

EVALUATION OF NUTRITIONAL QUALITY OF COMMON CARP (*CYPRINUS CARPIO* L.) LIPIDS THROUGH FATTY ACID RATIOS AND LIPID INDICES

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Abstract

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The purpose of the present study was to determine the nutritional quality of carp lipids on the basis of fatty acid ratios and lipid indices. The experiments for fatty acids content of lipids were carried out in 2012–2013 in common carp (*Cyprinus carpio* L.) for human consumption reared in production systems with various level of intensification (semi-intensive, intensive, super-intensive) and farming techniques (earth ponds, dam lakes, net cages). In this study, the biologically important ω -6: ω -3 fatty acid ratio in carp meat lipids was established. It was shown that in 7 out of the 9 studied production systems, ratios were within the optimum range according to modern concepts of healthy human nutrition (< 5.0). The determined ratios of polyunsaturated to saturated fatty acids in carp lipids were between 0.53–1.64. The lipids of the studied groups of carps from production systems with various level of intensity possessed very good anti-atherogenic and anti-thrombogenic properties, as the values of respective lipid indices were lower than 1.0 (index of atherogenicity from 0.24 to 0.51 and index of thrombogenicity from 0.39 to 0.61). The higher (< 1.0) cholesterolemic indices (2.03–4.62) determine the good hypocholesterolemic potential of meat lipids in studied carp production systems. This is a parameter of the relatively high functional and biological activity of meat lipids and their beneficial effect on human health.

Key words: carp, *Cyprinus carpio* L., fatty acid ratios, lipid indices, index of atherogenicity, index of thrombogenicity, cholesterolemic index

Introduction

The various biological functions of lipids are acknowledged. They are a source of energy and building materials for men, providing a number of essential substances – unsaturated fatty acids, phospholipids, fat-soluble vitamins, sterols etc. Fatty acids are the primary structural components of lipids, which determine their physical properties, oxidative stability, nutritional and biological values. The n-6/n-3 ratio is a crucial part of all investigations on the fatty acid composition of fish lipids. The studies of some researchers (Piggot and Tucker, 1990; Simopolous, 2003; Simopolous, 2013) outlined that the ω -6/ ω -3 fatty acid ratio could be utilised as an index for comparison of the relative nutritional

value of fish lipids. According to Arts et al. (2001) the nutritional value of C20 and C22 omega-3 fatty acids is higher than that of fatty acids with 18 carbon atoms. Namely, eicosapentaenoic and docosahexaenoic acids are responsible for the changes in omega-6/omega-3 ratio when they prevail. The polyunsaturated fatty acids/saturated fatty acids ratio (PUFA/SFA) is used for assessment of fish lipids on the basis of the proportions of the different fatty acids groups. It plays a significant role for cell membrane properties such as fluidity, contributing to the normal cell metabolism (Merdzhanova, 2014). One polyunsaturated fatty acid with anti-atherogenic properties are the linoleic acid (C18:2 ω -6), while the linolenic (C18:3 ω -3), eicosapentaenoic (C 20:5 ω -3) and docosahexaenoic (C22:6 ω -3) acids possess anti-

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thrombogenic effects (Badimon et al., 2010). All these data suggest that the omega-6/omega-3 fatty acid ratio could be a reliable parameter for evaluation of the relative nutritional value of lipids, whereas their functional properties could be assessed through primary lipid indices as atherogenic index, thrombogenic index and cholesterolemic index, calculated on the basis of fatty acids content.

The purpose of the present study was to determine the nutritional quality of carp lipids on the basis of fatty acid ratios and lipid indices.

Materials and Methods

The experiments for fatty acids content of lipids were carried out in 2012–2013 in common carp (*Cyprinus carpio* L.) for human consumption reared in production systems with various level of intensification (semi-intensive, intensive, super-intensive) and farming techniques (earth ponds, dam lakes, net cages). Semi-intensive systems (SemiIS) were as followed: The Tri Voditsi/ 10 Experimental base (SemiIS-1), Tsarimir 1 Dam Lake (SemiIS-2) and the free aquatory of the Bistritsa Dam Lake (SemiIS-3). Intensive systems (IS) were the Tundzha 73/4 fish farm (IS-1), the Tundzha 73/ 5 fish farm (IS-2), and Tsarimir 2 Dam Lake (IS-3). Super-intensive systems consisted of net cages in Bistritsa Dam Lake (SuperIS-1) and net cages in the Kardzhali Dam Lake (SuperIS-2). The 40 Izvora Dam Lake were used as control aquatic ecosystem (CAES) (Table 1).

Once monthly, from May to October for each year of the study, analysis of physico-chemical parameters of water in experimental ponds was performed. The obtained values for water temperature, water pH and dissolved oxygen were

within the technological allowances for cyprinids providing adequate farming conditions.

The fatty acid composition of carp meat triglycerides was analyzed by gas chromatography using a HP 5890 II gas chromatograph with flame ionization detector, 60 m DB-23 capillary column, column temperature – 130°C (1 min), 6.5°C/min increments up to 170°C, 3.0°C/min increments up to 215°C (12 min); 40.0°C/min up to 230°C (1 min); detector temperature – 280°C; injector temperature – 270°C, carrier gas – hydrogen (H₂), split 1:50 and software Data Apex Clarity TM 2.4.1.93/2005. The individual fatty acid content was identified with standards and through retention times. The results are expressed as g.100 g⁻¹ fat.

Fatty acid ratios: the ω-6/ω-3 fatty acid ratio; the PPU-FA/SFA ratio were calculated on the basis of individual fatty acid content of carp meat (Antova et al., 2014).

The index of atherogenicity (IA) and index of thrombogenicity (IT) were calculated on the basis of individual fatty acid content of carp meat (Antova et al., 2014) using the equations of Ulbricht and Sauthgate (1991):

$$(AI) = [(C12:0 + 4 \times C14:0 + C16:0)] / \Sigma M H M K + \Sigma \omega-6 + \Sigma \omega-3$$

$$(TI) = (C14:0 + C16:0 + C18:0) / [(0.5 \times \Sigma M H M K) + (0.5 \times \Sigma \omega-6) + (3 \times \Sigma \omega-3) + (\Sigma \omega-3 / \omega-6)]$$

Cholesterolemic index (h/H) was calculated as per Santos-Silva et al. (2002):

$$(h/H) = (C18:1\omega-9 + C18:2\omega-6 + C18:3\omega-3 + C18:3\omega-6 + C20:2\omega-6 + C20:3\omega-6 + C20:4\omega-6 + C20:5\omega-3 + C22:6\omega-3) / (C12:0 + C14:0 + C16:0)$$

Table 1

Characteristics of the studied production systems

Production systems	Semi-intensive			Intensive			Super-intensive		Control aquatic ecosystem
	SemiIS-1*	SemiIS-2	SemiIS-3	IS-1	IS-2	IS-3	SuperIS-1	SuperIS-2	CAES
Type of feed	grain / meal	grain / meal + CEF**	grain / grain screenings + CEF	CPF	CEF	CEF	CEF	CEF	for angling
Ratio of feed, %	50:50	73:16:11	70:30	100	100	100	100	100	–
area dka	45	500	204	750	200	40	–	–	489
m ³	–	–	–	–	–	–	80	156	–

*(SemiIS-1) – Tri Voditsi/ 10 Experimental base; (SemiIS-2) – Tsarimir 1 dam lake; (SemiIS-3) – the free aquatory of the Bistritsa dam lake; (IS-1) – Tundzha 73/ 4 fish farm; (IS-2) – Tundzha 73/ 5 fish farm; (IS-3) – Tsarimir 2 dam lake; (SuperIS-1) – net cages in Bistritsa dam lake; (SuperIS-2) – net cages in the Kardzhali dam lake; (CAES) – the 40 Izvora dam lake

**CEF – combined extruded feed; CPF – combined pelleted feed

The statistical analysis of data was done with the MS Office 2010 software. The significance of differences between two samples was evaluated with the Student's t-test at a level of significance $P < 0.05$.

Results and Discussion

Fatty acid ratios

ω -6/ ω -3 ratio

The calculated ω -6/ ω -3 fatty acid ratios are listed in Table 2. In studied production systems, this ratio varied within a rather broad range from 0.19 to 5.23. Those major differences are mainly attributed to the feeding regimens and production system type (Svoboda and Vykovska, 1986), as well as to fish species, the season, environmental conditions and type of food (Justi et al., 2003). The studies performed in The Tri Voditsi experimental base demonstrated that the good development of natural food in ponds, the good trophic level of zooplankton, the supplementation of fish with feeds (grain and sunflower meal) influenced the content of omega-3 and omega-6 fatty acids. In lipids of carp farmed in the Tri Voditsi /10 experimental base and the 40 Izvora Dam Lake, the proportions of the polyunsaturated eicosapentaenoic acid (C20:5 ω -3) were relatively high (4.93% and 4.06%, respectively), i.e. by 2 to 12 times higher as compared to the other studied groups of carps/ This fact showed that farming systems with well-developed planktonic organisms promoted the synthesis of eicosapentaenoic acid (C20:5 ω -3) in line with data reported by Mraz et al. (2011). Therefore, the carp groups in these systems had lower omega-6/omega-3 fatty acid ratios.

The fatty acid content of carp lipids from production systems where only extruded compound feed (ECF) was used (Tundzha 73/5 fish farm, Tsarimir 2 Dam Lake) as well as from systems utilising ECF, meal and grain (the

free aquatory of the Bistritsa Dam Lake; Tsarimir 1 Dam Lake) was characterized with higher level of linoleic (C18:2 ω -6) and lower content of linolenic (C18:3 ω -3) acids. According to Sargent et al. (2002) these two fatty acids are precursors in the synthesis of essential omega-6 and omega-3 polyunsaturated fatty acids, respectively. As a result, omega-6 fatty acids could be possibly synthesized in a greater amount than that of omega-3 fatty acids; hence, the omega-6/omega-3 fatty acid ratios were higher in farming systems using ECF vs those using natural feeding only (40 Izvora Dam Lake) and those where carps were fed natural food and supplemented with meal and grain (Tri Voditsi /10 experimental base).

The ratios established in this study were in agreement with the results of Buchtová et al. (2010) and Ćirković et al. (2011) in carps reared in production systems with different type of feeding.

The omega-6/omega-3 fatty acid ratios in carp lipids demonstrated in this study were lower than those in other foodstuffs. For instance, this ratio for animal fat ranges between 2 and 10, whereas in vegetable oils, commonly used in households, it is between 15 and 200 (Hossain, 2011; Usydus et al., 2011). This is a proof that fish fat is more balanced than both vegetable and animal fats with respect to the amounts of omega-3 and omega-6 fatty acids and their ratio.

The analysis of data suggested that in general, the omega-6/omega-3 fatty acid ratios of carp meat lipids from surveyed fish farms with different level of intensity were either lower or slightly higher than the value of 5.0 recommended by the WHO. Carp fat according to the results had a more balanced omega-3 and omega-6 fatty acids content than vegetable oil and animal fats and a more favorable ratio. From nutritional point of view, their participation in human nutritional schedule is desirable.

Table 2
Fatty acid ratios of carp in studied production systems

Production systems	ω -6/ ω -3		PUFA/SFA	
	x	Sx	x	Sx
Tri Voditsi/ 10 Experimental base	1.24	0.35	0.77	0.01
Tsarimir 1 dam lake	2.75	0.47	0.53	0.04
Free aquatory of the Bistritsa dam lake	3.36	1.11	1.21	0.20
Tundzha 73/ 4 fish farm	5.09	0.62	1.32	0.18
Tundzha 73/ 5 fish farm	2.22	0.67	1.26	0.18
Tsarimir 2 dam lake	2.80	0.93	0.69	0.09
Net cages in Bistritsa dam lake	5.23	0.54	1.64	0.06
Net cages in the Kardzhali dam lake	2.49	0.12	0.74	0.05
The 40 Izvora dam lake	0.19	0.22	0.57	0.05

Polyunsaturated fatty acids/saturated fatty acids (PUFA/SFA) ratio

On the basis of proportions of the different groups of fatty acids, the PUFA/SFA ratio (Table 2) varied from 0.53 to 1.64. According to the British Department of Health (1994) the minimum recommended PUFA/SFA ratio is 0.45. Other authors and literature sources (Kang and Leaf, 2000; AHA, 2005; EFSA, 2009; WHO, 2003; WHO, 2010; FAO/WHO, 2008) define an optimum value of 1.0 ± 0.2 ; i.e. PUFA/SFA ratios should be preferable within the range from ≥ 0.45 to 1.0.

The PUFA/SFA ratios of fish farmed in Tsarimir 1 Dam Lake, The 40 Izvora Dam Lake, the net cages in the Kardzhali Dam Lake and Tri Voditsi /10 fish farm varied within 0.53 – 0.77 i.e. within the recommended interval being higher than 0.45 (Department of Health, 1994). The results indicated that in cited fish farming systems using different types of feeds as grain and meal in ponds, mixed feeding with grain and extruded compound feed in dam lakes, carp meat lipids had a more favorable PUFA/SFA ratio. The ratios lower than 1.0 (Simopolous, 2013) in these production systems indicated a balanced distribution of fatty acid groups. The lipids of carps reared in IS-1 (Tundzha 73 /4 fish farm), IS-2 (Tundzha 73 /5 fish farm), SemiIS-3 (free aquatory of Bistritsa Dam Lake) and SuperIS-1 (net cages in Bistritsa Dam Lake) had ratios higher than the optimum value within 1.21–1.64. The probable reason was the higher proportion of the SFA group and more precisely, the higher relative share of palmitic acid (C16:0) in these farming systems. The PUFA/SFA ratios obtained in the present study corresponded to those reported in freshwater fish within the ranges of 0.71–1.26 (Merdzhanova, 2014) and 0.21–0.92 (Hadjinikolova, 2008).

Lipid indices

The calculated carp meat lipid indices in studied production systems are presented in Table 3.

Index of atherogenicity (IA)

The mean values of the index of atherogenicity (IA) varied from 0.24 to 0.51. The reason for the low IA of fish from SuperIS-1 (net cages in Bistritsa Dam Lake) was the low proportion of palmitic acid (15.03%), whereas fish with higher IA had also higher palmitic acid percentages: 18.70–22.97% (free aquatory of Bistritsa Dam Lake, Tri Voditsi /10 experimental bases). Exception were the lipids of carps farmed in net cages of the Kardzhali Dam Lake and The 40 Izvora Dam Lake, whose higher IA values (0.38 and 0.51) than the IA range of groups from the free aquatory of Bistritsa Dam Lake, Tundzha 73 /4 fish farm, Tundzha 73 /5 fish farm and Tsarimir 2 Dam Lake (0.24 – 0.31) were due not to higher palmitic acid content, but to lower values of the unsaturated fatty acids groups (73.67% and 65.57%) in particular, to monounsaturated fatty acids. The obtained IA values allowed concluding that the lipids of the mentioned groups of carps had a higher anti-atherogenic activity and could therefore exert a beneficial effect on human health, making them a suitable food. For lipids of animal origin, the recommended index of atherogenicity is from 0.5 to 1.0 (Senso et al., 2007). In all studied production systems, IA values of carp lipids were lower than 1.0, indicating their good anti-atherogenic properties.

Index of thrombogenicity (IT)

The average index of thrombogenicity (IT) in studied farming systems varied within a narrow range from 0.39 (net cages of the Bistritsa Dam Lake) to 0.61 (The 40 Izvora dam lake). The values lower than 1.0 provides evidence for good anti-thrombogenic properties. The IT values are determined by three saturated fatty acids – miristic (C14:0), palmitic (C16:0) and stearic (C18:0) fatty acids (Hornstra and Lussenberg, 1975). Out of the three,

Table 3
Lipid indices of carp in studied production systems

Production systems	IA		IT		h/H	
	x	Sx	x	Sx	x	Sx
Tri Voditsi/ 10 Experimental base	0.46	0.03	0.52	0.04	2.31	0.17
Tsarimir 1 dam lake	0.39	0.02	0.58	0.01	2.56	0.11
Free aquatory of the Bistritsa dam lake	0.33	0.04	0.46	0.02	3.39	0.48
Tundzha 73/ 4 fish farm	0.30	0.03	0.46	0.04	3.30	0.27
Tundzha 73/ 5 fish farm	0.32	0.03	0.39	0.05	3.13	0.29
Tsarimir 2 dam lake	0.31	0.08	0.48	0.01	3.12	0.44
Net cages in Bistritsa dam lake	0.24	0.01	0.39	0.02	4.62	0.40
Net cages in the Kardzhali dam lake	0.38	0.01	0.47	0.02	3.16	0.11
The 40 Izvora dam lake	0.51	0.06	0.61	0.03	2.03	0.29

it is believed that the stearic acid (C18:0) has the least thrombogenic potential (Hegsted et al., 1965; Mancini and Parillo, 1991). In the present study on the thrombogenicity of meat lipids in studied carp farming systems, the greatest effect was that of the palmitic acid, whose proportions were the most substantial (15.03–23.08%), followed by stearic acid.

Cholesterolemic index (h/H)

The mean values for the cholesterolemic index (h/H) ranged between 2.03 and 4.62. It should be emphasized that fish farmed in intensive and super-intensive systems had higher h/H indices as compared to both semi-intensive and control systems. The carps from the two super-intensive systems had statistically significantly higher lipid h/H values ($P < 0.05$) compared to the carps in the control aquatic ecosystem (The 40 Izvora Dam Lake) and semi-intensive production systems (SemiIS-1 and SemiIS-2). Regardless of the differences in h/H values, there were considerably higher than 1.0 for all studied farming systems, indicating a good hypocholesterolemic potential of studied groups of carp meat lipids.

The results about lipid indices established in the present study are in agreement with those reported by other researchers and similar to data of Stancheva and Merdzhanova (2011). The meat of carps from retail markets exhibited IA values about 0.65, IT – 0.36 and lower cholesterolemic index value – 1.32. Comparing these lipid indices with values for animal fat, it could be seen that lipid indices for pork meat had similar IA values (0.6) but higher IT (2.0). For lamb meat, both lipid indices had higher values compared to carps in the present study, i.e. IA = 1.75 and IT = 2.0. For poultry meat, IA and IT values were comparable to those of carps – IA < 1 and IT > 1 (Valfre et al., 2003).

The obtained results for lipid indices allowed summing up that in studied production systems, carp lipids possessed much better anti-atherogenic, anti-thrombogenic and anti-cholesterolemic properties as shown by IA and IT values lower than 1.0 and higher h/H values. In all studied fish farms, a tendency for higher cholesterolemic indices was observed, followed by values for indices of thrombogenicity and atherogenicity, i.e. h/H > IT > IA.

Conclusions

In this study, the biologically important ω -6: ω -3 fatty acid ratio in carp meat lipids was established. It was shown that in 7 out of the 9 studied production systems,

ratios were within the optimum range according to modern concepts of healthy human nutrition (< 5.0). The determined ratios of polyunsaturated to saturated fatty acids in carp lipids were between 0.53–1.64.

The lipids of the studied groups of carps from production systems with various level of intensity possessed very good anti-atherogenic and anti-thrombogenic properties, as the values of respective lipid indices were lower than 1.0 (index of atherogenicity from 0.24 to 0.51 and index of thrombogenicity from 0.39 to 0.61).

The higher (<1.0) cholesterolemic indices (2.03–4.62) determine the good hypocholesterolemic potential of meat lipids in studied carp production systems. This is a parameter of the relatively high functional and biological activity of meat lipids and their beneficial effect on human health.

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