A New Look at the Assessment of the Silver Carp (*Hypophthalmichthys molitrix* Val.) as a Food Fish

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Abstract

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The principal aim was to analyse the chemical composition (dry matter, protein, fat, saccharides, ash) and to calculate the energy value of 6 topographically distinct parts (cranial, medial and caudal dorsal/ventral part above/below the lateral line) of the fillets of the silver carp (*Hypophthalmichthys molitrix* Val.) in two weight categories, i.e. lightweight (LW) fish of 3.50 kg live weight, and heavyweight (HW) fish of 4.50 kg live weight. Another aim was to evaluate the lipid profile of the muscle tissue and internal fat (separated from the internal organs). The study demonstrated differences ($P < 0.05$) in the chemical composition (with the exception of saccharides) and energy values between the relatively lean dorsal sections of silver carp fillets, which rank the silver carp among medium to low-fat fish (fillet fat content: LW = 46.06 ± 5.54 g/kg, HW = 50.62 ± 5.51 g/kg), and the fatter ventral sections which, in contrast, rank the silver carp among high-fat fish (fillet fat content: LW = 158.14 ± 11.28 g/kg, HW = 157.42 ± 9.65 g/kg). The study showed that the internal fat lipids are an interesting alternative source of ∑PUFAn-3 and, in particular, of α-linolenic acid C18:3n-3 (LW = 4.79 ± 0.25, HW = 5.28 ± 0.33), EPA C20:5n-3 (LW = 2.70 ± 0.17, HW = 3.04 ± 0.15), and DHA C22:6n-3 (LW = 3.08 ± 0.20, HW = 3.41 ± 0.18).

Keywords: fish meat; composition; nutritional value; carp; fatty acids

Among the cultivated freshwater fishes, the silver carp (*Hypophthalmichthys molitrix* Val.) has attracted great attention due to its increasing production in the countries such as China, Bangladesh, India, the Russian Federation, and Iran, where the silver carp is a favourite meal for people of northern and southern regions (FAO 2009; Asgharzadeh *et al*. 2010; Hakimeh *et al*. 2010). In the European Union, the silver carp is produced (in tons live weight) most notably in Hungary (2484), Romania (1695), Croatia (434), and the Czech Republic (417) (Anonymous 2009; European Commission 2010). The silver carp (*Hypophthalmichthys molitrix* Val.) of the carp family (*Cyprinidae)* was brought to the Czech Republic (CR) from east Asia in the 1860s in order to enhance the biodiversity of freshwater fish cultivated as food in pond aquacultures where, along with other herbivorous fishes (*Ctenopharyngodon idella* Val. or *Aristichthys nobilis* Rich.), it helps reduce the excessive growth of aquatic plants.

This species is known to provide a high content of important constituents for the human diet such as nutritional and readily digestible proteins, lipid-soluble vitamins, microelements, and polyunsaturated fatty acids (Simopoulos 1997). Along with proteins and saccharides, lipids represent a source of energy, and have important biological

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functions because of the presence of essential fatty acids (Vujković *et al*. 1999).

In the CR, the meat of lightweight silver carp (max. 3.0 to 3.5 kg live weight) is considered good quality, fine-textured and white meat. Heavy-bodied fish have significant deposits of fat in the ventral (abdominal) side of the body, which is nutritionally interesting (PUFAn-3), but may have a negative effect on the sensory qualities of cooked fish meat and, consequently, on the silver carp consumption levels. Although the chemical composition of the silver carp (in the overall edible portion), including the profile of fatty acids in lipids, has been described in a number of publications both old and very recent (Steffens 1997; Vujković *et al*. 1999; Romvari *et al*. 2002; Hadjinikolova 2008; Asgharzadeh *et al*. 2010; Hakimeh *et al*. 2010), the official standards effective in the CR, known as Food Composition Tables, make no mention of the nutrient values of the silver carp (Anonymous 1992). Moreover, we have no information about the composition of lipids from the silver carp internal depot fat or the results of its comparison with the profile of fatty acids from intramuscular fat. For this reason, the aim of the present study was to provide the missing data and to relate the information on the chemical composition (in view of different fat contents in meat) to specific parts of the fish body. The information generated by the study and its concluding recommendations could make a positive contribution in helping bring about a change in the traditional assessment of the silver carp in the CR, and may serve as an impulse for a change in its use as a source of food, as is the case in some other parts of the world where new approaches to the silver carp use are being sought.

In the United States, carp (including the silver carp) are generally considered to be unsuitable for direct human consumption due to the bony nature of their carcasses. However, various carp species have rapidly begun populating major bodies of fresh water to such an extent that commercial processing is now of interest. Carp have become a subject of research aimed at introducing a method that would enable an efficient utilisation of their muscle protein and fat. The study by Taskaya *et al*. (2009) indicates that the materials recovered from the whole gutted silver carp using isoelectric solubilisation/precipitation have a high nutritional value and may be useful in the development of human food (or animal feeds). In China, the silver carp is considered the cheapest and most abundant freshwater fish. New fermented products from the silver carp that would extend the range of products made from its flesh and having no undesirable fish odour and flavour are being developed (Yongjin *et al*. 2008). Of all the various applications, the silver carp minced muscle has attracted great attention for its use in the production of surimi products (Asgharzadeh *et al*. 2010). The effect of various binding agents (microbial transglutaminase) on gel-forming capacity has been examined by Uresti *et al*. (2004).

The above innovative technologies presuppose a broad interest of customers in new, non-traditional fish products. In view of the persistently low levels of freshwater fish consumption in the Czech Republic (about 1 kg/person/year) and the fact that fresh (chilled) fish products are largely preferred, it is necessary to look for a conservative solution that would make experts aware of the differences in the chemical composition (or rather fat content) and energy values that need to be taken into account in nutritional recommendations and specific types of diet. An alternative possibility could be to divert high-fat parts of the silver carp from direct consumption and use them instead, along with the depot fats of the fish, as an alternative source of highly nutritious oil (or proteins). While the internal fat of the fish may be used for human consumption (Commission Regulation 1662/2006), its composition should be equal to the composition of intramuscular fat lipids.

MATERIAL AND METHODS

Starting material and processing. Silver carp (*Hypophthalmichthys molitrix* Val.) were collected during the autumn harvest (November 2009) from a randomly chosen fish farm (Fishpond Management Pohořelice, Czech Republic, 48°57'56.267''N latitude, 16°32'39.095''E longitude, 175 m.a.s.l.). The fish had a sufficient natural diet (plankton) available in the ponds for the growth. The fish were not fed in the winter (November–February) period during breeding. Fish at market maturity were harvested at the end of the fourth vegetation period. The fish were not sexually mature, and their sex was not determined. The fish were processed at the Mušov freshwater fish processing plant using a standard processing procedure. Of a total of 35 fish collected, we selected 15 whose live

weight was approximately 3.50 kg (lightweight fish – LW) and another 20 fish whose live weight was approximately 4.50 kg (heavyweight fish – HW). The fish were first weighed, then stunned, killed, scaled, gutted (separated from the internal organs), and filleted. Each fillet from the right side of the fish body was individually vacuum packed and chilled (+2 ± 2°C max.). Each fillet was divided into two parts in the laboratory, i.e. the dorsal (above the lateral line) and the ventral (below the lateral line) parts, and each of these parts was divided into three segments (cranial, medial, and caudal). A total of 210 portions were analysed.

The following parameters were determined when the fish were processed at the plant: live fish weight (in kg), unskinned fillet weight (in kg), and internal fat weight (in g). Two parameters (fillet yield and internal fat yield) were determined mathematically (in %).

Proximate analysis. The parameters examined (in g/kg) involved the composition of the samples i.e. dry matter (DM), crude protein (CP), fat (F), ash (A), saccharides, and energy value (in kJ/100 g).

The qualitative and quantitative fatty acid composition (in % of total fatty acids investigated) was determined on samples of both sets of fish (15 and 20, respectively). Ten fish from each set were selected (total 20). Laboratory analysis of the middle part of the fillet and the internal fat of each of the 20 fish was performed.

The DM content was determined gravimetrically in accordance with the international standard IS 1442/1997 for the determination of the moisture content in flesh by drying the sample with sand up to a constant weight at +103 ± 2°C (Binder FD 53, Binder GmbH, Tuttlingen, Germany). The CP content (IS 300/2003) was determined as the amount of organically bound nitrogen (recalculating coefficient f_1 = 6.25) using a Kjeltec 2300 analyzer (FOSS Tecator, Höganäs, Sweden). The fat content was determined quantitatively (IS 390/2003) by extraction with solvents using a Soxtec 2055 (FOSS Tecator, Höganäs, Sweden) after acid hydrolysis of the samples using a SoxCap 2047 (FOSS Tecator, Höganäs, Sweden). The ash content was determined gravimetrically (IS 936/1998) by burning weighed samples in a muffle furnace (Elektro LM 212.11, Linn Electro Therm, Eschenfelden, Germany) at 550°C until the disappearance of black carbon particles. The saccharide (S) content (S = DM – CP – F – A) and energy value (EV) (EV = (CP + S) × 17 + F × 37) were determined mathematically.

Fatty acid analysis. Total lipids in raw fillets and internal fats were extracted with hexan-isopropanol (Hara & Radin 1978). The determination of the fatty acid composition was performed by gas chromatography using a GC-2010 (Shimadzu, Kyoto, Japan) apparatus with a flame ionisation detector (FID) and a VB WAX capillary column (60 m × 0.32 mm × 0.25 μm). The optimum temperature gradient was 140°C to 240°C (5°C/min). The injector temperature was 280°C, the FID temperature was 300°C. Nitrogen was used as the carrier gas.

Statistical evaluation and targed. The basic statistical values (means ± SD and SEM) of the parameters investigated were of multifactorial (ANCOVA, Statgraphics 6.0) and one-way (ANOVA, Excel 97) variances. The groups with different alphabetic superscripts in lines differed significantly at $P < 0.05$ or $P < 0.01$. The numerically lower value is indicated by an "a".

The principal aim of the study was to analyse the chemical composition (dry matter, protein, fat, saccharides, ash) of 6 topographically distinct parts (cranial, medial, and caudal dorsal/ventral part above/below the lateral line) of the silver carp

Table 1. Growth and dressing out parameters of silver carp (*Hypophthalmichthys molitrix* Val.) of 3.50 kg and 4.50 kg live weight (mean ± SD)

Parameters	Live fish weight (kg)	Unskinned fillet weight (kg)	Fillet yield (%)	Internal fat weight (g)	Internal fat yield (%)
n = 15	3.50 ± 0.21^a	1.66 ± 0.09^a	47.33 ± 2.08^a	120.37 ± 54.56^a	3.50 ± 1.79^a
n = 20	4.45 ± 0.13^b	2.09 ± 0.10^b	46.91 ± 1.77^a	130.51 ± 26.29^a	2.93 ± 0.57^a
Statistical significance	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P > 0.05$	$P > 0.05$

One-way range test of analysis of variance (ANOVA, Excel 97).

Groups with different alphabetic superscript in lines differ significantly at $P < 0.01$; the numerically lower value is indicated by an "a"

Data with common alphabetical superscripts do not differ significantly at the given level ($P > 0.05$)

(*Hypophthalmichthys molitrix* Val.) fillets from fish of two weight categories (3.50 kg and 4.50 kg live weight), to calculate their energy values, and to determine statistical differences between the parameters observed. An additional aim was to analyse the lipid composition (in % of total fatty acids investigated) of the muscle tissue and internal fat separated from the organs removed from the fish body cavity, and to find out if there are any statistically significant differences in the fatty acid profile and FA sums (saturated fatty acids ∑SFA, monounsaturated fatty acids ∑MUFA, polyunsaturated fatty acids ∑PUFAn-6, ∑PUFAn-3, ∑PUFA and the ratio ∑PUFAn-6/n-3). The parameters of the growth and dressing out (live fish weight, unskinned fillet weight and its yield, internal fat weight and its yield) were also monitored and evaluated.

RESULTS AND DISCUSSION

This study presents new data on the chemical composition of fillets from a fish that is not only a commercially important species of the farmed fish in the Czech Republic, but also a fish species produced in large quantities around the world.

Evaluation of chemical composition

The study showed that the chemical composition of the silver carp may be different in different parts of its fillets, and that the lipid content may vary significantly. Mieth *et al.* (1989) published similar results. The silver carp is classified as a medium-fat fish with up to 10% of intramuscular fat. According to Romvari *et al.* (2002), the silver carp muscle (wet matter) contains 75.2% moisture and 24.8% dry matter, 17.6% protein, 5.5% lipids, and 1.3% ash. In our experiment, the only results corresponding to the above values were those obtained from the dorsal part of silver carp fillets (above the lateral line) in both sets of fish tested (lightweight – LW and heavyweight – HW) (Tables 2 and 3). The chemical composition of the silver carp complete fillet (see the bottom lines of Tables 2 and 3) was markedly modified by the values observed in the ventral part of the fillets (i.e. below their lateral line), which (with the exception of saccharides) was significantly ($P < 0.01$) different from the dorsal part (Tables 2 and 3). According to our results, the ventral cranial and medial segments in both weight categories of fish had more than 4× higher fat content than their dorsal counterparts, and the ventral caudal segments contained

Table 2. Chemical composition of (mean ± SEM) skinned fillets from silver carp (*Hypophthalmichthys molitrix* Val.) of 3.50 ± 0.21 kg live weight (n = 15)

Skinned fillet		Dry matter	Protein	Fat	Ash	Saccharides	Energy value (kJ/100 g)
		(g/kg)					
Dorsal part above lateral line	cranial	269.89 ± 19.16^{a}	172.53 ± 4.67^{b}	32.33 ± 7.25^{a}	11.00 ± 0.36^{a}	34.02 ± 5.48	471 ± 29.05^{a}
	medial	281.96 ± 16.20^{a}	171.57 ± 2.92^{b}	48.14 ± 10.89^{a}	10.79 ± 0.38^{a}	41.46 ± 8.79	540 ± 42.63^{ab}
	caudal	272.73 ± 9.98^{a}	167.26 ± 1.95^{b}	57.69 ± 9.45^{a}	10.66 ± 0.42^{a}	37.12 ± 5.63	561 ± 34.68^{ab}
Ventral part below lateral line	cranial	350.16 ± 16.31^{b}	146.41 ± 3.30^{a}	164.11 ± 17.53^{bc}	8.87 ± 0.43^{b}	30.78 ± 5.32	908 ± 59.85^{bc}
	medial	393.83 ± 14.45^{b}	141.16 ± 2.32^{a}	195.64 ± 12.36^{c}	8.33 ± 0.28^{b}	38.70 ± 6.60	1030 ± 42.44^{c}
	caudal	322.40 ± 23.76^{ab}	154.30 ± 5.44^{ab}	114.68 ± 19.98^{b}	10.10 ± 0.51^{a}	33.33 ± 4.26	743 ± 70.38^{b}
Statistical significance*		$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P < 0.01$
Average for whole	dorsal part	274.86 ± 8.74^{a}	170.45 ± 1.93^{b}	46.06 ± 5.54^{a}	10.82 ± 0.22^{b}	37.53 ± 3.83	524 ± 21.24^{a}
	ventral part	355.47 ± 11.72^{b}	147.29 ± 2.40^{a}	158.14 ± 11.28^{b}	9.10 ± 0.27^{a}	34.27 ± 3.11	894 ± 39.30^{b}
Statistical significance**		$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P < 0.01$
Average for whole fillet		315.16 ± 16.64	158.87 ± 3.44	102.10 ± 12.91	9.96 ± 0.40	35.90 ± 6.01	709 ± 46.50

*multiple range test of analysis of variance (ANCOVA, Statgraphics 6.0); **one-way range test of analysis of variance (ANOVA, Excel 97)

Groups with different alphabetic superscript in lines differ significantly at $P < 0.01$; the numerically lower value is indicated by an "a"

Data without alphabetical superscripts do not differ significantly at the given level ($P > 0.05$)

Table 3. Chemical composition (mean ± SEM) of skinned fillets on silver carp (*Hypophthalmichthys molitrix* Val.) of 4.45 ± 0.13 kg live weight (n = 20)

Skinned fillet		Dry matter	Protein	Fat	Ash	Saccharides	Energy value (kJ/100 g)
		(g/kg)					
Dorsal part above lateral line	cranial	259.80 ± 6.52^{a}	181.32 ± 3.61^{c}	38.90 ± 8.06^{a}	11.21 ± 0.35^{b}	28.36 ± 4.55	501 ± 26.62^{a}
	medial	267.88 ± 5.86^{a}	175.92 ± 2.59^{bc}	48.04 ± 10.23^{a}	10.67 ± 0.16^{b}	33.25 ± 3.91	533 ± 30.06^{a}
	caudal	274.93 ± 8.57^{a}	164.57 ± 3.37^{b}	64.92 ± 9.24^{a}	10.50 ± 0.24^{b}	34.94 ± 2.30	579 ± 32.82^{a}
Ventral part below lateral line	cranial	345.10 ± 8.25^{bc}	152.78 ± 3.19^{ab}	159.14 ± 13.84^{bc}	8.85 ± 0.79^{ab}	23.33 ± 8.58	888 ± 39.06^{bc}
	medial	377.53 ± 14.83^{c}	149.12 ± 2.55^{a}	196.14 ± 9.54^{c}	8.38 ± 0.27^{a}	33.90 ± 7.03	1037 ± 31.98^{c}
	caudal	325.81 ± 13.04^{b}	155.54 ± 2.83^{ab}	116.99 ± 16.43^{b}	9.18 ± 0.30^{ab}	34.10 ± 5.93	755 ± 54.12^{b}
Statistical significance*		$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P < 0.01$
Average for whole	dorsal part	267.54 ± 4.11^{a}	173.94 ± 2.21^{b}	50.62 ± 5.51^{a}	10.79 ± 0.16^{b}	32.18 ± 2.13	538 ± 17.73^{a}
	ventral part	349.48 ± 7.94^{b}	152.48 ± 1.67^{a}	157.42 ± 9.65^{b}	9.13 ± 0.31^{a}	30.44 ± 4.15	893 ± 31.98^{b}
Statistical significance**		$P < 0.01$	$P < 0.01$	$P < 0.01$	$P < 0.01$	$P > 0.05$	$P < 0.01$
Average for whole fillet		308.51 ± 9.51	163.21 ± 3.02	104.02 ± 11.22	9.96 ± 0.35	31.31 ± 5.38	716 ± 35.78

*multiple range test of analysis of variance (ANCOVA, Statgraphics 6.0); **one-way range test of analysis of variance (ANOVA, Excel 97)

Groups with different alphabetic superscript in lines differ significantly at $P < 0.01$; the numerically lower value is indicated by an "a"

Data without alphabetical superscripts do not differ significantly at the given level ($P > 0.05$)

twice as much fat as their dorsal counterparts (Tables 2 and 3). The higher fat content is linked with a correspondingly higher dry matter and energy values. In both sets of fish, the highest fat content was in the ventral medial segment (LW/HW = 195.64 ± 12.36/196.14 ± 9.54 in g/kg), the least fat content was found in the dorsal cranial segment (LW/HW = 32.33 ± 7.25/38.90 ± 8.06 in g/kg). The higher protein content in the dorsal part of the fillet is due to a higher proportion of meat containing less fat, with a maximum of leaner meat in the dorsal cranial segment (LW/HW = 172.53 ± 4.67/181.32 ± 3.61 in g/kg). The lowest proteins levels were found in the ventral medial part of the fillet (LW/HW = 141.16 ± 2.32/149.12 ± 2.55 in g/kg). The presence of mineral substances in the bones whose increased incidence in the low-fat dorsal muscle tissue can be assumed was the reason for the higher ash content (Tables 2 and 3). Similar relationships can also be found in the data published for the bighead carp (*Aristichthys nobilis* Rich.), a species closely related to the silver carp. Reporting on the bighead carp, Hadjinikolova (2008) mentioned, for example, lower levels of moisture (74.2%), proteins (14.56%), and ash (0.98%) in connection with a higher fat content (10.26%). On the other hand, according to Hakimeh *et al.* (2010), who published their data coming from a study on the silver carp weighing 1.0 kg to 1.10 kg, less fat (0.99%) in the muscle tissue corresponds to a higher level of moisture (78.71%), proteins (18.28%), and ash (1.04%).

We also found a number of interesting relations between the values of the individual parameters when we evaluated them in the craniocaudal direction. Protein and ash contents in the dorsal part decreased in the craniocaudal direction, while dry matter and lipid and energy contents, in contrast, increased. A contrary trend was found in the chemical composition of the ventral parts of the fillets, where protein (or rather ash) content increased in the craniocaudal direction and dry matter and lipid (or rather energy) contents decreased. The ventral medial segment with the lowest protein (or rather ash) values and the highest dry matter, fat and energy values was an exception to this. The saccharide contents of all 6 fillet segments monitored were practically identical.

By comparing identical fillet segments from fish in our two weight categories (e.g. dorsocranial segments from lightweight fish and heavyweight

fish) we found that there were practically no differences in the chemical composition between the two categories (note: for this reason there is no separate table for this evaluation), although the two sets of fish ($P < 0.01$; live weight, unskinned fillet weight) were statistically different (Table 1). This finding is of practical importance for aquaculture farming, because fish of both final weight categories (3.5 kg and 4.5 kg) are equal to one another in the chemical composition and yield, and thus the lightweight category of fish need not be preferred over the heavyweight category of fish. Different distributions of nutrients may nevertheless be found in the silver carp from the lower (2.50 kg) or higher (5.50, 6.50, 7.50 kg) weight categories, which were not, however, studied in our investigation. It would, therefore, be desirable to broaden the scope of this research to obtain information about these weight categories.

The basic chemical composition of fish flesh can be affected by biotic and abiotic factors (e.g. species, health, age, sex, living conditions, food availability), though the basic causes of the changes in the composition are usually the variations in the amount and quality of food that the fish eat and, in adult fish, the degree of their reproductive cycle. The differences in chemical composition are also measured in light (white) and dark (red) muscle running along the lateral line (Murray & Burt 2001).

The latest, still valid, edition of the Food Tables (Anonymous 1992) in the Czech Republic designed for all human nutrition and dietary specialists give the basic nutritional data only for the carp, tench, trout, pike and, eel, and no data for the silver carp is available. In view of the importance of this literary source, we recommend that the silver carp be included among the other freshwater fish species listed here, and that the chemical composition values of the two main parts of the fillet be listed separately in addition to the whole fillet mean chemical composition, as the leaner dorsal part of the fillet would rank the silver carp among medium to low-fat fish (up to 10% fat) while the fatter ventral part among high-fat fish (over 10% fat).

Evaluation of lipid composition

Although the rather fat and energy-rich and fairly low-protein-content ventral part of the silver carp fillet may be evaluated negatively from the sensory and dietetic points of view, the silver carp must be considered a valuable and wholesome fish as a source of highly unsaturated fatty acids (PUFAn-3 and PUFAn-6). The lipid composition of the silver carp under various experimental conditions has been the subject of a number of papers (Toth-Markus & Sass-Kiss 1993; Steffens 1997; Mareš *et al*. 2009), Vujković *et al*. (1999), some authors have studied the differences in lipid composition between the silver carp (*Hypophthalmichthys molitrix* Val.) and the bighead carp (*Aristichthys nobilis* Rich.), and the crossbreeds of the two species (*Hypophthalmichthys molitrix* vs *Aristichthys nobilis*) of the silver carp have also been studied (Vacha & Tvrzicka 1995). Previous investigations have shown that the muscle tissue of the silver carp (and bighead carp) may be a rich source of long-chained fatty acids that are extremely important to human health. They play an indispensable role in the synthesis of prostaglandins, tromboxaines, leukotrienes, and eicosanoids prostacyclins. Sufficient quantities of PUFAn-3 series (α-linolenic acid, EPA, DHA) have a positive effect on human health. Of freshwater fish, herbivorous species feeding on phytoplankton demonstrate higher levels of PUFAn-3. Excessive quantities of PUFAn-6 series (linoleic acid, arachidonic acid), on the other hand, have an inflammatory effect and may cause cardiovascular diseases (Steffens 1997). The decisive factor is the PUFAn-6/n-3 ratio. The lipids with lower ratios are considered biologically more important. WHO/FAO recommendations set the PUFAn-6/n-3 ratio in the total daily diet at 5:1. Okuyama *et al*. (1997) recommended a n-6/n-3 ≤ 2 ratio for freshwater fish.

Fatty acid composition of muscle tissue lipids

The fatty acid profile of fatty acids in intramuscular fat of both the LW and HW categories of the silver carp in our study was similar to that published for the silver carp by Vujković *et al*. (1999) and also corresponded to WHO/FAO nutritional recommendations. The fillets of both groups of fish in our research contained (in % of total fatty acids investigated) more PUFAn-3 (LW = 13.43 ± 1.02, HW = 12.82 ± 0.66) and much less of n-6 fatty acids (LW = 3.67 ± 0.47, HW = 3.62 ± 0.18), so the n-6/n-3 ratio was in a range from approx. 0.27 to approx. 0.28 in LW and HW

Table 4. SFA, MUFA and PUFA composition (mean ± SD) of skinned fillets and internal fat lipids of silver carp (*Hypophthalmichthys molitrix* Val.) of 3.50 and 4.50 kg live weight

Fatty acid (%) of total fatty acids investigated	Live fish weight 3.50 ± 0.21 kg (n = 10)		Statistical significance	Live fish weight 4.45 ± 0.13 kg (n = 10)		Statistical significance
	skinned fillet	internal fat		skinned fillet	internal fat	
SFA						
C10:0	0.00 ± 0.00	0.01 ± 0.00	$P > 0.05$	0.00 ± 0.00	0.01 ± 0.00	$P > 0.05$
C11:0	0.18 ± 0.07	0.15 ± 0.05	$P > 0.05$	0.10 ± 0.01^a	0.14 ± 0.03^b	$P < 0.05$
C12:0	0.11 ± 0.00^a	0.14 ± 0.01^b	$P < 0.05$	0.11 ± 0.01^a	0.15 ± 0.01^b	$P < 0.01$
C13:0	0.06 ± 0.00	0.06 ± 0.01	$P > 0.05$	0.06 ± 0.00	0.06 ± 0.00	$P > 0.05$
C14:0	1.86 ± 0.16^a	2.07 ± 0.09^b	$P < 0.05$	1.81 ± 0.10^a	2.24 ± 0.09^b	$P < 0.01$
C16:0	15.58 ± 1.15	16.40 ± 0.67	$P > 0.05$	14.55 ± 0.44^a	18.07 ± 0.50^b	$P < 0.01$
C17:0	0.50 ± 0.11	0.58 ± 0.09	$P > 0.05$	0.50 ± 0.03^a	0.72 ± 0.07^b	$P < 0.01$
C18:0	2.82 ± 0.33	2.85 ± 0.31	$P > 0.05$	2.86 ± 0.23^a	3.42 ± 0.16^b	$P < 0.01$
C20:0	0.13 ± 0.02	0.12 ± 0.02	$P > 0.05$	0.13 ± 0.01	0.14 ± 0.0	$P > 0.05$
C22:0	0.03 ± 0.02	0.04 ± 0.01	$P > 0.05$	0.02 ± 0.02	0.02 ± 0.00	$P > 0.05$
∑SFA	21.26 ± 1.13	22.41 ± 0.47	$P > 0.05$	20.14 ± 0.69^a	24.96 ± 0.66^b	$P < 0.01$
MUFA						
C14:1	0.07 ± 0.01^a	0.09 ± 0.01^b	$P < 0.05$	0.08 ± 0.01^a	0.09 ± 0.00^b	$P < 0.05$
C16:1	9.08 ± 0.74	9.55 ± 0.66	$P > 0.05$	8.43 ± 0.41^a	10.27 ± 0.49^b	$P < 0.01$
C17:1	0.51 ± 0.06	0.57 ± 0.05	$P > 0.05$	0.51 ± 0.02^a	0.61 ± 0.04^b	$P < 0.01$
C18:1n-9	28.94 ± 2.17	30.50 ± 1.74	$P > 0.05$	28.99 ± 1.69^a	34.83 ± 0.92^b	$P < 0.01$
C20:1n-9	1.16 ± 0.12	1.09 ± 0.03	$P > 0.05$	1.03 ± 0.07^a	1.18 ± 0.04^b	$P < 0.01$
C22:1n-9	0.03 ± 0.02	0.04 ± 0.01	$P > 0.05$	0.04 ± 0.01	0.04 ± 0.0	$P > 0.01$
∑MUFA	39.80 ± 2.68	41.84 ± 2.09	$P > 0.05$	39.08 ± 1.86^a	47.03 ± 1.50^b	$P < 0.01$
PUFA						
C18:2n-6	1.87 ± 0.18	1.87 ± 0.20	$P > 0.05$	1.80 ± 0.09^a	2.03 ± 0.11^b	$P < 0.01$
C18:3n-6	0.16 ± 0.02	0.16 ± 0.02	$P > 0.05$	0.16 ± 0.01^a	0.18 ± 0.01^b	$P < 0.01$
C20:2n-6	0.23 ± 0.02	0.22 ± 0.02	$P > 0.05$	0.20 ± 0.01^a	0.23 ± 0.01^b	$P < 0.01$
C20:3n-6	0.22 ± 0.02	0.20 ± 0.02	$P > 0.05$	0.20 ± 0.01^a	0.22 ± 0.02^b	$P < 0.05$
C20:4n-6	1.03 ± 0.19	0.79 ± 0.10	$P > 0.05$	1.04 ± 0.07^b	0.91 ± 0.04^a	$P < 0.01$
C22:4n-6	0.19 ± 0.04	0.15 ± 0.03	$P > 0.05$	0.22 ± 0.07	0.18 ± 0.02	$P > 0.05$
∑PUFAn-6	3.67 ± 0.47	3.39 ± 0.43	$P > 0.05$	3.62 ± 0.18	3.76 ± 0.19	$P > 0.05$
C18:3n-3	5.01 ± 0.47	4.79 ± 0.25	$P > 0.05$	4.91 ± 0.30	5.28 ± 0.3	$P > 0.05$
C20:3n-3	0.54 ± 0.07	0.49 ± 0.04	$P > 0.05$	0.48 ± 0.02^a	0.55 ± 0.05^b	$P < 0.05$
C20:5n-3	3.04 ± 0.20^b	2.70 ± 0.17^a	$P < 0.01$	2.98 ± 0.18	3.04 ± 0.15	$P > 0.05$
C22:5n-3	0.70 ± 0.12	0.60 ± 0.1	$P > 0.05$	0.58 ± 0.03^a	0.64 ± 0.07^b	$P < 0.05$
C22:6n-3	4.15 ± 0.40^b	3.08 ± 0.20^a	$P < 0.01$	3.86 ± 0.38^b	3.41 ± 0.18^a	$P < 0.05$
∑PUFAn-3	13.43 ± 1.02^b	11.67 ± 0.75^a	$P < 0.01$	12.82 ± 0.66	12.92 ± 0.81	$P > 0.05$
∑PUFA	17.11 ± 1.20^b	15.05 ± 1.00^a	$P < 0.01$	16.43 ± 0.78	16.68 ± 0.92	$P > 0.05$
Ratio PUFAn-6/n-3	0.27 ± 0.04	0.29 ± 0.03	$P > 0.05$	0.28 ± 0.01	0.29 ± 0.02	$P > 0.05$

One-way range test of analysis of variance (ANOVA, Excel 97).

Groups with different alphabetic superscript in lines differ significantly at $P < 0.01$; $P < 0.05$; the numerically lower value is indicated by an "a"

Data without alphabetical superscripts do not differ significantly at the given level ($P > 0.05$)

fish, respectively. The profiles of the fatty acids in fillet fat with respect to final fish weight (i.e. LW or HW) were very close to each other, although they were not the same, and sporadic significant differences were found (Table 5). Although the fish lived under identical living conditions and the samples were taken at the same time, the fatty acid profiles seem to have been influenced by the differences in the composition and type of the diet. The primary factors included the availability, type, and quantity of food received by individual fish (Bieniarz *et al*. 2000) and the related complex biochemical, enzymatic and metabolic processes in the fish organism (Hochachka & Mommsen 1995). As the samples were of identical origin, the effects of different ambient temperatures that might have affected the lipid profiles (Vacha & Tvrzicka 1995) can be ruled out.

Traditional aquaculture rearing of freshwater fish in the Czech Republic relies on the use of cereals (wheat) to supplement the energy that fish in fishponds naturally receive from phytoplankton and zooplankton. Oleic acid (produced by desaturation of saturated FA synthesised in the fish from energy-rich wheat) can be found in high quantities of up to 55% or more (Stephens 1997) in the omnivorous common carp (*Cyprinus carpio* L.) for example. In our experiment, muscle tissue lipids contained half the amount of this acid (about 28.9%), because, being a herbivorous fish, the silver carp preferred phytoplankton that naturally contains larger quantities of the essential α-linolenic acid and other PUFAn-3 (EPA = C20:5n-3, DHA = C22:6n-3). Phytoplankton consists predominantly of blue-green algae, whose composition depends largely on the environmental conditions, and there are marked differences between the individual species. The differences in the muscle tissue composition of the silver carp that feed on blue-green algae depend on the degree of the water bloom population digestibility (Mareš *et al*. 2009), which is the lowest in the period of the exponential growth of green-blue algae (Domaizon *et al*. 2000). It is only when the vegetable matter is scarce, i.e. especially early in the spring and perhaps also in late autumn, that the silver carp is also able to eat animal matter whose composition may also affect the lipid profile.

Table 5. Results of data on lipids composition of skinned fillets and internal fat of silver carp (*Hypophthalmichthys molitrix* Val.) – One-way range test of analysis of variance (ANOVA, Excel 97)

Compared with of light-weight fish fillets (3.50 ± 0.21 kg live weight), heavy-weight fish fillets (4.45 ± 0.13 kg live weight) contained		Compared with internal fat from light weight fish (3.50 ± 0.21 kg live weight), internal fat from heavy weight fish (4.45 ± 0.13 kg live weight) contained	
Fatty acid	statistical significance	fatty acid	statistical significance
Less C11:0	$P < 0.01$	more C14:0	$P < 0.05$
Less C16:0	$P < 0.05$	more C16:0	$P < 0.01$
Less ∑SFA	$P < 0.05$	more C17:0	$P < 0.05$
More C14:1	$P < 0.05$	more C18:0	$P < 0.05$
Less C16:1	$P < 0.05$	less C22:0	$P < 0.05$
Less C20:1n-9	$P < 0.01$	more ∑SFA	$P < 0.01$
Less C20:2n-6	$P < 0.01$	more C18:1n-9	$P < 0.01$
Less C20:3n-6	$P < 0.01$	more C20:1n-9	$P < 0.01$
Less C20:3n-3	$P < 0.05$	more ∑MUFA	$P < 0.01$
Less C22:5n-3	$P < 0.05$	more C20:4n-6	$P < 0.05$
		more C18:3n-3	$P < 0.05$
		more C20:5n-3	$P < 0.05$
		more C22:6n-3	$P < 0.05$
		more ∑PUFAn-3	$P < 0.05$
		more ∑PUFA	$P < 0.05$

Fatty acid composition of internal fat lipids

We were able to demonstrate that triacylglycerols of the body fat as the principal energy reservoir could be an important alternative source of ∑PUFAn-3, in particular α-linolenic acid: C18:3n-3 (LW = 4.79 ± 0.25, HW = 5.28 ± 0.33), EPA: C20:5n-3 (LW =2.70 ± 0.17, HW = 3.04 ± 0.15) and DHA = C22:6n-3 (LW = 3.08 ± 0.20, HW = 3.41 ± 0.18), these having been found in large quantities (in % of total fatty acids investigated). The profile of the internal fat fatty acids showed marked differences between lightweight and heavyweight fish, whereby more ∑SFA, ∑MUFA, and ∑PUFA (or rather ∑PUFAn-3) were found in the internal fat of heavyweight fish, i.e. those weighing 4.5 kg (Table 5). The information about the internal fat yield that we obtained in our experiment (LW = 3.50 ± 1.79%, HW = 2.93 ± 0.57%) (Table 1) could be of interest for the countries with a high annual production of the silver carp, as its internal fat could serve as a good source of pharmaceutically significant components (fish oil) if used as a raw material for the products such as dietary supplements (Taskaya *et al*. 2009).

Fatty acid composition of muscle tissue lipids vs FA composition of internal fat lipids

The compositions of the fillet lipids and internal fat lipids within one and the same weight category of the silver carp were not identical either. We found fewer differences in fish with a lower final weight (LW = 3.50 kg) whose compositions of fillet lipids and internal fat lipids were almost identical, particularly around the SFA, MUFA, and PUFAn-6 spectra (Table 4). Higher ($P < 0.05$) levels of the C20:5n-3, C22:6n-3 acids and ∑PUFAn-3 in the fillet lipids may be connected with a higher proportion of phospholipids as an integral component of biomembranes, which, in contrast to triacylglycerols, contain larger quantities of polyunsaturated fatty acids (Steffens 1997). This finding was not, however, repeated in the silver carp group with a final weight of 4.5 kg, where the total ∑PUFAn-3 contents in fillet and internal fats were the same; numerous statistical differences were, however, found in the spectrum of SFA and MUFA acids, which were found in larger quantities in the depot fat (Table 4). In addition to the factors already mentioned, lipid composition may also be influenced by the weight of the fish and the action of specific desaturases and elongases participating in lipid metabolism (Hochachka & Mommsen 1995).

CONCLUSIONS

The authors demonstrated statistically significant differences in the chemical composition (with the exception of saccharides) and energy value between the leaner dorsal part of the silver carp fillet, which ranks it among medium to low-fat fish (46.06 ± 5.54 g/kg and 50.62 ± 5.51 g/kg in fish with a live weight of 3.50 kg and 4.50 kg, respectively), and the fatter ventral part, which ranks the silver carp among high-fat fish (158.14 ± 11.28 g/kg and 157.42 ± 9.65 g/kg in fish with a live weight of 3.50 kg and 4.50 kg, respectively). It is recommended that the data found be incorporated into the normative reference (Anonymous 1992), as it is not included there and is important from the nutritional point of view. The authors also recommend similar analysis be performed on fish in other weight categories (2.50, 5.50, 6.50 kg and above).

The study also showed that the internal fat of the silver carp could serve as a good source of pharmaceutically significant components (fish oil) if used as a raw material for the products such as dietary supplements, because with respect to the composition of its lipids, it is equal to intramuscular fat lipids. Along with the fat ventral part of the fillet, it may be a suitable raw material in non-traditional fish processing, as is the case in a number of countries around the world (e.g. Taskaya *et al*. 2009), or may become an international trade commodity to be used in the food or pharmaceutical industries by the countries of destination.

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