ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LIX 2 Number 1, 2011

FATTY ACIDS PROFILE IN MECHANICALLY RECOVERED MEAT FROM COMMON CARP (*CYPRINUS CARPIO*, L.) AND SILVER CARP (*HYPOPHTHALMICHTHYS MOLITRIX*, VAL.)

H. Buchtová

Received: July 9, 2010

Abstract

BUCHTOVÁ, H.: *Fatty acids profile in mechanically recovered meat from common carp (Cyprinus carpio, L.) and silver carp (Hypophthalmichthys molitrix, Val.).* Acta univ. agric. et silvic. Mendel. Brun., 2011, LIX, No. 1, pp. 15–22

The aim of this study was to analyze the fatty acids (FA) profile (in $g.kg^{-1}$) and FA sums (ΣSFA: saturated FA, ΣMUFA: monounsaturated FA, ΣPUFA: polyunsaturated FA, ratio $\Sigma PUFA_{n-6/n-3}$) in wet tissue of mechanically recovered meat (MRM) from common carp (*Cyprinus carpio*, L.) and silver carp (*Hypophthalmichthys molitrix*, Val.), and in the case of silver carp to analyze the fatty acids profile (in % of total fatty acids investigated) in internal fat. MRM from silver carp contained (in $g.kg^{-1}$) more ($P < 0.01$) ΣPUFA: 18.90 ± 1.24 as a result of high levels of α-linolenic acid (5.37 ± 0.36), eicosapentaenoic acid (4.30 ± 0.31) and docosahexaenoic acid (4.15 ± 0.30). Common carp MRM contained (in $g.kg^{-1}$) more ($P < 0.01$) $\Sigma PUFA_{n-6}$ (9.70 ± 0.26), especially linoleic acid (8.03 ± 0.20). $\Sigma PUFA_{n-3}$ in common carp MRM was present in small quantity (4.38 ± 0.14 $g.kg^{-1}$). The internal fat from silver carp contained (in % of total fatty acids investigated) more ΣMUFA ($P < 0.01$) and ΣPUFA ($P < 0.05$) in comparison with silver carp MRM fat, however the $\Sigma PUFA_{n-6/n-3}$ ratio in silver carp MRM (0.22 ± 0.01) and internal fat samples (0.24 ± 0.01) was comparable. This study indicates that the fatty acids profile in MRM and in the internal fat, particularly from silver carp (*Hypophthalmichthys molitrix* Val.), is valuable for human health.

separated or deboned fish meat, lipid composition, quality

This experimental study was supported by the Ministry of Education, Youth and Sports of the Czech Republic: Research Plan "Veterinary aspects of food safety and quality" MSM 6215712402. The author is grateful to Professor Straková, Ph.D. from the Institute of Nutrition and Dietetics of Farm Animals (Faculty of Veterinary Hygiene and Ecology of the University of Veterinary and Pharmaceutical Sciences in Brno) for making qualitative and quantitative determinations of fatty acids by GC.

The production of mechanically recovered meat (MRM) from certain species of marine fish (especially from cod and salmon) and its processing is currently a routine component of processing activities by fish processing enterprises. Good technological characteristics and a comparatively low cost make it a profitable raw material for food production such as fishfingers, sticks (surimi) or fishburgers. Production of MRM from freshwater fish has a shorter tradition, though it may become a potentially attractive raw material for food production in the future. Moreover, the preparation of MRM enables more economical use of biological waste and a reduction of its amount. According to the FAO report, world inland aquaculture production of fish has grown in the last few years, from production of 24 (7.1 excluding China) million tonnes in 2002 to production of 31.6 (10.1 excluding China) million tonnes in 2006 (FAO, 2009). In the case of cyprinid fish, the production of common carp and silver carp in the European Community was 61,733 and 3,658 tonnes live weight respectively this year (European Commision,

2010). The statistics indicates a global role for carp (*Cyprinidae*) in fulfilling human nutritional needs. The fish proteins and lipids may be used as dietary supplements or an ingredient in functional foods (Taskaya *et al.*, 2009).

This paper is a follow-up study to an investigation in which the chemical composition (dry matter, protein, collagen, fat, ash) and shelf life (free fatty acids, peroxide values, ammonia nitrogen) parameters and the level of microbiological contamination of mechanically recovered meat (MRM) produced from common carp and silver carp were analysed (Buchtová and Cupáková, 2009). According to this study MRM is a good quality raw material, although in the Czech Republic it is an untraditional product and its annual production is insignificant. However, carp is seen as the cheapest and by far the most commonly consumed fresh water fish in the world (Taskaya *et al.*, 2009). Therefore MRM made from carp could be increasingly used in the development a new type of fish products around the world and the production of this raw material could become an interesting business strategy.

This study evaluates the fatty acids profile in mechanically recovered meat (MRM) made from common carp and silver carp, as there is no paper concerning these data. From human nutrition point of view, polyunsaturated fatty acids (PUFA) are the most important part of fish meat. The fatty acid composition of MRM is largely determined by the chemical composition of the input raw materials for its production. It is assumed that mechanical equipment has no effect on MRM composition. The composition of muscle tissue from different fish species will differ according to fish size, sex cycle, nutritional and health status, and certain other conditions in the external environment of the fish. The most variable component are lipids, whose content and composition are largely determined by the type and amounts of food consumed in the course of the year (Kmínková *et al.*, 2001).

The methods of fish rearing and the character of the aquatic environment in which the fish live are also extremely important. The spectrum of fatty acids in the fat of carp that live in natural waters in the wild and consume only natural foods is markedly different from the fatty acid composition reported in carp raised in pond aquacultures. The product of traditional carp rearing based on a natural diet supplemented with cereals (wheat) are fish whose lipids contain a high proportion of oleic acid (C18:1n-9) and negligible amounts of n-3 polyunsaturated fatty acids (PUFA). The uptake of eicosapentaenoic acid (C20:5n-3) and docosahexaenoic acid (C22:6n-3) from wheat was practically zero, as these acids are not present in wheat (Steffens, 1997).

The dominant component of phytoplankton are cyanobacterial water blooms, whose metabolites may affect the fish organism (Malbrouck and Kestemont, 2006). The presence of certain cyanobacteria (genus *Microcystis*) in the aquatic environment may adversely affect the chemical composition of fish muscle tissues. In the herbivorous silver carp, these changes depend on the degree of water bloom population digestibility, which is lowest in the exponential growth phase (Mareš *et al.*, 2009).

The aim of the present study was to analyze the fatty acids profile (in $g.kg^{-1}$) in wet tissue of MRM made from common carp (*Cyprinus carpio*, L.) and silver carp (*Hypophthalmichthys molitrix*, Val.) – fish primarily destined for filleting and subsequent processing of their residual skeletons by mechanical separation. In the case of silver carp, an additional aim was to analyze the fatty acids profile (in % of total fatty acids investigated) in internal fat that was separated from internal organs removed from the fish body cavity. These silver carp were primarily destined for evisceration only. The reason for this evaluation is the fact that fish fat may be obtained from wholesome fish (there are no grounds for declaring the fish unfit for human consumption) and used for food production (Commission Regulation, 2005).

MATERIALS AND METHODS

The fish were reared under standard conditions for pond fish farming in the Czech Republic with semi-intensive management. Fish had their natural diet available in the ponds (plankton, benthos). For additional feeding of the fish, uncrushed whole wheat was used. Fish were processed at the freshwater fish processing plant using a standard processing procedure. Samples of MRM from common carp and silver carp were taken using Baader processing equipment (Lübeck, Germany). A total of 5 production batches of each MRM type were examined. Fifty kg of the raw material (3/4 was made up of the cranial part of the body including the pectoral fin and the caudal peduncle, and 1/4 was made up of skeletal remains – spine including ribs after filleting) was used for the preparation of each production batch of MRM. Ten individual samples of each MRM type weighing about 500 g were vacuum packed and stored at (+2 ± 2 °C) ambient temperature.

18 pieces of fish were randomly selected of a set of silver carp. Fish were gutted, internal fat was separated from the internal organs. The live weight of fish (5.08 ± 1.43 kg) and weight of internal fat (237.29 ± 111.36 g) and its yield (4.43 ± 1.28%) were determined. Internal fat was used to determine of the fatty acids composition. A total of 5 pooled samples were examined. Each pooled sample consisted of internal fat separated from 3 or 4 pieces of silver carp.

The total lipids in raw MRM were extracted into a hexan-isopropanol extract (Hara and Radin, 1978). The determination of fatty acids composition was performed by gas chromatography using GC – 2010 (Shimadzu, Japan) apparatus with a flame ionization detector (FID) and capillary column VB WAX (60 m x 0.32 mm x 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.

The aim of the study was to find out if there are differences in fatty acids profile and FA sums: saturated fatty acids ΣSFA (FA that have no double bonds in the FA chain), monounsaturated fatty acids ΣMUFA (FA that have a single double bond in the FA chain), polyunsaturated fatty acids ΣPUFA

I: *Fatty acids profile (in g.kg^{-1}) in wet tissue of MRM from common carp (Cyprinus carpio, L.) and silver carp (Hypophthalmichthys molitrix, Val.).*
MRM: mechanically recovered meat, ΣSFA: saturated fatty acids, ΣMUFA: monounsaturated fatty acids, ΣPUFA: polyunsaturated fatty acids, $PUFA_{n-6/n-3}$: ratio $\Sigma PUFA_{n-6}$:$\Sigma PUFA_{n-3}$
Groups with a different alphabetic superscript in lines differ significantly at $P < 0.05$ or $P < 0.01$. The numerically lower value is indicated by an "a".
Note: Statistically significant differences between fatty acids present in amounts tens of milligrams per kg have no practical importance.

FA_s in g.kg^{-1} in wet tissue	Mechanically recovered meat (MRM)		Statistical significance
	n = 5 batches from Common Carp Mean ± S.D.	n = 5 batches from Silver Carp Mean ± S.D.	
Fat in MRM *	**92.3 ± 2.69^a**	**126.2 ± 2.75^b**	**P < 0.05**
C10:0	0.03 ± 0.02^a	0.03 ± 0.03^b	P < 0.05
C11:0	0.00 ± 0.00^a	0.02 ± 0.01^b	P < 0.01
C12:0	0.03 ± 0.01^a	0.16 ± 0.01^b	P < 0.01
C13:0	0.01 ± 0.01^a	0.07 ± 0.01^b	P < 0.01
C14:0	1.02 ± 0.03^a	2.28 ± 0.10^b	P < 0.01
C16:0	14.78 ± 0.39^a	19.91 ± 0.81^b	P < 0.01
C17:0	0.18 ± 0.01^a	0.43 ± 0.03^b	P < 0.01
C18:0	3.60 ± 0.10^a	3.80 ± 0.13^b	P < 0.05
C20:0	0.09 ± 0.01^a	0.15 ± 0.01^b	P < 0.01
C22:0	0.03 ± 0.01^a	0.04 ± 0.01^b	P < 0.05
C23:0	0.04 ± 0.01^b	0.00 ± 0.00^a	P < 0.01
C24:0	0.04 ± 0.02^a	0.08 ± 0.03^b	P < 0.05
ΣSFA	19.86 ± 0.51^a	26.19 ± 0.99^b	P < 0.01
C14:1	0.07 ± 0.01^a	0.09 ± 0.01^b	P < 0.01
C16:1	7.43 ± 0.21^a	10.16 ± 0.49^b	P < 0.01
C17:1	0.19 ± 0.01^a	0.31 ± 0.15^a	P > 0.05
C24:1	0.05 ± 0.01^b	0.00 ± 0.00^a	P < 0.01
C18:1n9	35.98 ± 0.71^a	37.15 ± 1.36^a	P > 0.05
C20:1n9	1.44 ± 0.03^b	1.27 ± 0.14^a	P < 0.05
C22:1n9	0.05 ± 0.01^b	0.03 ± 0.01^a	P < 0.01
ΣMUFA	45.20 ± 0.91^a	49.01 ± 2.00^b	P < 0.01
C18:2n6	8.03 ± 0.20^b	1.71 ± 0.13^a	P < 0.01
C18:3n6	0.20 ± 0.01^a	0.20 ± 0.01^a	P > 0.05
C20:2n6	0.31 ± 0.02^b	0.22 ± 0.02^a	P < 0.01
C20:3n6	0.25 ± 0.01^b	0.18 ± 0.01^a	P < 0.01
C20:4n6	0.77 ± 0.04^a	0.96 ± 0.05^b	P < 0.01
C22:4n6	0.14 ± 0.01^a	0.19 ± 0.05^a	P > 0.05
$\Sigma PUFA_{n6}$	9.70 ± 0.26^b	3.45 ± 0.21^a	P < 0.01
C18:3n3	2.10 ± 0.05^a	5.37 ± 0.36^b	P < 0.01
C20:3n3	0.12 ± 0.01^a	0.48 ± 0.04^b	P < 0.01
C20:5n3	1.09 ± 0.05^a	4.30 ± 0.31^b	P < 0.01
C22:6n3	0.74 ± 0.04^a	4.15 ± 0.30^b	P < 0.01
C22:5n3	0.34 ± 0.01^a	1.15 ± 0.10^b	P < 0.01
$\Sigma PUFA_{n3}$	4.38 ± 0.14^a	15.44 ± 1.08^b	P < 0.01
ΣPUFA	14.08 ± 0.37^a	18.90 ± 1.24^b	P < 0.01
$PUFA_{n6/n3}$	2.22 ± 0.06^b	0.22 ± 0.01^a	P < 0.01

* (Buchtová and Cupáková, 2009)

(FA that have more double bonds in the FA chain), $\Sigma PUFA_{n-6}$, $\Sigma PUFA_{n-3}$ (the distinction between $_{n-6}$ and $_{n-3}$ relates to the position of the first double bond in the carbon chain), and ratio $\Sigma PUFA_{n-6/n-3}$ between MRM made from common carp (*Cyprinus carpio*, L.) and silver carp (*Hypophthalmichthys molitrix*, Val.) (in $g.kg^{-1}$ in wet tissue), and between MRM fat and internal fat from silver carp (in % of total fatty acids investigated). Mean and the standard deviation (S.D.) of the parameters and statistical significance (one-

II: *Fatty acids profile (in % of total fatty acids investigated) in MRM fat from silver carp (Hypophthalmichthys molitrix, Val.) and in internal fat that was separated from internal organs removed from fish body cavity of the same species.*
MRM: mechanically recovered meat, ΣSFA: saturated fatty acids, ΣMUFA: monounsaturated fatty acids, ΣPUFA: polyunsaturated fatty acids, $PUFA_{n-6/n-3}$: ratio $\Sigma PUFA_{n-6} : \Sigma PUFA_{n-3}$
Groups with a different alphabetic superscript in lines differ significantly at $P < 0.05$ or $P < 0.01$. The numerically lower value is indicated by an "a".
Note: Statistically significant differences between fatty acids present in amounts tens of milligrams per kg have no practical importance.

FAs in % of total fatty acids investigated	Silver Carp		Statistical significance
	n = 5 batches of MRM Mean ± S.D.	n = 5 batches of internal fat* Mean ± S.D.	
C10:0	0.03 ± 0.03[b]	0.00 ± 0.00[a]	P < 0.05
C11:0	0.02 ± 0.00[a]	0.03 ± 0.01[a]	P > 0.05
C12:0	0.13 ± 0.01[a]	0.17 ± 0.04[a]	P > 0.05
C13:0	0.05 ± 0.00[a]	0.07 ± 0.01[b]	P < 0.01
C14:0	1.81 ± 0.08[a]	1.98 ± 0.15[a]	P > 0.05
C16:0	15.78 ± 0.64[a]	16.03 ± 0.63[a]	P > 0.05
C17:0	0.34 ± 0.02[a]	0.36 ± 0.01[a]	P > 0.05
C18:0	3.01 ± 0.10[a]	3.33 ± 0.28[b]	P < 0.05
C20:0	0.12 ± 0.01[a]	0.15 ± 0.02[a]	P > 0.05
C22:0	0.03 ± 0.01[a]	0.04 ± 0.01[a]	P > 0.05
C24:0	0.07 ± 0.02[b]	0.03 ± 0.02[a]	P < 0.05
ΣSFA	**21.39 ± 0.78**[a]	**22.18 ± 0.84**[a]	P > 0.05
C14:1	0.07 ± 0.01[a]	0.08 ± 0.00[b]	P < 0.01
C16:1	8.05 ± 0.39[a]	8.33 ± 0.64[a]	P > 0.05
C17:1	0.24 ± 0.12[a]	0.47 ± 0.03[b]	P < 0.01
C18:1n9	29.44 ± 1.08[a]	33.11 ± 1.39[b]	P < 0.01
C20:1n9	1.01 ± 0.11[a]	1.10 ± 0.13[a]	P > 0.05
C22:1n9	0.02 ± 0.00[a]	0.03 ± 0.01[b]	P < 0.05
ΣMUFA	**38.84 ± 1.59**[a]	44.60 ± 1.47[b]	P < 0.01
C18:2n6	1.36 ± 0.11[a]	1.64 ± 0.14[b]	P < 0.01
C18:3n6	0.16 ± 0.01[a]	0.19 ± 0.02[b]	P < 0.05
C20:2n6	0.17 ± 0.01[a]	0.19 ± 0.02[a]	P > 0.05
C20:3n6	0.14 ± 0.01[a]	0.14 ± 0.01[a]	P > 0.05
C20:4n6	0.76 ± 0.04[a]	0.77 ± 0.06[a]	P > 0.05
C22:4n6	0.15 ± 0.04[a]	0.19 ± 0.05[a]	P > 0.05
$\Sigma PUFA_{n6}$	**2.74 ± 0.17**[a]	3.12 ± 0.28[b]	P < 0.05
C18:3n3	4.25 ± 0.29[a]	4.95 ± 0.31[b]	P < 0.01
C20:3n3	0.38 ± 0.03[a]	0.33 ± 0.19[a]	P > 0.05
C20:5n3	3.41 ± 0.24[a]	3.94 ± 0.19[b]	P < 0.01
C22:6n3	3.28 ± 0.24[a]	3.32 ± 0.15[a]	P > 0.05
C22:5n3	0.91 ± 0.08[a]	0.84 ± 0.06[a]	P > 0.05
$\Sigma PUFA_{n3}$	**12.24 ± 0.85**[a]	13.78 ± 0.39[b]	P < 0.05
ΣPUFA	**14.97 ± 0.98**[a]	16.50 ± 0.67[b]	P < 0.05
$PUFA_{n6/n3}$	**0.22 ± 0.01**[a]	**0.23 0.01**[a]	P > 0.05

*Internal fat was removed from 18 silver carps: fish live weight: 5.08 ± 1.43 kg, internal fat weight: 237.29 ± 111.36 g, yield of internal fat: 4.43 ± 1.28 %

way analysis of the variance Anova) were evaluated in Excel 2003.

RESULTS

The fatty acids profile (in $g.kg^{-1}$) in wet tissue of MRM made from common carp and silver carp is given in Tab. I.

The fatty acids profile including the levels of ΣSFA, ΣMUFA, $\Sigma PUFA_{n-6}$, $\Sigma PUFA_{n-3}$, ΣPUFA and ratio $\Sigma PUFA_{n-6/n-3}$ in MRM made from common carp compared with MRM made from silver carp was statistically ($P < 0.01$, $P < 0.05$) different. Only the content of four fatty acids (cis-10-heptadecenoic acid: C17:1, oleic acid: C18:1n9, γ-linolenoic acid: C18:3n6 and dokosatetraenoic acid: C22:4n6) were practically identical. Quantitatively most important FA was oleic acid: C18:1n9 (common carp: 35.98 ± 0.71 $g.kg^{-1}$, silver carp: 37.15 ± 1.36 $g.kg^{-1}$) followed by palmitic acid: C16:0 (common carp: 14.78 ± 0.39 $g.kg^{-1}$, silver carp: 19.91 ± 0.81 $g.kg^{-1}$).

Compared with common carp MRM, ΣSFA: 26.19 ± 0.99 $g.kg^{-1}$, ΣMUFA: 49.01 ± 2.00 $g.kg^{-1}$ and ΣPUFA: 18.90 ± 1.24 $g.kg^{-1}$ was higher ($P < 0.01$) in silver carp MRM as a result of higher proportions $\Sigma PUFA_{n-3}$: 15.44 ± 1.08 $g.kg^{-1}$ and particularly high levels of α-linolenoic acid C18:3n-3: 5.37 ± 0.36 $g.kg^{-1}$, eicosapentaenoic acid C20:5n-3: 4.30 ± 0.31 $g.kg^{-1}$ and docosahexaenoic acid C22:6n-3: 4.15 ± 0.30 $g.kg^{-1}$.

Common carp MRM contained more ($P < 0.01$) $\Sigma PUFA_{n-6}$: 9.70 ± 0.26 $g.kg^{-1}$ as a result of higher proportions of, in particular, linoleic acid C18:2n-6: 8.03 ± 0.20 $g.kg^{-1}$. All $PUFA_{n-3}$ in common carp MRM were present in small quantities ($P < 0.01$), which was reflected in a low value of $\Sigma PUFA_{n-3}$: 4.38 ± 0.14 $g.kg^{-1}$.

The above differences between common carp MRM and silver carp MRM were the reason for the more advantageous $\Sigma PUFA_{n-6/n-3}$ ratio in silver carp MRM (0.22 ± 0.01 $g.kg^{-1}$) compared with common carp MRM (2.22 ± 0.06 $g.kg^{-1}$).

The fatty acids profile (including the levels of ΣSFA, ΣMUFA, $\Sigma PUFA_{n-6}$, $\Sigma PUFA_{n-3}$, ΣPUFA and ratio $\Sigma PUFA_{n-6/n-3}$) in MRM fat produced from silver carp and in the internal fat of the same fish (in % of total fatty acids investigated) is given in Tab. II.

Compared with MRM fat, the internal fat from silver carp contained higher percentage ΣMUFA ($P < 0.01$) and $\Sigma PUFA_{n-6}$, $\Sigma PUFA_{n-3}$, and ΣPUFA ($P < 0.05$). More specifically, oleic fatty acid: C18:1n-9 (33.11 ± 1.39 in %), essential linoleic acid: C18:2n-6 (1.64 ± 0.14 in %) and α-linolenoic acid: C18:3n-3 (4.95 ± 0.31 in %) were found in greater abundance. The $\Sigma PUFA_{n-6/n-3}$ ratio in the internal fat (0.24 ± 0.01 in %) and MRM fat (0.22 ± 0.01 in %) was comparable.

DISCUSSION

The results of this study broaden knowledge about the fatty acids profile in an untraditional product of freshwater fish processing – MRM made from two species of cyprinids. This untraditional raw material, particularly from silver carp, could serve as a good source of biomedically significant components that positively affect human health (Taskaya *et al*., 2009) or as a valuable raw material for the manufacture of special functional foods from fish (Tellez-Luis *et al*., 2002). In particular, $\Sigma PUFA_{n-3}$ in MRM from silver carp was found in the present study at a higher level ($P < 0.01$: 15.44 ± 1.08 $g.kg^{-1}$). Eicosanoids of the prostacyclin type derived from eicosapentaenoic acid (C20:5n-3) are considered particularly valuable. Their anti-inflammatory, antithrombotic, antiarrhytmic and immunomodulating properties can be helpful in the prevention of coronary heart diseases, hypertension, atherosclerosis and other diseases (Steffens, 1997).

Common carp farmed in aquaculture systems preferentially consume the cereals (wheat) supplied and their fat therefore contains high amounts of oleic acid (C18:1n-9), which is produced by the desaturation of saturated fatty acids synthesized in the fish organism from energy-rich supplemented feed (Henderson, 1996). This acid had a predominant share in MRM from common carp 35.98 ± 0.71 $g.kg^{-1}$ in the present study. The low proportion of $\Sigma PUFA_{n-3}$ (4.38 ± 0.14 $g.kg^{-1}$) suggests that the natural potential of the common carp's organism to produce more highly unsaturated n–3 fatty acids is not produced use of when common carp are raised in aquaculture systems. A number of experiments involving alternative feed components fed to fish reared in aquaculture systems to enhance the quality of their lipids are underway around the world. Feedstuffs containing large amounts of $PUFA_{n-3}$ are oils (fish, linseed, rapeseed or hempseed oils). Rapeseed and linseed oils are commonly used as fish oil substitutes in salmonid fish diets (Picková and Morkore, 2007). The biologically active substance sesamine is also used for this role (Trattner *et al*., 2008).

The composition of common carp and silver carp lipids may be significantly affected by the presence of cyanobacteria (*Microcystis aeruginosa*, *Microcystis ichthyoblabe*) in their aquatic environment. Bluegreen algae have a particularly adverse effect on the PUFA spectrum, causing an increase in the abundance of $\Sigma PUFA_{n-6}$ in the lipids of experimental fish compared with the controls. Experimental fish were exposed to naturally developing cyanobacterial bloom for 4 weeks; control fish were kept under the same conditions, but without exposure to cyanobacteria. Both fish groups were reared without additional feeding and foraged natural food (Mareš *et al*., 2009).

In our experiment, the compositions of fatty acids present in the internal fat of silver carp and MRM fat from the same fish were not completely identical. With the exception of caproic acid (C10:0) and lignoceric acid (C24:0), quantitatively higher number of fatty acids with significant ($P < 0.05$ and $P < 0.01$ respectively) differences in values were found in the internal fat (Tab. II). From the point of view of economic evaluation, silver carp contained internal fat which, thanks to its composition, could

be interesting complementary alternative source of $\Sigma PUFA_{n-3}$ 13.78 ± 0.39%, in particular α-linolenoic acid: C18:3n-3 (4.95 ± 0.31%), eicosapentaenoic acid C20:5n-3: (3.94 ± 0.19%) and docosahexaenoic acid C22:6n-3: (3.32 ± 0.15%) were found in greater abundance (in % of total fatty acids investigated). Given the internal fat yield that we found in our experiment (4.43 ± 1.28 %), this information could be interesting for states with high annual production of silver carp (within the European Union, e.g. Hungary with 2,484 and Romania with 1,695 tonnes live weight of silver carp in 2007); (European Commision, 2010). The internal fat from silver carp could serve as a good source of pharmaceutically significant components if used as a raw material for products such as dietary supplements.

CONCLUSION

From the viewpoint of the fatty acids composition, this study suggests that mechanically recovered meat and internal fat, especially from silver carp (*Hypophthalmichthys molitrix* Val.) may be an interesting alternative raw material for food production, like the production of MRM from marine fish (cod, salmon). Production of MRM from silver carp and separation of its internal fat may be a good business strategy.

SUMMARY

The aim of the study was to analyze the fatty acids (FA) profile and FA sums (ΣSFA: saturated FA, ΣMUFA: monounsaturated FA, ΣPUFA: polyunsaturated FA, ratio $\Sigma PUFA_{n-6/n-3}$) (in $g.kg^{-1}$) in wet tissue of mechanically recovered meat (MRM) from common carp (*Cyprinus carpio*, L.) and silver carp (*Hypophthalmichthys molitrix*, Val.), and in the case of silver carp to analyze the fatty acids profile (in % of total fatty acids investigated) in internal fat. The fatty acids profile in MRM from common carp compared with MRM from silver carp was statistically ($P < 0.01$, $P < 0.05$) different. Quantitatively most important FA (in $g.kg^{-1}$) in MRMs of both species was oleic acid: C18:1n9 (common carp: 35.98 ± 0.71, silver carp: 37.15 ± 1.36). MRM from silver carp contained (in $g.kg^{-1}$) more ($P < 0.01$) ΣSFA: 26.19 ± 0.99, ΣMUFA: 49.01 ± 2.00 and ΣPUFA: 18.90 ± 1.24 as a result of higher proportions $\Sigma PUFA_{n-3}$: 15.44 ± 1.08, and particularly high levels of α-linolenoic acid C18:3n-3: 5.37 ± 0.36, eicosapentaenoic acid C20:5n-3: 4.30 ± 0.31 and docosahexaenoic acid C22:6n-3: 4.15 ± 0.30. Common carp MRM contained (in $g.kg^{-1}$) more ($P < 0.01$) $\Sigma PUFA_{n-6}$: 9.70 ± 0.26 as a result of higher proportions of linoleic acid C18:2n-6: 8.03 ± 0.20 in particular. All $PUFA_{n-3}$ in common carp MRM were present in small quantities ($P < 0.01$), which was reflected in a low value of $\Sigma PUFA_{n-3}$ 4.38 ± 0.14. The $\Sigma PUFA_{n-6/n-3}$ ratio in silver carp MRM (0.22 ± 0.01) compared with common carp MRM (2.22 ± 0.06) was more favourable. The internal fat from silver carp contained (in % of total fatty acids investigated) more ΣMUFA ($P < 0.01$) and ΣPUFA ($P < 0.05$) in comparison with silver carp MRM fat. However, the $\Sigma PUFA_{n-6/n-3}$ ratio in silver carp MRM (0.22 ± 0.01) and internal fat samples (0.24 ± 0.01) was comparable. This study indicates that the fatty acids profile in MRM and in the internal fat, particularly from silver carp (*Hypophthalmichthys molitrix* Val.), is valuable for human health.

REFERENCES

BUCHTOVÁ, H., CUPÁKOVÁ, Š., 2009: Composition of mechanically recovered meat of Common Carp (*Cyprinus carpio*, L.) and Silver Carp (*Hypophthalmichthys molitrix*, Val.). *Archiv für Lebensmittelhygiene,* 60: 104108. ISSN 0003-925X.

COMMISSION REGULATION (EC) No. 1662/2006 of 6 November 2006 amending Regulation (EC) No. 853/2004 of the European Parliament and of the Council laying down specific hygiene rules for food of animal origin. *Official Journal* L 320, 1–10.

DOMAIZON, I., DESVILETTES, C., DEBROAS, D., BOURDIER, G., 2000: Influence of zooplankton and phytoplankton on the fatty acid composition of digest and tissue lipids of silver carp: mesocosm experiment. *Journal of Fish Biology,* 57: 417–432. ISSN 0022-1112.

EUROPEAN COMMISION, 2010: Eurostat, Fisheries, Introduction, Data, Database, Aquaculture production – Quantities (Tonnes live weight: 2007) /2010-5-31/. Available from: http://appsso.eurostat.ec.europa.eu/nui/setupModifyTableLayout.do.

FAO, 2009: Fisheries and Aquaculture Department, The State of World Fisheries and Aquaculture 2008. *Food and Agriculture Organization of the United Nations*, Rome, 1–196.

HARA, A., RADIN, N. S., 1978: Lipid extraction of tissues with a low-toxicity solvent. *Analytical Biochemistry,* 90: 420–426. ISSN 0003-2697.

HENDERSON, R. J., 1996: Fatty acid metabolism in freshwater fish with particular reference to polyunsaturated fatty acids. *Archive für Tierernährung,* 4: 5–22. ISSN 0003942X.

KMÍNKOVÁ, M., WINTEROVÁ, R., KUČERA, J., 2001: Fatty acids in lipids of carp (*Cyprinus carpio*) tissues. *Czech Journal of Food Science,* 19: 177–181. ISSN 1212-1800.

MALBROUCK, C. H., KESTEMONT, P., 2006: Effects of microcystins on fish. *Journal of Environmental Toxicology and Chemistry*, 25: 72–86. ISSN 1552-8618.

MAREŠ, J., PALÍKOVÁ, M., KOPP, R., NAVRÁTIL, S., PIKULA, J., 2009: Changes in the nutritional parameters of muscles of the common carp (*Cyprinus carpio*) and the silver carp (*Hypophthalmichthys molitrix*) following environmental exposure to cyanobacterial water bloom. *Aquaculture Research,* 40: 148–156. ISSN 1355-557X.

PICKOVÁ, J., MORKORE, T., 2007: Alternate oils in fish feeds. *European Journal of lipid science and technology*, 109: 256–263. ISSN 1438-7697.

STEFFENS, W., 1997: Effects of variation in essential fatty acids in fish feeds on nutritive value of freshwater fish for humans. *Aquaculture,* 151: 97–119. ISSN 0044-8486.

TASKAYA, L., CHEN, Y. Ch., BEAMER, S., TOU, J. C., JACZYNSKI, J., 2009: Compositional characteristics of materials recovered from whole gutted silver carp (*Hypophthalmichthys molitrix*) using isoelectric solubilisation/precipitation. *Journal of Agricultural and Food Chemistry*, 57: 4259–4266. ISSN 0021-8561.

TELLEZ-LUIS, S. J., URESTI, R. M., RAMIREZ, J. A., VAZQUEZ, M., 2002: Low–salt restructured fish products using microbial transglutaminase as binding agent. *Journal of the Science of Food and Agricultural,* 82: 953–959. ISSN 1097-0010.

TRATTNER, S., RUYTER, B., OSTBYE, T. K., GJOEN, T., ŽLÁBEK, V., KAMAL–ELDIN, A., PICKOVÁ, J., 2008: Sesamin Increases Alpha–Linolenic Acid Conversion to Docosahexaenoic Acid in Atlantic Salmon (*Salmo salar* L.) Hepatocytes: Role of Altered Gene Expression. *Journal of Lipid Researchs*, 43: 999–1008. ISSN 1539-7262.

Address

doc. MVDr. Hana Buchtová, Ph.D., Ústav hygieny a technologie masa, Fakulta veterinární hygieny a ekologie, Veterinární a farmaceutická univerzita Brno, Palackého 1/3, 612 42 Brno, Česká republika, e-mail: buchtovah@vfu.cz