbow trout in Munzur River. Saglık Aslan, Guven, Gezgin, Alpaslan, & Tekinay (2007) have also reported that major SFA is palmitic acid both wild and cultured trout. In our study, wild brown trout (28.38%) contained more total SFA contents than cultured rainbow trout (25.80%). Similar results were observed by Yeşilayer and Genç (2013) for wild (27.7%) and cultured trout (21.4%) and Łuczyńska, Tońska, Krejszeff & Żarski, (2016) for wild perch (31.82%) and pond-cultured (30.7%). As can be seen from Table 1, significant differences ($P \leq 0.05$) were determined between total SFA of wild brown trout and cultured rainbow trout. It may be originated from food type and nutrition regime. Wang, Ma, Wang, & Liu (2012) stated that

the reduction of SFAs in cultured fish could be because of low level of SFAs in the commercial feed. Dietary fatty acids in fish muscle reflect the dietary lipid (Steffens, 1997).

Oleic acid (C 18:1 ω9) was identified as the major MUFA in both species. Cultured rainbow trout contained significantly more oleic acid than wild rainbow trout as shown in Table 1. It has also been reported in other studies that oleic acid is the major MUFA in wild and cultured trout (Yeşilayer & Genç, 2013), wild and cultured perch (Łuczyńska, Tońska, Krejszeff & Żarski, 2016) and wild and farmed seabream (Rincón et al., 2016). Similar results have also been reported in farmed rainbow trout (Harlioğlu, 2012). Similarly, Saglık Aslan, Guven, Gezgin, Alpaslan, & Tekinay (2007) have also reported that major MUFA is oleic acid in wild and cultured trout. Oleic acid is a characteristic monounsaturated fatty acid in fish (Steffens, 1997). In farmed rainbow trout (Yeşilayer & Genç, 2013) and wild seabream (Rincón et al., 2016), oleic acid has been reported to be present at high level. In the present study, the second most abundant MUFA was palmitoleic acid (C 16:1 ω7). Palmitoleic acid was significantly higher in wild brown trout (7.24%) than cultured fish (3.74%). Similar results for wild and cultured trout have been reported (Akpinar, Akpinar, Gorgun, & Akpinar, 2015). Kaya & Erdem (2009) have also reported that oleic acid and palmitoleic acid are predominant MUFA in wild and farmed trout. In our study, cultured rainbow trout contained more total MUFA than wild brown trout. Similar results were obtained by Blanchet et al. (2005), Fallah, Saei-Dehkordi & Nematollahi (2011) and Yeşilayer & Genç (2013) for cultured rainbow trout and by Rincón et al. (2016) for other fish species. As can be seen from Table 1, significant differences were determined between total MUFA of wild brown trout and cultured rainbow trout. The reason for these results may be the environmental factors. Various environmental conditions and diets affect the fatty acid composition of wild and reared fish (Akpinar, Akpinar, Gorgun & Akpinar, 2015; Blanchet et al., 2005).

DHA was identified as the most abundant PUFA in both fish species and was significantly higher in cultured rainbow trout than wild brown trout which is in good agreement with in other study for wild and cultured trout (Dal Bosco, Mugnai, Roscini & Castellini, 2013). DHA is important for maintaining normal brain structure and function (Horrocks & Yeo, 1999; Innis, 2003). In the present study, the second major PUFA was EPA and linoleic acid (C 18:2 ω6) in wild brown trout and cultured rainbow trout, respectively. Linolenic acid (C 18:3 ω3), arachidonic acid (C 20:4 ω6), docosapentaenoic acid (C 22:5 ω3) and EPA values in the wild brown trout were significantly higher than cultured rainbow trout as shown in Table 1. Similar results were reported for wild and cultured trout (Akpinar, Akpinar, Gorgun, & Akpinar, 2015). Kaya & Erdem (2009), Fallah, Saei-Dehkordi, & Nematollahi (2011), Yeşilayer & Genç (2013) and Taşbozan, Gökçe, & Erbaş (2016) also reported that these fatty acids were higher in wild trout than rainbow trout. These fatty acids of fishes are affected by whether they are cultured and wild. The percentages of PUFA are dependent on diet in fish muscle (Sargent, 1997). Variations in fatty acid composition might be related to the changes in nutritional habits of the fishes (Norrobin, Olsen & Tande, 1990). In cultured fish, the ω3 PUFA is generally lower than that of wild fish because of possibly the lack of lipids originating from phytoplankton and aquatic organisms in cultured diets (Ackman & Takeuchi, 1986). Similarly, Ozogul et al. (2013) stated that wild fish had much higher ω3 fatty acids than their cultured ones. This situation could result from the feed. Fatty acid compositions of fish depend upon the diet. The quantities of EPA and DHA differ among species according to environmental variables such as diet and whether fish are wild or farm raised (Kris-Etherton, Harris & Appel, 2002). In our study, cultured rainbow trout had a significantly higher level of linoleic acid than wild rainbow trout. This result is in accord with Blanchet et al. (2005), Kaya & Erdem (2009), Yeşilayer & Genç (2013) and Taşbozan, Gökçe & Erbaş, (2016) for rainbow trout. Similar results were obtained by Rincón et al. (2016) for a high level of linoleic acid in farmed blackspot seabream. Steffens (1997) stated that DHA and linoleic acid are influenced by the fish diet. In our study, the percentage of total PUFA was similar ($P>0.05$) in wild (44.77%) and cultured trout (45.01%). Salmonid fish are particularly rich sources of long chain ω3 fatty acids (Nettleton, 1991). In our study, the muscle of wild brown trout contained significantly more total ω3 fatty acids than cultured rainbow trout as shown in Table 1 and Figure 3. Saglık Aslan, Guven, Gezgin, Alpaslan, & Tekinay, (2007) reported that the total ω3 fatty acids were higher in wild trout than cultured fish in flesh. Blanchet et al. (2005) stated that wild and farmed rainbow trout displayed similar ω3/ω6 ratio whereas farmed rainbow trout contained less ω3 than wild species. Blanchet et al. (2005) also stated that consumption of farmed salmonoids may had beneficial health effects for consumers since provides high level of ω3 highly unsaturated fatty acids.

Fatty acid composition and ω3/ω6 ratio depend upon the feed consumed in fish (Steffens, 1997). The ω3/ω6 ratio is useful indicator for comparing relative nutritive values of fish oils (Pigott & Tucker, 1990). Some studies suggest that human beings evolved on a diet with ω6/ω3 essential fatty acids ratio of 1/1 whereas in Western diets the ratio is 15-17/1 Excessive amounts of ω6 PUFA and a very high ω6/ω3 ratio promote cardiovascular disease, cancer, inflammatory and autoimmune diseases, whereas increased levels of ω3 PUFA apply suppressive effects. (Simopoulos, 2004). A ratio of 1:1 to 2:1 ω6/ω3 fatty acids should be the ideal ratio for

beneficial to health. (Simopoulos, 2010). The Department of Health of the United Kingdom (1994) recommends ω6/ω3 value below 4. Consuming higher dietary quantities of ω3PUFAs is an approach to normalizing high ω6/ω3 ratios (Wong et al., in press; McDaniel, Ickes, & Holloman, 2013). In our study, ω3/ω6 ratio was found to be 3.84 in wild brown trout and 1.56 in cultured rainbow trout as shown in Table 1 and Figure 4. Wild brown trout had significantly higher ω3/ω6 ratio compared to cultured rainbow trout. Similar results were reported by Kaya & Erdem (2009), Fallah, Saei-Dehkordi, & Nematollahi, (2011) and Akpinar, Akpinar, Gorgun, & Akpinar (2015) for wild and farmed trout. Similarly, Akpinar, Görgün & Akpinar (2009) stated that muscle of *S. trutta macrostigma* is a wild fish species having a high nutritional value for human consumption due to its high ω3/ω6 ratio (2.26-2.59) compared to other studies (Haliloğlu, Aras, & Yetim, 2002; Guler, Aktumsek, Citil, Arslan, Torlak, 2007). Kaya & Erdem (2009), Saglık Aslan, Guven, Gezgin, Alpaslan, & Tekinay (2007) and Yeşilayer & Genç (2013) stated that the ω3/ω6 ratio in wild trout was higher than farmed trout. When compared with other studies (Akpinar, Görgün & Akpinar, 2009; Akpinar, Akpinar, Görgün & Akpinar, 2015; Kaya & Erdem, 2009; Saglık Aslan, Guven, Gezgin, Alpaslan, & Tekinay, 2007), wild brown trout muscles used in our study have a higher ω3/ω6 ratio. Ateş et al. (2013) determined that seasonal variations of fatty acid composition of wild brown trout (*Salmo trutta macrostigma*). The authors stated that wild brown trout living in Munzur river could be considered as an important ω3 fatty acid source according to the nutritional quality results evaluated. Similar ω3/ω6 ratio compared to our study was reported by Fallah, Saei-Dehkordi & Nematollahi, (2011) (3.88) and Yeşilayer & Genç (2013) (3.5) for wild trout.

Conclusion

Muscle fatty acid composition of wild brown trout and cultured rainbow trout determined and compared. This is the first study to report the fatty

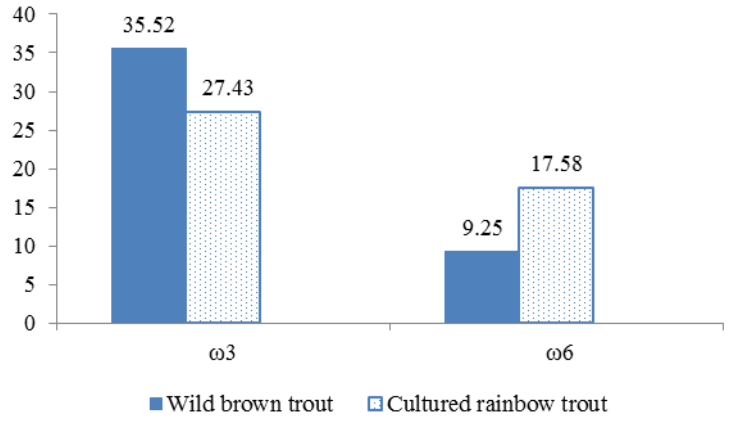

Figure 3. Percentage of total ω3 and ω6 fatty acids of fish species.

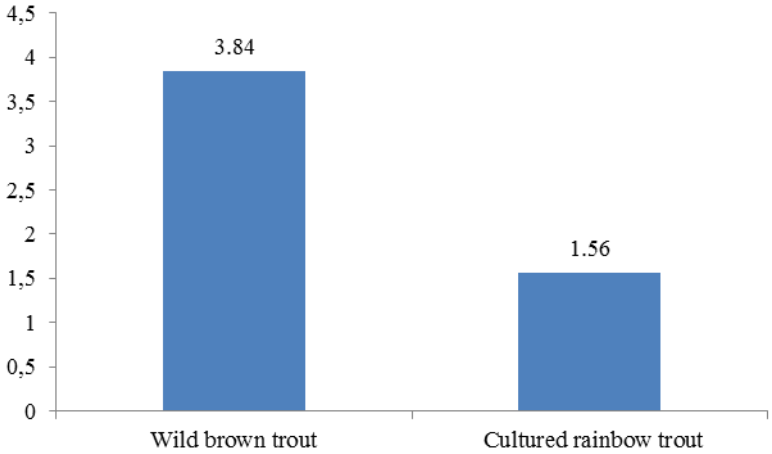

Figure 4. Comparison of ω3/ω6 ratio of wild brown trout and cultured rainbow trout.

acid composition of wild brown trout and cultured rainbow trout in Gezende Dam Lake. When compared with cultured rainbow trout, the wild brown trout with its high ω3 fatty acids, ω3/ω6 ratio, EPA, DPA, arachidonic acid and linolenic acid could be a potential healthy food for human consumption in terms of nutritional value.

Acknowledgments

This research was supported by Selcuk University Scientific Research Foundation (BAP). The authors wish to acknowledge their support of this project.

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