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Spectrum of Fatty Acids for Different Morpho-Ecological Groups of Baikal Omul *Coregonus autumnalis migratorius*(Georgi, 1775)

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Abstract

Fatty acid content in muscular tissue and liver of three morpho-ecological groups of the Baikal omul was determined for the first time. Among total lipids in all the fish individuals studied, prevailing groups are presented by polyunsaturated (38.5–53.8 % of the total acid content) and saturated (31.8–36.5 %) fatty acids. Polyunsaturated acids are presented mainly by 22:6(n-3) and 20:5(n-3), their sum varies within the range of 16.8–33.3 %. The lipids of muscles contain a high fraction of polyunsaturated fatty acids at the expense of docosahexaenic acid (13.28–24.66 %). No considerable differences were revealed between different morpho-ecological groups of omul concerning the composition of fatty acids of lipids. Due to a moderate total fat content (6.37–7.65 %) and a balanced polyunsaturated fatty acid n-3/n-6 ratio in muscular tissue, the Baikal omul may be considered a high-quality dietetic foods as well as a raw material for obtaining biologically active supplements.

Key words: polyunsaturated fatty acids, morpho-ecological groups, Baikal omul

INTRODUCTION

For the last time, the studies on biochemical composition of fishes are paid with steadfast attention in connection with the development of aqua- and mariculture industrial complexes [1]. One of important biochemical components and key factors determining the growth and controlling the quality of the biomass of living organisms is represented by ω-3 (n-3) polyunsaturated fatty acids (PUFA) [2].

In the dietary intake of contemporary humans the main place is occupied by fats of terraneous mammals containing ω-6 (n-6) PUFA, however, the consumption of n-3 PUFA by the population is insufficient even in developed countries. In this connection, for planning actions aimed at the rational use of fish resources of fresh-water and sea ecosystems one should have data concerning the content of fatty acids (FA) in fishes [3]. All this determines the importance of carrying out biochemical investigations concerning Baikal fishes not only from the standpoint of studying ecology and systematization, but also for revealing their nutritional value.

The omul (Fig. 1) is the main food fish of the Baikal Lake, whose annual take ranges from 2–3 up to 9 thousand tons [4, 5]. The Baikal omul is presented by three morpho-ecological groups (MEG) of populations and subpopulations such as pelagic, coastal pelagic and near-bottom abyssal MEG [6–8], represent an actively migrating species with complex food strategy. According to the estimation of annu-

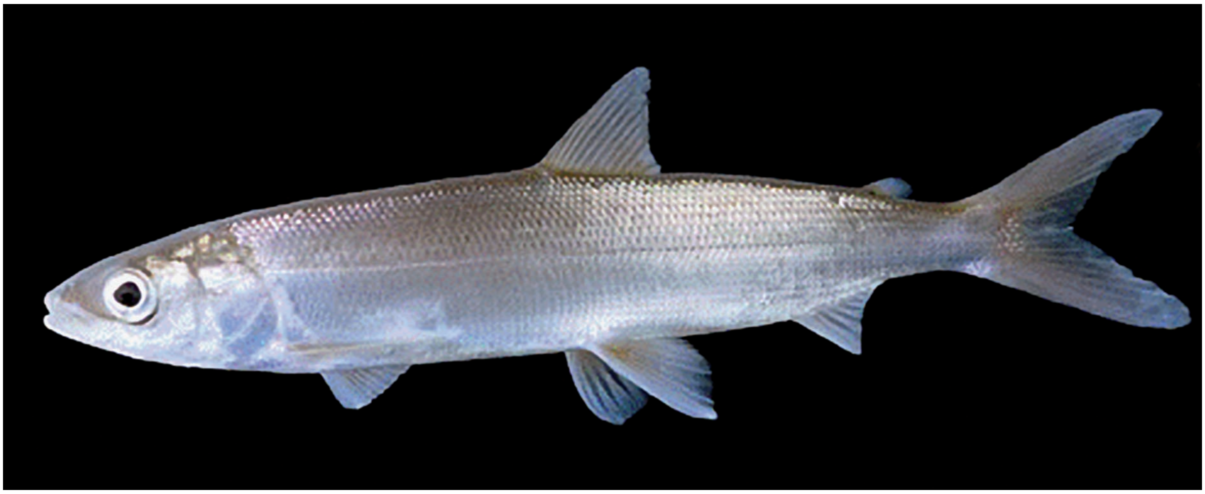

Fig. 1. Baikal omul *Coregonus autumnalis migratorius* (photo by S. I. Didorenko).

al dietary intake inherent in the omul belonging to different MEG, the main fodder organisms of the pelagic omul represent zooplankton (41 % in the annual dietary intake), the young of pelagic amphipoda macrohectopus (23 %), the young and larvae of the Baikal oilfish. The near-bottom abyssal omul eats mainly large macrohectopus (52 %), the young of the Baikal oilfish and goby (Comephoridae, Gobiidae) fishes (25 %) and bottom-dwelling amphipoda (12 %). The omul of coastal pelagic MEG equally eats both zooplankton (23 %), and larger organisms (macrohectopus – 34 %, the young of goby-like fishes – 26 %) [9, 10].

A number of works [11–16] are devoted to studies on the biochemical composition of Baikal fishes; however the Baikal omul is insufficiently explored from this standpoint. The investigations carried out earlier resulted in characterizing the content of moisture, lipids, proteins, carbohydrates, vitamin A, mineral substances and caloricity for the Baikal omul [12.] The quantitative content and fractional composition of lipids was determined only for the near-bottom abyssal omul [11].

In the studies carried out earlier, the biochemical analysis of fishes was performed with the use of classical methods of lipidology, however with no taking into account intraspecies structure of the Baikal omul. In this connection, the purpose of the present work consisted in determining the spectrum of fatty acids in muscles and liver of the Baikal omul belonging to different MEG within the period their maximal divergence with respect to food niches.

EXPERIMENTAL

As the object of investigations, we selected 96 specimens of the Baikal omul, caught in the course of expeditions performed within the period from September, 30 to October 9, 2006 in the Chivyrkuy gulf of the Baikal Lake. The fishes were caught by means of gill net (14–24 mm mesh) and fishhook tackle. In order to determine the belonging of each individual to either MEG we used the system of morphological attributes [7]: 1) the amount of gill rakers; 2) the relative length of head; 3) the height of caudal peduncle; 4) the height of head neat the nape.

Fishes were prepared immediately after catching, muscles and liver were fixed using a chloroform/methanol mixture at a ratio of 1 : 2. Females and males were analyzed separately. The quantitative determination of overall lipids was carried out according to Bligh and Dyer method [17, 18].

Methyl esters of fatty acids (MEFA) from overall lipid extracts were obtained using Carreau and Dubacq method [19], then they were purified from impurities using the method of thin layer chromatography, with benzene as the eluent. The determination of MEFA was carried out using a Shimadzu GC-17A gas chromatograph equipped with a Supelcowax-10 column. Helium was used as the carrier gas. The

TABLE 1

Content of total lipids in muscles and liver of the Baikal omul belonging to different morpho-ecological groups (MEG), % of crude mass

MEGs	Muscles		Liver	
	Males	Females	Males	Females
Coastal	6.38±0.43	6.37±0.26	9.50±0.16	8.41±0.27
Pelagic	7.65±0.38	7.07±0.31	10.64±0.38	9.97±0.22
Near-bottom abyssal	7.42±0.65	6.98±0.54	9.89±0.43	9.93±0.56

identification of MEFA peaks on chromatographic profiles was carried out by comparing with the retention time values for standards and by calculating the equivalent chain length indices [20, 21].

RESULTS AND DISCUSSION

Taking into account the content of lipids in muscles and liver, the Baikal omul belongs to moderately fatty fish species. The content of total lipids in muscles amounts to 6.37–7.65 %, that in liver ranges within 8.41–10.64 %. Fishes belonging to pelagic and near-bottom abyssal MEG appeared the most "fatty" ones (Table 1).

Investigations carried out earlier demonstrated, that the total content of lipids in the Baikal omul tissues can range from 3.8 to 9.9 %, whereas for the homogenates of male and female fishes it is this value is different. So, the content of lipids in the tissues of males is higher as compared to the content in the tissues females, amounting to 4.40–5.39 and 3.63–4.88 %, respectively [12–14].

Studies on the lipid composition of the Baikal omul liver and muscles carried out earlier allowed one to reveal the presence of the following fractions: sterol esters, triglycerides, nonesterifyed fatty acids, diglycerides, cholesterol, monoglycerides and phosholipids [11].

The investigation of FA spectrum for the Baikal omul demonstrated that the qualitative composition of FA inherent in the muscles of fishes belonging to all the MEG does not depend on their sexual belonging (see Table 1).

Our analysis of the Baikal omul resulted in the identification of more than 36 fatty acids (Table 2).

A high content of docosahexaenoic acid (DHA) as against eucosapentaenoic acid (EPA) is inherent in the Baikal omul (Table 3). In this case, the content of DHA in omul is 2–4 times higher than the content in other fresh-water and sea fish species [2, 22].

For the near-bottom abyssal MEG of the Baikal omul we revealed an increase in the content of PUFA, especially EPA and DHA, as compared to the samples belonging to the pelagic MEG. The increased content of EPA could be caused by its accumulation in the course of eating amphipods by the omul, since a high content of this fatty acid is inherent in amphipods (for example, such Baikal amphipod species as *Brantia parasitica* and *Eulimnogammarus cyaneus*, exhibit the acid content equal to 4.5 and 12.3 %, respectively). The content of DHA in amphipods ranges from 3.1 to 4.9 %. However, the amphipod species under investigation were not revealed in the food spectrum of fishes, whereas there is), unfortunately, no literature data available concerning the biochemical characteristics of the basic fodder objects of the Baikal omul (epischura and macrohectopus.). Only overall parameters concerning the fat content are known for these organisms, those for the epischura can range from 2.2 to 6.3 %, whereas for the macrohectopus this value ranges from 1.0 to 2.7 % [13]. In this connection, the issue concerning the dynamics of quantitative parameters for this group of acids in the Baikal omul as well as concerning the mechanisms of their accumulation is remaining open.

In the tissues of the Baikal omul from all the MEGs there is a high percentage of saturated myristic (2.26–9.55 %), palmitic (19.02–24.67 %) and stearic (2.91–3.98 %) fatty acids observed. Among unsaturated monoene acids, there are palmitoleic (3.04–8.76 %) and oleic (9.17–12.64 %) acids prevailing.

TABLE 2

Spectrum of fatty acids from total lipids in the Baikal omul muscles and liver of different MEG

Fatty acids	Near-bottom abyssal				Pelagic				Coastal	
	Females		Males		Females		Males		Males	
	Muscles	Liver	Muscles	Liver	Muscles	Liver	Muscles	Liver	Muscles	Liver
					Saturated fatty acids					
>14:0	–	0.40	–	0.20	–	0.37	–	–	0.41	–
14:0	2.26	7.68	6.78	7.31	3.11	7.52	4.16	2.55	9.55	7.05
15:0-iso	0.26	1.04	0.30	0.30	0.30	1.04	0.40	0.31	0.41	0.34
15:0-ai	–	–	0.47	0.51	–	–	0.13	–	–	–
15:0	0.54	0.68	0.72	0.75	0.69	0.69	0.74	0.62	0.80	0.58
16:0-iso	0.10	0.12	0.11	0.11	0.10	0.12	0.11	–	0.13	0.15
16:0	24.67	19.46	20.45	21.10	22.52	19.85	20.89	21.95	19.69	19.30
17:0-iso	0.35	0.31	0.28	0.26	0.29	0.33	0.27	0.34	–	–
17:0-ai	0.39	0.45	0.36	0.37	–	0.45	0.42	0.45	0.49	0.28
17:0	0.57	1.63	1.96	2.00	0.39	1.81	0.89	0.56	1.85	0.35
18:0-iso	0.28	0.38	0.40	0.46	0.33	0.42	0.30	0.31	0.42	0.27
18:0	2.91	3.45	3.22	3.17	3.51	3.51	3.17	3.19	3.13	3.20
					Monounsaturated fatty acids					
14:1	–	0.20	1.02	1.18	–	0.20	–	–	1.29	0.19
16:1(n-9)	–	0.77	1.06	1.05	–	–	0.46	–	0.95	0.46
16:1(n-7)	3.68	7.13	7.17	7.51	3.90	8.06	3.53	3.99	7.83	4.03
16:1(n-5)	0.29	0.47	0.51	0.55	0.43	0.46	0.50	0.68	0.50	0.29
18:1(n-9)	10.01	10.80	10.40	10.37	10.54	11.10	6.65	10.38	9.17	9.72
18:1(n-7)	2.54	2.75	2.37	2.32	2.67	2.72	2.14	2.71	2.49	2.94
18:1(n-6)	0.26	0.17	0.13	0.11	0.19	0.17	0.19	0.21	0.12	0.21
20:1(n-11)	–	0.44	–	0.24	–	0.45	–	–	0.41	–
20:1(n-9)	0.22	–	0.25	–	0.23	0.10	0.15	0.36	–	–
20:1(n-7)	0.10	–	–	–	–	–	0.42	–	0.10	–
22:1(n-9)	–	0.12	–	–	–	0.11	–	–	0.11	–
					Polyunsaturated fatty acids					
16:2(n-6)	–	0.27	0.30	0.30	–	0.29	–	–	0.31	–
16:2	0.31	0.45	–	–	–	0.32	0.34	0.23	0.68	–
16:3(n-3)	0.34	0.34	0.25	0.43	0.37	0.38	0.31	0.35	0.31	0.28
16:3(n-1)	–	0.18	–	–	–	0.20	–	–	0.21	–
16:4(n-3)	0.14	0.13	0.13	0.14	0.21	0.16	0.28	0.23	0.15	0.17
16:4(n-1)	–	0.15	0.18	0.19	–	0.15	–	–	0.18	–
18:2(n-6)	2.99	4.67	4.40	4.38	3.14	4.81	3.22	2.63	4.71	3.09
18:3(n-6)	0.30	0.27	0.53	0.33	0.31	0.28	0.37	0.38	0.32	0.25
18:3(n-3)	2.60	3.62	3.53	3.51	2.27	3.69	2.85	1.79	3.93	2.14
18:4(n-3)	–	–	–	–	–	–	0.11	–	–	–
18:4(n-1)	0.93	2.55	2.70	2.71	0.79	2.61	1.51	0.62	3.09	–
20:2(n-6)	0.59	0.40	0.30	0.28	0.51	0.41	–	0.62	0.34	0.39
20:3(n-6)	–	0.28	0.19	0.19	0.13	0.26	0.11	0.32	0.16	0.10
20:4(n-6)	6.26	2.27	3.07	2.96	7.25	2.27	6.77	7.85	2.06	6.22
20:3(n-3)	0.35	0.22	0.19	0.18	0.27	0.22	0.24	0.30	0.17	0.19
20:4(n-3)	0.71	0.73	0.91	0.86	0.62	0.73	0.88	0.69	0.82	0.79
20:5(n-3)	8.81	4.28	5.54	5.34	6.97	4.31	9.78	8.39	4.12	5.38
22:3(n-6)	–	0.15	0.12	0.13	–	0.19	0.18	–	0.16	–
22:4(n-6)	0.12	0.24	0.29	0.24	–	0.26	0.21	–	0.23	–
22:5(n-6)	1.27	1.42	1.45	1.36	1.54	1.40	1.40	1.74	1.54	1.65
22:5(n-3)	1.03	1.34	1.37	1.29	1.39	1.33	1.54	1.20	1.03	1.46
24:1	–	0.27	–	–	–	0.28	0.20	–	–	–
22:6(n-3)	23.36	14.26	15.48	14.80	24.66	13.97	23.53	24.13	13.28	17.18

TABLE 3

Fatty acid group content for total lipids from tissues of the Baikal omul of different MEG, % of total fatty acids

Fatty	Pelagic				Near-bottom abyssal				Coastal	
acid	Females ($n = 5$)		Males ($n = 7$)		Females ($n = 5$)		Males ($n = 8$)		Males ($n = 3$)	
groups	Muscles	Liver	Muscles	Liver	Muscles	Liver	Muscles	Liver	Muscles	Liver
HFA	31.23	36.12	36.46	34.93	35.62	32.34	35.05	36.53	37.22	31.52
MHFA	17.96	23.38	14.03	18.33	22.85	17.10	22.90	23.32	22.97	17.84
PUFA	50.43	38.52	53.83	51.49	38.48	50.12	40.93	39.61	37.80	26.36
EPA + DHA	31.63	18.28	33.31	32.52	18.53	32.17	21.02	20.13	24.29	28.15
Σn-3	24.80	36.76	23.81	39.51	24.92	37.09	27.39	26.54	38.57	26.90
Σn-6	10.33	13.07	9.96	12.46	10.14	13.75	10.79	10.28	9.71	11.94
n-3/n-6	2.40	2.81	2.39	3.17	2.46	2.70	2.54	2.58	3.97	2.26
Vitamin F	10.77	12.66	12.27	12.84	11.85	10.56	10.85	11.00	9.46	11.45

In the muscular tissues of the Baikal omul from all the MEGs there is a high content of vitamin F (13.6 %) observed. The males of the Baikal omul belonging to the pelagic MEG possess the highest percentage of irreplaceable nutritionally valuable acids, both with respect to total PUFA (53.6 %), and the content of n-3 PUFA (37.3 %). The n-3/n-6 PUFA ratio in the tissues of the Baikal omul amounts to 3 : 1 and differs insignificantly from those for some sea and fresh-water fish species [3, 23].

CONCLUSION

Among of the general lipids of the muscles and liver of all the investigated fishes under investigation, there are polyunsaturated fatty acids (38.5–53.8 % of the total sum of acids) and saturated fatty acids (31.8–36.5 %) prevailing. Polyunsaturated acids are mainly presented by 22:6n-3 and 20:5n-3, their total content amounting to 16.8–33.3 %. The lipids of muscles contain a high percentage of polyunsaturated fatty acids at the expense of docosahexaenoic acid (13.28–24.66 %). No considerable differences in the structure of the fatty acids of general lipids between the MEG of the Baikal omul were revealed.

Fat content and biochemical composition of fish tissues reflect their feeding for the previous period of time, however, the issue remains open concerning the duration of this period. In this connection one should carry out the further studies concerning the determination of seasonal changing these parameters for the tissues of the basic fodder organisms for the Baikal omul and fishes themselves, as well as to perform a series of experiments concerning the food assimilation rate by fishes.

The data obtained concerning the structure of fatty acids of the general lipids are necessary for the search of the natural sources of biologically active substances of lipid nature and for the further biochemical researches in different fields of fresh-water hydrobionts' aquiculture.

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