



Comparison of Fatty Acid Compositions and ω 3/ ω 6 Ratios of Wild Brown Trout and Cultured Rainbow Trout

Gokalp Ozmen Guler^{1*}, Gokhan Zengin², Yavuz Selim Çakmak³, Abdurrahman Aktumsek²

¹Necmettin Erbakan University, Ahmet Kelesoglu Education Faculty, Department of Biological Education, 42075, Konya, Turkey

²Selcuk University, Science Faculty, Department of Biology, Campus, 42250, Konya, Turkey

³Aksaray University, Science and Arts Faculty, Department of Biotechnology and Molecular Biology, 68100, Aksaray, Turkey

Phone: +90 332 323 82 20

E-mail: gguler@konya.edu.tr

Abstract

Fish are a unique dietary source beneficial to human health. These valuable effects originate from ω 3 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 ω 3 fatty acids and has higher ω 3/ ω 6 ratio than cultured fish. In conclusion, wild brown trout may have a higher nutritional value considering total ω 3 fatty acids (35.52-27.43%) and ω 3/ ω 6 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 ω 3 PUFAs (Sidhu, 2003). ω 3 PUFA also have beneficial effects on human health (Kinsella, Lokesh & Stone, 1990; Steffens, 1997). Because ω 3 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 ω 3 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 ω 3-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, ω 3 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 ω 3 PUFAs, such as eicosapentaenoic acid (EPA; C 20:5 ω 3) and docosahexaenoic acid (DHA; C 22:6 ω 3). These long chain polyunsaturated fatty acids have been reported to have beneficial effects on human health (Ackman, 2001; Sidhu, 2003). ω 3 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). ω 3 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 ω 3 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 ω 3 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 ω 3/ ω 6 fatty acid ratio in diet is beneficial 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 (Akpınar, Görgün, & Akpınar, 2009; Bayır et al., 2010; Çelik, Difer, & Küçükgülmez, 2005; Guler, Aktumsek, Cakmak, Zengin, & Cıtil, 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, & Ulupınar, 2006). Another important factor affecting fatty acid composition is whether the fish is wild or cultured. Wild fish contain more ω 3 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 (Łuczynska, 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 (DSL, 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 (Akpınar, Akpınar, Gorgun & Akpınar, 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 2. All fish used in this study are almost at the same size and age (over 2 years old). Total weight and 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 °C 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% BF₃ (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 °C, respectively. The oven was programmed at 160 °C initial temperature and 2 min initial time. Thereafter the temperature was increased to 185 °C at 4 °C/min, then increased to 200 °C at 1 °C/min and held at 200 °C 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 ω 9) (17.88-20.49%) and DHA (C 22:6 ω 3) (14.08-18.89) were the most abundant fatty acids in both species. These results were similar to those reported by Akpınar, Görgün, & Akpınar (2009), Haliloğlu, Bayır, 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* (Akpınar, Görgün, & Akpınar, 2009; Ateş et al., 2013; Haliloğlu, Bayır, 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 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. Sağlık 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, Krejszef & 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 ω 9) 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, Krejszef & Żarski, 2016) and wild and farmed seabream (Rincón et al., 2016). Similar results have also been reported in farmed rainbow trout (Harlioğlu, 2012). Similarly, Sağlık 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 ω 7). 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 (Akpınar, Akpınar, Gorgun, & Akpınar, 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 (Akpınar, Akpınar, Gorgun & Akpınar, 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 ω 6) in wild brown trout and cultured rainbow trout, respectively. Linolenic acid (C 18:3 ω 3), arachidonic acid (C 20:4 ω 6), docosapentaenoic acid (C 22:5 ω 3) 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 (Akpınar, Akpınar, Gorgun, & Akpınar, 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 ω 3 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 ω 3 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 ω 3 fatty acids (Nettleton, 1991). In our study, the muscle of wild brown trout contained significantly more total ω 3 fatty acids than cultured rainbow trout as shown in Table 1 and Fig 3. Sağlık Aslan, Guven, Gezgin, Alpaslan, & Tekinay, (2007) reported that the total ω 3 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 ω 3/ ω 6 ratio whereas farmed rainbow trout contained less ω 3 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 ω 3 highly unsaturated fatty acids.

Fatty acid composition and ω 3/ ω 6 ratio depend upon the feed consumed in fish (Steffens, 1997). The ω 3/ ω 6 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 ω 6/ ω 3 essential fatty acids ratio of 1/1 whereas in Western diets the ratio is 15-17/1 Excessive amounts of ω 6 PUFA and a very high ω 6/ ω 3 ratio promote cardiovascular disease, cancer,



inflammatory and autoimmune diseases, whereas increased levels of $\omega 3$ PUFA apply suppressive effects. (Simopoulos, 2004). A ratio of 1:1 to 2:1 $\omega 6/\omega 3$ fatty acids should be the ideal ratio for beneficial to health. (Simopoulos, 2010). The Department of Health of the United Kingdom (1994) recommends $\omega 6/\omega 3$ value below 4. Consuming higher dietary quantities of $\omega 3$ PUFAs is an approach to normalizing high $\omega 6/\omega 3$ ratios (Wong et al., in press; McDaniel, Ickes, & Holloman, 2013). In our study, $\omega 3/\omega 6$ ratio was found to be 3.84 in wild brown trout and 1.56 in cultured rainbow trout as shown in Table 1 and Fig 4. Wild brown trout had significantly higher $\omega 3/\omega 6$ 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 $\omega 3/\omega 6$ ratio (2.26-2.59) compared to other studies (Haliloğlu, Aras, & Yetim, 2002; Guler, Aktumsek, Cital, Arslan, Torlak, 2007). Kaya & Erdem (2009), Sağlık Aslan, Guven, Gezgin, Alpaslan, & Tekinay (2007) and Yeşilayer & Genç (2013) stated that the $\omega 3/\omega 6$ 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; Sağlık Aslan, Guven, Gezgin, Alpaslan, & Tekinay, 2007), wild brown trout muscles used in our study have a higher $\omega 3/\omega 6$ 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 $\omega 3$ fatty acid source according to the nutritional quality results evaluated. Similar $\omega 3/\omega 6$ 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 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 $\omega 3$ fatty acids, $\omega 3/\omega 6$ 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.

References

- Ackman, R. G. & Takeuchi, T. (1986). Comparison of fatty acids and lipids of smolting hatchery-fed and wild Atlantic salmon (*Salmo salar*). *Lipids*, 21(2), 117-120. Doi: 10.1007/BF02534431
- Ackman, R. G. (2001). *Fish is more than a brain food*. Paper presented at the Proceedings of the IIFET 2000 Conference, Corvallis, Oregon.
- Akpinar, M. A., Görgün, S., & Akpinar, A. E. (2009). A comparative analysis of the fatty acid profiles in the liver and muscles of male and female *Salmo trutta macrostigma*. *Food Chemistry*, 112(1), 6-8. doi: 10.1016/j.foodchem.2008.05.025



- Akpınar, N., Akpınar, M. A., Gorgun, S., & Akpınar, A. E. (2015). Fatty acid composition and ω 3/ ω 6 ratios in the muscle of wild and reared *Oncorhynchus mykiss*. *Chemistry of Natural Compounds*, 51(1), 22-25. doi: 10.1007/s10600-015-1194-y
- Arslan, M., Sirkecioglu, N., Bayir, A., Arslan, H., & Aras, M. (2012). The influence of substitution of dietary fish oil with different vegetable oils on performance and fatty acid composition of brown trout, *Salmo trutta*. *Turkish Journal of Fisheries and Aquatic Sciences*, 12(3), 575-583. doi: 10.4194/1303-2712-v12_3_04
- 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. doi: 10.4194/1303-2712-v13_4_06
- Bayır, A., Sirkecioglu, A. N., Aras, N. M., Aksakal, E., Haliloğlu, H. İ., & Bayır, M. (2010). Fatty acids of neutral and phospholipids of three endangered trout: *Salmo trutta caspius* Kessler, *Salmo trutta labrax* Pallas and *Salmo trutta macrostigma* Dumeril. *Food Chemistry*, 119(3), 1050-1056. doi: 10.1016/j.foodchem.2009.07.064
- Balcı Akova, S., (2015). Aquaculture and its distribution in Turkey. *Journal of Aquaculture Engineering and Fisheries Research*, 1(4), 160-190. doi: 10.3153/JAEFR15018
- Blanchet, C., Lucas, M., Julien, P., Morin, R., Gingras, S., & Dewailly, É. (2005). Fatty acid composition of wild and farmed Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*). *Lipids*, 40(5), 529-531. doi: 10.1007/s11745-005-1414-0
- Chávez-Mendoza, C., García-Macias, J. A., Alarcón-Rojo, A. D., Ortega-Gutiérrez, J. Á., Holguín-Licón, C., & Corral-Flores, G. (2014). Comparison of fatty acid content of fresh and frozen fillets of rainbow trout (*Oncorhynchus mykiss*) Walbaum. *Brazilian Archives of Biology and Technology*, 57(1), 103-109. doi: 10.1590/S1516-89132014000100015
- Connor, W. E. (2000). Importance of n-3 fatty acids in health and disease. *The American Journal of Clinical Nutrition*, 71(1), 171S-175S.
- Coste, T. C., Gerbi, A., Vague, P., Pieroni, G., & Raccach, D. (2003). Neuroprotective effect of docosahexaenoic acid-enriched phospholipids in experimental diabetic neuropathy. *Diabetes*, 52(10), 2578-2585.
- Çelik, M., Diler, A., & Küçükgülmez, A. (2005). A comparison of the proximate compositions and fatty acid profiles of zander (*Sander lucioperca*) from two different regions and climatic conditions. *Food Chemistry*, 92(4), 637-641. doi: 10.1016/j.foodchem.2004.08.026
- Dal Bosco, A., Mugnai, C., Roscini, V., & Castellini, C. (2013). Fillet fatty acid composition, estimated indexes of lipid metabolism and oxidative status of wild and farmed brown trout (*Salmo trutta* L.). *Italian Journal of Food Science*, 25(1), 83-89.
- Department of Health of the United Kingdom, (1994). *Nutritional Aspects of Cardiovascular Disease*. Report of the Health and Social Subject, vol 46. Her Majesty's Stationery Office, London
- DSI, (2013). <http://www2.dsi.gov.tr/baraj/detay.cfm?BarajID=131>.
- Fallah, A. A., Saei-Dehkordi, S. S., & Nematollahi, A. (2011). Comparative assessment of proximate composition, physicochemical parameters, fatty acid profile and mineral content in farmed and wild rainbow trout (*Oncorhynchus mykiss*). *International Journal of Food Science & Technology*, 46(4), 767-773. doi: 10.1111/j.1365-2621.2011.02554.x
- Folch, J., Lees, M., & Sloane Stanley, G. H. (1957). A simple method for the isolation and purification of total lipides from animal tissues. *The Journal of Biological Chemistry*, 226, 497-509.
- Food and Agriculture Organization of the United Nations (FAO), (2010). *Fats and fatty acids in human nutrition*. Report of an expert consultation. FAO Food and Nutrition Paper 91, Rome.
- Freeman, M. P. (2000). Omega-3 Fatty Acids in Psychiatry: A Review. *Annals of Clinical Psychiatry*, 12(3), 159-165.
- Geldiyar, R., & Balık, S. (1996). Türkiye Tatlı Su Balıkları, Ege Üniversitesi, Su Ürünleri Fakültesi Yayın No: 46. *Ders Kitabı*. Dizin(16).
- Gottrand, F. (2008). Long-chain polyunsaturated fatty acids influence the immune system of infants. *The Journal of Nutrition*, 138(9), 1807S-1812S.
- Guler, G. O., Aktumsek, A., Cıtil, O. B., Arslan, A., & Torlak E. (2007). Seasonal variations on total fatty acid composition of fillets of zander (*Sander lucioperca*) in Beyşehir Lake (Turkey). *Food Chemistry*, 103, 1241-1246. doi:10.1016/j.foodchem.2006.10.029
- Guler, G., Aktumsek, A., Cakmak, Y., Zengin, G., & Cıtil, O. (2011). Effect of season on fatty acid composition and n-3/n-6 ratios of zander and carp muscle lipids in Altınapa Dam Lake. *Journal of Food Science*, 76(4), C594-C597. doi: 10.1111/j.1750-3841.2011.02136.x
- Haliloğlu, H. İ., Aras, N. M., & Yetim, H. (2002). Comparison of muscle fatty acids of three trout species (*Salvelinus alpinus*, *Salmo trutta fario*, *Oncorhynchus mykiss*) raised under the same conditions. *Turkish Journal of Veterinary and Animal Sciences*, 26, 1097-1102.
- Haliloğlu, H. İ., Bayır, A., Sirkecioglu, A. N., Aras, N. M., & Atamanalp, M. (2004). Comparison of fatty acid composition in some tissues of rainbow trout (*Oncorhynchus mykiss*) living in seawater and freshwater. *Food Chemistry*, 86(1), 55-59. doi: 10.1016/j.foodchem.2003.08.028
- Haliloğlu, H. İ., Bayır, A., Sirkecioglu, A. N., & Aras, N. M. (2005). Fatty acid profiles of different tissues in mature trout (*Salmo trutta macrostigma*) from Pulur Creek in Karasu Region, Turkey. *Journal of Applied Animal Research*, 27(2), 81-84. doi: 10.1080/09712119.2005.9706545
- Harlioğlu, A. G. (2012). Fatty acid composition, fat soluble vitamins and cholesterol content of farmed rainbow trout (*Oncorhynchus mykiss*). *Pakistan Journal of Zoology*, 44(4), 1013-1019.



- Henderson, R. J., & Tocher, D. R. (1987). The lipid composition and biochemistry of freshwater fish. *Progress in Lipid Research*, 26(4), 281-347. doi: 10.1016/0163-7827(87)90002-6
- Hibbeln, J. R. (1998). Fish consumption and major depression. *Lancet*, 351(9110), 1213. doi: 10.1016/S0140-6736(05)79168-6
- Holm, T., Andreassen, A. K., Aukrust, P., Andersen, K., Geiran, O. R., Kjekshus, J., Simonsen, S., Gullestad, L. (2001). Omega-3 fatty acids improve blood pressure control and preserve renal function in hypertensive heart transplant recipients. *European Heart Journal*, 22(5), 428-436. doi: 10.1053/ehj.2000.2369
- Holub, B. J. (2001). Docosahexaenoic acid in human health. In Shahidi F., Finley JW (editors). *Omega-3 fatty acids, chemistry, nutrition and health effects*. ACS Symposium series 788 ACS Press. p. 54-65.
- Horrocks, L. A., & Yeo, Y. K. (1999). Health benefits of docosahexaenoic acid (DHA). *Pharmacological Research*, 40(3), 211-225. doi: 10.1006/phrs.1999.0495
- Hu, F. B., Cho, E., Rexrode, K. M., Albert, C. M., & Manson, J. E. (2003). Fish and long-chain ω -3 fatty acid intake and risk of coronary heart disease and total mortality in diabetic women. *Circulation*, 107(14), 1852-1857. doi: 10.1161/01.CIR.0000062644.42133.5F
- Hu, F. B., & Willett, W. C. (2002). Optimal diets for prevention of coronary heart disease. *JAMA*, 288(20), 2569-2578. doi: 10.1001/jama.288.20.2569
- Innis, S. M. (2003). Perinatal biochemistry and physiology of long-chain polyunsaturated fatty acids. *Journal of Pediatrics*, 143(4), 1-8. doi: 10.1067/S0022-3476(03)00396-2
- IUPAC, (1979). Standard methods for the analysis of oils, fats and derivatives: Paquot, C. (ed.), Oxford Pergamon Press.
- Kalyoncu, L., Yaman, Y., & Aktumsek, A. (2010). Determination of the seasonal changes on total fatty acid composition of rainbow trout, *Oncorhynchus mykiss* in Ivriz Dam Lake, Turkey. *African Journal of Biotechnology*, 9(30), 4783-4787. doi: 10.5897/AJB10.497
- Kaya, Y., & Erdem, M. E. (2009). Seasonal comparison of wild and farmed brown trout (*Salmo trutta forma fario* L., 1758): crude lipid, gonadosomatic index and fatty acids. *International Journal of Food Sciences and Nutrition*, 60(5), 413-423. doi: 10.1080/09637480701777886
- Kinsella, J. E., Lokesh, B., Stone, R. A. (1990). Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: possible mechanism. *The American Journal of Clinical Nutrition*, 52(1), 1-28.
- Kris-Etherton, P. M., Harris, W. S., & Appel, L. J. (2002). Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. *Circulation*, 106(21), 2747-2757. doi: 10.1161/01.CIR.0000038493.65177.94
- Leaf, A., & Weber, P. C. (1988). Cardiovascular effects of n-3 fatty acids. *The New England Journal of Medicine*, 318(9), 549-557. doi: 10.1056/NEJM198803033180905
- Lee, K. W., & Lip, G. Y. (2003). The role of omega-3 fatty acids in the secondary prevention of cardiovascular disease. *QJM An International Journal of Medicine*, 96(7), 465-480. doi: 10.1093/qjmed/hcg092
- Łuczyńska, J., Tońska, E., Krejszef, S., & Żarski, D. (2016). Comparison of fatty acids in the muscles and liver of pond-cultured and wild perch, *Perca fluviatilis* (L.), in Poland. *Turkish Journal of Fisheries and Aquatic Sciences*, 16(1), 19-27. doi: 10.4194/1303-2712-v16_1_03
- Lunn, J., & Theobald, H. E. (2006). The health effects of dietary unsaturated fatty acids. *Nutrition Bulletin*, 31, 178-224. doi: 10.1111/j.1467-3010.2006.00571.x
- McDaniel, J., Ickes, E., & Holloman, C. (2013). Beneficial n-3 polyunsaturated fatty acid levels and n6:n3 ratios after 4-week EPA + DHA supplementation associated with reduced CRP: A pilot study in healthy young adults. *Modern Research in Inflammation*, 2(4), 59-68. doi: 10.4236/mri.2013.24008
- Nettleton, J. A. (1991). Omega-3 fatty acids: Comparison of plant and seafood sources in human nutrition, *Journal of the American Dietetic Association*, 91(3), 331-337.
- Norrobin M.F., Olsen R.E., & Tande K.S. (1990). Seasonal variation in lipid class and fatty acid composition of two small copepods in Balsfjorden, northern Norway. *Marine Biology*, 105(2), 205-211. doi: 10.1007/BF01344288
- Ozogul, F., Yavuzer, E., Ozogul, Y., & Kuley, E. (2013). Comparative quality loss in wild and cultured rainbow trout (*Oncorhynchus mykiss*) during chilling storage. *Food Science and Technology Research*, 19(3), 445-454. doi: 10.3136/fstr.19.445
- Pigott, G. M., & Tucker, B. (1990). *Seafood: effects of technology on nutrition* (Vol. 39): CRC press.
- Pike, I. H. (1999). Health benefits from feeding fish oil and fish meal. *The role of long chain omega-3 polyunsaturated fatty acids in animal feeding*. IFOMA, Herts, UK.
- Rasmussen, B. M., Vessby, B., Uusitupa, M., Berglund, L., Pedersen, E., Riccardi, G., Rivellese, A. A., Tapsell, L., & Hermansen, K., (2006). Effects of dietary saturated, monounsaturated, and n-3 fatty acids on blood pressure in healthy subjects. *The American Journal of Clinical Nutrition*, 83, 221-226.
- Rincon, L., Castro, P. L., Álvarez, B., Hernández, M. D., Álvarez, A., Claret, A., Guerrero, L., & Ginés, R. (2016). Differences in proximal and fatty acid profiles, sensory characteristics, texture, colour and muscle cellularity between wild and farmed blackspot seabream (*Pagellus bogaraveo*). *Aquaculture*, 451, 195-204. doi: 10.1016/j.aquaculture.2015.09.016
- Rose, D. P. (1997). Dietary fatty acids and cancer. *The American Journal of Clinical Nutrition*, 66(4), 998-1003.
- Sargent, J.R. (1997). Fish oils and human diet. *British Journal of Nutrition*, 78(1), S5-S13. doi: 10.1079/BJN19970131
- Sabetian, M., Delshad, S. T., Moini, S., Islami, H. R., & Motalebi, A. (2012). Identification of fatty acid content, amino acid profile and proximate composition in rainbow trout (*Oncorhynchus mykiss*). *Journal of American Science*, 8(4), 670-677.
- Saglık Aslan, S., Guven, K. C., Gezgin, T., Alpaslan, M., & Tekinay, A. (2007). Comparison of fatty acid contents of wild and cultured rainbow trout *Oncorhynchus mykiss* in Turkey. *Fisheries Science*, 73(5), 1195-1198. doi: 10.1111/j.1444-2906.2007.01452.x



- Sardenne, F., Kraffe, E., Amiel, A., Fouché, E., Debrauwer, L., Ménard, F., & Bodin, N. (2017). Biological and environmental influence on tissue fatty acid compositions in wild tropical tunas. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 204, 17-27. doi: 10.1016/j.cbpa.2016.11.007
- Shirai, N., Suzuki, H., Tokairin, S., Ehara, H., & Wada, S. (2002). Dietary and seasonal effects on the dorsal meat lipid composition of Japanese (*Silurus asotus*) and Thai catfish (*Clarias macrocephalus* and hybrid *Clarias macrocephalus* and *Clarias galipinus*). *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 132(3), 609-619. doi: 10.1016/S1095-6433(02)00081-8
- Sidhu, K. S. (2003). Health benefits and potential risks related to consumption of fish or fish oil. *Regulatory Toxicology and Pharmacology*, 38(3), 336-344. doi: 10.1016/j.yrtph.2003.07.002
- Simopoulos, A. P. (1991). Omega-3 fatty acids in health and disease and in growth and development. *The American Journal of Clinical Nutrition*, 54(3), 438-463.
- Simopoulos, A.P. (2002). The importance of the ratio of omega-6/ omega-3 essential fatty acids. *Biomedicine and Pharmacotherapy*, 56(8), 365-379.
- Simopoulos, A. P. (2004). Omega-6/omega-3 essential fatty acid ratio and chronic diseases. *Food Reviews International*, 20(1), 77-90. doi: 10.1081/FRI-120028831
- Simopoulos, A. P. (2010). The omega-6/omega-3 fatty acid ratio: Health implications. *Oilseeds and Fats, Crops and Lipids*, 17(5), 267-275. doi: 10.1684/ocl.2010.0325
- Steffens, W. (1997). Effects of variation in essential fatty acids in fish feeds on nutritive value of freshwater fish for humans. *Aquaculture*, 151(1-4), 97-119. doi: 10.1016/S0044-8486(96)01493-7
- Sushchik, N. N., Rudchenko, A. E., & Gladyshev, M. I. (2017). Effect of season and trophic level on fatty acid composition and content of four commercial fish species from Krasnoyarsk Reservoir (Siberia, Russia). *Fisheries Research*, 187, 178-187. doi: 10.1016/j.fishres.2016.11.016
- Taşbozan, O., Gökçe, M. A., & Erbaş, C. (2016). The effect of different growing conditions to proximate composition and fatty acid profiles of rainbow trouts (*Oncorhynchus mykiss*). *Journal of Applied Animal Research*, 44(1), 442-445. doi: 10.1080/09712119.2015.1091323
- TÜİK, Turkish Statistical Institute, (2011). *Fishery Statistics 2011*, Ankara.
- Uysal, K., Yerlikaya, A., Aksoylar, M., Yöntem, M., & Ulupinar, M. (2006). Variations in fatty acids composition of pikeperch (*Sander lucioperca*) liver with respect to gonad maturation. *Ecology of Freshwater Fish*, 15(4), 441-445. doi: 10.1111/j.1600-0633.2006.00174.x
- 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. doi: 10.4314/sajas.v43i1.11
- Wang, F., Ma, X., Wang, W., & Liu, J. (2012). Comparison of proximate composition, amino acid and fatty acid profiles in wild, pond- and cage-cultured longsnout catfish (*Leiocassis longirostris*). *International Journal of Food Science and Technology*, 47, 1772-1776. doi: 10.1111/j.1365-2621.2012.03033.x
- Wong, T. C., Chen, Y. T., Wu, P. Y., Chen, T. W., Chen, H. H., Chen, T. H., Hsu, Y. H., & Yang, S.H. (in press). Ratio of dietary n-3 and n-6 fatty acids independent determinants of muscle mass- in hemodialysis patients with diabetes. *Nutrition*. doi: 10.1016/j.nut.2016.02.015

**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



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



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

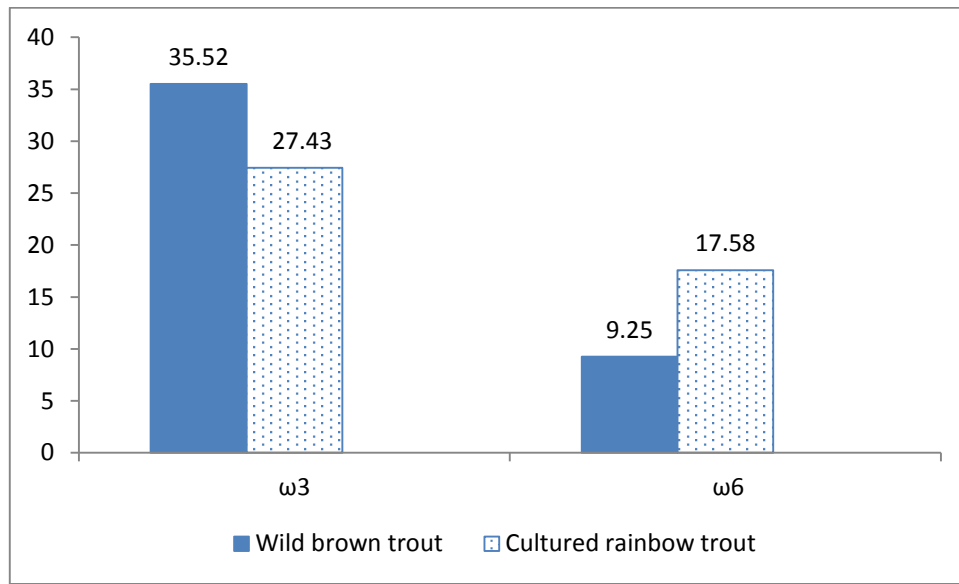


Figure 3. Percentage of total ω 3 and ω 6 fatty acids of fish species

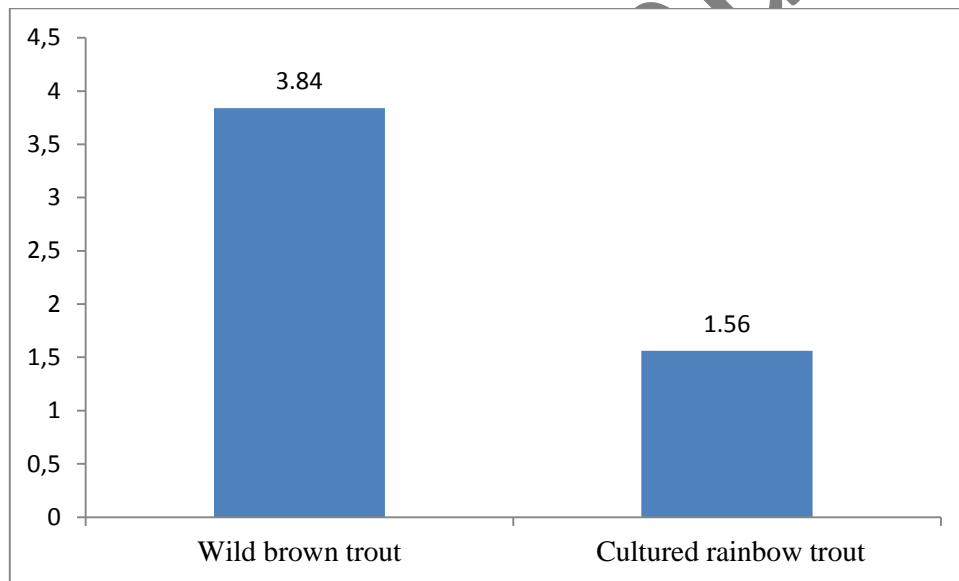


Figure 4. Comparison of ω 3/ ω 6 ratio of wild brown trout and cultured rainbow trout.