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Seasonal effects of the fatty acid composition of phospholipid and triacylglycerol in the muscle and liver of male *Salmo trutta macrostigma*

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SUMMARY: The seasonal effects on the fatty acid composition of triacylglycerol (TAG) and phospholipid (PL) in the muscle and liver of male *Salmo trutta macrostigma* were determined using the gas chromatographic (GC) method. The fatty acid (FA) compositions of total lipid, PL and TAG fractions were determined in muscle and liver tissues of *S. trutta macrostigma.* The phospholipids contained a higher proportion of 16:0 compared to the TAG in the muscle tissue of *S. trutta macrostigma.* Docosahexaenoic acid (22:6 ω-3) and eicosapentaenoic acid (20:5 ω-3) contents were high in both muscle and liver tissues. The total lipid contents in the muscle and liver were 1.07-2.45 and 3.00-4.64%, respectively. *S. trutta macrostigma* is a rich source of ω-3 and ω-6, polyunsaturated fatty acids (PUFA) with numerous benefits to human health.

KEYWORDS: *Fatty acid; Phospholipid; Triacylglycerol;* Salmo trutta macrostigma; *Seasonal changes.*

RESUMEN: ***Efecto estacional de la composición de ácidos grasos de fosfolípidos y triacilgliceroles en el músculo e hígado de* Salmo trutta macrostigma *macho*.** El efecto estacional sobre la composición de ácidos grasos de los triacilgliceroles (TAG) y fosfolípidos (PL) en el músculo e hígado de *Salmo trutta macrostigma* macho se determinaron mediante cromatografía de gases (GC). Se han determinado las composiciones de ácidos grasos (FA) de lípidos totales, fracciones de PL y TAG en tejidos musculares y hepáticos de *S. trutta macrostigma*. Los fosfolípidos contenían una mayor proporción de 16:0 en comparación con los TAG en el tejido muscular de *S. trutta macrostigma*. El contenido de ácido docosahexaenoico (22:6 ω-3) y ácido eicosapentaenoico (20:5 ω-3) es alto en el tejido muscular y hepático. El contenido total de lípidos de los músculos e hígado fue de 1,07-2,45% y 3,00-4,64%, respectivamente. *S. trutta macrostigma* es una fuente rica de ω-3 y ω-6 que son ácidos grasos poliinsaturados (PUFA) con numerosos beneficios para la salud humana.

PALABRAS CLAVE: *Ácidos grasos; Cambios estacionales; Fosfolípidos;* Salmo trutta macrostigma; *Triacilgliceroles.*

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1. INTRODUCTION

S. trutta macrostigma inhabiting the River Munzur shows distribution in an area of 80 km, starting 1-2 km south of Munzur Gozeleri on the east of Ovacik, Tunceli, Turkey, up to Tunceli, Turkey, especially in the streams of Munzur and Mercan. This endemic species not only creates an economic value for its taste but also creates an important potential for tourism. They prefer to live in cool (12-19 °C) and oxygen-rich trout zones of a gravel-bed stream with high velocity and upriver areas (Aras *et al.,* 1997). Their spawning season occurs in the period of December-February.

Fish meat, especially trout, is a delicious nutritional source with rich nutritional components that play an important role in meeting the animal protein needs of people (Justi *et al.,* 2003). The deliciousness of fish meat is due to the fats and fatty acids in its structure (Kinsella, 1987). These are not just high energy sources, but they are also very important in that they contain fat-soluble vitamins, combine with proteins to form lipoproteins, and play a role in blood lipid levels.

Fish muscle is the main part of the fish used as human food. Liver tissue is important for fat metabolism and it undertakes important functions, such as the intake, oxidation and transformation of FAs and the provision of long-chain polyunsaturated fatty acids (PUFA) to other tissues (Rincon-Sanchez *et al.,* 1992).

Fish meat is the only animal source of ω-3 group FAs, eicosapentaenoic acid (EPA, 20:5 ω-3) and docosahexaenoic acids (DHA, 22:6 ω-3). The fatty acids in fish meat, especially EPA and DHA, have numerous benefits for human health thanks to their biochemical, metabolic, nutritional properties, and pharmacological effects (Sushchik *et al.,* 2007). These fatty acids play an important role in the membrane biochemistry of cells, such as the fluidity and permeability of the cell membrane; while they also have a direct effect on intermembrane processes such as osmoregulation, absorption and transport of nutrients (Christiansen *et al.,* 1989).

The lipid contents in fish generally depend on seasonal changes and accordingly, nutrient availability, temperature, pH, and salinity of the water where they were caught, spawning cycle, size and physiological status of fish. The FA composition of living things comes from their diets (Kaushik *et al.,* 2006).

It was reported that the FA composition in fish can vary depending on various environmental factors, as well as the species, which are significantly influenced by their bio-cycle capacities (Sargent, 1995), and there may be significant differences between the tissues of a fish due to lipid metabolism (Haliloğlu, 2001). Another important environmental factor, salinity, on the other hand, is known to be effective in the digestion of proteins, fats, and some dietary FAs, especially in some trout species (Borlongan and Benitez, 1992).

The FA content in the food of the fish directly affects the FA content of the fish tissues (Bell *et al.,* 2003). For example, herbivorous fish feeding on algae contain high levels of 18-carbon polyunsaturated fatty acids, with fewer rates of 20 and 22-carbon PUFAs (Henderson and Tocher, 1987). Like trout, carnivorous (flesh-eating) fish can complete the elongation (chain extension) and desaturation (increased degree of unsaturation) process since they feed on other fish and aquatic organisms. These fish, therefore, contain long-chain ω-3 PUFAs at a high rate and linoleic acid at a low rate.

Phospholipids and TAGs play different roles in fish metabolism. Triacylglycerols, also known as neutral oils, are the main component of the fats in our body that are taken from nutrients and make up more than 95% of pure fats. TAGs, mainly stored in adipose tissue, function as energy reserves (Sargent *et al.,* 1995). PLs, which form a small portion of total fats, are the major component of the cell membrane and structure, and 20-carbon polyunsaturated fatty acids that serve as precursors to eicosanoids.

Several studies have been carried out about the FA composition of total lipids of *S. trutta macrostigma* (Aras *et al.,* 2003; Akpınar *et al.,* 2009; Kayım *et al.,* 2011; Ateş *et al.,* 2013) and there are two published reports on the FA composition of the PL and TAG of this fish living in Erzurum (Bayır *et al.,* 2010) and living in the Munzur River (Kayhan *et al.,* 2015). However, the FA composition of PL and TAG of muscle and liver tissue of this species has not been reported previously. In this framework, the objective of this study was to determine the seasonal changes in lipid content and FA composition in the muscle and liver tissue of the brown trout *S. trutta macrostigma* in the Munzur stream, Tunceli, Turkey.

2. MATERIALS AND METHODS

Brown trout (22.93 cm; 137.33 g) were collected by electrofishing at site (39º 21¢ 67² N, 39º 13¢ 55²) in the

Munzur stream, Ovacık, Tunceli. Fish samples were collected every two months for a year (November, January, April, June, July, October). Muscle samples were taken for analyses from the fish body above the lateral line. Fish sex was determined by their gonads. The captured samples varied between 18.35 (in July) and 27 (in April) cm, with weights between 88 and 191 g.

Total lipids were extracted from 1 g of liver and 2 g of muscle tissue. The muscle and liver extracted were homogenized in a chloroform-methanol mixture (Folch, 1957). The thin-layer chromatography technique was used to fractionate the total lipids in the samples. Total lipid extracts of the samples were spotted on plates in a straight line. Total lipids were run in a mixture of petroleum ether-diethyl ether-acetic acid. The bands of the PL and TAG fractions determined by the standards were scraped and transferred to the reaction test-tubes. 3 ml of methanol and 3-5 drops of sulfuric acid were added to each fraction separately and they were heated at 85 °C under refrigerant for 2 hours. Thus, the transformation of fatty acids to fatty acid methyl esters was carried out. Methyl esters were extracted using hexane after the solution was cooled down. A gas chromatography device with Flame Ionization Detector (FID) was used for the analysis of fatty acid methyl esters.

Esterified samples were diagnosed on gas chromatography devices according to the study of Kayhan *et al.* (2015). A SPSS 16 computer program was used to compare fatty acid percentage rates. All data obtained from our study were obtained from the average of three replicates. In the gas chromatographic analysis of fatty acid methyl esters, three samples from each period were injected separately and the three values of the same fatty acid were averaged. A comparison of fatty acid percentages was made by one-way analysis of variance. Differences were determined by the Tukey HSD test. As a result of the statistics, it was accepted that the differences were significant when the data were $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1. FA profile of the total lipid of muscle and liver tissue

The ΣSFA of the fish examined was between 31.19-33.72% in muscle tissue. Although there was an irregular increase and decrease in the amount of ΣSFA during the year, it was determined that the amount of ΣSFA did not change significantly during the year, and that it was more stable than ΣMUFA and ΣPUFA and its amount was at the highest level in November, which was also the pre-spawning season and the water temperature was low. It was found that the amounts of ΣSFA and 16:0 and 18:0, which form the majority of ΣSFAs, were not significantly affected by the spawning season or water temperature. The majority of ΣSFA were formed by 16:0 fatty acids (21.98-24.19%) and it was seen that the amount of ΣSFA was affected by the changes in the amount of 16:0.

There were no significant seasonal differences in the amount of 16:0. This indicates that 16:0 fatty acids were key metabolites in fish and their quantity was not affected by food (Ackman *et al.,* 1975).

The most abundant fatty acid in SFAs after 16:0 was 18:0 (4.45-6.32%), and it was found that its amount did not show significant variations during the year.

The amount of ΣMUFA in trout was determined to be 22.01-35.30%. 18:1 ω-9 and accordingly, the lowest ΣMUFA amounts were found in the month of April (post-spawning season) and the highest ΣMUFA was in January (spawning season). 18:1 ω-9 and 16:1 ω-7 FAs were fatty acids with the highest percentages among the MUFAs. The excessive increase in the amount of ΣMUFA was due to the 16:1 ω-7 and 18:1 ω-9 increase in the month of January.

In our study, it was determined that the amount of 16:1 ω-7 and 18:1 ω-9 in ΣMUFA was high. Similar data were obtained in studies carried out on *Oncorhynchus mykiss* (Haliloğlu *et al.,* 2004, Görgün and Akpınar 2007).

The amount of ΣPUFA in trout was determined to be 33.35-46.52%. 22:6 ω-3 and 20:5 ω-3 and accordingly, the highest ΣPUFA amount was found in April. 18:2 ω-6 and 20:4 ω-6 from ω-6 FAs and 18:3 ω-3, 20:5 ω-3, 22:5 ω-3 and 22:6 ω-3 from ω-3 FAs were found to form the vast majority of ΣPUFAs, and showed fluctuations during the year.

There were DHA ω-3 FAs in the muscle tissues of fish at the highest levels. It was determined that the amount of DHA varied during the year, and the amount was the lowest in January and reached the highest level in April. Besides, it was found that the amount of DHA was higher than the amount of EPA in each season. The amount of EPA and DHA was found between 7.16-9.75% and 7.63-22.00%.

Table 1. Fatty acid composition in total lipids of muscle from male *S. trutta macrostigma* (% of total FA)*

Fatty acids	November (2009)	January (2010)	April (2010)	June (2010)	July (2010)	October (2010)
C10:0	-	-	-	-	-	-
C12:0	0.64±0.01a**	0.78±0.03b	-	0.30±0.01c	0.36±0.01c	-
C13:0	-	0.02±0.05a	-	0.62±0.07b	-	1.06±0.01b
C14:0	2.04±0.23a	2.54±0.26b	1.68±0.21a	2.34±0.11ab	1.90±0.10a	1.79±0.21a
C15:0	0.34±0.07a	0.26±0.01b	0.33±0.05a	0.17±0.05c	0.22±0.04bc	0.28±0.06b
C16:0	23.80±0.98a	21.98±0.76b	23.18±0.56a	23.49±0.68a	24.19±0.84c	23.08±0.53a
C17:0	0.58±0.12a	1.17±0.04b	0.46±0.06a	0.53±0.05b	0.80±0.07ab	0.65±0.06ab
C18:0	6.32±0.53a	4.45±0.41b	5.54±0.38ab	5.68±0.51ab	5.39±0.49ab	4.69±0.31b
ΣS.F.A***	33.72±1.01a	31.20±0.96b	31.19±0.86b	33.13±0.87a	32.86±0.72ab	31.55±0.67b
C16:1 ω-7	3.28±0.28a	11.70±0.81b	4.63±0.46a	6.04±0.28c	7.43±0.63bc	7.90±0.72bc
C18:1 ω-9	20.79±0.91a	21.19±0.75a	16.17±056b	18.90±0.48c	19.80±0.59ac	18.28±0.92c
C20:1 ω-9	0.72±0.03a	2.41±0.16b	1.21±0.08c	2.97±0.07b	2.98±0.13b	1.27±0.06c
ΣM.U.F.A.	24.79±0.68a	35.30±1.06b	22.01±0.59c	27.91±0.72d	30.21±0.84bd	27.45±0.67d
C18:2 ω-6	4.62±0.44a	4.05±0.31b	3.90±0.25b	3.63±0.32b	4.54±0.38a	4.81±0.34a
C18:3 ω-3	5.18±0.30a	11.08±0.17b	4.20±0.21c	5.92±0.92a	6.98±0.24d	9.90±0.36db
C20:2 ω-6	0.28±0.06a	0.13±0.01b	0.39±0.03c	0.12±0.03b	0.41±0.04c	0.26±0.07a
C20:3 ω-6	0.47±0.09a	0.27±0.06b	0.33±0.02ab	0.28±0.24b	0.31±0.11ab	0.46±0.07a
C20:4 ω-6	2.02±0.15a	0.80±0.08b	2.45±0.36c	1.68±0.62ab	1.99±0.29ab	1.12±0.36ab
C20:5 ω-3	7.53±0.23a	7.16±0.12a	9.66±0.32b	8.52±0.45ab	9.11±0.37b	9.75±0.42b
C22:5 ω-3	2.90±0.08a	2.23±0.12a	3.59±0.19b	3.03±0.22ab	2.68±0.17a	2.86±0.11a
C22:6 ω-3	18.50±0.57a	7.63±0.51b	22.00±0.64c	15.64±0.73d	10.77±0.56bd	13.46±0.38db
ΣP.U.F.A.	41.50±1.03a	33.35±0.96b	46.52±1.13c	38.82±0.92ab	36.79±0.76ab	42.62±1.04a
ω3	34.11±0.98a	28.10±0.68b	39.45±1.02c	33.11±0.89a	29.54±0.68b	35.97±1.01a
ω6	7.39±0.56a	5.25±0.43b	7.07±0.49a	5.71±0.53b	7.25±0.66a	6.65±.61ab
ω3/ω6	4.61	5.35	5.57	5.79	4.07	5.40

* Means are the averages of 3 replicates

** Values reported are means ± standard error; means followed by different letters in the same line are significantly different ($p < 0.05$) according to Tukey's test.

*** **SFA:** saturated fatty acids, **MUFA:** monounsaturated fatty acids, **PUFA:** polyunsaturated fatty acids

In the month of January, the spawning period, the amount of 18:3 ω-3 was found to be quite high compared to the other months, and the amount of DHA was significantly lower.

18:2 ω-6, 20:2 ω-6, 18:3 ω-3, 20:5 ω-3, 22:5 ω-3 and 22:6 ω-3 were found to form the vast majority of ΣPUFAs in trout. As found in studies performed on other trout, the highest percentage of fatty acids among ω-6 FAs was 18:2 ω-6 (Aras *et al.,* 2003a; Aras *et al.,* 2003b; Akpınar *et al.,* 2009; Kalyoncu *et al.,* 2010).

Due to the high amounts of ω-3 FAs such as EPA and DHA in our study, it can be said that *S. trutta macrostigma* has an important place in human nutrition. Various types of trout, including *S. trutta macrostigma*, were studied previously and it was seen that the most abundant ω-3 FAs in PUFAs were DHA and EPA (Haliloğlu *et al.,* 2002; Aras *et al.,* 2003a; Aras *et al.,* 2003b; Görgün and Akpınar 2007; Kalyoncu *et al.,* 2010).

The fact that the amount of DHA was found to be significantly lower in the month of January, the spawning period, it is believed to have arisen from the fact that DHA in the muscles may have moved to the gonads with the onset of the gonad maturation stage (Jeong *et al.,* 2002).

In our study, the percentage of total unsaturated FAs in all seasons was higher than the percentage of total SFAs.

Fish are poikilothermic living things, in other words, their body temperature changes according to the ambient conditions. Studies have found that tem-

perature is directly effective on fatty acid metabolism. A decrease in the water temperature in the environment where the fish inhabit causes an increase in the carbon numbers of FAs in their structural lipids, and unsaturation (Williams and Hazel 1992). It was stated that the percentage of total SFAs in fish can never exceed the percentage of total unsaturated FAs since they are poikilothermic living things (Akpınar, 1987).

It was found that in the muscle total FA composition of the fish, ω-3 FAs changed more than ω-6 FAs during the year and the amount of ω-3 PUFAs was higher than ω-6 PUFAs in each period. This was effective in determining the ω-3/ ω-6 ratios. The ω-3/ ω-6 ratio was found as 4.07-5.79.

The high ω-3/ω-6 ratio was believed to happen due to the ω-3PUFA content that plays a role in adaptation to high altitude and long winter conditions in trout caught from the River Munzur. The ω-3/ω-6 ratio in the muscle tissue of *S. trutta macrostigma* was found to be higher than many freshwater fish (Haliloğlu *et al.,* 2002; Güler *et al.,* 2007).

Table 2 shows the variations in the liver total FA composition of *S. trutta macrostigma* by months.

The amount of ΣSFA in the liver of trout was determined as 29.41-33.64%. The liver ΣSFA amount showed fluctuations during the year and was found to be higher in the month of January (spawning season) compared to other months. It was found that the 16:0 level was the highest in January and that this finding directly affected the amount of ΣSFA. In many fish species examined, especially trout, it was found that the most abundant component in SFAs in

Table 2. Fatty acid composition in total lipids of liver from male *S. trutta macrostigma* (% of total FA)*

Fatty acids	November (2009)	January (2010)	April (2010)	June (2010)	July (2010)	October (2010)
C12:0	0.10±0.02a**	0.41±0.11b	-	-	-	-
C13:0	-	-	-	-	-	0.03±0.01
C14:0	2.11±0.23a	2.57±0.13a	1.59±0.30b	1.26±0.24c	1.89±0.21b	1.09±0.24c
C15:0	0.49±0.16a	0.46±0.20a	0.29±0.14b	0.19±0.07b	0.25±0.11b	0.14±0.05c
C16:0	20.88±0.44a	23.02±0.34b	20.20±0.38a	21.01±0.34c	21.33±0.52c	21.94±0.45c
C17:0	0.61±0.13a	0.78±0.18b	0.50±0.12a	0.35±0.08c	0.23±0.11c	0.39±0.17c
C18:0	6.78±0.19a	6.40±0.33a	6.83±0.35a	8.09±0.41b	7.54±0.42ab	6.50±0.41a
ΣS.F.A***	30.97±1.03a	33.64±0.65b	29.41±0.54a	30.90±0.73a	31.24±0.65ab	30.09±1.01a
C16:1 ω-7	3.08±0.05a	8.08±0.10b	3.56±0.29c	3.28±0.63a	3.46±0.24ac	3.14±0.18a
C18:1 ω-9	20.88±0.52a	19.98±0.47b	14.54±0.53c	19.65±0.61b	18.45±0.51ab	13.87±0.48c
C20:1 ω-9	0.37±0.11a	1.42±0.10b	0.54±0.21c	0.83±0.20d	0.88±0.22d	0.41±0.30a
ΣM.U.F.A.	24.33±0.95a	29.48±0.76b	18.64±0.65c	23.76±0.68a	22.79±0.44d	17.42±0.25c
C18:2 ω-6	6.19±0.21a	4.21±0.33b	2.66±0.12bc	3.73±0.34c	3.11±0.30c	3.74±0.51c
C18:3 ω-3	2.82±0.10a	6.18±0.12b	2.38±0.20a	3.39±0.33c	2.76±0.21a	3.62±0.19c
C20:2 ω-6	0.50±0.14a	0.30±0.06ab	0.38±0.06ab	0.41±0.03b	0.27±0.03c	0.27±0.12c
C20:3 ω-6	0.41±0.02a	0.27±0.13b	0.28±0.01b	0.39±0.02c	0.28±0.06b	0.40±0.05a
C20:4 ω-6	4.85±0.11a	2.42±0.15b	5.79±0.33c	5.83±0.20c	5.21±0.21ac	4.57±0.22a
C20:5 ω-3	8.42±0.45a	10.87±0.54ab	11.85±0.23b	10.00±0.34ab	11.91±0.10b	12.43±0.31c
C22:5 ω-3	2.27±0.11a	2.26±0.12a	4.24±0.15b	3.28±0.23ab	2.66±0.10a	2.96±0.11a
C22:6 ω-3	19.17±0.10a	10.32±0.19b	24.18±0.38c	18.15±0.71d	19.70±0.41a	24.35±0.19c
ΣP.U.F.A	44.63±1.01a	36.83±1.18b	51.76±1.13c	45.18±1.24a	45.90±1.08a	52.34±1.05c
ω3	32.68±0.99a	29.63±0.99b	42.65±0.99c	34.82±1.05a	37.03±0.99d	43.36±0.71c
ω6	11.95±0.90a	7.20±0.65b	9.11±0.91c	10.36±0.65a	8.87±0.65b	8.98±0.90b
ω3/ω6	2.73	4.11	4.68	3.36	4.17	4.82

* Means are the averages of 3 replicates

** Values reported are means ± standard error; means followed by different letters in the same line are significantly different ($p < 0.05$) according to Tukey's test.

*** **SFA:** saturated fatty acids, **MUFA:** monounsaturated fatty acids, **PUFA:** polyunsaturated fatty acids

the liver, as in the muscles, was 16:0 (Haliloğlu *et al.,* 2002, Aras *et al.,* 2003a, b, Akpınar *et al.,* 2009).

The amount of ΣMUFA in trout was determined as 17.42-29.48%. Like the ΣSFAs, the amount of ΣMUFA was found to show fluctuations during the year and it was higher in the spawning season compared to other periods. The FAs with the highest percentage in the liver ΣMUFAs were 18:1 ω-9 and 16:1 ω-7. 18:1 ω-9 and 16:1 ω-7 are characteristic components for freshwater fish (Osman *et al.,* 2001).

The increase in the amount of ΣMUFA was due to the increase in the amount of 16:1 ω-7. The fact that the amount of ΣMUFA was at its lowest level in the month of October was due to 18:1 ω-9, which was at a minimum level during this period.

The amount of ΣPUFA in the liver was determined as 36.83-52.34%. The highest ΣPUFA amount was found in the month of October and the lowest ΣPUFA was in the month of January, the spawning season. Just like in muscle tissue, it was found that the amount of ΣPUFA in the liver was affected by the spawning season; whereas the amount decreased in this period and increased in the month of April, the post-spawning season. Just like in the muscles, the most common ω-3 FAs in the liver ΣPUFAs of the fish were 20:5 ω-3 and 22:6 ω-3 FAs. It was determined that the amount of ΣPUFA was significantly affected by changes in the amount of 20:5 ω-3 and 22:6ω-3. For example, the reason for the high number of PUFAs in October compared to other periods was due to the increase in the 22:6 ω-3 rate in this period. ω-6 FAs, on the other hand, were found to be more abundant than ΣPUFAs 18:2ω-6 and 20:4 ω-6. It was seen that both the amount of DHA, which is very important for the structure and functions of cells, and AA, the primer substance of the biologi-

Table 3. Fatty acid composition in the phospholipid fraction of muscle from male *S. trutta macrostigma* (% of total FA)*

Fatty acids	November (2009)	January (2010)	April (2010)	June (2010)	July (2010)	October (2010)
C14:0	1.15±0.22a**	0.67±0.13b	0.91±0.34ab	1.08±0.24a	1.01±0.21a	0.82±0.21ab
C15:0	0.36±0.16a	0.18±0.10b	0.26±0.22ab	0.21±0.07ab	0.10±0.01c	0.21±0.15ab
C16:0	32.81±0.52a	27.58±0.65b	25.50±0.44c	36.07±0.49d	27.41±0.32b	26.40±0.35bc
C17:0	0.56±0.13a	0.43±0.28b	0.52±0.41a	0.39±0.17b	0.24±0.14c	0.26±0.12bc
C18:0	6.68±0.42a	4.83±0.51b	6.75±0.38a	8.91±0.42c	5.43±0.28ab	3.64±0.44d
ΣS.F.A***	41.56±1.02a	33.69±0.76b	33.94±0.54b	46.66±1.24c	34.19±0.92b	31.33±0.64d
C16:1 ω-7	1.74±0.52a	1.66±0.31a	2.25±0.10b	1.29±0.33c	1.50±0.21ac	1.39±0.41c
C18:1 ω-9	12.65±0.36a	8.44±0.55b	11.52±0.45a	14.16±0.47c	13.50±0.56ac	12.67±0.48a
C20:1 ω-9	0.46±0.12a	0.66±0.24b	0.53±0.21a	0.76±0.20b	0.95±0.22c	0.34±0.30d
ΣM.U.F.A.	14.85±0.39a	10.76±0.42b	14.30±0.48a	16.21±0.28c	15.95±0.5ac	14.40±0.67a
C18:2 ω-6	2.43±0.41a	1.39±0.23b	2.67±0.21a	2.44±0.34a	2.86±0.36c	18.65±0.61d
C18:3 ω-3	4.08±0.25a	4.48±0.32a	2.74±0.29b	3.32±0.33ab	3.79±0.22ab	3.07±0.19ab
C20:2 ω-6	-	0.16±0.06a	0.30±0.04b	0.25±0.10ab	0.37±0.13b	0.16±0.08a
C20:3 ω-6	2.51±0.12a	0.23±0.06b	0.35±0.11c	0.35±0.02c	0.40±0.05c	0.18±0.07b
C20:4 ω-6	-	1.98±0.15a	2.94±0.32b	2.15±0.24ab	2.82±0.27b	1.46±0.22c
C20:5 ω-3	9.60±0.42a	15.01±0.51b	10.93±0.33a	7.96±0.44c	13.28±0.23ab	8.97±0.35c
C22:5 ω-3	2.80±0.13a	4.65±0.18b	4.31±0.15b	2.89±0.22a	4.06±0.16b	2.65±0.12a
C22:6 ω-3	22.09±0.54a	27.58±0.39b	27.27±0.48b	17.62±0.51c	22.27±0.44a	19.07±0.49d
ΣP.U.F.A.	43.51±0.84a	55.48±1.18b	51.51±1.03c	36.98±0.71d	49.85±0.65c	54.21±1.05b
ω3	38.57±0.68a	51.78±0.97b	45.25±0.59ab	31.79±0.53c	43.40±0.49ab	33.76±0.70a
ω6	4.94±0.61a	3.76±0.56b	6.26±0.73c	5.19±0.55ac	6.45±0.46c	20.45±0.31d
ω3/ω6	7.80	13.77	7.22	6.12	6.72	1.65

* Means are the averages of 3 replicates

** Values reported are means ± standard error; means followed by different letters in the same line are significantly different ($p < 0.05$) according to Tukey's test.

*** **SFA:** saturated fatty acids, **MUFA:** monounsaturated fatty acids, **PUFA:** polyunsaturated fatty acids

Table 4. Fatty acid composition in the triacylglycerol fraction of muscle from male *S. trutta macrostigma* (% of total FA)*

Fatty acids	November (2009)	January (2010)	April (2010)	June (2010)	July (2010)	October (2010)
C10:0	-	-	-	0.06±0.01**	-	-
C12:0	1.36±0.23a	0.79±0.31b	0.92±0.40c	0.65±0.28d	0.77±0.29b	-
C13:0	1.84±0.34a	-	0.43±0.17b	-	0.21±0.14c	1.49±0.25d
C14:0	5.18±0.28a	3.03±0.19b	3.29±0.41b	4.49±0.35ab	4.01±0.38ab	2.22±0.33c
C15:0	4.60±0.27a	0.39±0.21b	0.99±0.32c	0.34±0.13b	0.27±0.09d	0.26±0.12d
C16:0	16.49±0.69a	22.77±0.41b	25.84±0.61c	26.59±0.55c	23.89±0.52bc	19.70±44d
C17:0	6.63±0.53a	1.34±0.18b	0.98±0.25c	0.57±0.21d	0.38±0.14d	0.79±0.18dc
C18:0	9.20±0.56a	4.36±0.62b	7.32±0.39c	6.21±0.38c	3.69±0.33b	3.29±0.23b
ΣS.F.A***	45.30±0.71a	32.68±0.55b	39.77±0.63c	38.91±0.42c	33.22±0.42b	27.75±0.63d
C16:1 ω-7	4.31±0.34a	13.64±0.63b	6.24±0.69c	7.85±0.43d	10.68±0.52db	9.25±0.32db
C18:1 ω-9	19.16±0.24a	24.30±0.044b	18.76±0.29a	33.70±081c	23.94±0.62b	21.54±0.62ab
C20:1 ω-9	0.79±0.53a	2.10±0.47b	1.45±0.42c	2.31±0.35b	3.94±0.42d	1.45±0.26c
ΣM.U.F.A.	24.26±0.43a	40.04±1.21b	26.45±0.41a	43.86±0.31c	38.56±0.74b	32.24±0.048ab
C18:2 ω-6	11.57±0.73a	4.86±0.73b	4.51±0.52b	5.46±0.93c	5.94±0.87c	19.11±0.72d
C18:3 ω-3	5.00±0.39a	11.80±0.36b	4.59±0.25a	5.34±0.49a	8.35±0.38c	10.94±0.54b
C20:2 ω-6	3.82±0.32a	0.24±0.14b	0.54±0.24b	0.25±0.15b	0.16±0.06b	0.33±0.13b
C20:3 ω-6	-	0.24±0.11a	0.59±0.23b	0.28±0.11a	0.32±0.04ab	0.34±0.14ab
C20:4 ω-6	-	0.73±0.23a	2.05±0.31b	0.58±0.18a	1.05±0.35c	0.63±0.29a
C20:5 ω-3	3.80±0.33a	4.92±0.46b	8.53±0.22c	2.77±0.43d	6.56±0.34bc	4.20±0.25b
C22:5 ω-3	1.51±0.23a	1.42±0.17a	2.32±0.36b	0.73±0.13c	1.45±0.27a	1.53±0.21a
C22:6 ω-3	4.66±0.34a	2.44±0.22b	10.60±0.55c	1.61±0.25d	3.72±0.33ab	2.79±0.24b
ΣP.U.F.A	30.36±0.41a	26.65±0.58b	33.73±0.65a	17.02±0.41c	27.55±0.28b	39.87±0.43d
ω3	14.97±0.72a	20.58±0.83b	26.04±0.68c	10.45±.05d	20.08±1.05b	19.46±1.06b
ω6	15.39±0.90a	6.07±0.91b	7.69±0.96b	6.57±1.48b	7.47±0.46b	20.41±0.63c
ω3/ω6	0.97	3.39	3.38	1.59	2.68	0.95

* Means are the averages of 3 replicates

** Values reported are means ± standard error; means followed by different letters in the same line are significantly different ($p < 0.05$) according to Tukey's test.

*** **SFA:** saturated fatty acids, **MUFA:** monounsaturated fatty acids, **PUFA:** polyunsaturated fatty acids

cally active substances eicosanoids, decreased significantly in January and decreased to the lowest level observed during the year.

It was found that the amounts of ω-3 FAs in liver total lipids were in the muscle tissue and that they was considerably higher than the amounts of ω-6 FAs in every period and that the amount reaches its maximum level in October. The ω-3/ω-6 ratio in this period was determined to be at its highest level due to the increase in the amount of ω-3. This ratio was between 2.73-4.82.

It was determined that the amount of liver ΣPUFA was higher than the amounts of ΣMUFA and ΣSFA in every season. Our results were consistent with the results obtained in previous studies which examined various freshwater fish, including *S. trutta macrostigma* (Akpınar *et al.,* 2009, Aras *et al.,* 2003b, Görgün and Akpınar, 2007). In some studies, on the other hand, it was found that the amount of liver ΣSFA was higher than the amounts of ΣMUFA and ΣPUFA (Aras *et al.,* 2003a, Bayır *et al.,* 2010). This difference is believed to have arisen from several factors such as species of the fish, living environment, the temperature of the water where it was caught, season, differences in the food chain, and the physiological status of the fish, such as gonad maturation, and reproduction during the year (Ackman, 1967).

In our study, we found that long-chain PUFAs varied more than SFAs. It was suggested that gonad maturation and spawning seasons directly affected these variations (Akpınar, 1986).

3.2. FA profile of the PL and TAG fraction of muscle and liver tissue

Tables 3 and 4 show the changes in the FA compositions of the muscle PL and TAG fractions of S. *trutta macrostigma* from the River Munzur by months.

The amount of ΣSFA in the muscle PL fraction of the trout examined in this study was found between 31.33-46.66%. Although it is a PL fraction, the amount of 16:0 with the highest percentage in ΣSFA ratio and SFAs was found to be quite high.

Similar findings were reported in all three types of trout, including *S. trutta macrostigma* from our study (Bayır *et al.,* 2010). Bayır *et al.* (2010), reported that the high 16:0 ratio in the PL fraction may have been caused by increased water temperature in summer and reproductive activity in autumn.

The amount of ΣMUFA in the PL fraction was between 10.76-16.21%. Just like ΣSFAs, the highest amount of ΣMUFA was found in the month of June. The lowest ΣMUFA amount was found in the month of January. ΣMUFAs, which were much lower than ΣPUFA and ΣSFA, and 18:1 ω-9 and 16:1 ω-7, did not vary much during the year.

The amount of ΣPUFA in the PL fraction was found to be 36.98-55.48%. The most common components in the ΣPUFAs were 20:5 ω-3 and 22:6 ω-3. The amount of ΣPUFA due to the decrease in the amount of these components was also low in June, when the air temperature was high compared to other periods.

ω-3 FAs in the PL fraction were significantly higher than ω-6 FAs in each season and were found to be the highest in the month January (spawning season). The ω-3/ω-6 ratio was between 1.65-13.77. The reason for the low rate of ω-3/ω-6 in October was that the amount of 18:2 ω-6 of ω-6 FAs in this period was quite high. The increase in the amount of ω-3/ω-6 in January was due to the increase in the amount of 20:5 ω-3 and 22:6 ω-3.

In the PL fraction, the highest amount was found in ΣPUFA and then in ΣSFA in all periods except June. The lowest amount was in ΣMUFA. Similar findings were obtained in studies examining other freshwater fish (Ackman *et al.,* 2002; Kayhan *et al.,* 2015). Another interesting finding was that the amount of 18:2 ω-6 was quite high in October compared to other periods.

Bayır *et al.* (2010) found that ΣMUFAs were present in the neutral lipid fraction in *S. trutta caspius*. However, the same researchers found the amount of ΣSFA in the PL fraction to be higher than the amount of ΣPUFA. This difference is thought to have arisen from the fact that the fish were caught from different water resources and accordingly the temperature values of their inhabiting areas changed, along with the fatty acid contents of the living things constituting their food. The high amount of ΣPUFA in our study is thought to have arisen from the fact that the water temperature of the River Munzur, where the fish were caught, was lower. It is known that the rate of unsaturated FAs increases especially in fish living in cold water because cells can change the lipid composition of their membranes to adapt to changing temperatures. For example, fish living in cold environments increase the unsaturated fatty acids in their phospholipids as an adaptation to prevent the cell membranes from solidifying in winter. Thus, when the degree of unsaturation of FAs increases, the melting point decreases (Çelik *et al.,* 2008).

The amount of ΣSFA in the muscle TAG fraction of the trout examined was found to be 27.75-45.30%. The lowest ΣSFA amount in the TAG fraction, as in the PL fraction, was found in the month of October. The highest amount of ΣSFA in TAGs was found in the month of November, which is pre-spawning season. This shows that the amount of ΣSFA in TAGs was not affected by the spawning season.

It was determined that the increase in the amount of ΣSFA in the muscle TAG fraction in November resulted from the increase in the amount of 14:0, 15:0, 17:0 and 18:0, rather than the amount of 16:0.

The amount of ΣMUFA in the muscle tissue TAGs of the examined trout was determined as 24.26-43.86%. 18:1 ω-9 and accordingly, the amount of ΣMUFA, was found at their peak in the month of June. The amount of 18:1 ω-9, which has the highest percentage among ΣMUFAs, showed irregular increases and decreases.

The TAG fraction ΣPUFA amount of *S. trutta macrostigma* was found as 17.02-39.87%. The most important reason for the increase in ΣPUFAs in October was that 18:2 ω-6 was found in this period, especially as in PL, in a very high amount. The change

in this main fatty acid is thought likely to have arisen from food.

The amount of 18:2 ω-6, which was quite high in TAG in October, and accordingly, the amount of ω-6 FAs, were found to be quite high. This situation affected the ω-3/ω-6 ratio of the TAG fraction in the muscle tissue and the ω-3/ω-6 ratio was found to be lower than 1 in these periods.

The amounts of ΣSFA and ΣMUFA were higher than ΣPUFAs, except in October. This was due to the fact that the fish mostly store saturated and monounsaturated FAs (Kozlova and Khotimchenko, 2000).

In the TAG fraction of muscle tissue, the ω-3/ω-6 ratio was found at values between 0.95-3.39.

When the PL and TAG fractions of the muscle lipids of *S. trutta macrostigma* were compared, the ΣSFA percentages were expected to be higher in the TAG fraction than the PL. However, due to the fact that 16:0, which is the most important component of SFAs in the PL fraction of brown trout, was higher than expected, ΣSFA ratios in both fractions were found close to each other. This result was also found in the study carried out by Bayır *et al.* (2010), on three types of trout, including *S. trutta macrostigma*. From these results, we can affirm that the fact that the amount of 16:0 in the PL fraction was higher than TAG is characteristic of trout (Ackman *et al.,* 2002).

In freshwater fish, on the other hand, this component was found in greater amounts in the TAG fraction.

In our study, the amount of ΣMUFA and the fatty acids forming the ΣMUFA, 16:1 ω-7 and 18:1 ω-9, were higher in the TAG fraction than the PL fraction. The amounts of ΣPUFA and the 20:5 ω-3 and 22:6 ω-3 ratios of ω-3 FAs forming the ΣPUFA were found to be higher in the PL fraction. The increase in the ratios of these components caused an increase in the ω-3/ω-6 ratio in the PL. 18:2 ω-6 and 18:3 ω-3 rates, among other important PUFAs, were found to be higher in the TAG fraction compared to PL.

The fatty acids 20:5 ω-3, 22:5 ω-3 and 22:6 ω-3 abounds in PL, while 16:1 ω-7, 18:1 ω-9, 18:2 ω-6 and 18:3 ω-3 in the TAG fraction. The effect of nutritional lipids on the FA composition of body lipids differs between triacylglycerol and phospholipids. Studies have shown that the FA composition of phospholipids was more greatly affected than triacylglycerols. In freshwater fish, linoleic and linolenic acid, which are taken with food, are exposed to chain extension and their degree of unsaturation is increased. In this way, these fatty acids are transformed to AA, docosapentaenoic, and docosahexaenoic acids. Moreover, it was found that these FAs are involved in the structure of PLs and these components taken with nutrients are stored in triacylglycerols without being changed. Similar data have been previously reported for different types of trout and freshwater fish (Aras *et al.,* 2003; Aras *et al.,* 2003b; Bayır *et al.,* 2010).

The ΣSFA ratio in the liver PL fraction of the trout examined increased in April, June and July, when the temperature was relatively high. In liver PLs, as in muscle tissue, the most common FAs in SFA are 16:0 and 18:0. The changes in the amount of ΣSFA during the year were directly affected by changes in the amount of these FAs. ΣMUFA amounts were found between 16.87-25.42%. The highest amounts of 18:1 ω-9 and ΣMUFA were found in June and the lowest amounts of 18:1 ω-9 and ΣMUFA in October (Table 5).

The highest amount of ΣPUFA was found in October (51.05%) and the lowest amount of ΣPUFA was found in April (32.85%). Most of the fatty acids found in the PUFAs were 20:5 ω-3 and 22:6 ω-3 in PL, just like in the muscle tissue. The amounts of EPA, DHA, and ΣPUFA decreased in April, June, and July, which are warmer compared to other periods, and the amount of these components increased in the pre-spawning seasons, October and November when the temperature began to drop.

As in the muscle PL fraction, in October, the 18:2 ω-6 ratio of ω-6 FAs was found to be significantly higher in liver PL fraction than in other periods. It is thought that this increase was due to the FA contents of the aquatic organisms that the fish feed on during this period. In the PL fraction, ΣPUFA rates were significantly higher than ΣSFA and ΣMUFA in November, January and October; while the ΣMUFA rate was lower than ΣPUFA and ΣSFA.

ω-3/ω-6 ratio was found between 2.25-4.75. The decrease in the rate of ω-3/ω-6 in October was due to the fact that the amounts of ω-6 FAs 18:2 ω-6 were quite high in this period.

The amounts of EPA, DHA, and ΣPUFA decreased in April, June, and July, which are warmer than other periods; while the amount of these components increased in October and November, pre-spawning season, when the temperature began to decrease. Such a relationship between the temperature change and the

Table 5. Fatty acid composition in the phospholipid fraction of liver from male *S. trutta macrostigma* (% of total FA)*

Fatty acids	November (2009)	January (2010)	April (2010)	June (2010)	July (2010)	October (2010)
C14:0	1.38±0.32a**	1.77±0.21b	1.71±0.30b	1.39±0.27a	1.98±0.24c	0.68±0.14d
C15:0	0.41±0.06a	1.07±0.13b	0.40±0.21a	0.25±0.17c	0.32±0.08ac	0.24±0.03c
C16:0	21.37±0.96a	22.08±0.51a	29.06±1.04b	26.26±0.76c	30.07±1.11b	24.11±0.65a
C17:0	0.65±0.23a	0.26±0.09b	0.82±0.14c	0.50±0.11d	0.48±0.15d	0.49±0.06d
C18:0	7.46±0.32a	8.59±0.41b	10.72±0.53c	10.31±0.37c	8.48±0.42b	6.41±0.44ab
ΣS.F.A***	31.27±1.20a	33.77±0.98b	42.71±1.14c	38.71±1.24d	41.33±1.28c	31.93±1.20a
C16:1 ω-7	2.03±0255a	4.17±0.31b	2.80±0.39a	2.31±0.23a	3.75±0.29ab	1.93±0.19a
C18:1 ω-9	15.43±0.33a	17.63±0.51b	21.16±0.69c	22.17±0.76c	21.44±0.66c	14.66±0.65a
C20:1 ω-9	0.30±0.07a	0.68±0.12b	0.35±0.06a	0.55±0.13b	0.23±0.03c	0.28±0.09ac
ΣM.U.F.A.	17.76±0.96a	22.48±1.03b	24.31±1.09c	25.03±0.45d	25.42±0.54d	16.87±0.67a
C18:2 ω-6	2.68±0.51a	6.28±0.43b	3.43±0.33c	3.58±0.34c	1.82±0.29a	11.17±0.63d
C18:3 ω-3	2.31±0.10a	2.64±0.16b	1.91±0.21a	2.47±0.34ab	1.10±0.20c	2.50±0.19ab
C20:2 ω-6	0.41±0.14a	0.37±0.06ab	0.42±0.12a	0.34±0.05b	0.36±0.06ab	0.25±0.11c
C20:3 ω-6	0.25±0.10a	0.32±0.06a	0.41±0.11b	0.42±0.05b	0.57±0.06c	0.50±0.07c
C20:4 ω-6	5.51±0.16a	3.67±0.15b	4.82±0.33ab	4.83±0.20ab	3.53±0.21b	3.78±0.26b
C20:5 ω-3	10.43±0.45a	10.60±0.52a	7.45±0.32b	7.63±0.33b	7.49±0.43b	9.60±0.41a
C22:5 ω-3	3.06±0.13a	3.28±0.12a	2.46±0.15b	3.23±0.23a	3.25±0.10a	2.72±0.14b
C22:6 ω-3	26.24±0.64a	16.45±0.49b	11.95±0.38c	13.68±0.71c	15.02±0.44b	20.53±0.49d
ΣP.U.F.A.	50.89±1.23a	43.61±1.18b	32.85±0.98c	36.18±0.68d	33.14±054c	51.05±1.05a
ω3	42.04±0.99a	32.97±0.42b	23.77±0.38c	27.01±.65bc	26.86±0.72bc	35.35±0.59d
ω6	8.85±0.40a	10.64±0.63b	9.08±0.41ab	9.17±0.64ab	6.28±0.49c	15.70±0.93d
ω3/ω6	4.75	3.09	2.61	2.94	4.27	2.25

* Means are the average of 3 replicates

** Values reported are means ± standard errors; means followed by different letters in the same line are significantly different ($p < 0.05$) according to Tukey's test.

*** **SFA:** saturated fatty acids, **MUFA:** monounsaturated fatty acids, **PUFA:** polyunsaturated fatty acids

amount of ΣPUFA is a natural consequence. Farkas and Csenger (1976), stated that fish liver has the ability to adjust fatty acid biosynthesis very quickly to the appropriate temperature. Previous studies on various freshwater fish have reported that the amount of ΣPUFA in liver PL and TAG fractions was affected by temperature changes and increased with decreasing temperature (Bayır *et al.,* 2010). 18:2 ω-6 was found to be quite high in October compared to other periods. This increase is thought to have arisen from the FA contents of the aquatic organisms that the fish feed on during this period because 18:2 ω-6 is an essential ingredient in many other invertebrates, and in vertebrates, including fish. This is an ingredient that must be taken externally with nutrients.

The amount of ΣSFA in the TAG fraction of trout liver varied between periods depending on the increase in 16:0, which was between 28.94 and 54.65% (Table 6). The lowest amount of ΣSFA was detected in October; while the highest ΣSFA amount was detected in the month of November, pre-spawning season. It was determined that the amount of ΣSFA during the year was due to the increase in 16:0. However, the excessive increase in the amount of ΣSFA in November was caused by the excessive increase in 14:0 rather than 16:0. ΣMUFA amounts were found between 14.64-34.82%. In November, the pre-spawning period, the rate of 18:1 ω-9, which was the most abundant component in the percentage distribution, decreased by half compared to other periods. The rate of 16:1 ω-7, another MUFA component, decreased significantly in this period compared to other periods.

The amount of ΣPUFA was determined as 25.75-45.99%. As in the PL fraction, the highest amount of ΣPUFA was found in October. The most common fatty acids in the PUFAs were 18:2 ω-6, 18:3 ω-3,

20:5 ω-3 and 22:6 ω-3. FAs other than these formed a small proportion of the PUFAs. Just like in PL, the rate of 18:2 ω-6 in the TAG fraction was found to be significantly higher in October than in other periods.

The ratio of ω-3/ω-6 in the TAG fraction was determined as 0.49-2.98. Since the 18:2 ω-6 percentage of ω-6 FAs in October was higher in this period compared to other periods, it was found that the ratio of ω-3/ω-6 was at its lowest value during the year.

In the TAG fraction, the 18:2 ω-6 in October was significantly higher than in other periods. Hazel (1979) stated that the FAs in the liver triacylglycerol of *Oncorhynchus mykiss* increased due to the decrease in temperature of the FAs that form the ω-3 and ω-6 PUFAs. However, in our study, since 18:2 ω-6, one of the most important ω-6 FA components of PUFAs, was very high in October, PUFAs were found to be high in this period, and not in January when the temperature was the lowest.

CONCLUSION

As a result of the study, it was concluded that, compared to many other freshwater fish, the brown trout *S. trutta macrostigma* is a rich source of ω-3 and ω-6 polyunsaturated fatty acids with numerous benefits to human health, and accordingly the ω-3/ω-6 ratio. It can be said that consuming these fish as nutrients will have important effects on human health.

Table 6. Fatty acid composition in the triacylglycerol fraction of liver from male *S. trutta macrostigma* (% of total FA)*

Fatty acids	November (2009)	January (2010)	April (2010)	June (2010)	July (2010)	October (2010)
C10:0	-	-	-	0.38±0.05**	-	-
C12:0	-	0.43±0.12a	1.44±0.18b	0.41±0.15a	-	-
C13:0	-	0.36±0.12a	0.63±0.10b	-	-	0.77±0.08b
C14:0	14.38±0.34a	4.78±0.42b	4.37±0.31b	2.38±0.25c	3.06±0.42bc	1.39±0.24d
C15:0	2.48±0.26a	2.23±0.17a	1.05±0.35c	0.71±0.17c	1.05±0.11c	0.21±0.04d
C16:0	29.61±0.85a	24.40±0.25bc	24.80±0.36bc	26.77±0.42b	22.27±054c	21.80±0.42c
C17:0	1.68±0.23a	0.87±0.17b	1.10±0.21c	0.57±0.20d	0.52±0.14d	0.41±0.07d
C18:0	6.50±0.12a	7.47±0.31ab	6.00±0.43a	8.63±0.45b	5.37±0.30c	4.36±0.34c
ΣS.F.A***	54.65±1.20a	40.54±1.02b	39.39±1.05b	39.85±0.84b	32.27±0.68c	28.94±0.55d
C16:1 ω-7	2.38±034a	9.61±0.75b	8.15±0.49c	4.11±0.63d	8.20±0.54c	4.29±0.24d
C18:1 ω-9	11.46±0.51a	22.49±0.43b	24.28±0.39bc	26.27±0.45c	24.98±0.61bc	20.21±0.48b
C20:1 ω-9	0.80±0.10a	1.49±0.21bc	1.77±0.23b	1.11±0.08c	1.64±0.12b	0.61±0.33a
ΣM.U.F.A.	14.64±0.56a	33.59±0.46bc	34.20±0.49b	31.49±0.65c	34.82±0.54b	25.11±0.57d
C18:2 ω-6	4.95±0.48a	5.49±0.40b	4.93±0.31a	6.73±0.34c	5.10±0.30b	29.10±0.51d
C18:3 ω-3	3.19±0.20a	7.38±0.32c	4.71±0.14b	4.37±0.34b	3.60±0.32a	4.51±0.29b
C20:2 ω-6	0.72±0.14a	0.20±0.06b	0.34±0.04bc	0.41±0.05c	0.17±0.03b	0.28±0.12bc
C20:3 ω-6	2.25±0.22a	0.46±0.13b	0.24±0.07c	0.38±0.02bc	0.20±0.03c	0.23±0.05c
C20:4 ω-6	6.61±0.21a	0.99±0.25b	2.16±0.30c	2.69±0.24c	2.72±0.23c	1.25±0.12d
C20:5 ω-3	4.06±0.35a	6.05±0.50ab	7.31±0.22b	5.92±0.33ab	9.45±0.28c	4.48±0.36a
C22:5 ω-3	1.16±0.12a	1.60±0.10bc	1.50±0.25b	1.64±0.14bc	1.77±0.10c	1.24±0.13a
C22:6 ω-3	7.04±0.25ab	3.58±0.11d	5.15±0.35c	6.36±0.41a	9.74±0.46b	4.90±0.29c
ΣP.U.F.A	29.98±0.68a	25.75±0.57b	26.34±0.73b	28.50±0.52a	32.75±1.02c	45.99±1.05d
ω3	15.45±0.39a	18.61±0.65b	18.67±0.71b	18.29±0.49b	24.56±0.84c	15.13±0.51a
ω6	14.53±0.50a	7.14±0.35b	7.67±0.43b	10.21±0.35c	8.19±0.45b	30.86±0.40d
ω3/ω6	1.06	2.60	2.43	1.79	2.98	0.49

* Means are the averages of 3 replicates

** Values reported are means ± standard error; means followed by different letters in the same line are significantly different ($p < 0.05$) according to Tukey's test.

*** **SFA:** saturated fatty acids, **MUFA:** monounsaturated fatty acids, **PUFA:** polyunsaturated fatty acids

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