Fatty Acids in Lipids of Carp (*Cyprinus carpio*) Tissues

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Abstract

KMÍNKOVÁ M., WINTEROVÁ R., KUČERA J. (2001): **Fatty acids in lipids of carp** (*Cyprinus carpio*) **tissues**. Czech J. Food Sci., **19**: 177–181.

The content of fat in carp (*Cyprinus carpio)* tissue was evaluated throughout one year. The following tissues were evaluated: skeletal muscle, soft roe, hard roe, fat tissue, and hepatopancreas. Respective fatty acids were determined using gas liquid chromatography (GLC). The highest content of valuable polyunsaturated acids, like eicosahexaenoic acid, was found in soft roe and in skeletal muscle during summer, in hepatopancreas during spring, in hard roe during fall. The content of eicosahexaenoic acid in hard roe remains high in all seasons except summer. Saturated fatty acids like palmitic acid and stearic acid do not fluctuate very much throughout the year. The maximum concentration of oleic acid was found in summer. Differences in fatty acid concentration among different carp tissues depended on the living style, but their variation in the same tissue within the year depended on the main fodder of fish.

Keywords: freshwater fish; carp; fatty acids; seasonal variation

Fish, both freshwater and marine, are extremely rich source of polyunsaturated fatty acids for human consumption. Polyunsaturated fatty acids are known to diminish the level of blood cholesterol (ITAKURA 1993). They also play an important role in the structure and function of cellular membranes and are precursors of lipid mediators, which are key factors in cardiovascular and inflammatory diseases (CARLIER *et al*. 1991). Chronic renal failure (CRF) may be accelerated by secondary lipid and immune abnormalities that could be antagonized by polyunsaturated fatty acids (CAPPELLI *et al*. 1997). Moreover, diets with higher levels of ω-3 polyunsaturated fatty acids suppress tumorigenesis (CAVE 1991). From this point of view any information concerning the actual concentration of polyunsaturated fatty acids in tissue used for food preparation may be of high importance.

Freshwater fish living in seasonally fluctuating conditions (temperature, oxygen access etc.) periodically changes the way of life and, consequently, the content of different compounds. Recently we have shown the activity of proteolytic enzymes (KMÍNKOVÁ *et al*. 1997), alkaline phosphatase (KMÍNKOVÁ *et al*. 1994) and some other enzymes (VÁCHA *et al*. 1995, 1998) to be dependent on seasonal changes in fish activity. The same is true for bile acid concentration (BALDISSEROTTO *et al*. 1990) and, as we have shown in the present work, for different fatty acid content of fish fat. We have selected carp (*Cyprinus carpio*), the fish consumed in the Czech Republic most frequently, as a model to follow the course of seasonal variation of individual fatty acids in fish fat.

MATERIAL AND METHODS

The fish individuals were obtained from Benešov-Líšno Fishery, Czech Republic. Scaled carp *(Cyprinus carpio*) was caught in different ponds in the central part of Bohemia. The fish and its viscera were frozen immediately after killing and resection and kept at –25°C until analyzed. Prior to analysis the hepatopancreas, hard roe, soft roe and muscle were separated and weighed.

Carps were caught in April, August, December and February (in spring, summer, fall and winter). Average temperature of water in ponds was 20–25°C one meter under the surface in summer and 1–3°C in winter. In ponds carp was fed by wheat, rye, barley and pea.

For analysis 6–8 adult fish weighing 2.3–3.0 kg were used. Average samples were prepared by collecting separated parts of the same kind of viscera (hepatopancreas,

Supported by the National Agency for Agricultural Research (NAZV) of the Czech Republic, Grant No. EP6255.

roe, etc.) from all individuals and grinding them together in the kitchen mill.

The muscle samples were always taken in the form of a vertical strip behind the head. The skin and the larger bones were discarded and the remaining muscle was ground.

Lipids were extracted by the chloroform-methanol solvent according to FOLCH *et al*. (1957).

Lipid samples were converted to their constituent fatty acid methyl esters by methanol and methanolic potassium hydroxide according to ČSN ISO 5509. The fatty acid composition of individual carp organs was determined by gas chromatography on a Hewlett-Packard 5890 chromatograph, using the capillary DB-WAX column (30 m × 0.32 mm i.d., Supelco) and quantified by a flame ionization detector. Polyethylenglycol was used as the stationary phase, and nitrogen with flow rate 1.9 ml/min as the mobile phase. The following chromatographic conditions were used: injection port temperature 220°C; flame ionization detector temperature 250°C. The temperature program had two steps: step l 85–150°C, step 2 150–230°C, hold time 10 min. Hydrogen with pressure 100 kPa and air with pressure 300 kPa were used as detection gas. Sample volume was 1 µl. Individual compounds were identified by comparison with retention times of known standards.

All chemicals were of reagent grade (Sigma Fine Chemicals).

RESULTS AND DISCUSSION

The lipid content values of different parts of carp are summarized in Table 1. Within the parts examined the lipid content varied significantly. The concentration of fat in muscle was almost constant during the year except in spring, when the vital activity of fish started prior to increased fodder availability. The maximum fat values were found in hepatopancreas, the only part of carp body that is not commonly used as food. Fat concentration in hepatopancreas was found to reach its maximum during spring, but to be high even in summer. The content of fat in hepatopancreas decreased during fall and winter, approaching fat level of muscle. Lowest fat values were found in hard roe throughout all seasons, having slight maximum in fall. Soft roe contained maximum fat levels in spring, but still less than muscle. It can be concluded from Table 1 that hepatopancreas is the optimum source of carp fat, namely during spring and summer.

Table 1. Lipid content of different carp tissue in seasons

Tissue	Fat (g per100 g of tissue)			
	spring	summer	fall	winter
Hepatopancreas	11.72	10.01	5.09	4.75
Soft roe	1.72	3.15	1.45	0.46
Hard roe	0.65	0.96	1.08	0.42
Muscle	2.08	5.92	5.71	5.03
Fatty tissue	47.18	46.86	43.18	50.51

Relative concentration of (ω-3) to (ω-6) polyunsaturated fatty acids is even more important than total lipids. As shown in Table 2, this ratio favouring (ω-3) was found in all tissues except the fat tissue itself. Namely soft roe and hard roe have high content of (ω-3) polyunsaturated fatty acids.

Table 2. The relative concentration of ω-3 to ω-6 polyunsaturated fatty acid in different carp tissue in seasons

Tissue	(ω-3)/(ω-6)			
	spring	summer	fall	winter
Hepatopancreas	1.145	0.869	0.818	1.009
Soft roe	2.413	1.471	0.920	1.897
Hard roe	1.986	2.128	1.040	1.867
Muscle	1.345	0.954	0.925	0.776
Fatty tissue	1.066	0.497	0.708	0.605

The concentration of individual fatty acids in different carp tissue changes within the year according to the living activity of fish and fodder availability. The data showing the seasonal variation of individual acids (saturated, unsaturated, and polyunsaturated) in different tissues throughout the year are summarized in Table 3.

Palmitic (C 16:0), palmitoleic (C 16:1), oleic (C 18:1), arachidonic (C 20:4), eicosapentaenoic (C 22:5), and docosahexaenoic (C 22:6) fatty acids were found to be the major acids in smelt, sucker, rainbow trout and lake trout muscle (KINSELLA *et al*. 1977). The same is true for carp muscle, but carp fatty tissue is relatively low in docosapentaenoic (C 22:5) acid, and high in α-linolenic (C 18:3), and γ-linolenic (C 18:3) acids (Table 3). Palmitic (C 16:0), palmitoleic (C 16:1), oleic (C 18:1), α-linolenic (C 18:3), eicosapentaenoic (C 20:5), and docosahexaenoic (C 22:6) fatty acid are the major fatty acids of carp hepatopancreas, with negligible amout of γ-linolenic (C 18:3) acid, and lower in arachidonic (C 20:4) acid. Soft roe is rich in palmitic (C 16:0), oleic (C 18:1), eicosapentaenoic (C 20:5), and docosahexaenoic (C 22:6) acids, while hard roe is high in palmitic (C 16:0), oleic (C 18:1), and docosahexaenoic (C 22:6) acids.

Fat tissue itself has a remarkably high content of oleic acid, eicosapentaenoic and docosahexaenoic acids. Their concentrations are relatively steady throughout the year. Nevertheless, the utilization of carp fatty tissue for human alimentation seems very unlikely. Hepatopancreas, the part of carp viscera that is used only scarcely as human food, could serve as another very useful source of these fatty acids.

Table 3. The seasonal variation of individual fatty acids in different carp tissue

Fatty acid		Content in mg per 100 g of tissue			
		spring	summer	fall	winter
Hepatopancreas					
C 14:0	myristic	159.4	118.1	70.2	53.2
C 14:1	myristo-oleic	44.5	22.0	10.7	10.
C 16:0	palmitic	2 183.4	1 980.0	917.7	892.1
C 16:1	palmito-oleic	1 034.9	992.0	596.0	455.5
C 18:0	stearic	537.9	599.6	263.2	293.6
C 18:1	oleic	4 109.0	3 933.9	2 267.1	1 938.5
C 18:2	linoleic	923.5	684.7	324.7	253.7
C 18:3	γ-linolenic	21.1	22.0	10.7	7.1
C 18:3	α-linolenic	617.6	284.3	184.3	114.5
C 20:1	eicosanoic	309.4	224.2	140.0	136.8
C 20:4	arachidonic	158.2	173.2	30.0	70.3
C 20:5	eicosapentaenoic	325.8	172.2	61.1	90.7
C 22:5	docosapentaenoic	118.4	66.1	20.9	45.6
C 22:6	docosahexaenoic	318.8	308.3	53.4	128.7
Soft roe					
C 14:0	myristic	12.6	29.0	16.8	1.7
C 14:1	myristo-oleic	–	7.6	3.5	0.6
C 16:0	palmitic	290.2	622.4	260.3	78.8
C 16:1	palmito-oleic	106.0	267.1	142.8	15.7
C 18:0	stearic	90.8	205.1	80.2	34.1
C 18:1	oleic	360.5	1 032.6	640.3	75.9
C 18:2	linoleic	76.2	159.4	96.9	15.3
C 18:3	γ-linolenic	2.9	6.6	3.0	0.5
C 18:3	α-linolenic	60.4	68.7	55.0	3.0
C 20:1	eicosanoic	30.4	62.1	35.1	10.6
C 20:4	arachidonic	89.1	104.9	19.0	37.7
C 20:5	eicosapentaenoic	145.0	120.0	23.9	34.0
C 22:5	docosapentaenoic	44.4	34.0	7.8	11.1
C 22:6	docosahexaenoic	200.6	209.8	30.5	64.4
Hard roe					
C 14:0	myristic	6.57	10.66	15.44	3.28
C 14:1	myristo-oleic	2.21	2.69	2.38	0.97
C 16:0	palmitic	134.55	216.77	200.66	81.06
C 16:1	palmito-oleic	55.97	71.14	123.77	24.91
C 18:0	stearic	35.88	60.77	57.67	26.08
C 18:1	oleic	198.64	286.75	488.16	103.78
C 18:2	linoleic	38.94	40.51	73.55	13.36
C 18:3	γ-linolenic	1.24	1.44	3.02	0.71
C 18:3	α-linolenic	25.81	17.86	39.10	5.21
C 20:1	eicosanoic	13.07	16.42	27.86	6.05
C 20:4	arachidonic	18.98	38.30	8.10	25.70
C 20:5	eicosapentaenoc	26.72	38.88	15.55	19.95
C 22:5	docosapentaenoic	13.07	20.26	6.70	9.49
C 22:6	docosahexaenoc	64.94	114.05	33.37	49.10

Table 3 to be continued

Fatty acid		Content in mg per 100 g of tissue			
		spring	summer	fall	winter
Muscle					
C 14:0	myristic	27.2	58.6	73.1	53.3
C 14:1	myristo-oleic	7.3	12.4	14.8	8.0
C 16:0	palmitic	398.3	1 117.1	994.1	894.8
C 16:1	palmito-oleic	206.3	647.6	595.6	501.5
C 18:0	stearic	99.0	338.0	270.1	305.8
C 18:1	oleic	763.6	2 433.7	2 473.0	2 246.9
C 18:2	linoleic	149.3	407.3	389.4	295.8
C 18:3	γ-linolenic	3.7	18.4	14.3	8.0
C 18:3	α-linolenic	103.8	145.0	250.7	112.2
C 20:1	eicosanoic	44.3	126.7	151.3	134.3
C 20:4	arachidonic	26.6	107.2	37.1	55.8
C 20:5	eicosapentaenoic	82.2	149.2	113.1	91.0
C 22:5	docosapentaenoic	24.5	56.2	35.4	31.2
C 22:6	docosahexaenoic	55.7	214.3	44.0	76.0
Fatty tissue					
C 14:0	myristic	598.2	478.0	565.7	601.1
C 14:1	myristo-oleic	117.8	75.0	90.7	85.9
C 16:0	palmitic	8 963.1	8 851.9	7 504.7	9 086.7
C 16:1	palmito-oleic	5 294.0	5 777.8	4 451.9	4 854.0
C 18:0	stearic	2 242.0	2 478.9	2 495.8	3 262.9
C 18:1	oleic	22 071.1	21 621.2	20 912.1	23 997.3
C 18:2	linoleic	84.8	3 261.5	2 919.0	2 949.8
C 18:3	γ-linolenic	1 733.3	117.2	90.7	90.9
C 18:3	α-linolenic	1 026.8	1 002.8	1 545.8	1 217.3
C 20:1	eicosanoic	927.9	1 040.3	1 127.0	1 328.4
C 20:4	arachidonic	249.6	192.1	194.3	197.0
C 20:5	eicosapentaenoic	927.9	449.9	544.1	530.4
C 22:5	docosapentaenoic	212.0	117.2	177.0	166.7
C 22:6	docosahexeanoic	249.6	323.3	177.0	212.1

All carp body parts analyzed in this study were found to be a superior source of oleic acid, the content of which only slightly varies during the year. According to some reports (e.g. CHONG & NG 1991; PETERSON *et al*. 1994), this acid is known to prevent cardiovascular diseases.

The fatty acid composition of different carp body parts, as described here, shows marked differences in quantities of polyunsaturated fatty acids among respective parts and significant seasonal differences. Namely the quantities of polyunsaturated fatty acids were observed to fluctuate. The variation in saturated fatty acids was remarkably lower. ACKMAN (1974) summarized and reviewed numerous studies showing effects of freshwater fish location, age, diet, size, and ambient temperature on these components, but no data on seasonal differences in fat composition of individual tissues are available. The only tissue analyzed was muscle, and sometimes also roe, with special focus on salmon roe.

The ratio of unsaturated vs. saturated fatty acids is of much importance in edible fat. The value of more than 0.35 is usually believed to be beneficial. Table 4 shows these values in fat of different carp tissues. Even from this point of view carp fat is beneficial for human nutrition.

While knowledge of fatty acid composition *per se* is useful for comparative purposes, actual quantities of individual fatty acids are needed for nutritional evaluation. These data can be calculated from Table 3. They indicate

Table 4. Relationship between unsaturated and saturated fatty acids in carp tissues

Tissue	Unsaturated/saturated			
	spring	summer	fall	winter
Hepatopancreas	2.62	2.44	2.83	2.48
Soft roe	1.31	1.61	2.28	0.9
Hard roe	2.07	1.92	2.37	2.02
Muscle	2.16	2.22	2.38	2.27
Fatty tissue	2.96	2.25	2.39	2.23

that carp would be a very suitable component of low fat highly polyunsaturated acid diets. Moreover, Table 3 shows that hepatopancreas, the scarcely utilized part of carp viscera, can be highly recommended to be included into such formulation in the proper period of the year.

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Received for publication July 30, 2000
Accepted for publication December 12, 2000

Souhrn

KMÍNKOVÁ M., WINTEROVÁ R., KUČERA J. (2001): **Mastné kyseliny v tuku kapra** (*Cyprinus carpio*). Czech J. Food Sci., **19**: 177–181.

V průběhu jednoho roku jsme sledovali obsah tuku v různých tkáních kapra (*Cyprinus carpio)*. Ke sledování jsme zvolili tyto tkáně kapra: kosterní sval, mlíčí, jikry, tukovou tkáň a hepatopankreas. Nejvyšší obsah tuku jsme zjistili ve svalu v létě (5,92 %), v hepatopankreatu na jaře (11,72 %), v mlíčí v létě (3,15%) a v jikrách na podzim (pouhých 1,08 %). Nejnižší obsah tuku jsme nalezli ve svalu na jaře (2,08 %) a v hepatopankreatu v zimě (4,75 %). Tuk kapra ve všech tkáních obsahuje relativně vysokou koncentraci polynenasycených mastných kyselin. V létě tvoří kyselina dokosahexaenová celých 200 mg/100 g tkáně tuku v mlíčí a 114 mg/100 g v jikrách. Sval (214 mg/100 g) a hepatopankreas dosahují nejvyšší koncentrace této kyseliny na jaře a v létě (318,8 a 308,3 mg/100 g). Tyto výsledky ukazují, že obsah polynenasycených mastných kyselin v tuku kapra je určován z větší části dostupným krmivem. Na druhé straně to znamená, že při umělém odchovu by bylo možné koncentraci příznivě působících polynenasycených mastných kyselin ovlivnit krmivem.

Klíčová slova: ryby sladkovodní; kapr; mastné kyseliny; sezonní změny

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