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Original scientific paper

Effect of frying on the fatty acid composition of silver carp and common carp

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A b s t r a c t: The effects of deep frying in sunflower oil or pork fat on the fatty acids (FAs) of silver carp (Hypophthalmichthys molitrix) and common carp (Cyprinus carpio) fillets were determined. The use of sunflower oil and pork fat for frying increased the proportion of polyunsaturated (PUFAs) and saturated fatty acids (SFA), respectively, in the fish fillets. In the fried fish fillets, the linoleic acid content (C18:2n-6) increased after frying in sunflower oil, while n-3 PUFAs, in particular C20:5n-3 (EPA) and C22:6n-3 (DHA), decreased compared with their contents in raw fillets. The apparent retention values of n-3 PUFAs were higher in silver carp (69–78%) than in common carp (21–43%) when the fillets were fried in sunflower oil. After frying the fish fillets in pork fat, contents of SFAs, especially palmitic (C16:0) and stearic (C18:0) acids, were increased compared with the raw fillets. From the public health point of view, it is important to highlight that the ratio of n-6/n-3 in fillets of silver carp and common carp increased after deep frying in sunflower oil (2.61; 28.50), as opposed to frying in pork fat (1.20 7.99). Deep frying the fish fillets in sunflower oil increased the total fat content of silver carp fillets by about 85% and common carp fillets by about 343%, while frying in pork fat increased the total fat content of silver carp fillets by about 78% and common carp fillets by about 191%. The choice of culinary oils/fats affects the total FA contents and the fat composition of prepared, fried fish fillets.

Keywords: *frying, sunflower oil, pork fat, cooking, fish, fat content*

Introduction

Fish species from different ecosystems are known to differ in their fatty acid (FA) composition; therefore, studies of polyunsaturated fatty acid (PUFA) contents of diverse fish from various locations are of great importance for revealing their potential value as sources of the essential n-3 acids in human nutrition (Cirkovic et al., 2011; *Trbovic et al.*, 2013; *Ahlgren et al.*, 1994). Meanwhile, information about PUFA contents of raw fish may have limited value for any conclusion as to their actual food quality. Several studies were undertaken to determine the effects of different cooking methods on the FAs of fish species, in particular boiling, pan-frying, deep fat-frying and oven-baking (*Candela et al.*, 1998; *Al-Saghir et al.*, 2004; *Sioen et al.*, 2006; *Gladyshev et al.*, 2007). The quality of the heating medium is of great concern, since most oils used for this purpose are now vegetable oils containing linoleic (18:2n-6) acid but only low amounts of linolenic (18:3n-3) acid. Such PUFA are susceptible to oxidation and to thermal damage from local excess heating (*Sebedio et al.,* 1993; *Sioen et al.,* 2006). Less attention has been paid to the transfer of lipids between the food item and the frying medium (*Peers and Swoboda*, 1982; *Thompson and Aust*, 1983; *Sebedio et al.,* 1990). Frying is a frequently applied cooking method and gives flavour characteristics to the food that are highly appreciated by consumers. In Serbia, carp is the most commonly consumed species of medium fatty fish (*Markovic and Poleksic,* 2011; Cirkovic et al., 2011). In this study, the effects of frying in sunflower oil or pork fat on the FA composition of silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio*) were determined.

Materials and methods

Fish sampling, storage and cooking

Commercially available fish were collected at the same time from the Ecka fish farm (Zrenjanin, Serbia). The fish species were silver carp (*Hypophthalmichthys molitrix*) and common carp (*Cyprinus carpio*). Upon arrival to the laboratory, fish were held in frozen storage below −20°C. The

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raw fish were thawed at room temperature for about one hour prior to analyses. Muscle tissues (fillets) below the dorsal fin were removed from the thawed fish. Three fishes of each species were used in each analysis, i.e., were studied for each treatment: control (raw) and fried. Therefore, the muscle tissues of six fishes were analyzed. Frying was conducted at 150–170°C for 15–20 min using either sunflower oil, the most common cooking oil in Serbia, or pork fat. The fried fish were analyzed within one hour after frying.

Chemical analysis and FA analysis

To measure moisture content, about 10–15 g of tissue wet weight were taken from the studied fillets and dried to a constant weight at 105°C according to ISO (1997). Lipid extraction after acid hydrolysis of fish tissue was conducted using petroleum ether according to ISO (1973). Fatty acid methyl esters (FAMEs) were analyzed using conditions that have been previously reported (*Spiric et al.,* 2010). Briefly, total lipids for FA determination were extracted from fish muscle tissues by accelerated solvent extraction (ASE 200, Dionex, Sunnyvale, CA) with a mixture of n-hexane and iso-propanol (60:40 v/v) in a 33 ml extraction cell at 100°C and nitrogen pressure of 10.3 MPa. The solvent was removed under a stream of nitrogen in a solvent cabinet (Dionex SE 500, Sunnyvale, CA) at 50°C until dryness. The fat extract was further used for FA determination.

FAMES were prepared by transesterification using trimethylsulfonium hydroxide, according to ISO (2000). The gas chromatograph Shimadzu 2010 (Kyoto, Japan) used for FAME determination was equipped with a fused silica cianopropyl HP-88 column (length 100 m, i.d. 0.25 mm, film thickness 0.20 µm, J&W Scientific, USA), and flame ionization detector. The column temperature was programmed. Injector temperature was 250°C and detector temperature was 280°C. The carrier gas was nitrogen at a flow rate of 1.33 ml/min and injector split ratio 1:50. Injected volume was 1 µl and total analysis time was 50.50 min. The chromatographic peaks in the samples were identified by comparing relative retention times of FAME peaks with peaks in a Supelco 37 Component FAME mix standard (Supelco, Bellefonte, USA).

Calculation of apparent retention values for fried carp fillets

The apparent retention value (ARV) of fried fish was calculated using the formula:

% ARV = (nutrient content per g of fried food) / (nutrient content per g of raw food) × 100 (*Flakemore et al.*, 2017).

Results and Discussion

The FA content of the sunflower oil and pork fat used is presented in Table 1. Sunflower oil was characterized by a high content of linoleic acid (C18:2n-6) and high total PUFA content. The contents of groups of FAs in sunflower oil decreased in the order PUFA > MUFA > SFA. Pork fat was characterized by high contents of palmitic (C16:0), stearic (C18:0) and oleic (C18:1n-9) acids. The contents of groups of FAs in the pork fat decreased as follows: MUFA > SFA > PUFA.

Table 1. Fatty acid composition (% of total fatty acids) of sunflower oil and pork fat (mean ± SEM)

Fatty acids	Sunflower oil	Pork fat
C16:0	6.21±0.19	24.54±1.52
C16:1	0.11±0.00	2.09±0.19
C17:0	0.03±0.00	0.38±0.03
C18:0	2.50±0.04	12.81±0.55
C18:1n-9	28.47±0.87	42.32±0.05
C18:2n-6	54.71±2.10	13.84±0.41
C20:0	0.21±0.01	0.23±0.02
C18:3n-3	0.06±0.00	0.63±0.08
C20:1	0.29±0.11	0.93±0.10
C22:0	0.67±0.02	0.00±0.00
C24:0	0.14±0.06	0.00±0.00
SFA	9.75±0.14	39.07±0.92
MUFA	28.87±0.76	45.33±0.33
PUFA	54.77±2.10	15.32±0.64
n-3	0.06±0.00	0.62±0.13
n-6	54.71±2.10	13.80±0.50

Legend: SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids;

The FA contents of raw silver carp and silver carp after deep fat-frying in sunflower oil or pork fat and the calculated ARVs are shown in Table 2.

The most abundant FAs in the raw silver carp fillets in this study were MUFAs (51.66%), with oleic acid (C18:1n-9) being the most common MUFA. n-3 PUFAs were the next most common group of FAs (12.78%), with α-linolenic acid (C18:3n-3), eicosapentaenoic acid (C20:5n-3) and docosahexaenoic acid (C22:6n-3) being the most common n-3 PUFAs. Linoleic acid (C18:2n-6) was the most abundant n-6 PUFA in raw silver carp

Table 2. Fatty acid composition (% of total fatty acids; means) of silver carp (n = 3) before and after deep fat-frying in sunflower oil or pork fat and mean apparent retention values of the fried fish

Fatty acid or ratio	Raw fish	Fish fried in sunflower oil	Fish fried in pork fat	ARV (%) Fried in sunflower oil	ARV (%) Fried in pork fat
C14:0	2.25	1.43	1.75	64	78
C15:0	0.67	0.41	0.39	61	58
C16:0	21.94	16.95	23.96	77	109
C16:1	14.15	8.97	10.36	63	73
C17:0	0.84	0.59	0.64	70	76
C18:0	3.73	3.72	7.74	100	208
C18:1n-9	34.95	31.82	38.45	91	110
C18:2n-6	2.45	22.87	6.93	933	283
C20:0	0.16	0.16	0.10	100	63
C18:3n-6	0.11	0.08	0	73	0
C18:3n-3	3.49	2.17	1.77	62	51
C20:1	2.56	1.67	1.69	65	66
C20:2	0.16	0.07	0.21	44	131
C20:3n-6	0.40	0.32	0.24	80	60
C20:3n-3	0.25	0.15	0.13	60	52
C22:1+C20:4	2.85	2.01	1.39	71	49
C20:5n-3	3.53	2.77	1.82	78	52
C22:5n-3	1.37	0.94	0.71	69	52
C22:6n-3	4.13	2.9	1.72	70	42
SFA	29.59	23.26	34.57	79	117
MUFA	51.66	42.46	50.51	82	98
PUFA	15.9	32.27	13.53	203	85
n-3	12.78	8.93	6.15	70	48
n-6	3.12	23.34	7.39	748	237
n-3/n-6	4.10	0.38	0.83	9	20
n-6/n-3	0.24	2.62	1.20	1092	500

Legend: SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ARV – apparent retention value (%)

fillets, comprising 2.45% of the total FAs, but the amount of linoleic acid was much greater after frying in sunflower oil (22.87%), while frying in pork fat also increased the linoleic acid content to 6.93%. ARVs for linoleic acid were 933% and 283% in sunflower-fried and pork fat-fried silver carp, respectively. Among the n-3 PUFAs in raw silver carp fillets, EPA (C20:5n-3) and DHA (C22:6n-3) were the most abundant, 3.53% and 4.13%, respectively. Their contents decreased in silver carp after frying in sunflower oil to 2.77% and 2.90%, respectively. The ARVs of EPA and DHA after frying silver carp in sunflower oil were 78% and 70% respectively. The content of EPA and DHA decreased in silver carp fillets after frying in pork fat to 1.82% and 1.72%, respectively, and ARVs after frying in pork fat were 52% and 42% respectively. As a rule of thumb, the greater the ARV, the worse the impact of frying.

Pan-frying in margarine also changed the FA profile of cod (*Sioen et al.* 2006). While PUFA accounted for 56.0% and SFA for 25.9% of the total FAs in raw cod, frying in margarine resulted in decreased PUFA and increased SFA contents of 16.7% and 50.7%, respectively. The n-6/n-3 ratio altered from 0.10 before frying to 0.73 after pan-frying. In addition, whereas EPA and DHA accounted for 49.7% of

the total FAs in the raw cod, they only accounted for 9.8% after pan-frying. The content of EPA and DHA after pan-frying cod in margarine amounted only to, respectively 66.5% and 74.7% of the original content (*Sioen et al.* 2006). After pan-frying, SFA accounted for 27.2% of the total FAs, whereas 22.8% of the total FAs were SFA before pan-frying. Frying in margarine did not affect the PUFA content of cod. The n-6/n-3 ratio altered from 0.30 before to 0.32 after pan-frying. In the case of cod fillets, the PUFA content decreased from 11.40% to 9.46% whereas it increased from 11.43% to 16.54% in salmon fillets after pan-frying. Frying salmon fillets in margarine also caused notable decreases in the percentages of SFA and MUFA (*Sioen et al.* 2006).

The FA contents of raw common carp and common carp after deep fat-frying in sunflower oil or pork fat and the calculated ARVs are shown in Table 3.

The most abundant FAs in the raw common carp fillets were MUFAs (49.01%), with oleic acid being the most common one. Linoleic acid (C18:2n-6) was the most abundant n-6 PUFA in common carp, comprising 17.67% of total FAs, but it comprised even more of the total FAs after frying in sunflower oil (34.05%), while frying in pork fat

Table 3. Fatty acid composition (% of total fatty acids; means) of common carp (n = 3) before and after deep fat-frying in sunflower oil or pork fat and mean apparent retention values of the fried fish

Fatty acid or ratio	Raw fish	Fish fried in sunflower oil	Fish fried in pork fat	ARV (%) fried in sunflower oil	ARV (%) fried in pork fat
C14:0	0.70	0.43	0.88	61	126
C15:0	0.19	0.06	0.15	32	79
C16:0	18.48	11.99	22.15	65	120
C16:1	6.44	4.52	7.67	70	119
C17:0	0.27	0.10	0.28	37	104
C18:0	5.71	4.19	8.32	73	146
C18:1n-9	40.09	40.98	45.39	102	113
C18:2n-6	17.67	34.05	10.45	193	59
C20:0	0.14	0.13	0.11	93	79
C18:3n-6	0.31	0.11	0.08	35	26
C18:3n-3	1.34	0.39	0.65	29	49
C20:1	2.48	1.32	1.81	53	73
C20:2	0.56	0.12	0.36	21	64
C20:3n-6	0.75	0.21	0.22	28	29
C20:3n-3	0.11	0	0.05	0	45
C22:1+C20:4	2.34	0.58	0.73	25	31
C20:5n-3	0.70	0.19	0.23	27	33
C22:5n-3	0.52	0.11	0.15	21	29
C22:6n-3	1.22	0.52	0.31	43	25
SFA	25.48	16.90	31.88	66	125
MUFA	49.01	46.81	54.88	96	112
PUFA	23.16	35.71	12.51	154	54
n-3	3.87	1.21	1.39	31	36
n-6	19.29	34.49	11.11	179	58
n-3/n-6	0.20	0.04	0.13	20	65
n-6/n-3	4.98	28.46	7.99	571	160

Legend: SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, ARV – apparent retention value (%)

reduce the linoleic acid content to 10.45%. ARVs for linoleic acid were 193% and 53% in sunflower-fried and pork fat-fried common carp fillets, respectively. α-linolenic acid (C18:3n-3) was most abundant n-3 PUFA in common carp fillets, comprising 1.34%, but there was even less of this fatty acid after fish fillets were fried in sunflower oil (0.39%) or pork fat (0.65%). ARVs for α-linolenic acid were 29% and 49% in sunflower-fried and pork fat-fried common carp, respectively.

Using sunflower oil to fry silver carp and common carp fillets resulted in decreased amounts of SFAs (ARVs were from 66 to 79%), decreased MUFAs (ARVs were from 82 to 96%), but increased PUFAs (ARVs were from 154 to 203%). n-6 PUFA contents increased in fish fried in sunflower oil (179 to 748%), and thus, decreased n-3 PUFAs (31 to 70%) were measured. The lowest ARVs for n-6 and n-3 FAs were calculated for common carp. Hence, from a public health point of view, it is important to stress that the n-6/n-3 ratios in carp fillets (silver carp and common carp) altered after frying the fish in sunflower oil (2.62 and 28.46, respectively).

Sánchez-Muniz et al. (1992) showed the FA composition of raw and fried sardines. Frying involves an exchange of FAs between the fat in the sardines and the culinary fat used, which caused significant changes in the FA composition of the oily fish. Pan-frying cod fillets in olive oil resulted in decreased amounts of SFA and PUFA (from 23.9% to 18.6% and from 53.2% to 21.6%, respectively) and increased MUFAs (from 22.9% to 59.8%) (*Sioen et al.,* 2006). The n-6/n-3 ratio altered from 0.10 before to 0.40 after pan-frying (*Sioen et al.,* 2006). Pan-frying in olive oil did not affect the FA profile in a significant way, and the n-6/n-3 ratio altered only from 0.34 before to 0.32 after pan-frying. In the case of cod fillets, the PUFA content decreased from 8.51% to 6.49%, whereas it increased from 8.51% to 12.2% after pan-frying salmon fillets. Over the whole study, the mean recoveries varied between 41.9% and 102% for cod and between 59.0% and 87.0% for salmon (*Sioen et al.,* 2006).

PUFA degradation occurs more readily in combination with oxygen and PUFA undergo pronounced oxidative effects (*Little et al.,* 2000). In the case of oxidation, it is important to note that different FAs respond in different ways to heat treatment. SFA are fairly heat stable in the range of temperatures commonly encountered during cooking. However, above 150°C, and when oxygen is present, a variety of oxidation products can be detected. Possible mechanisms for the changes occurring in the culinary process are absorption of culinary fat in the fish, moisture loss of the food, leaching of fat soluble molecules out of the food and oxidation reactions with free radicals generated in the hot culinary fat (*Little et al.,* 2000).

Frying silver carp fillets in pork fat resulted in significant increases in the total SFAs and n-6 PUFAs (ARVs were 117 and 237, respectively). Frying in pork fat also changed the FA profile of common carp fillets. While n-6 PUFA accounted for 19.29% of the total FAs in raw common carp, frying in pork fat increased the total SFAs and MUFAs (ARVs were 125 and 112%, respectively) but decreased n-6 and n-3 PUFAs (ARVs were 58 and 36%, respectively). In common carp, the n-6/n-3 ratio altered from 4.98 in raw fillets to 7.99 after frying in pork fat.

Table 4. Mean moisture content (MC %), fat content (FC %) and apparent retention values (ARV %) of raw and fried silver carp (n = 3)

Nutrient	Raw	Fried in sunflower oil	Fried in pork fat	ARV% fried in sunflower oil	ARV% fried in pork fat
MC %	74.39	71.46	69.96	96	94
FC %	4.16	7.68	7.39	85	78

Table 5. Mean moisture content (MC %), fat content (FC %) and apparent retention values (ARV %) of raw and fried common carp (n = 3)

Nutrient	Raw	Fried in sunflower oil	Fried in pork fat	ARV% fried in sunflower oil	ARV% Fried in pork fat
MC %	77.98	67.41	71.07	86	91
FC %	2.58	11.42	7.50	343	191

The silver carp and common carp in our study belong to the medium fatty fish species, containing less than 4 g fat per 100 g fish (*Huss,* 1995). Frying in sunflower oil increased the fat content of silver carp from 4.16 to 7.68 g/100 g (i.e. by ~85%), whereas for common carp, the fat content increase was greater (from 2.58 to 11.42 g/100 g, i.e. by ~343%, Tables 4 and 5). Using pork fat to fry silver carp increased the fat content from 4.16 to 7.39 g/ 100 g (~78%) while in common carp, the fat content increase was greater (from 2.58 to 7.50 g/100 g, i.e. by ~191%, Tables 4 and 5). Fish that have a low fat content absorb more fat (*Sánchez-Muniz et al.,* 1992). The moisture content varied in both species of raw fish from about 74% to 78% (Tables 4 and 5). Higher moisture contents were characteristic of common carp, and lower contents were found for silver carp. When fillets from both carp species were fried, they lost water and so an explicit trend of decreased moisture contents after frying occurred (Tables 4 and 5). This is in accordance with the study of *Sánchez-Muniz et al.* (1992).

Conclusion

Comparing the use of culinary fats with different FA profiles is relevant to investigate their influence on the FA profile of the food after preparation, and as would be consumed. Using sunflower oil significantly increased the total PUFA content in fried fillets from both carp species, whereas using pork fat resulted in increased SFAs in the fried silver carp and common carp fillets. Hence, control over the FA composition of the consumed fried fish can be achieved to some extent by the selection of culinary fat. The fish fillets that contained lower levels of total FAs tended to uptake more FA from the culinary fat (data not shown). Consequently, the culinary oil/fat selection affects the total FA content and composition of fried carp fillet.

Uticaj prženja na sastav masnih kiselina mesa tolstolobika i šarana

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A p s t r a k t: Ispitan je uticaj dubokog prženja u suncokretovom ulju i svinjskoj masti na sastav masnih kiselina (MK) tolstolobika (Hypophthalmichthys molitrix) i šarana (Cyprinus carpio). Upotreba suncokretovog ulja i svinjske masti povećao je udeo polinezasićenih MK i zasićenih MK, respektivno. Rezultati su pokazali povećanje sadržaja linolne kiseline (C18:2n-6) u ribi koja je pržena u suncokretovom ulju i smanjenje n-3 polinezasićenih MK, naročito u prženoj ribi C20:5n-3 (EPA) i C22:6n-3 (DHA). Očigledna vrednost zadržavanja n-3 polinezasićenih MK u tolstolobiku (69–78%) je bila veća nego u šaranu (21–43%). Rezultati su pokazali, da riba koja je pržena u svinjskoj masti, pokazala je povećanje zasićenih MK, naročito palmitinske kiseline (C16:0) i stearinske kiseline (C18:0). Sa stanovišta javnog zdravlja, važno je napomenuti da se odnos n-6/n-3 u filetima tolstolobika i šarana povećao nakon prženja u suncokretovom ulju (2,61; 28,50), za razliku od prženja u svinjskoj masti (1.20 7.99). Duboko prženje ribe u suncokretovom ulju povećalo je ukupni sadržaj masti u tolstolobiku za oko 85%, a šarana za oko 343%, dok je prženje u svinjskoj masti povećalo ukupni sadržaj masti u tolstolobiku za oko 78%, a šarana za 191 %. Izbor kulinarskih ulja/masti utiče na ukupan sadržaj FA i sastav pripremljenog ribljeg filea

Ključne reči: *prženje, suncokretovo ulje, svinjska mast, tolstolobik, šaran.*

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