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Determination of fatty acid profiles of total, neutral, and polar lipids in different tissues of *Vimba vimba* (L., 1758) from Eğirdir Lake (Isparta, Turkey)

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Abstract: Fatty acid profiles of total, neutral, and polar lipids in the liver, muscle, and intestine of female individuals of *Vimba vimba* (L., 1758) were determined by gas chromatography. C16:0, C16:1 n-7, C18:1 n-7, and C18:1 n-9 were the most abundant fatty acids in total and neutral lipids in all tissues investigated. In addition to these acids, C20:4 n-6 (arachidonic acid) and C22:6 n-3 (docosahexaenoic acid) were the other fatty acids having high percentages in the polar lipid fraction of the tissues. The highest and lowest n-3 to n-6 ratios, which are a good indicator of the quality of fish oils, were determined in the muscle (1.68) and liver (0.68) in the polar lipid fraction, respectively. It was determined that the species had low levels of the n-3 forms of polyunsaturated fatty acids in the investigated tissues. For a better understanding of fatty acid metabolism of *V. vimba*, more detailed studies are required in terms of feeding experiments.

Key words: *Vimba vimba* (L., 1758), fatty acid profile, lipid fractions, liver, muscle, intestine

1. Introduction

Eicosapentaenoic acid (EPA; C20:5 n-3) and docosahexaenoic acid (DHA; C22:6 n-3) are known as n-3 forms of polyunsaturated fatty acids (PUFAs) and cannot be effectively synthesized by humans (Russo, 2009). These forms of fatty acids are produced by some algae living in aquatic environments as a result of photosynthesis (Moffat and McGill, 1993). However, fish is the main source for humans to obtain long-chain PUFAs (Cakmak et al., 2012). In clinical studies, the health-improving effects of EPA and DHA in fish tissues have been proven in human subjects in terms of cardiovascular parameters and inflammatory processes (Harris et al., 2007).

Many studies have emphasized that the fatty acid profiles of fish tissues show great variation depending on external and internal factors such as age, rations, climatic conditions, sex, water temperature, season, and reproduction period (Kiessling et al., 2001; Uysal et al., 2006; Görgün and Akpınar, 2007; Sushchik et al., 2007; Uysal et al., 2008; Kalyoncu et al., 2009; Görgün and Akpınar, 2012). Among the fatty acids in fish tissues, EPA and DHA were the primary candidates in which the most remarkable changes were observed (Szlinder-Richert et al., 2010).

The lipid classes referred to as neutral and polar fractions have different functions in organisms. Neutral lipids function as lipid depots in the energy-obtaining processes while polar lipids are structural components of the biological membranes and serve as precursors in eicosanoid production (Henderson and Tocher, 1987; Suloma and Ogata, 2012). At the same time, Cengiz et al. (2012) emphasized that estimations of the fatty acid composition of the polar and neutral fractions in fish tissues can result in important data on the determination of the nutritive value of fish. In addition, some studies determined the nutritive value of the edible portion of fish on the basis of contents (mg/g) (Gladyshev et al., 2007, 2012). This point of view is also important to understand the fish tissue in terms of human nutrition.

V. vimba is a fish species of inland waters of many countries, including Turkey (Okgerman et al., 2013). This fish species might be a potential food source for local people. It appears that there are only a limited number of studies on the fatty acid composition of the lipid fractions

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of the fish tissues from Turkish freshwater (Cengiz et al., 2012; Satar et al., 2012). One study only dealt with the muscle fatty acid composition of *V. vimba* in terms of season (Kalyoncu et al., 2009). However, there is no report on the fatty acid profiles of other tissues such as the liver and intestine or the neutral and polar lipid fractions of these tissues. For this reason, the main purpose of the present study was to determine the fatty acid profiles of total, neutral, and polar lipids in the liver, muscle, and intestine of *V. vimba.*

2. Materials and methods

2.1. Sample collection

Female individuals of *V. vimba* (L., 1758) were caught from Eğirdir Lake (Isparta, Turkey) in September. Mature female fish were sought after and exclusively used in this study. Three fish were selected for the extraction of total lipids and fatty acids. The weights and the fork lengths of the fish used during the extraction studies were 485 ± 3.27 g and 31.15 ± 0.37 cm, respectively. Three grams each of the muscle, intestine, and liver from each fish were used to obtain the total lipids from the tissues. The area underneath the dorsal fin was used for the sampling of the muscle tissue. Complete intestinal tissue covering the proximal, middle, and distal parts was thoroughly scraped and cleaned in physiological saline solution (0.9% NaCl) and washed with distilled water.

2.2. Lipid extraction and lipid class purification

The extraction of total lipids from the tissues investigated was carried out according to the method of Folch et al. (1957). A 50-µL volume of 2% butylated hydroxytoluene in chloroform was used to minimize the autoxidation of the long-chain PUFAs during the extraction procedure of each tissue (Cengiz et al., 2012). A column chromatography method using silica gel (Davisil® grade 633, pore size 60 Å, 200–425 mesh) was used to isolate polar and neutral lipid fractions (Kozlova and Khotimchenko, 2000). Briefly, equal aliquots of the total lipids in chloroform were applied to the column (8 × 1 cm). The column was first washed with 40 mL of chloroform to elute neutral lipids and then with 40 mL of methanol to elute polar lipids. The obtained solvents of total lipids and the lipid fractions of the tissues investigated were evaporated in a rotary evaporator. The saponification of the lipid samples and the subsequent derivatization to fatty acid methyl esters (FAMEs) were carried out according to Moss et al. (1974), as explained in the study of Görgün and Akpınar (2012). All steps covering the chromatographic procedures were performed in 3 replicates.

Gas chromatographic studies (3 replicates) of FAMEs in hexane/chloroform (4/1, v/v) were carried out according to the method of Guler et al. (2010) in a HP Agilent 6890N model gas chromatographer (Hewlett Packard, Palo Alto, CA, USA), fitted with an HP-88 capillary column (0.2 µm thickness, 0.25 mm ID, and 100 m length) using a flame ionization detector.

2.3. Statistical analyses

Statistical analyses of the data obtained were carried out with SPSS 15.0 (SPSS Inc., Chicago, IL, USA). A one-way analysis of variance (ANOVA) was performed to analyze the data obtained. The results in the study are expressed as mean ± standard error (SE). The comparisons between means were carried out with the Tukey test at $P \leq 0.05$.

3. Results and discussion

3.1. Fatty acid composition of total lipid

The average total lipid contents (% wet weight basis) of liver, muscle, and intestine of *V. vimba* were found to be 3.52%, 1.59%, and 2.85%, respectively. The fatty acid compositions of the total lipids in the *V. vimba* tissues investigated can be seen from Table 1. C16:0, C16:1 n-7, C18:1 n-7, and C18:1 n-9 were the most abundant fatty acids. There were quantitative differences between individual fatty acids of the tissues.

Many studies from the fish living in freshwater systems revealed that C16:0 and C18:0 were the main components of the saturated fatty acids (SFAs) (Uysal et al., 2006; Guler et al., 2007; Cakmak et al., 2012; Görgün and Akpınar, 2012). The present study also found C16:0 and C18:0 to be the primary fatty acids of SFAs in the *V. vimba* tissues. It was found that C16:0 values ranging from 25.58% (liver) to 20.37% (muscle) were higher than C18:0 values changing between 6.37% (liver) and 3.04% (muscle). The highest and lowest levels of SFAs were determined in the intestine (36.50%) and muscle (28.17%), respectively.

Monounsaturated fatty acids (MUFAs), the most dominant fatty acid class of the tissues of *V. vimba*, were 52.22% in the liver, 50.07% in muscle, and 42.77% in the intestine. C18:1 n-9 had the highest levels in all tissues investigated and varied between 37.98% (liver) and 23.65% (intestine) ($P \leq 0.05$). C16:1 n-7 was the second dominant fatty acid of the MUFAs with statistical differences in the tissues ($P \leq 0.05$). C18:1 n-7 levels varied between 4.73% (liver) and 5.98% (intestine). Rahnan et al. (1995) and Uysal et al. (2008) revealed that MUFA concentrations in freshwater fish were higher than the proportions of PUFAs and SFAs and that C18:1 n-9 was the major component of the MUFA fraction. Kalyoncu et al. (2009) reported similar results in the muscle of *V. vimba*, in which MUFA levels were found to be higher than PUFAs and SFAs in all seasons investigated. At the same time, Cakmak et al. (2012) emphasized that *V. vimba* was a fish species rich in MUFAs when compared to fish species such as *Sander lucioperca*, *Capoeta capoeta*, and *Pseudophoxinus anatolicus*. The data obtained in the present study on the MUFA levels in different tissues of *V. vimba* seem

Table 1. Fatty acid composition of the total lipids in the liver, muscle, and intestine of *V. vimba* (%)[A].

Fatty acids	Liver Mean ± SE	Muscle Mean ± SE	Intestine Mean ± SE
C 8:0	0.01 ± 0.00a[B]	0.02 ± 0.00a	0.01 ± 0.00a
C 10:0	0.01 ± 0.00a	0.01 ± 0.00a	0.01 ± 0.00a
C 11:0	0.01 ± 0.00a	0.01 ± 0.00a	0.02 ± 0.00a
C 12:0	0.10 ± 0.03a	0.30 ± 0.06b	0.97 ± 0.11c
C 13:0	0.03 ± 0.00a	0.11 ± 0.02b	0.41 ± 0.06c
C 14:0	2.49 ± 0.07a	2.27 ± 0.10a	3.48 ± 0.22b
C 15:0	0.30 ± 0.05a	0.68 ± 0.14b	1.28 ± 0.20c
C 16:0	25.58 ± 0.46a	20.37 ± 0.19b	22.83 ± 0.37c
C 17:0	0.49 ± 0.05a	0.58 ± 0.11a	1.43 ± 0.20b
C 18:0	6.37 ± 0.31a	3.04 ± 0.11b	5.07 ± 0.23c
C 19:0	0.31 ± 0.06ab	0.20 ± 0.01a	0.43 ± 0.04b
C 20:0	0.04 ± 0.00a	0.04 ± 0.00a	0.07 ± 0.01a
C 21:0	0.08 ± 0.02a	0.47 ± 0.09b	0.38 ± 0.05b
C 22:0	0.04 ± 0.00a	0.05 ± 0.01a	0.08 ± 0.01a
C 24:0	0.01 ± 0.00a	0.02 ± 0.00a	0.03 ± 0.00a
Σ SFA	**35.87 ± 0.54a**	**28.17 ± 0.27b**	**36.50 ± 0.33a**
C 14:1 n-5	0.11 ± 0.02a	0.17 ± 0.03a	0.15 ± 0.02a
C 15:1 n-5	0.24 ± 0.04	0.34 ± 0.05	0.53 ± 0.09
C 16:1 n-7	8.77 ± 0.28a	14.55 ± 0.49b	12.00 ± 0.33c
C 17:1 n-8	0.18 ± 0.03a	0.08 ± 0.01b	0.17 ± 0.02a
C 18:1 n-9	37.98 ± 1.02a	29.51 ± 0.77b	23.65 ± 0.44c
C 18:1 n-7	4.73 ± 0.23a	5.12 ± 0.19b	5.98 ± 0.27c
C 20:1 n-9	0.17 ± 0.04a	0.25 ± 0.10a	0.23 ± 0.06a
C 22:1 n-9	0.03 ± 0.00a	0.03 ± 0.00a	0.04 ± 0.00a
C 24:1 n-9	0.01 ± 0.00a	0.02 ± 0.00a	0.02 ± 0.00a
Σ MUFA	**52.22 ± 0.36a**	**50.07 ± 0.35a**	**42.77 ± 0.22b**
C 18:2 n-6	0.94 ± 0.09a	2.80 ± 0.22b	2.76 ± 0.17b
C 18:3 n-6	0.10 ± 0.02a	0.19 ± 0.02b	0.26 ± 0.08b
C 20:2 n-6	0.08 ± 0.02a	0.17 ± 0.04b	0.28 ± 0.07c
C 20:3 n-6	0.32 ± 0.09a	0.42 ± 0.06b	0.44 ± 0.12b
C 20:4 n-6	2.62 ± 0.17a	4.04 ± 0.25b	4.18 ± 0.20b
C 22:2 n-6	0.05 ± 0.01a	0.12 ± 0.02a	0.12 ± 0.01a
C 22:4 n-6	0.02 ± 0.00a	0.04 ± 0.01a	0.06 ± 0.00a
C 22:5 n-6	0.47 ± 0.11a	0.72 ± 0.05b	1.88 ± 0.19c
Σ n-6 PUFA	**4.60 ± 0.13a**	**8.50 ± 0.19b**	**9.98 ± 0.27c**
C 18:3 n-3	1.94 ± 0.16a	1.20 ± 0.08b	0.84 ± 0.12c
C 20:3 n-3	0.15 ± 0.03a	0.33 ± 0.04b	0.27 ± 0.02b
C 20:5 n-3	1.20 ± 0.18a	4.90 ± 0.33b	4.27 ± 0.25
C 22:3 n-3	0.21 ± 0.04a	0.63 ± 0.10b	1.20 ± 0.21c
C 22:5 n-3	0.54 ± 0.04a	1.61 ± 0.14b	1.88 ± 0.22b
C 22:6 n-3	3.27 ± 0.19a	4.55 ± 0.13b	2.27 ± 0.15c
Σ n-3 PUFA	**7.31 ± 0.15a**	**13.22 ± 0.21b**	**10.73 ± 0.19c**
Σ PUFA	**11.91 ± 0.17a**	**21.72 ± 0.23b**	**20.71 ± 0.27b**
n-3/n-6	**1.59**	**1.56**	**1.08**

[A]: Average of 3 lots analyzed, [B](a-b-c-d): values for samples with different letters in the same fraction are significantly different at $P \leq 0.05$. Σ SFA = total saturated fatty acid, Σ MUFA = total monounsaturated fatty acid, Σ n-6 PUFA = total n-6 polyunsaturated fatty acid, Σ n-3 PUFA = total n-3 polyunsaturated fatty acid, and Σ PUFA= total polyunsaturated fatty acid.

compatible with these studies. From this point of view, it appears that high MUFA levels might be a characteristic feature of the fatty acid metabolism of *V. vimba*.

In the present study, C20:4 n-6 (arachidonic acid, ARA) was the major constituent of the n-6 PUFAs. The lowest and highest levels of ARA were determined in the liver (2.62%) and intestine (4.18), respectively. EPA levels of the muscle (4.90%) and intestine (4.27%) were higher than determined for the liver (1.20%). The highest level (4.55%) of C22:6 n-3 (DHA) was determined in the muscle tissue, as in the case of EPA. Total PUFA levels were found to be higher in the muscle (21.72%) and intestine (20.71%) than in the liver (11.91%). It has been emphasized that the n-3/n-6 ratios of fish tissues are a good indicator of the quality of the fish oils (Piggot and Tucker, 1990). In this study, the n-3/n-6 ratios were 1.59, 1.56, and 1.08 for the liver, muscle, and intestine, respectively. Considering other marine and freshwater species, we observe, for example, that Özogul et al. (2007), Guler et al. (2007), and Donmez (2009) reported higher n-3/n-6 ratios than those determined for the tissues of *V. vimba*. By considering all of these results, *V. vimba* seems to be a fish species poor in terms of the n-6 and n-3 forms of PUFAs.

3.2. Fatty acid composition of neutral and polar lipid fractions

The fatty acid compositions of the neutral and polar lipid fractions of the liver, muscle, and intestine of *V. vimba* are given in Tables 2 and 3, respectively.

C16:0 was the main fatty acid of the SFA fraction of neutral lipids (NLs) and polar lipids (PLs) in all tissues investigated. There were statistical differences between the tissues in terms of C16:0 levels. In the NL fraction, the percentage of this acid was the highest in the liver (40.10%). In the PL fraction, the level of C16:0 was the highest in the intestine at 31.50%. The second fatty acid with a high percentage among SFAs in both the NL and the PL fractions was C18:0. Muscle tissue showed the lowest levels of SFAs in both the NL (27.90%) and the PL (33.70%) fractions, when compared to that of the liver (53.77% in the NLs and 44.25% in the PLs) and intestine (34.02% in the NLs and 54.22 in the PLs) of *V. vimba*. One study found that C16:0 and C18:0 were the main fatty acids of SFAs in the NLs and the PLs (Kozlova and Khotimchenko, 2000). In the PL fraction, C18:1 n-9 levels (the main acid of MUFAs in NLs and PLs) of the muscle (11.12%) and intestine (11.87%) did not show any statistical differences ($P \geq 0.05$), while the liver had the highest percentage (21.26%). When compared to the PL fraction, it was found that the NL fraction had higher levels of C18:1 n-9 in all tissues ($P \leq 0.05$). C16:1 n-7 and C18:1 n-7 were the other fatty acids having substantial levels in MUFAs in the NL and PL fractions. Similar results were reported in the studies of Desvilettes et al. (1997) and Satar et al. (2012).

In the muscle and intestinal tissues of the present study, it was found that MUFAs levels were higher in the NL fraction with respect to the PL fraction. In the liver, however, MUFA levels were quite similar (38.71% and 32.32%) in the NL and PL fractions, respectively. According to Kozlova and Khotimchenko (2000), the MUFA levels were the most dominant group and PUFAs were the lowest in the NL fraction of *Comephorus baicalensis*, which can be a possible result of the accumulation of depot lipids in the form of monoene and saturated fatty acids. In this context, the data obtained in the present study exhibit remarkable similarities with the results from different fish species.

In the NL fraction and among n-6 PUFAs in all tissues, C20:4 n-6 (ARA) was found to be the first in percentage, with C18:2 n-6 (LA, linoleic acid) as the second (Table 2). The PL fraction also showed a similar pattern with great quantitative differences. The highest level of LA in the PLs was determined for the liver at 5.47%. LA levels in the muscle and intestine were found to be 1.28% and 1.22%, respectively. However, these values were not different in the statistical analyses ($P \geq 0.05$). ARA levels of PLs were determined to be 5.72% in liver, 12.11% in the muscle, and 6.15% in the intestine. These data might be explained by taking into account that PLs are the main structural components of biological membranes and substantial amounts of ARA are deposited in the membranes (Tocher et al., 2008). In the NL fraction, EPA was found in good percentages in the muscle (4.65%) and intestine (4.43%) ($P \geq 0.05$). In the PL fraction, the levels of this acid ranged from 7.12% (muscle) to 0.94% (liver). The highest percentage of C22:6 n-3 (DHA) in the NLs was determined for the muscle at 3.50%. However, higher levels of DHA were determined in the PLs of the liver (5.67%), muscle (17.37%), and intestine (4.35%). High levels of DHA in the PLs can be explained by considering that PLs are the main resources used by fish to adapt to environmental changes by ensuring constant fluidity of the biological membranes, and one of the strongest candidates for this purpose is specifically DHA (Uysal et al., 2008). The n-3/n-6 ratios in the NLs were determined to be 1.33 in the liver, 1.56 in the muscle, and 1.25 in the intestine. These ratios were determined in the PLs as 0.68, 1.68, and 1.16 for the liver, muscle, and intestine, respectively.

This study has revealed the fatty acid composition of total, neutral, and polar lipids in the different tissues of *V. vimba*. The results of the present study showed that different tissues of *V. vimba* had substantial quantitative differences in terms of fatty acid percentages in total lipids and lipid fractions. The most important data obtained in this study revealed that *V. vimba* had high levels of MUFAs as unsaturated fatty acids in the tissues investigated and was a fish species poor in terms of PUFAs. However, muscle

Table 2. Fatty acid composition of neutral lipids in the liver, muscle, and intestine of *V. vimba* (%)*.

Fatty acids	Liver Mean ± SE	Muscle Mean ± SE	Intestine Mean ± SE
C 8:0	0.02 ± 0.00a	0.01 ± 0.00a	0.01 ± 0.00a
C 10:0	0.01 ± 0.00a	0.01 ± 0.00a	0.01 ± 0.00a
C 11:0	0.02 ± 0.00a	0.01 ± 0.00a	0.01 ± 0.00a
C 12:0	0.12 ± 0.01a	0.33 ± 0.07b	0.93 ± 0.21c
C 13:0	0.02 ± 0.00a	0.12 ± 0.02b	0.38 ± 0.06c
C 14:0	1.95 ± 0.17a	2.50 ± 0.20b	3.35 ± 0.26c
C 15:0	0.27 ± 0.03a	0.63 ± 0.07b	0.24 ± 0.09a
C 16:0	40.10 ± 0.87a	20.31 ± 0.57b	22.14 ± 0.60c
C 17:0	0.66 ± 0.10a	0.51 ± 0.07b	1.36 ± 0.13c
C 18:0	10.13 ± 0.59a	2.60 ± 0.27b	4.86 ± 0.33c
C 19:0	0.23 ± 0.02a	0.21 ± 0.06a	0.15 ± 0.03b
C 20:0	0.03 ± 0.00a	0.06 ± 0.01a	0.09 ± 0.02a
C 21:0	0.15 ± 0.04a	0.50 ± 0.08b	0.40 ± 0.05c
C 22:0	0.03 ± 0.00a	0.09 ± 0.02a	0.06 ± 0.01a
C 24:0	0.03 ± 0.00a	0.01 ± 0.00a	0.03 ± 0.00a
Σ SFA	**53.77 ± 0.50a**	**27.90 ± 0.17b**	**34.02 ± 0.23c**
C 14:1 n-5	0.10 ± 0.01a	0.16 ± 0.03b	0.24 ± 0.03c
C 15:1 n-5	0.17 ± 0.04a	0.37 ± 0.10b	0.52 ± 0.13c
C 16:1 n-7	6.35 ± 0.28a	15.70 ± 0.48b	12.64 ± 0.36c
C 17:1 n-8	0.13 ± 0.02a	0.26 ± 0.08b	0.16 ± 0.04a
C 18:1 n-9	28.30 ± 0.51a	30.56 ± 0.62b	25.64 ± 0.49c
C 18:1 n-7	3.47 ± 0.16a	5.28 ± 0.31b	6.15 ± 0.37c
C 20:1 n-9	0.08 ± 0.01a	0.24 ± 0.05b	0.24 ± 0.11a
C 22:1 n-9	0.02 ± 0.00a	0.14 ± 0.02b	0.03 ± 0.00a
C 24:1 n-9	0.09 ± 0.02a	0.11 ± 0.03a	0.01 ± 0.00b
Σ MUFA	**38.71 ± 0.44a**	**52.82 ± 0.21b**	**45.63 ± 0.24c**
C 18:2 n-6	1.12 ± 0.13a	2.85 ± 0.23b	2.89 ± 0.17b
C 18:3 n-6	0.07 ± 0.01a	0.20 ± 0.03b	0.27 ± 0.06b
C 20:2 n-6	0.09 ± 0.02a	0.13 ± 0.04a	0.27 ± 0.09b
C 20:3 n-6	0.19 ± 0.05a	0.38 ± 0.07b	0.47 ± 0.10c
C 20:4 n-6	1.43 ± 0.12a	3.24 ± 0.22b	4.12 ± 0.19c
C 22:2 n-6	0.04 ± 0.00a	0.15 ± 0.03b	0.19 ± 0.03b
C 22:4 n-6	0.09 ± 0.01a	0.01 ± 0.00b	0.03 ± 0.00c
C 22:5 n-6	0.19 ± 0.04a	0.55 ± 0.08b	0.43 ± 0.13c
Σ n-6 PUFA	**3.22 ± 0.18a**	**7.51 ± 0.14b**	**8.67 ± 0.11c**
C 18:3 n-3	1.42 ± 0.14a	1.23 ± 0.10b	0.94 ± 0.18c
C 20:3 n-3	0.13 ± 0.02a	0.35 ± 0.07b	0.29 ± 0.11b
C 20:5 n-3	0.76 ± 0.03a	4.65 ± 0.33b	4.43 ± 0.20b
C 22:3 n-3	0.12 ± 0.02a	0.52 ± 0.13b	1.06 ± 0.14c
C 22:5 n-3	0.30 ± 0.04a	1.48 ± 0.16b	1.96 ± 0.20c
C 22:6 n-3	1.56 ± 0.14a	3.50 ± 0.21b	2.17 ± 0.11c
Σ n-3 PUFA	**4.29 ± 0.11a**	**11.73 ± 0.15b**	**10.85 ± 0.17c**
Σ PUFA	**7.51 ± 0.10a**	**19.24 ± 0.30b**	**19.52 ± 0.27b**
n-3/n-6	**1.33**	**1.56**	**1.25**

*: Explanations are given under Table 1.

Table 3. Fatty acid composition of polar lipids in the liver, muscle, and intestine of *V. vimba* (%)*.

Fatty acids	Liver Mean ± SE	Muscle Mean ± SE	Intestine Mean ± SE
C 8:0	0.02 ± 0.00a	0.04 ± 0.01a	0.03 ± 0.00a
C 10:0	0.05 ± 0.00a	0.23 ± 0.04b	0.11 ± 0.03c
C 11:0	0.20 ± 0.03a	0.33 ± 0.05b	0.28 ± 0.06ab
C 12:0	0.83 ± 0.09a	0.17 ± 0.02b	0.84 ± 0.07a
C 13:0	0.15 ± 0.03a	0.15 ± 0.01a	0.36 ± 0.07b
C 14:0	2.33 ± 0.21a	1.08 ± 0.15b	3.58 ± 0.26c
C 15:0	0.54 ± 0.10a	1.66 ± 0.18b	2.70 ± 0.27c
C 16:0	27.72 ± 0.71a	17.85 ± 0.58b	31.50 ± 0.81c
C 17:0	0.74 ± 0.09a	0.94 ± 0.16a	2.73 ± 0.22b
C 18:0	11.01 ± 0.34ab	10.74 ± 0.41b	11.21 ± 0.28a
C 19:0	0.09 ± 0.02a	0.21 ± 0.06b	0.13 ± 0.04a
C 20:0	0.03 ± 0.00a	0.02 ± 0.00a	0.09 ± 0.02b
C 21:0	0.15 ± 0.04ab	0.10 ± 0.02b	0.23 ± 0.06a
C 22:0	0.33 ± 0.07a	0.12 ± 0.02b	0.37 ± 0.04a
C 24:0	0.06 ± 0.01a	0.06 ± 0.01a	0.06 ± 0.02a
Σ SFA	**44.25 ± 0.43a**	**33.70 ± 0.41b**	**54.22 ± 0.37c**
C 14:1 n-5	0.44 ± 0.05a	0.55 ± 0.09a	1.18 ± 0.22b
C 15:1 n-5	0.24 ± 0.08a	0.29 ± 0.06a	1.34 ± 0.27b
C 16:1 n-7	6.61 ± 0.44a	3.23 ± 0.19b	5.79 ± 0.38c
C 17:1 n-8	0.22 ± 0.03a	0.45 ± 0.06b	0.28 ± 0.09a
C 18:1 n-9	21.26 ± 0.53a	11.12 ± 0.37b	11.87 ± 0.39b
C 18:1 n-7	3.25 ± 0.24a	2.60 ± 0.21b	4.26 ± 0.31c
C 20:1 n-9	0.14 ± 0.03a	0.09 ± 0.01a	0.17 ± 0.03a
C 22:1 n-9	0.03 ± 0.00a	0.06 ± 0.01a	0.08 ± 0.01a
C 24:1 n-9	0.13 ± 0.02a	0.16 ± 0.01a	0.03 ± 0.00a
Σ MUFA	**32.32 ± 0.27a**	**18.55 ± 0.24b**	**25.00 ± 0.22c**
C 18:2 n-6	5.47 ± 0.41a	1.28 ± 0.33b	1.22 ± 0.10b
C 18:3 n-6	0.07 ± 0.01a	0.07 ± 0.00a	0.07 ± 0.00a
C 20:2 n-6	0.55 ± 0.11a	0.51 ± 0.07a	0.18 ± 0.03b
C 20:3 n-6	0.21 ± 0.04a	0.19 ± 0.02a	0.17 ± 0.02a
C 20:4 n-6	5.72 ± 0.26a	12.11 ± 0.66b	6.15 ± 0.50c
C 22:2 n-6	0.04 ± 0.01a	0.13 ± 0.02a	0.14 ± 0.01a
C 22:4 n-6	0.57 ± 0.10a	0.93 ± 0.21b	0.80 ± 0.15ab
C 22:5 n-6	1.17 ± 0.09a	2.39 ± 0.27b	0.78 ± 0.19a
Σ n-6 PUFA	**13.80 ± 0.31a**	**17.61 ± 0.20b**	**9.51 ± 0.28c**
C 18:3 n-3	1.28 ± 0.22a	0.60 ± 0.07b	0.77 ± 0.11b
C 20:3 n-3	0.21 ± 0.02a	0.19 ± 0.02a	0.23 ± 0.04a
C 20:5 n-3	0.94 ± 0.13a	7.12 ± 0.41b	2.45 ± 0.28c
C 22:3 n-3	0.64 ± 0.07a	1.53 ± 0.16b	1.78 ± 0.24b
C 22:5 n-3	0.71 ± 0.11a	2.74 ± 0.25b	1.45 ± 0.18c
C 22:6 n-3	5.67 ± 0.24a	17.37 ± 0.59b	4.35 ± 0.33c
Σ n-3 PUFA	**9.45 ± 0.14**	**29.55 ± 0.36**	**11.03 ± 0.17**
Σ PUFA	**23.25 ± 0.22**	**47.16 ± 0.33**	**20.54 ± 0.21**
n-3/n-6	**0.68**	**1.68**	**1.16**

*: Explanations are given under Table 1.

tissue, the main edible part of fish tissue for humans, had higher levels of PUFAs than the liver and the intestine in the polar lipids. In both the neutral and total lipids, PUFAs are more abundant in muscle than in the liver and have similar amounts in muscle and the intestine. All of the data reported here might be the result of fatty acid metabolism. More studies are required in terms of feeding characterization of this species for a better understanding of the complex nature of the metabolism.

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