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Comparison of fatty acid composition in some tissues of rainbow trout (*Oncorhynchus mykiss*) living in seawater and freshwater

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Abstract

The effects of salinity on the fatty acid profiles of liver, gonad, muscle and adipose tissues of rainbow trout (*Oncorhynchus mykiss*) kept in cages suspended in a seawater (SW) and freshwater (FW), respectively, and fed with the same commercially available diets before marketing, were investigated.

In muscle tissue, the effect of salinity (0.17%) was found to be insignificant in terms of the total monounsaturated fatty acid (MUFA), total polyunsaturated fatty acid (n-3, n-6 PUFA) and total saturated fatty acid (SFA), but significant in terms of the eicosapentaenoic acid (EPA)/docosahexaenoic acid (DHA) ratio. In gonad and liver tissues, MUFA and n-3 PUFA were found to be significantly affected by salinity, but not SFA or n-6 PUFA. In adipose tissues, all the parameters were significantly affected by salinity. Also n-3/n-6 PUFA and EPA/DHA ratios were characteristic for FW and SW fish.

While the salinity significantly affected the n-3/n-6 ratio in the adipose and liver tissues, it did not have any significant effect in the muscle and gonads. Additionally, the EPA/DHA ratio was found to be significantly affected by the salinity in all the tissues examined.

Keywords: Salinity; Freshwater; *Oncorhynchus mykiss*; Tissue; Fatty acid composition

1. Introduction

Lipids and fatty acids play a significant role in membrane biochemistry and have a direct impact on membrane-mediated processes such as osmoregulation, nutrient assimilation and transport. On the other hand, the nature and quantity of these lipids in fish vary according to species and habitat (Ackman & Eaton, 1966; Aras, Haliloğlu, Ayık, & Yetim, 2003a; Aras, Haliloğlu, Bayır, Atamanalp, & Sirkecioğlu, 2003b; Christiansen, Ringo, & Farkas, 1989; Crowford, Cusacj, & Parle, 1986; Haliloğlu, 2001; Haliloğlu, Aras, & Yetim, 2002).

Fish lipids are well known to be rich in long-chain n-3 polyunsaturated fatty acids (LC n-3 PUFA), especially EPA and DHA. LC n-3 PUFA cannot be synthesised by humans and must be obtained from the diet (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002). It is known that n-3 fatty acids are essential for neural development in the infant in utero and during the first few years after birth (Montaño, Gavino, & Gavino, 2001) and other data support the notion that n-3 PUFAs have beneficial effects in hypertension, inflammation, arrhyhmias, psoriasis, aggression, depression, coronary heart disease, inflammatory and auto-immune disorders and cancer (Candela, Astiasarán, & Bello, 1997; Pike, 1999).

Compositions of lipids and fatty acids present in some fish species are available, but no major work has been done on rainbow trout (*O. mykiss*) in the Black Sea.

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Water salinity has an effect on FA composition, particularly the PUFA levels of fish and the n-3 to n-6 FA ratio is much lower in fish living in a FW than a SW environment (Steffens, 1997). It has also been claimed that salinity affects the digestibility of protein, and lipid and some of the dietary fatty acids in some trout species (Ackman, 1967; Borlongan & Benitez, 1992; Gruger, Nelson, & Standsby, 1964; Standsby, 1967).

Bautista, Valle, and Orejana (1991) reported that the flavour of milk fish (*Chanos chanos*), taken from FW pens, is of inferior quality when compared to that of fish taken from brackish water ponds, claiming that environmental conditions could affect the composition of fish.

In this study, we investigated the effects of salinity on the lipid composition of gonads, liver, muscle and adipose tissues of fish fed with the same commercially available feed and kept in cages located in the Black Sea and in fresh water ponds.

2. Materials and methods

2.1. Fish and feed materials

Commercial rainbow trout (*Oncorhynchus mykiss*) reared in SW cages (Aquaculture Research Institute of Trabzon-Yomra Harbour, 0.17% salinity) and FW ponds were used in this study. The mean weight of a trout was 200 g.

Two groups were fed with the same commercial feed as ad libitum feeding. The fatty acid profile of the feed is given in Table 1.

The muscle tissues examined in this research were obtained from the point between linear lateral and dorsal fin (Fig. 1). The adipose tissue was from the intravisceral area, and the gonad was from the ovaries.

2.2. Analyses of lipids and fatty acids

Preparation and analysis of fatty acid methyl esters (FAMEs) from these fish tissues were performed according to a previous method (Anon, 2000).

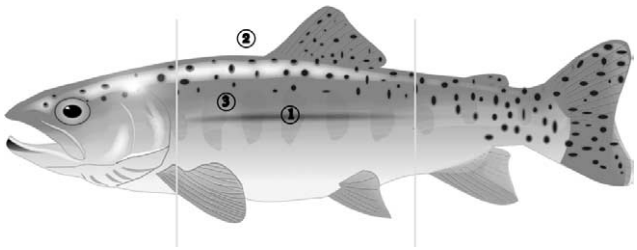

Fig. 1. Sampling points of a fish (1: lateral line; 2: dorsal fin; 3: the muscle and sampling location).

2.3. Statistical analysis

In the statistical analysis, the data were subjected to ANOVA and the significant means were compared by Tukey's multiple range tests SAS (SAS, 1996), and presented as means ± SEM. A p value less than 0.05 was accepted as statistically significant.

3. Results and discussion

Salinity caused statistically significant differences in the fatty acid composition of muscle tissue of fish being fed with the same diet; for example, 14:0 (myristic), 20:5 n-3 (EPA) and 20:3 n-6 fatty acids were significant at $p < 0.05$, 16:1 n-7, 18:0 (stearic), 22:6 n-3 (DHA) and 22:5 n-3, and EPA/DHA percentage had highly significant differences at the $p < 0.01$ level (Table 3). Total SFA value was found to be 30% in each group, being mainly composed of palmitic, stearic and myristic acids, respectively. Among MUFA, the most commonly found ones were 18:1 n-9, 16:1 n-7, 18:1 n-9t and 20:1 n-9, respectively. In PUFA, the content of n-3 fatty acids was nearly twice that of n-6 fatty acids, and the percentage of n-3/n-6 was found to be three times that of the diet, but had no statistical importance.

In adipose tissue, salinity caused important impacts ($p < 0.01$) on all fatty acid compounds (EPA, DHA, n-3, n-6 PUFA, SFA, MUFA and EPA/DHA) (Table 2). In gonad tissue, the fatty acids (15:0, 16:1 n-9, 17: 1 n-8, 17:0, 18:3 n-6, 18:4 n-3, 20:3 n-6 and 20:1 n-9), important

Table 1
The percentage fatty acid profile (% of total fatty acids[a]) of feed used in the research

Fatty acid	%	Fatty acid	%	Fatty acid	%
14:0	8.51	18:1 n9	18.2	18:3 n-6	0.29
15:0	0.96	20:1 n9	0.67	18:2 n-6	12.3
16:0	21.7	18:1 n9t	2.01	20:4 n-6	0.55
17:0	0.54	∑MUFA	32.5	20:3 n-6	0.15
18:0	3.72	18:4 n-3	1.62	20:2 n-6	–
∑SFA	35.4	20:5 n-3	4.48	∑n-6 PUFA	13.3
16:1 n9	0.57	22:6 n-3	6.74	n-3/n-6	0.57
16:1 n7	8.22	22:5 n-3	0.51	EPA/DHA	0.66
17:1 n8	0.37	∑n-3 PUFA	13.4		

[a] Values are expressed as percentages of total fatty acids.

Table 2
Comparison of the compositions (% of total fatty acids*) of fatty acids in adipose and gonad tissues of fish living in seawater and freshwater

Fatty acid	Adipose mean ± SE ($n = 7$)			Gonad mean ± SE ($n = 7$)		
	Seawater %	Freshwater %	F	Seawater %	Freshwater %	F
14:0	7.12 ± 0.32 a	3.7 ± 0.28 b	**	2.11 ± 0.23	2.02 ± 0.23	ns
15:0	0.69 ± 0.05 a	0.49 ± 0.05 b	*	–	–	–
16:0	17.3 ± 0.35 a	16.0 ± 0.31 b	*	22.9 ± 1.04	21.49 ± 1.04	ns
17:0	0.35 ± 0.03	0.28 ± 0.03	ns	–	–	–
18:0	2.23 ± 0.19	2.82 ± 0.17	ns	4.61 ± 0.89	6.17 ± 0.89	ns
SFA	27.4 ± 0.47 a	23.4 ± 0.42 b	**	28.9 ± 1.55	29.9 ± 1.55	ns
16:1 n-9	0.41 ± 0.04	0.57 ± 0.04	ns	–	–	–
16:1 n-7	9.36 ± 0.46 a	6.82 ± 0.61 b	**	3.03 ± 0.32	3.93 ± 0.32	ns
17:1 n-8	0.44 ± 0.01 a	0.32 ± 0.01 b	**	–	–	–
18:1 n-9	22.5 ± 0.61 b	36 ± 0.55 a	**	18.6 ± 1.05 b	27.3 ± 1.05 a	**
20:1 n-9	0.68 ± 0.09	0.84 ± 0.1	ns	–	–	–
18:1 n-9t	2.36 ± 0.11	2.4 ± 0.1	ns	2.41 ± 0.06	2.89 ± 0.06	ns
MUFA	34.3 ± 0.83 b	45.9 ± 0.74 a	**	21.6 ± 1.17 b	32.9 ± 1.17 a	**
18:4 n-3	1.78 ± 0.05 a	0.88 ± 0.04 b	**	–	–	–
20:5 n-3	5.38 ± 0.23 a	1.88 ± 0.26 b	**	7.08 ± 0.54 a	2.35 ± 0.54 b	**
22:6 n-3	12.4 ± 0.79 a	6.5 ± 0.71 b	**	28.3 ± 2.06	20.8 ± 2.06	ns
22:5 n-3	1.71 ± 0.06 a	0.52 ± 0.06 b	**	3.06 ± 0.19	3.02 ± 0.19	ns
n-3 PUFA	20.9 ± 0.96 a	9.7 ± 0.86 b	**	37.4 ± 2.21 a	23.2 ± 2.21 b	**
18:3 n-6	0.42 ± 0.06	0.56 ± 0.05	ns	–	–	–
18:2 n-6	11.9 ± 0.58 b	16.9 ± 0.51 a	**	7.6 ± 1.11	10.6 ± 1.11	ns
20:4 n-6	0.71 ± 0.06	0.79 ± 0.05	ns	5.04 ± 0.64	3.44 ± 0.64	ns
20:3 n-6	0.51 ± 0.08 b	0.81 ± 0.07 a	*	–	–	–
20:2 n-6	0.58 ± 0.1	0.79 ± 0.07	ns	–	–	–
n-6 PUFA	14.8 ± 0.54 b	19.8 ± 0.49 a	**	12.6 ± 1.33	14.0 ± 1.33	ns
n-3/n-6	1.39 ± 0.08 a	0.48 ± 0.08 b	**	3.07 ± 0.42	1.71 ± 0.42	ns
EPA/DHA	0.45 ± 0.02 a	0.29 ± 0.02 b	**	0.25 ± 0.02 a	0.12 ± 0.02 b	**

*: Values are expressed as percentages of total fatty acids.

–: Not detected.

a, b means in a row with identical letters are not significantly different. Values given as means ± SE. ns = $p > 0.05$, **($p < 0.01$), *($p < 0.05$), ($n = 7$).

in the diet, were not detected. Salinity significantly decreased 18:1 n-9 and consequently MUFA, and increased EPA (20:5 n-3) and consequently PUFA (Table 2).

As shown in Table 2, while very significant differences were found in MUFA, n-3 PUFA ($p < 0.01$), only a slight difference was determined in the n-3/n-6 ratio ($p < 0.05$). Similarly, of prominent difference in EPA was also reflected in the EPA/DHA ratio; 15:0, 16:1 n-9, 17:1 n-8, 17:0, 18:3 n-6 and 18:4 n-3, found in the diet were not observed in liver tissue, as in the case of gonad tissue (Tables 2 and 3).

Rainbow trout is highly tolerant of temperature and turbidity changes (Gall & Crandell, 1992). The salinity was low in the SW research area (Trabzon Yomra Harbour). Okumuş, Başçınar, Alkan, and Kurtoğlu (1988) reported that *Salvelinus fontinalis* was succesfully reared in the same research area throughout the year, except July and August. Transferring fish from FW to SW cages did not create any risk in terms of growth and survival.

There are close relationships between the fish lipid composition and the diets of fish (Castell, 1979; Chen, Chapman, Wei, & Keefe, 1995; McKenzie et al., 2000). Salinity changes essential FA compositions of fish (Gruger et al., 1964; Hoar, 1976; Sheridan, Allen, & Kerstetter, 1985). FA profiles of fish fed with the same diet can be affected. As a matter of fact, salinity caused a significant increase in total SFA, n-3 PUFA, and EPA in adipose tissue, while it caused a significant decrease in MUFA and n-6 PUFA (Table 2). The salinity significantly changed total MUFA, n-3 PUFA and the EPA/DHA ratio in gonad and liver tissues. In muscle tissue, only the EPA/DHA ratio was changed significantly by salinity. In other words, salinity increased EPA by 100% and decreased DHA by 33%.

Studies have shown that the fatty acid composition, especially the PUFA levels, of fish were affected by the salinity of the water, and according to all these studies, the ratio of n-3 to n-6 fatty acids ranged from 1.7 to 3.5 and from 7.5 to 19.5 for FW and marine species, respectively (Ackman, 1967; Gruger et al., 1964; Standsby, 1967). In accordance with the results mentioned above, the unsaturated FA ratio of (n-3) to (n-6) FA and the levels of n-3 PUFAs were higher in SW- than in FW-reared fish in our research. The changes in lipid composition, in all the tissues of rainbow trout, were attributed to salinity.

In a similar study on guppy (*Poecilia reticulata*), the FA composition was affected by the rearing salinity (Daikoku, Yano, & Masui, 1982). Differences in FA

Table 3
Comparison of the compositions (% of total fatty acids*) of fatty acids in liver and muscle tissue of fish living in seawater and freshwater

Fatty acid	Liver mean ± SE ($n = 7$)			Muscle mean ± SE ($n = 7$)		
	Seawater %	Freshwater %	F	Seawater %	Freshwater %	F
14:0	1.89 ± 0.12	1.62 ± 0.12	ns	4.04 ± 0.49 a	2.38 ± 0.49 b	*
15:0	–	–	–	–	–	–
16:0	19.7 ± 1.3	16.4 ± 1.3	ns	19.6 ± 0.99	21.3 ± 0.99	ns
17:0	–	–	–	–	–	–
18:0	7.93 ± 0.94	6.43 ± 0.94	ns	4.39 ± 0.5 b	6.79 ± 0.5 a	**
SFA	30.1 ± 1.18	24.5 ± 1.81	ns	30.6 ± 1.51	30.5 ± 1.51	ns
16:1 n-9	–	–	–	–	–	–
16:1 n-7	3.43 ± 0.41	3.65 ± 0.41	ns	6.91 ± 0.65 a	4.16 ± 0.58 b	**
17:1 n-8	–	–	–	–	–	–
18:1 n-9	15.2 ± 0.74 b	22.3 ± 0.74a	**	22.1 ± 0.89	22.2 ± 0.89	ns
20:1 n-9	0.48 ± 0.19 b	1.46 ± 0.12 a	**	1.08 ± 0.15	0.67 ± 0.18	ns
18:1 n-9t	2.65 ± 0.15	2.46 ± 0.14	ns	2.68 ± 0.10	2.43 ± 0.10	ns
MUFA	21.3 ± 1.48 b	31.3 ± 1.48 a	**	32.4 ± 1.14	29.3 ± 1.14	ns
18:4 n-3	–	–	–	–	–	–
20:5 n-3	6.16 ± 0.56 a	2.45 ± 0.56 b	**	6.02 ± 0.7 a	3.52 ± 0.7 b	*
22:6 n-3	25.9 ± 1.16	24.9 ± 1.16	ns	16.5 ± 1.36 b	22.7 ± 1.36 a	**
22:5 n-3	1.99 ± 0.15 a	1.15 ± 0.13 b	**	1.63 ± 0.10 a	0.85 ± 0.12 b	**
n-3 PUFA	34.0 ± 0.9 a	28.1 ± 0.9 b	**	23.8 ± 2.03	25.1 ± 2.06	ns
18:3 n-6	–	–	–	–	–	–
18:2 n-6	6.8 ± 1.16	7.4 ± 1.16	ns	10.2 ± 0.81	10.4 ± 0.81	ns
20:4 n-6	4.66 ± 0.56	4.41 ± 0.56	ns	1.39 ± 0.41	2.56 ± 0.41	ns
20:3 n-6	0.68 ± 0.27	1.38 ± 0.21	ns	0.41 ± 0.15 b	1.17 ± 0.13 a	*
20:2 n-6	0.62 ± 0.18 b	1.31 ± 0.14 a	*	0.76 ± 0.10	1.03 ± 0.11	ns
n-6 PUFA	12.3 ± 1.1	14.9 ± 1.1	ns	12.9 ± 0.87	14.1 ± 0.87	ns
n-3/n-6	2.71 ± 0.2 a	1.94 ± 0.2 b	*	1.87 ± 0.21	1.83 ± 0.21	ns
EPA/DHA	0.24 ± 0.02 a	0.10 ± 0.02 b	**	0.32 ± 0.02 a	0.16 ± 0.02 b	**

*: Values are expressed as percentages of total fatty acids.
–: Not detected.
a,b means in a row with identical letters are not significantly different.
Values given as mean ± SE, ns = $p > 0.05$, **($p < 0.01$), *($p < 0.05$), ($n = 7$).

composition, in response to salinity, have been observed in migratory fishes. The ratio of (n-3) to (n-6) FA in sweet smelt (*Plecoglossus altivelis*) decreased dramatically within one month of migration from the SW to FW (Ota & Tagaki, 1977). Nevertheless, opposite changes were observed in the masu salmon as they migrated from FW to SW (Ota, 1976). The role of PUFA in membrane permeability and plasticity may be one of the factors accounting for the differences in contents of FA between FW- and SW-reared fish. On the other hand, we found the most dominant FA to be palmitic acid (16:0), the most plentiful SFA in the eggs and other tissues of most fish species (Ashton, Farkvan, & March, 1993; Czesny & Dabrowski, 1998). Additionally, 18:1 n-9 and 18:2 n-6 were found at higher levels in MUFA. This is in agreement with data reported for other fish species (Chen et al., 1995; Harrell & Woods, 1995).

It is known that, in SW fish, the EPA and DHA levels are higher than in FW fish (Czesny, Kolkovski, Dabrowski, & Culver, 1999; Steffens, 1997). Likewise, the results of our study revealed that the most abundant individual FAs were DHA and EPA in all of the tissues examined. Sargent (1996) reported that n-3 PUFA, principally DHA, has a role in maintaining the structure and functional integrity of fish cells. In addition, DHA has a specific and important role in neural cell membranes, i.e. the brain and eyes. Moreover, it is considered a desirable property in fish for human nutrition and health.

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