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SEASONAL VARIATIONS OF FATTY ACID COMPOSITION OF COMMON CARP (*CYPRINUS CARPIO*, L. 1758) FROM AQUACULTURE AND OPEN WATERS IN MACEDONIA

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ABSTRACT

Seasonal variations (spring and autumn) of the fatty acid composition of common carp from aquaculture (cyprinid - warm water fish farm) and open waters (Prespa Lake) from Macedonia were examined. Aquaculture carp contain almost similar saturated fatty acid (SFA) content (25.95% - spring and 30.77% - autumn) compared to open water carp (25.84% - spring and 31.91% - autumn). Palmitic acid was the major SFA in both aquaculture and open water carp. Regarding monounsaturated fatty acid (MUFA) content, it is significantly higher in both seasons in aquaculture (63.27% - spring; 59.85% - autumn) compared to open water carp (48.11% - spring; 54.12% - autumn). Oleic acid was identified as the major MUFA. In both seasons, the value of polyunsaturated fatty acid (PUFA) is significantly higher in open water (26.17% - spring; 13.97% - autumn) compared to aquaculture carp (10.90% - spring; 9.39% - autumn).
The most optimal results in terms of nutritional value of fish meat were found in open water carp, in the spring, due to high PUFA content, especially linoleic (n-6), as well as EPA and DHA (n-3) fatty acids. This is the result of diet, because carp consumes phyto and zooplankton from the lake's benthos, which are especially rich in essential fatty acids.

Keywords: common carp, aquaculture, open waters, fatty acid composition

INTRODUCTION

In Europe, especially in Central and Eastern Europe, cyprinids are one of the most important fish families, especially in aquaculture production. The Cyprinidae family dominates the world's aquaculture, and common carp (*Cyprinus carpio* L. 1785) is one of the most consumed fish species belonging to this family (**Balon, 2006**).
Common carp is one of the most valuable and consumed fish species in Macedonia. It is successfully bred in aquaculture (cyprinid warm water pond and cage farms) in Macedonia, where it covers 60 - 80% of the total fish production. Regarding the open waters, common carp is one of the most important components in the overall ichthyomass of Prespa Lake.
According **FAO (2006)**, common carp are omnivorous, with a high tendency towards the consumption of animal food, such as water insects, larvae of insects, worms, mollusks and zooplankton. The carp farming is based on the ability of the species to accept and utilize cereals supplied by the farmers.
Fish is a rich source of omega-3 (n-3) long-chain fatty acids, and the positive effects of these fatty acids on human health have been proven in numerous studies (**Von Shacky, 2001; Mozaffarian *et al.*, 2004; Sahena *et al.*, 2009; Barcelo-Coblijn & Murphy, 2009**), which confirms the association of fish consumption with its effect on preventing coronary heart disease, especially myocardial infarction, arteriosclerosis, hypertension and other diseases of the cardiovascular system (**Kris-Etherton *et al.*, 2002; Myneris-Perxachs *et al.*, 2010**). N-3 long-chain polyunsaturated fatty acids (PUFA) cannot be synthesized in the human body and must therefore be ingested through food (**Alasalvar *et al.*, 2002**).
Cahu *et al.* (2004) suggest that freshwater fish may also be a source of n-3 PUFA (EPA and DHA fatty acids), due to the fact that they have a greater ability to dissociate some fatty acids and transform those into PUFA (EPA and DHA) with long chains, unlike marine fish (**Lichtenstein *et al.*, 2006**).
The aim of this study was to analyze the seasonal variations in the fatty acid composition of common carp meat, which originates from aquaculture (cyprinid - warm water fish farm) and open water carp (Lake Prespa), during the spring and autumn.

MATERIAL AND METHODS

In this study, examinations were performed on samples of common carp from two different environments: aquaculture facility (cyprinid fish farm) and open waters (Prespa Lake). Carp samples were taken in the spring and autumn.
The average weight and length of carp samples from aquaculture taken in the spring was 1200 g and 42 cm, while in the autumn, 1750 g and 62 cm, respectively.
The average weight and length of carp samples from the lake in the spring was 1450 g and 70 cm, while in the autumn, 1750 g and 82 cm, respectively.
The cyprinid fish farm Zhabeni is located in the Bitola region (Macedonia), i.e. the southeastern part of Pelagonia. It was built in 1960/61 by enclosing part of the old riverbed of Crna Reka with two embankments. It covers an area of 170 ha and it is the biggest cyprinid fish farm in Macedonia. The land on the old riverbed of Crna Reka is very fertile, which contributes to the fish farm being very productive, i.e. rich in zoo and phytoplankton. The traditional approach to carp breeding is based on food that is naturally present in the fish farm (zooplankton and benthos, i.e the flora and fauna at the bottom), but the diet is supplemented with unprocessed cereals (wheat, corn, barley).
Prespa Lake is the second largest natural lake in Macedonia. In terms of the composition of the fish settlement, it is typically cyprinid lake. The autochthonous ichthyofauna in Prespa Lake consists of the following fish species: common carp (*Cyprinus carpio*), Prespa bleak (*Alburnus belvica*), Prespa spirlin (*Alburnoides prespensis*), Prespa minnow (*Pseudophoxinus prespensis*), Prespa spined loach (*Cobitis meridionalis*) etc.
During examinations, gas chromatography - AOAC method 996.06 for determination of fatty acid composition in fish meat at Veterinary Institute - Skopje (Macedonia) was performed.

RESULTS AND DISCUSSION

The results of the fatty acid composition of the common carp (*Cyprinus carpio*, L. 1758) from aquaculture and open waters are presented in table 1 and table 2.

Table 1 Fatty acid composition (%) of common carp (*Cyprinus carpio*, L. 1758) from aquaculture, by seasons

Lipid numbers	Name	Type	Spring	Autumn
C14:0	Myristic acid	SFA	1.39	1.31
C15:0	Pentadecanoic acid	SFA	0.15	0.16
C16:0	Palmitic acid	SFA	19.17	25.30
C17:0	Heptadecanoic acid	SFA	0.15	0.10
C18:0	Stearic acid	SFA	4.99	3.80
C24:0	Lignoceric acid	SFA	0.10	0.10
TOTAL SFA (saturated fatty acid)			**25.95**	**30.77**
C14:1 n-5	Myristoleic acid	MUFA	0.10	0.17
C15:1	Cis-10 - Pentadecanoic acid	MUFA	0.12	0.10
C16:1 n-7	Palmitoleic acid	MUFA	13.32	13.95
C17:1	Cis-10- Heptadecanoic acid	MUFA	0.55	0.31
C18:1 n-9 c	Oleic acid	MUFA	47.83	44.00
C20:1	Cis-11- Eicosenoic acid	MUFA	1.08	1.11
C22:1 n-9	Erucid acid	MUFA	0.27	0.21
TOTAL MUFA (monounsaturated fatty acid)			**63.27**	**59.85**
C18:2 n-6 c	Linoleic acid	PUFA	6.88	3.54
C18:3 n-3	α- linolenic acid	PUFA	1.82	2.57
C20:3 n-6	Eicosatrienoic acid	PUFA	0.80	1.78
C20:4 n-6	Arachidonic acid	PUFA	0.56	0.33
C20:5 n-3	Eicosapentaenoic acid	PUFA	0.27	0.45
C22:6 n-3	Docosahexaenoic acid	PUFA	0.57	0.72
TOTAL PUFA (polyunsaturated fatty acid)			**10.90**	**9.39**
Total UFA (unsaturated fatty acid)			74.05	69.24
Total PUFA n-6			8.24	5.65
Total PUFA n-3			2.66	3.74
n-6/n-3			3.09	1.51
n-3/n-6			0.32	0.66
UFA/SFA			2.85	2.25
PUFA/SFA			0.42	0.30
PUFA/MUFA			0.17	0.15

Table 2 Fatty acid composition of common carp (*Cyprinus carpio*, L. 1758) from Prespa Lake, by seasons

Lipid numbers	Name	Type	Spring	Autumn
C14:0	Myristic acid	SFA	2.42	3.64
C15:0	Pentadecanoic acid	SFA	0.23	0.62
C16:0	Palmitic acid	SFA	18.97	23.72
C17:0	Heptadecanoic acid	SFA	0.48	0.93
C18:0	Stearic acid	SFA	3.56	2.87
C24:0	Lignoceric acid	SFA	0.18	0.13
TOTAL SFA			**25.84**	**31.91**
C14:1 n-5	Myristoleic acid	MUFA	0.36	0.20
C15:1	Cis-10 - Pentadecenoic acid	MUFA	0.25	0.74
C16:1 n-7	Palmitoleic acid	MUFA	22.00	27.65
C17:1	Cis-10- Heptadecanoic acid	MUFA	1.25	1.69
C18:1 n-9 c	Oleic acid	MUFA	22.52	21.87
C20:1	Cis-11- Eicosenoic acid	MUFA	1.61	1.87
C22:1 n-9	Erucid acid	MUFA	0.12	0.10
TOTAL MUFA			**48.11**	**54.12**
C18:2 n-6 c	Linoleic acid	PUFA	9.86	1.51
C18:3 n-3	α- linolenic acid	PUFA	2.20	3.02
C20:3 n-6	Eicosatrienoic acid	PUFA	2.66	2.38
C20:4 n-6	Arachidonic acid	PUFA	0.80	1.97
C20:5 n-3	Eicosapentaenoic acid	PUFA	5.44	2.41
C22:6 n-3	Docosahexaenoic acid	PUFA	5.21	2.68
TOTAL PUFA			**26.17**	**13.97**
Total UFA			74.16	68.09
Total PUFA n-6			13.32	5.86
Total PUFA n-3			12.85	8.11
n-6/n-3			1.03	0.72
n-3/n-6			0.96	1.38
UFA/SFA			2.86	2.13
PUFA/SFA			1.01	0.43
PUFA/MUFA			0.54	0.25

The results for comparative indicators of fatty acid composition of common carp (*Cyprinus carpio*, L. 1758) from aquaculture and open waters in spring and autumn are presented in table 3 and table 4.

Table 3 Comparative indicators of fatty acid composition of common carp (*Cyprinus carpio*, L. 1758) from aquaculture and open waters, in spring

Lipid numbers	Name	Type	Fish farm	Prespa Lake
C14:0	Myristic acid	SFA	1.39	2.42
C15:0	Pentadecanoic acid	SFA	0.15	0.23
C16:0	Palmitic acid	SFA	19.17	18.97
C17:0	Heptadecanoic acid	SFA	0.15	0.48
C18:0	Stearic acid	SFA	4.99	3.56
C24:0	Lignoceric acid	SFA	0.10	0.18
TOTAL SFA			**25.95**	**25.84**
C14:1 n-5	Myristoleic acid	MUFA	0.10	0.36
C15:1	Cis-10 - Pentadecanoic acid	MUFA	0.12	0.25
C16:1 n-7	Palmitoleic acid	MUFA	13.32	22.00
C17:1	Cis-10- Heptadecanoic acid	MUFA	0.55	1.25
C18:1 n-9 c	Oleic acid	MUFA	47.83	22.52
C20:1	Cis-11- Eicosenoic acid	MUFA	1.08	1.61
C22:1 n-9	Erucid acid	MUFA	0.27	0.12
TOTAL MUFA			**63.27**	**48.11**
C18:2 n-6 c	Linoleic acid	PUFA	6.88	9.86
C18:3 n-3	α- linolenic acid	PUFA	1.82	2.20
C20:3 n-6	Eicosatrienoic acid	PUFA	0.80	2.66
C20:4 n-6	Arachidonic acid	PUFA	0.56	0.80
C20:5 n-3	Eicosapentaenoic acid	PUFA	0.27	5.44
C22:6 n-3	Docosahexaenoic acid	PUFA	0.57	5.21
TOTAL PUFA			**10.90**	**26.17**
Total UFA			74.05	74.16
Total PUFA n-6			8.24	13.32
Total PUFA n-3			2.66	12.85
n-6/n-3			3.09	1.03
n-3/n-6			0.32	0.96
UFA/SFA			2.85	2.86
PUFA/SFA			0.42	1.01
PUFA/MUFA			0.17	0.54

Table 4 Comparative indicators of fatty acid composition of common carp (*Cyprinus carpio*, L. 1758) from aquaculture and open waters, in autumn

Lipid numbers	Name	Type	Fish farm	Prespa Lake
C14:0	Myristic acid	SFA	1.31	3.64
C15:0	Pentadecanoic acid	SFA	0.16	0.62
C16:0	Palmitic acid	SFA	25.30	23.72
C17:0	Heptadecanoic acid	SFA	0.10	0.93
C18:0	Stearic acid	SFA	3.80	2.87
C24:0	Lignoceric acid	SFA	0.10	0.13
TOTAL SFA			**30.77**	**31.91**
C14:1 n-5	Myristoleic acid	MUFA	0.17	0.20
C15:1	Cis-10 - Pentadecanoic acid	MUFA	0.10	0.74
C16:1 n-7	Palmitoleic acid	MUFA	13.95	27.65
C17:1	Cis-10- Heptadecanoic acid	MUFA	0.31	1.69
C18:1 n-9 c	Oleic acid	MUFA	44.00	21.87
87C20:1	Cis-11- Eicosenoic acid	MUFA	1.11	1.87
C22:1 n-9	Erucid acid	MUFA	0.21	0.10
TOTAL MUFA			**59.85**	**54.12**
C18:2 n-6 c	Linoleic acid	PUFA	3.54	1.51
C18:3 n-3	α- linolenic acid	PUFA	2.57	3.02
C20:3 n-6	Eicosatrienoic acid	PUFA	1.78	2.38
C20:4 n-6	Arachidonic acid	PUFA	0.33	1.97
C20:5 n-3	Eicosapentaenoic acid	PUFA	0.45	2.41
C22:6 n-3	Docosahexaenoic acid	PUFA	0.72	2.68
TOTAL PUFA			**9.39**	**13.97**
Total UFA			69.24	68.09
Total PUFA n-6			5.65	5.86
Total PUFA n-3			3.74	8.11
n-6/n-3			1.51	0.72
n-3/n-6			0.66	1.38
UFA/SFA			2.25	2.13
PUFA/SFA			0.30	0.43
PUFA/MUFA			0.15	0.25

Considering the results of the fatty acid composition of the common carp from aquaculture, in both spring and autumn (Table 1), it can be concluded that in total fatty acid content, SFA participate with 25.95% (spring) and 30.77% (autumn). From those, the most dominant are palmitic (19.17% - spring; 25.30% - autumn) and stearic (4.99% - spring; 3.80% - autumn) fatty acid.

MUFA have the greatest participation in common carp meat, with 63.27% (spring) and 59.85% (autumn). From this group, the most dominant is oleic (47.83% - spring; 44.00% - autumn), followed by palmitoleic acid (13.32% - spring; 13.95 - autumn).

PUFA participate with 10.90% (spring) and 9.39% (autumn) in total fatty acid content, from which, the most dominant are linoleic (6.88% - spring; 3.54% - autumn) and α - linolenic (1.82% - spring; 2.57% - autumn), followed by eicosatrienoic (0.80% - spring; 1.78% - autumn), docosahexaenoic DHA (0.57% - spring; 0.72% - autumn), arachidonic (0.56% - spring; 0.33% - autumn) and eicosapentaenoic EPA (0.27% - spring; 0.45% - autumn).

N-6 (omega 6) fatty acids participate with 8.24% (spring) and 5.65% (autumn), while n-3 (omega 3) with 2.66% (spring) and 3.74% (autumn). The n-3/n-6 ratio is 0.32 (spring) and 0.66 (autumn), while n-6/n-3 ratio is 3.09 (spring) and 1.51 (autumn). UFA/SFA ratio is 2.85 (spring) and 2.25 (autumn), PUFA/SFA is 0.42 (spring) and 0.30 (autumn), while PUFA/MUFA is 0.17 (spring) and 0.15 (autumn).

Considering the results of the fatty acid composition of the common carp from open waters (Prespa Lake), in both spring and autumn (Table 2), it can be concluded that in total fatty acid content, SFA participate with 25.84% (spring) and 31.91% (autumn). From those, the most dominant are palmitic (18.97% - spring; 23.72% - autumn), stearic (3.56% - spring; 2.87% - autumn) and myristic (2.42% - spring; 3.64% - autumn) fatty acid.

MUFA have the greatest participation in common carp meat, with 48.11% (spring) and 54.12% (autumn). From this group, the most dominant is oleic (22.52% - spring; 21.87% - autumn) and palmitoleic acid (22.00% - spring; 27.65% - autumn).

PUFA participate with 26.17% (spring) and 13.97% (autumn) in total fatty acid content, from which, in spring, the most dominant are linoleic (9.86%), followed by EPA (5.44%), DHA (5.21%), eicosatrienoic (2.66%), α - linolenic (2.20%) and arachidonic (0.80%) fatty acid. Regarding autumn, α - linolenic (3.02%) is represented in the largest percentage, followed by DHA (2.68%), EPA (2.41%), eicosatrienoic (2.38%), arachidonic (1.97%) and linoleic (1.51%) fatty acid.

N-6 (omega 6) fatty acids participate with 13.32% (spring) and 5.86% (autumn), while n-3 (omega 3) with 12.85% (spring) and 8.11% (autumn). The n-3/n-6 ratio is 0.96 (spring) and 1.38 (autumn), while n-6/n-3 ratio is 1.03 (spring) and 0.72 (autumn). UFA/SFA ratio is 2.86 (spring) and 2.13 (autumn), PUFA/SFA is 1.01 (spring) and 0.43 (autumn), while PUFA/MUFA is 0.54 (spring) and 0.25 (autumn).

With comparison of the results for the fatty acid composition of aquaculture and open water carp (Table 3 and Table 4), it can be concluded that in spring the SFA content is slightly higher in aquaculture carp (25.95%) compared to open water carp (25.84%), while in the autumn the SFA content is slightly higher in open water carp (31.91%) compared to aquaculture carp (30.77%).

Regarding MUFA content, it is significantly higher in both seasons in aquaculture carp (63.27% - spring; 59.85%- autumn) compared to open water carp (48.11% - spring; 54.12% - autumn).

In both seasons, the value of PUFA is significantly higher in open water carp (26.17% - spring; 13.97% - autumn) compared to that in aquaculture carp (10.90% - spring; 9.39% - autumn). Consequently, in the spring, the amount of n-3 is significantly higher in open water carp (12.85%) compared to that in aquaculture carp (2.66%), and the amount of n-6 fatty acids is higher in open water carp (13.32%) compared to aquaculture carp (8.24%). In the autumn, the amount of n-6 fatty acids is almost similar in open water carp (5.86%) compared to aquaculture carp (5.65%), while the n-3 content is significantly higher in open water carp (8.11%) compared to aquaculture carp (3.74%).

In both seasons, the value obtained from the UFA/SFA ratio in aquaculture carp (2.85 - spring; 2.25 - autumn) is almost similar to the value in open water carp (2.86 - spring; 2.13 - autumn), while the PUFA/SFA and PUFA/MUFA ratio are higher in open water carp (1.01 and 0.54, respectively - spring; 0.43 and 0.25, respectively - autumn) compared to the values in aquaculture carp (0.42 and 0.17, respectively - spring; 0.30 and 0.15, respectively - autumn). Also, the value of the n-3/n-6 ratio is higher in open water carp (0.96 - spring; 1.38 - autumn) compared to aquaculture carp (0.32 - spring; 0.66 - autumn), while the ratio n-6/n-3 is higher in aquaculture carp (3.09 - spring; 1.51 - autumn) compared to the open water carp (1.03 - spring; 0.72 - autumn).

According to **Guler *et al.* (2008)**, generally the fish meat has low SFA values (<30%), which correlates with our research, where we found SFA content of 25.95% (spring) - 30.77% (autumn) in aquaculture carp and 25.84% (spring) - 31.91% (autumn) in open water carp.

Regarding MUFA, a characteristic feature of freshwater fish is the presence of high levels of oleic and palmitoleic acid (**Andrade *et al.*, 1995**), which is correlated with the values obtained in our research, where we found oleic acid content of 47.83% (spring) - 44.00% (autumn) in aquaculture carp and 22.52% (spring) - 21.87% (autumn) in open water carp, while palmitoleic acid content was 13.32% (spring) - 13.95% (autumn) in aquaculture carp and 22.00% (spring) - 27.65% (autumn) in open water carp.

Fish that normally consume plankton have high levels of PUFA (**Arrayed *et al.*, 1999**). According **Steffens & Wirth (2007)**, **Buchtová *et al.* (2010), Ćirković *et al.* (2011)**, carp grown with natural food from fish farms themselves showed high levels of n-6 and n-3 fatty acids. On the other hand carp that was additionally fed with wheat, which is characterized by low content of n-3 fatty acids, results in slightly lower concentrations of these fatty acids and high oleic acid content, which is in correlation with our findings.

Antova *et al.* (2014) in a study of the fatty acid composition of common carp from cage systems in Bulgaria found that within PUFA, the percentage of n-6 fatty acids (29.80%) is higher compared to n-3 fatty acids (5.70%), which correlates with our findings. The same authors, in a study of the fatty acid composition of carp from fish farms, reservoirs and cage systems in Bulgaria found that the carp from fish farm contains a high percentage of EPA (4.93%), whose content is 2-12 times higher than the other two researched carp groups. This finding is in correlation with our results, while it is probably due to the good natural nutrient base in the fishpond and the optimal level of zooplankton, which adequately supplement the fish diet based on cereals. This fact proves that growing technology, including the good development of planktonic organisms, is prone to EPA synthesis, which is consistent with our research.

Guler *et al.* (2008) found that oleic (15.1 - 20.3%) and palmitoleic (5.1 - 13.2%) acids are primary and secondary to MUFA in carp in all seasons, which correlates with our findings on the predominance of oleic acid in aquaculture carp (47.83% - spring and 44.00% - autumn) and open water carp (22.52% - spring and 21.87% - autumn), as well as the presence of palmitoleic acid in aquaculture carp (13.32% - spring and 13.95% - autumn) and open waters carp (22.00% - spring and 27.65% - autumn), where significantly higher values are observed. **Kminkova *et al.* (2001)** obtained similar results during the four seasons, i.e. the oleic acid content was significantly higher in aquaculture carp compared to that in open water carp, which is closely correlated with our findings. The data of **Yeganeh *et al.* (2012)** show that high levels of oleic acid increase the content of MUFA in all seasons, as the same in our study. The reason for this result is probably due to the nutritional habits of the fish.

According to the results of **Kminkova *et al.* (2001)** and **Yeganeh *et al.* (2012)** the content of MUFA in carp was higher compared with that of SFA and PUFA in all seasons, while the content of PUFA was lower compared to SFA, which correlates with our findings where we found that the total content of MUFA in carp from aquaculture (63.27% - spring and 59.85% - autumn) and open water carp (48.11% - spring and 54.12% - autumn) is significantly higher in both seasons, compared to the contents of SFA and PUFA.

Yeganeh *et al.* (2012) found that in open water carp, in winter and spring, the PUFA content was higher than in SFA, while in aquaculture carp, PUFA content was highest in all seasons except spring. In open water carp, palmitic, oleic and DHA fatty acids were present in the largest percentage within SFA, MUFA and PUFA, respectively, which is closely correlated with our findings on the predominant participation of these fatty acids in carp from Prespa Lake. In aquaculture carp, the content of SFA and MUFA was similar to that in open water carp, but linolenic acid was present with the highest percentage of PUFA in all seasons. Under SFA, palmitic acid has been primary in carp in all seasons, which correlates with our findings on the predominant presence of this fatty acid in both aquaculture carp (19.17% - spring and 25.30% - autumn) and open waters carp (18.97% - spring and 23.72% - autumn).

Our results shown significantly higher values of arachidonic AA (0.80% - spring and 1.97% - autumn), EPA (5.44% - spring and 2.41% - autumn) and DHA (5.21% - spring and 2.68% - autumn) fatty acid in carp samples from open waters compared to those in aquaculture carp. High levels of arachidonic fatty acid have been reported in open water carp by **Grigorakis *et al.* (2002)**.

Yeganeh *et al.* (2012) found that open water carp provides consumers with much higher levels of AA, DHA, EPA, n-3, and a more favorable n-3/n-6 ratio, which correlates with our findings. The same authors found that seasonal fluctuations in the fatty acid profile showed that the content of PUFA, n-3 and n-6 increased during the colder months of the year. These results are attributed to temperature variations, food availability, and reproductive status.

In fish farms, carp use natural and additional food. Vegetable, natural and mineral nutrients and vitamin supplements are used as additional food for the carp offspring. In practice, for rejuvenation and carp fattening, the diet with complete pelleted feed turned out to be satisfactory. The carp is feed additionally only during the summer. The diet of aquaculture carp in this study was based on food that is naturally present in the fish farm (zooplankton and benthos, i.e. the flora and fauna at the bottom), but it was supplemented with unprocessed cereals (wheat, corn, barley).

The benthic zone is essential part of the lake's biotope. Nutrients, organic matter and microorganisms are present here at a much higher density compared to those in fishpond water. The carp covers its food needs from the bottom of the lake, so their characteristics affect the quality of the fish meat, directly through their consumption and indirectly through the water.

Carp specimens that consume natural food from the lake's benthos contain more EPA and DHA, which correlates with our research. The concentration of these fatty acids is high, especially in zooplankton (**Steffens *et al.*, 1998**). According to

Guo *et al.* (2008), the fatty acid composition of plankton varies depending on the seasonal changes. The content of n-3 (especially DHA) is high in cases where cryptophytes and DHA-rich copepods become an important group in the composition of the plankton.
According to **Guler *et al.* (2008)**, the fatty acid composition of carp muscle tissue may depend on the feeding period and the season. The fatty acid composition, especially the PUFA composition, is essentially controlled by the fatty acid composition of food fats (**Bakir *et al.*, 1993**).
In the studies of **Bauer *et al.* (2009)** the fat content, the fatty acid profile and the total composition of the fish meat were analyzed. These authors concluded that breeding technology has an impact on the fatty acid profile of carp, mainly according to the type of food consumed and the degree of development of the planktonic organisms.
Ćirković *et al.* (2011) found the possibility to influence the fatty acid composition of fish meat through growing conditions, especially the type of food. According to **Buchtova *et al.* (2010)** and **Ćirković *et al.* (2012)**, aquaculture carp grown with natural foods have a high content of both n - 6 and n - 3 fatty acids.
According to research of **Khorramgah *et al.* (2007)**, in aquaculture carp the content of n-6 is higher than the content of n-3, which is correlated with our research, where in the aquaculture carp the content of n-6 (8.24% - spring and 5.65% - autumn) is significantly higher compared to the content of n-3 (2.66% - spring and 3.74% - autumn).
The nutritional value of freshwater fish is better compared to marine fish, as the fatty acid composition of freshwater fish is characterized by high proportions of n-6 PUFA, especially linolenic and arachidonic fatty acids. According **Malović *et al.* (2010)**, the ratio of total n- 3/n-6 fatty acids is much lower in freshwater compared to marine fish and ranges from 0.5 - 3.
The n-3/n-6 ratio is an important indicator of the role of fatty acids in human health, as well as, nutritional value of carp meat (**Tokur *et al.*, 2006**). According **Jabeen (2011)**, in freshwater fish, the content of n-6 is higher compared to the content of n-3. **Simopoulos (2002)** recommends values from 1.1 - 1.4 as an appropriate balance for the n-3/n-6 ratio. According to **Steffens *et al.* (2005)**, the ratio of n-3/n-6 in the carp varies greatly and ranges from 0.8 - 2.4, which is in correlation with our results of n-3/n-6 ratio in open water carp (0.96 - spring; 1.38 - autumn). Other researchers found a lower n-3/n-6 ratio of 0.54 (**Ćirković *et al.*, 2010**), 0.5 (**Fajmonova *et al.*, 2003**), 0.26 (**Trbović *et al.*, 2009**) and 0.14 (**Ljubojević *et al.*, 2011**), which is in correlation with our results of n-3/n-6 ratio in aquaculture carp (0.32 - spring; 0.66 - autumn). **Yeganeh *et al.* (2012)** found n-3/n-6 ratio higher than 1 in open water carp and lower than 1 in aquaculture carp, so these values are variable during different seasons, which is correlated with the findings obtained from our results.
The n-3/n-6 ratio is generally lower in cultured fish compared to wild fish (**Orban *et al.*, 2003**), which correlates with the results of our research where it is 0.32 (spring) and 0.66 (autumn) in aquaculture carp and 0.96 (spring) and 1.38 (autumn) in open water carp. The differences in n-3/n-6 ratio can be explained by the wide variability of fat levels in fish muscles, which depends on the species, age, size, reproductive period and the fatty acid composition of food.
In terms of the n-6/n-3 ratio, according to **Scollan *et al.* (2006)** the recommended value is less than 4, which is in correlation with our results, where we obtained 3.09 (spring) and 1.51 (autumn) in aquaculture carp and 1.03 (spring) and 0.72 (autumn) in open water carp.
The UFA/SFA ratio is very important in edible fats. It is believed that the value of this ratio above 0.35 is beneficial to the body. From this point of view, carp fat is good for the human diet. **Kminkova *et al.* (2001)** consider a value higher than 0.35 to be sufficient for human health. In our research, this ratio is 2.85 (spring) and 2.25 (autumn) in aquaculture carp and 2.86 (spring) and 2.13 (autumn) in open water carp, which correlated with these recommendations.
The minimum recommended value for the PUFA/SFA ratio is 0.45 (**HMSO, 1994**) which is closely correlated with our findings of 0.42 (spring) and 0.30 (autumn) ratio in aquaculture carp and 1.01 (spring) and 0.43 (autumn) ratio in open water carp. **Ćirković *et al.* (2011)** noted that the PUFA/SFA ratio is most favorable in carp fed with a complete fodder mixture, and less favorable in carp fed in corn and wheat. On the other hand, the PUFA/SFA ratio is recommended to be above 0.4, so most carp samples in our study have a favorable PUFA/SFA ratio.

CONCLUSION

Based on the results of our research, it can be concluded that aquaculture carp contain almost similar SFA content (25.95% - spring and 30.77% - autumn) compared to open water carp (25.84% - spring and 31.91% - autumn). Palmitic acid was the major SFA in both aquaculture and open water carp. Regarding MUFA content, it is significantly higher in both seasons in aquaculture carp (63.27% - spring; 59.85% - autumn) compared to open water carp (48.11% - spring; 54.12% - autumn). Oleic acid was identified as the major MUFA in both aquaculture and open water carp. In both seasons, the value of PUFA is significantly higher in open water carp (26.17% - spring; 13.97% - autumn) compared to aquaculture carp (10.90% - spring; 9.39% - autumn). This difference can be related to the type of diet and the way of growing.
Our research shows that all analyzed carp samples are good source of n-6 fatty acids (especially linoleic) and n-3 fatty acids (especially α-linolenic, EPA and DHA). These results come from the diet of a carp with phytoplankton, which is usually rich in essential fatty acids.
Open water carp contain more n-3 PUFA. However, this amount varies considerably depending on the diet (herbivores, omnivores, carnivores), the fish environment, the fish age, the food origin (natural food or artificial supplements) as its composition (primarily rich in n-3 polyunsaturated fatty acids or saccharides).
In industrial production systems, diet is a factor that has the most significant effect on the chemical and fatty acid composition of fish meat, as the composition of the food may partially alter the accumulation of the components that build up the tissue as well as the energy sources. The fat content of meat in fish species that are grown naturally cannot be changed by man and it is influenced by the type and amount of available food. The differences in the fatty acid composition can be influenced by the quality and quantity of the food, especially the availability of phytoplankton.
Generally, the most optimal results in terms of nutritional value of fish meat were found in open water carp, i.e Prespa Lake, in the spring, due to low fat content and high PUFA content, especially linoleic (n-6), as well as EPA and DHA (n-3) fatty acids, which result from the way of feeding, because carp consume natural foods from the lake's benthos itself, i.e phyto and zooplankton, which are especially rich in essential fatty acids.

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