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EFFECTS OF DIFFERENT HEAT TREATMENTS ON LIPID QUALITY OF STRIPED CATFISH (*PANGASIUS HYPOPHTHALMUS*)

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Background. As a result of consumer acceptance and low price production, sales of striped catfish fillets continue to grow. Striped catfish fillets, due to their white meat and lack of fish scent, can be an alternative to fish such as cod or hake. The paper analysed the influence of four different kinds of heat treatment: boiling with and without the addition of salt, frying, microwave cooking, microwave cooking without water) on the composition of fatty acids and the lipid oxidation and hydrolysis level of striped catfish fillets.
Material and methods. Assays were performed on striped catfish fillets (*Pangasius hypophthalmus*, Sauvage 1878), which were bought from local supermarket. Fillets one year before expiration date were assayed. Quality of fish lipids was determined by an analysis of the following factors: peroxide value (PV), anisidine value (AsV), TOTOX value, conjugated dienes (CD), acid value (AV), along with an analysis of the composition of fatty acid (FA) via gas chromatography.
Results. It was shown that conventional cooking and microwave cooking of striped catfish fillets results in an approximately 10% change in the amount of PUFA, including EPA and DHA, whereas the percentages of SFA and MUFA remain unchanged. The amount of the sum of EPA and DHA in 100 g of raw fillet was 16.5 mg, whereas after conventional cooking, microwave cooking and frying the sum of EPA and DHA was respectively: 12, 22 and 23 mg. It was observed that conventional cooking causes an average 10% loss of fat, a change not observed in case of microwave cooking. In spite of a substantial influence of heat treatment on the amount of both primary and secondary oxidation products, striped catfish lipids maintained good quality after the treatment – PV of every sample was below 3 meq O_2/kg lipids, and AsV below 1.5. The addition of salt during boiling caused a 16-fold increase in the amount of peroxides and a fourfold increase in the amount of secondary oxidation products.
Conclusions. A 100 g portion of fillet, depending on the applied method of heat treatment delivers between 12 and 23 mg of the EPA + DHA sum, which is as little as 2.5 to 5% of daily reference value for these acids. Taking into account that n-3 PUFA deficiency involves mainly long-chain acids, striped catfish fillets are not a valuable source of these

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acids, however, due to low fat content and a proper n-6/n-3 PUFA ratio they can be alternative to products such as pork. When cooking catfish fillets in salted water it is worth bearing in mind that their oxidation level will greatly increase.

Key words: aquaculture, striped catfish, heat treatments, fatty acids, lipid oxidation

INTRODUCTION

In 2008 aquacultured fish output reached 60% of the overall fish consumption worldwide [FAO 2010]. It is expected that consumption of fish will continue to rise, and it will be not possible to satisfy the consequent increased demand with captured fish only, especially that many stocks are overfished and many species of fish are in danger of extinction. The above makes fish farming the only successful solution that meets the demand of the market. One of the examples of a rapidly growing market is the farming of catfish. The binomial name of the species is *Pangasius hypophthalmus* (Sauvage 1878), in Vietnam, the place of the origin of the fish is called "ca tra". The product is almost totally exported to over 100 countries as frozen fillets, as an acceptable alternative to white fish. Catfish is farmed mostly in earthen ponds, up to 4 m deep, in nine provinces in the Mekong Delta in South Vietnam [Phan et al. 2009].

Catfish fillets are available in 4 colours: white (mainly exported to the US), light pink (desired in Europe), pink (acceptable in Europe), light yellow (available in Poland and Eastern Europe) and yellow (offered in Asia) [Kulikowski 2006].

Regardless of many controversial issues regarding this fish, in particular its farming conditions, striped catfish meat, in comparison with meat of other fish, including sea fish, contains less heavy metals, PCB, PCBB and PBDE, which attests to high standards of catfish farming conditions [Polak-Juszczak 2007, Orban et al. 2008, Leeuwen et al. 2009]. Market demand for striped catfish fillets continues to rise, another fact that proves that the fish has been accepted by consumers almost all over the world [Orban et al. 2008, Phan et al. 2009]. According to Vietnam Association of Seafood Exporters and Producers in the first 11 months of 2010, Vietnamese pangasius export has reached 595.3 thousand MT, worth US$ 1.28 billion, up 6.3% in volume and 2.8% in value compared to the same period last year [VASEP 2011]. Unlike cod fillets, for which they are often substituted because of their white flesh, Pangasius fillets are characterised by absence of fishy odour, small bones and skin. When cooked, their flavour is delicate and their texture firm, allowing a wide range of culinary preparations [Orban et al. 2008]. The above factors are not necessarily decisive for the popularity of striped catfish in the catering industry. In my opinion the factor that makes striped catfish fillets popular in Europe is their price, which is 30% to 40% lower than the price of fish such as cod, hake or Alaska pollock. Feeding costs are a major contributor to the overall price, constituting as much as 50% of the overall costs of aquaculture, determining whether it is profitable or not [El-Sayed 1999]. Therefore the feed used in catfish farming must be of a relatively low quality making possible such low prices of fillets. Striped catfish is considered an omnivore, feed used in catfish farming are mostly agricultural by-products. Rice bran alone can constitute as much as 80% of the feed [Orban et al. 2008, Phan et al. 2009]. Due to the fact that composition of feed, particularly its lipid profile, determines the amount and composition of fish lipid fatty acids [Steffens 1997, Kołakowska et al. 2006, Asdari et al. 2011] nutritional value of catfish lipids is low

because of a small amount of n-3 family PUFA [Polak-Juszczak 2007, Orban et al. 2008, Karl et al. 2010]. An important factor determining, among others, the nutritional value of lipids is their level of oxidation, which can occur during various technological processes. Primary and secondary oxidation products accumulated during lipid peroxidation may not only degrade biological properties of fat, but also be the main factor responsible for cell damage and, in many cases, cell death [Bird and Draper 1980, Dianzani 1993, Bartosz and Kołakowska 2010].

Despite increasing consumption of striped catfish fillets, there is no research, in the available literature, on the influence of heat treatment on catfish lipid quality. Because cooking and frying are the main methods of heat treatment of fish, including catfish, this research focused mainly on these two forms of heat treatment, additionally taking into account the addition of NaCl during cooking.

The aim of the research was to determine the influence of heat treatment of striped catfish fillets on the composition and lipid oxidation level of fatty acids.

MATERIAL AND METHODS

Samples and sample preparations

Assays were performed on striped catfish fillets (*Pangasius hypophthalmus*, Sauvage 1878). Sample consisted of approximately 7 kg of frozen IQF fillets, which were bought from a local supermarket. Fillets one year before expiration date were assayed. After defrosting (at the temp. 4°C for 12 h), fillets were rinsed in tap water, then left dripping and carefully dried with a paper towel afterwards. For each method of heat treatment 8 fillets with average weight of 120 g were selected. Heat treatment was applied until a temperature of 75°C in the thickest part of the fillet was reached.

Cooking procedures

- boiling (**B**) the fish was put into boiling water, fish to water ratio of 1:1.5, time 9 min
- boiling with salt (**Bs**) the fish was put into boiling water (1% NaCl solution), fish to water ratio 1: 1.5, time 9 min
- microwave cooking with water (**Mw**): LG MS – 191 MC cooking oven, fillets were poured with boiling water, fish to water ratio 1:1.5, power 600 W, time 7 min
- microwave cooking without water (**M**): LG MS – 191 MC cooking oven, fillets were placed on a plate, power 600 W, time 7 min
- frying (**F**) fillets were fried in rapeseed oil ("Kujawski") at a temperature 180°C, KROMET PE-0/5 electric plate, time 6 min (3 min each side).

Raw fillets and after heat treatments were shredded with an electric tool equipped with a sieve with 2 mm mesh.

Analytical procedures

Moisture content was determined gravimetrically at 105°C for 6 h.

Lipids were extracted from raw fillets and after heat treatments with a chloroform: methanol mixture (1:2 v/v) according to Bligh and Dyer [1957], extraction was performed twice. Lipid content was determined gravimetrically and expressed as g/100 g wet weight.

Quality of fish lipids was determined by an analysis of the following factors: peroxide value (PV), anisidine value (AsV), TOTOX value, conjugated dienes (CD), acid value (AV), along with an analysis of the composition of fatty acid (FA) via gas chromatography. PV of lipids were determined with the thiocyanate technique [Pietrzyk 1958], based on oxidation of ferrous salt with hydroperoxides and the reaction of ferric salts with potassium isothiocyanate. The red ferric complexes formed were determined spectrophotometrically. PV expressed as meq O_2/kg lipids. Anisidine value and total oxidation value (Totox) were determined according to the ISO [1988], method 6885. Totox values were calculated from the relationship TOTOX = 2PV + AV. Acid value (AV) and conjugated dienes (CD) were determined according to the AOCS [2004] methods Cd 3d-63 and Ti 1a-64 respectively.

Fatty Acid Methyl Esters (FAME) were prepared according to the AOCS [2004] Ce 1b-89 method [2004]. GC analysis of FAME was carried out in a Agilent model 7890A instrument equipped with a split/splitless injector, MSD and a column, SP^{TM} column: 2560, 100 × 0.25 mm ID, 0.20 µm film, catalog number 24056. The initial temperature of the column was 145°C, injection port temperature 220°C, detector temperature 220°C, initial time 5 min, temperature increment 4°C/min, final temperature 220°C, and the total time of analysis 45 min. Carrier gas helium: constant flow rate of 1.2 cm^3/min, split ratio 1:50.

FA analysis parameters: SP^{TM} column – 2560, 100 × 0.25 mm ID, 0.20 µm film, catalog number 24056, carrier gas helium: constant flow rate of 1.2 cm^3/min, split ratio 1:50, injector temperature 220°C; detector temperature 220°C; oven temperature: 140°C (5 min) increase to 240°C in 4°C/min, total time of analysis 45 min.

Interpretation of chromatograms was made by comparing the retention times and the mass spectra of individual FAME of the examined sample with the retention times and mass spectra of the respective Sigma FAME standards (Lipid Standard). The results were recorded and processed using ChemStation (E.01.00) software. The quantification of EPA and DHA was done according to AOCS [2004] method (Ce 1b-89/1).

Statistical analysis

Numbers presented in the tables and pictures are the mean values of three concurrent iterations. Statistical analysis was based on the one-way analysis of variance, homogeneous groups were formed according to the Duncan test for $p < 0.05$. The data were statistically analysed using STATISTICA (data analysis software system) by StatSoft Inc. (2005), version 7.1, www.statsoft.com.

RESULTS AND DISCUSSION

The amounts of water and fat in raw fish and in fish after heat treatment are presented in Table 1.

The amounts of fat and water in raw catfish were usual for this species and amounted to respectively 2.23% and 81.57% (Table 1). The obtained results are

consistent with those quoted by other authors, who observed that the amount of fat in catfish available in Italy was between 1.1% and 3.04% [Orban et al. 2008], in Germany between 1.7% and 2.9% [Karl et al. 2010] and in Poland 1.34% on average. The amount of water in fish meat was between 80% and 85% [Orban et al. 2008] and 82.82% [Polak-Juszczak 2007].

Table 1. Fat and moisture content of raw and cooked fish fillets

Weat treatment	Content of		
	moisture % wet wt	fat % wet wt	fat % dry wt
R	81.57 ±0.57[a]	2.23 ±0.08[a]	12.14 ±0.59[a]
B	80.75 ±0.48[a]	2.01 ±0.06[a]	10.44 ±0.45[a]
Bs	79.98 ±0.72[a]	2.05 ±0.07[a]	10.24 ±0.49[a]
Mw	79.35 ±0.60[a]	3.01 ±0.08[b]	14.58 ±0.53[a]
M	75.38 ±0.45[a]	3.75 ±0.09[c]	15.23 ±0.50[a]
F	63.28 ±0.37[a]	9.65 ±0.26[d]	26.28 ±0.98[a]

R – raw, B – boiling, Bs – boiling with salt, Mw – microwave cooking with water, M – microwave cooking without water, F – frying.

a, b – values represented by the same letters in column are not significantly different from each other with $p < 0.05$.

After examining the samples after heat treatment it was observed that, with exception of microwave cooking and frying, heat treatment causes an insignificant (approximately 3%) loss in the amount of water (Table 1). The minimal loss of water can most likely be attributed to the presence of polyphosphates (E452) in the fillets; as indicated on the labels. Producers often add polyphosphates to catfish to make the meat bind water [Karl et al. 2010]. The main purpose of polyphosphates is to improve the hydration of meat of slaughter animals and fish [Kołakowski 1986, Turan et al. 2003].

As far as fat is concerned, loss introduced by heat treatment is not as explicit as in the case of water. Boiling, both with and without the addition of salt and, caused a substantial (10% on average) drop in the amount of fat, and in case of microwave cooking, both with and without water an increase of respectively 35% i 68% in the amount of fat was observed (Table 1). The highest amount of fat of 9.65% was observed in fried fillets (Table 1). During frying, catfish meat displayed properties characteristic of low-fat fish that absorb large quantities of oil when fried [Agren and Hanninen 1993, Candela et al. 1997, Sioen et al. 2006, Weber et al. 2008]. Lower amounts of lipids in boiled samples were presumably the result of the spread of fat into stock during boiling. Loss of fat due to spreading during heat treatment was also observed by Kołakowska et al. [2006] in the trout and by Larsen et al. [2010] in boiled king salmon fillets. Microwave cooking without water (M), employed in this research, unlike the method used by Larsen et al. [2010] on salmon, caused an increase of the amount of fat in fillets of approximately 39% (Table 1). This discrepancy can most likely be attributed to the differences between catfish and salmon – catfish is a low-fat fish much less susceptible to fat drip during heat treatment than high-fat fish such as salmon. This is

confirmed by the research of Weber et al. [2008] on silver catfish, which revealed that microwave cooking caused a near 30% increase of the amount of fat in meat.

According to some authors, changes in the amounts of lipids after the forms of heat treatment such as steaming and roasting depend on fish species, treatment temperature, portion size and heatable surface area [Gall et al. 1983]. A higher fat content of the Mw sample (microwave cooking with water), in comparison with the B sample (boiling; Table 1), can be attributed to the shorter cooking time. When presenting the measured amounts of lipid in proportion to the dry mass it was observed that fillets cooked in a microwave had on average 45% more lipids than the conventionally cooked ones (Table 1).

Increased amount of lipids in fillets cooked in a microwave is presumably a result of water drip during heating and, as Larsen et al. [2010] suggest, easier and thus more efficient extraction of lipids from samples after heating.

Interactions in meat might also have affected the level of fat in the microwave cooked samples. Research by Pikul and Wojciechowska [1994], Regulska-Ilow et al. [1996], and Kołakowska and Bienkiewicz [1999] revealed that heat treatment may increase or decrease lipid extractability. Although the extraction of lipids in this research was performed using a mixture of polar and non-polar solvent (chloroform and methanol), due to interactions between the constituents of tissue some amount of lipids is permanently bound and thus unextractable. According to Pokorny [Pokorny and Janićek 1975] unextractable lipids are bound by covalent bonding.

The analysis of the composition of striped catfish fatty acids revealed that the dominant groups of fatty acids in catfish fillet lipids are saturated (SFA) and monounsaturated (MUFA) fatty acids, representing respectively 47.1% and 40.4% of the total FA (Table 2). The dominant FA in the SFA group were the palmitic acid (C16:0) and stearic acid (C18:0) that represented respectively 70% and 19% of the group. MUFA were in 90% dominated by oleic acid (C18:1; Table 2). The least numerous group of fatty acids were polyunsaturated fatty acids (PUFA), representing only 12.5% of the total FA (Table 2). The dominant FA in this group was the linoleic acid (C18:2) representing 60% of the group. The percentage of EPA and DHA in lipids was respectively 0.21% and 0.83%. Four dominant FA (16:0, C18:0, C 18:1, 18:2) constituted almost 87% of the total FA (Table 2). In general, the observed composition of fatty acids are consistent with results quoted by other authors, who also observed that the dominant FA group in catfish are SFA and MUFA [Orban et al. 2008, Asdari et al. 2011, Karl et al. 2010, Thammapat et al. 2010].

The greatest discrepancies were found when comparing the obtained results with results quoted by other authors involved amounts of EPA and DHA. In this research the sum of EPA and DHA in raw fish amounted to 1.04% (Table 2), whereas the results obtained by Karl et al. [2010] for the sum of those acids were 100-150% higher. Main possible causes of the discrepancy in the results are the type of feed and the method of fish farming. Research by Karl et al. [2010] showed that even in conventionally farmed fish differences in percentages of EPA and DHA can be as high as 50%. It is believed that composition of feed, particularly its lipid profile determines the amount and composition of fish lipid fatty acids [Steffens 1997, Kołakowska et al. 2006, Asdari et al. 2011]. Striped catfish feed is mostly vegetable-based and consists of rice and soy bran and agricultural by-products [Orban et al. 2008], that attests to the high amounts of linoleic acid in PUFA. The percentage of vegetables in catfish feed is very high, for example rice bran alone can constitute as much as 80% of the feed in relation to the dry mass.

In general, no substantial influence of heat treatment, with an exception of frying, on the percentage of SFA and MUFA was observed (Table 2). The largest observed changes involved mainly polyunsaturated fatty acids of the n-3 PUFA family (Table 2).

Table 2. Fatty acids composition of raw and cooked fish fillets, % of total fatty acid

FA	R		B		Bs		M		Mw		F	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
C 12:0	0.14	0.00	0.12	0.00	0.17	0.00	0.05	0.00	0.15	0.00	0.00	0.00
C 14:0	3.77	0.11	3.49	0.09	3.38	0.12	3.67	0.12	3.97	0.12	0.85	0.03
C 15:0	0.77	0.01	0.92	0.02	1.26	0.03	0.63	0.08	0.66	0.01	0.07	0.00
C 16:0	32.60	0.98	32.15	1.03	31.97	1.02	32.50	0.32	33.36	1.00	9.30	0.28
C 17:0	0.38	0.01	0.35	0.01	0.33	0.01	0.36	0.02	0.37	0.01	0.01	0.00
C 16:1	1.10	0.01	1.11	0.03	0.89	0.02	1.36	0.05	0.98	0.01	0.15	0.00
C 18:0	9.14	0.21	9.40	0.23	9.49	0.34	9.46	0.09	8.56	0.20	2.44	0.06
C 18:1	37.59	1.20	37.88	1.14	38.11	1.33	38.60	1.52	37.97	1.21	62.33	2.13
C 18:2 n-6	7.53	0.09	7.50	0.24	7.45	0.19	7.26	0.02	7.83	0.09	15.91	0.36
C 20:0	0.15	0.01	0.14	0.00	0.11	0.00	0.16	0.00	0.15	0.01	0.09	0.00
C 18:3 n-3	0.43	0.01	0.43	0.01	0.37	0.01	0.47	0.01	0.42	0.01	6.73	0.23
C 20:1 n-9	1.12	0.03	1.19	0.02	1.25	0.04	1.10	0.08	1.07	0.03	0.84	0.02
C 20:2 n-6	0.42	0.01	0.37	0.01	0.41	0.01	0.33	0.01	0.32	0.01	0.11	0.00
C 22:1 n-9	0.59	0.02	0.57	0.01	0.75	0.02	0.35	0.02	0.56	0.02	0.18	0.00
C 20:4 n-6	0.89	0.02	0.91	0.01	0.82	0.02	0.69	0.00	0.79	0.02	0.24	0.00
C 20:4 n-3	1.33	0.04	1.39	0.03	1.25	0.03	1.01	0.00	1.07	0.03	0.25	0.01
C 20:5 n-3	0.21	0.01	0.16	0.01	0.09	0.00	0.20	0.01	0.13	0.00	0.06	0.00
C 21:0	0.19	0.00	0.16	0.00	0.20	0.01	0.11	0.01	0.17	0.00	0.00	0.00
C 22:4 n-3	0.55	0.01	0.57	0.02	0.54	0.02	0.39	0.01	0.46	0.01	0.10	0.00
C 22:5 n-3	0.26	0.01	0.26	0.01	0.26	0.01	0.31	0.01	0.16	0.00	0.11	0.00
C 22:6 n-3	0.83	0.03	0.93	0.02	0.89	0.03	1.00	0.03	0.82	0.03	0.23	0.01
∑ SFA	47.15	0.90^{b}	46.73	0.85^{b}	46.91	0.92^{b}	46.94	0.98^{b}	47.41	1.00^{b}	12.76	0.32^{a}
∑ MUFA	40.41	0.93^{a}	40.75	1.02^{a}	41.00	0.82^{a}	41.40	0.65^{a}	40.59	0.85^{a}	63.50	1.21^{b}
∑ PUFA	12.45	0.42^{a}	12.53	0.49^{a}	12.09	0.39^{a}	11.66	0.35^{a}	12.00	0.30^{a}	23.74	0.50^{b}
∑ n-3	3.60	0.11^{c}	3.74	0.09^{c}	3.40	0.12^{b}	3.38	0.09^{b}	3.06	0.07^{a}	7.48	0.24^{d}
∑ n-6	8.84	0.22^{b}	8.78	0.18^{b}	8.68	0.16^{ab}	8.28	0.21^{a}	8.94	0.25^{b}	16.26	0.49^{c}
∑ n-6/∑ n-3	2.46	0.05^{bc}	2.36	0.04^{b}	2.55	0.08^{c}	2.45	0.06^{bc}	2.92	0.08^{d}	2.17	0.07^{a}

Explanations as in Table 1.

Substantial changes in the amounts of n-3 PUFA were observed both during microwave cooking with water (–15%) and during microwave cooking without water (–6%; Table 2). Contrary to the expectations a significant loss in the amount of the sum of EPA and DHA was observed only during microwave cooking with water and it was as little as 9%. Microwave cooking without water (M) resulted in a near 6% significant decrease in the amount of PUFA and n-6 PUFA (Table 2). Boiling with and without the addition of salt did not significantly affect the percentage of PUFA, including the sum of EPA and DHA (Table 2). No substantial influence of heat treatment (boiling, roasting, grilling, microwave heating) on the percentage of n-3 PUFA, including DHA, was observed by Weber et al. [2008] applying heat treatment to silver catfish.

When presenting the sum of EPA and DHA in absolute amounts (in milligrams) in 100 g of meat tissue it was observed that 100 g of raw fillet contained only 16.5 mg of these acids (Table 3). After conventional boiling, both with and without the addition of salt, it was observed that 100 g of filled contained only 12-13 mg of EPA and DHA, a 25% loss (Table 3). In case of microwave cooking with water (Mw) and without water (M), a substantial increase, in comparison with raw fillets, in the amount of EPA and DHA of approximately 27% to 21 mg/100 g of meat on average, was observed (Table 3). 20%-30% higher amount of EPA and DHA, in comparison with raw fillets, was observed by Gladyshev et al. [2006, 2007] in boiled humpback salmon and trout fillets, in boiled herring fillets the amount of these acids was almost 20% lower. The research by Kołakowska et al. [2001] showed that forms of heat treatment such as conventional and microwave heating applied to Baltic herring had no substantial influence on the percentage of EPA and DHA, however, as a result of lipid loss during cooking, absolute amounts of these acids decreased substantially by 20% on average. Changes in amounts of EPA and DHA observed in the research were caused by changes in amounts of water and fat rather than a consequence of applying heat during cooking. Changes in lipid extractability had also some influence on the amount of measured EPA and DHA, what in turn directly affected percentages and composition of fatty acids [Domiszewski and Bienkiewicz 2010].

Table 3. The contents of n-3 PUFA and EPA + DHA of raw and cooked fish fillets, mg/100 g wet weight

Weat treatment	EPA + DHA mg/100 g	Recommended amount* EPA + DHA 0.5 g/day
R	16.47 ±0.64^{c}	3.04
B	13.25 ±0.41^{b}	3.77
Bs	12.23 ±0.32^{a}	4.09
Mw	22.18 ±0.64^{de}	2.25
M	21.20 ±0.66^{d}	2.36
F	22.95 ±0.54^{e}	2.18

*Amounts of meat (g) that contain the recommended amount of EPA + DHA.
Explanations as in Table 1.

Due to high fat absorption by low-fat fish during frying [Candela et al. 1997, Weber et al. 2008] influence of this method of heat treatment are discussed separately in this paper, without contrasting frying with other forms of heat treatment. Frying striped catfish fillets resulted in a substantial increase in the percentages of MUFA and PUFA and a decrease in the SFA percentage (Table 2). Oleic acid constituted approximately 63%, and linoleic acid nearly 16% of catfish lipids (Table 2). In general, percentages of various fatty acids in the sample after frying were similar to the FA profile of rapeseed oil that was used for frying. According to Agren and Hanninen [1993] the type of oil used for frying determines the composition of fatty acids of low-fat fish. Despite the decrease in the percentage of EPA and DHA in the total FA from 1.04% to 0.23% after frying, the amount of these acids in 100g of meat increased by nearly 50% from 16.5 mg to 22.9 mg (Table 2, 3). The increase in the absolute amount of EPA and DHA in pangasius, when using canola oil, can only be explained by moisture loss during frying, because the oil used does not contain those fatty acids. The research by Sioen et al. [2006] on cod also confirmed that frying causes an almost 50% increase in the amount of the sum of EPA and DHA per 100 g of product. In general, it can be said that changes in the amounts of fatty acids in catfish due to heating are similar to those observed in other fish species. Nutritional value of lipids is determined not only by the composition of fatty acids, but also by their ratio [Simopoulos 1999, Schmitz and Ecker 2008]. Imbalance in the ratio of n-6 and n-3 acids (which should be about 3-5:1) can contribute to the development of cancer and the development of various kinds of inflammation [El-Badry et al. 2007]. This research demonstrates that, in both raw and processed samples, the n-6/n-3 ratio was between 2.4 do 2.92, a proper ratio from the nutritional perspective (Table 2). Compared to trout, also a farmed fish, striped catfish has lower n-6/n-3 ratio, which can be attributed to the difference in feed – catfish feed consists mainly of fishmeal and oils rich in n-3 PUFA [Haliloglu et al. 2004, Kołakowska et al. 2006].

It is commonly known that fish meat is beneficial for the body. Lipids rich in LC n-3 PUFA are particularly worth noting, as they reduce the development of ischaemic heart disease. According to the International Society for the Study of Fatty Acids and Lipids [ISSFAL 2004], the minimum daily consumption of EPA and DHA by healthy persons that reduces the risk of developing cardiovascular diseases is at least 500 mg. This paper shows that in order to meet the above norm it would be necessary to consume between 2 and 4 kg of striped catfish meat (Table 3), thus, in comparison with other fish species, catfish is not a practical source of EPA and DHA.

Fish lipids, due to high amounts of unsaturated fatty acids and low amounts of natural antioxidants, auto-oxidises at a much more rapid rate than other kinds of lipids [Sikorski and Kołakowska 1990, Drozdowski 2002, Eymard et al. 2009]. The result is most often deterioration of sensory qualities, lower nutritional value of these products along with increased health risk to consumers. The changes do not involve fatty acids only, but also other compounds such as vitamins or sterols [Pena-Ramos and Xiong 2003, Wąsowicz et al. 2004].

The analysis of the oxidation level of raw striped catfish fillets revealed low amounts of both primary (PV) and secondary (AsV) oxidation products of respectively 1.35 meq O_2/kg of lipids and 0.8 (Table 4). Despite heat treatment (with an exception of boiling with the addition of salt) a substantial increase in amounts of peroxides (40-90%), aldehydes and ketones (45-70%) was observed, however the absolute amounts remained at a relatively low level (2.16-2.68 meq O_2/kg of fat for PV and 1.1-

-1.33 for AsV), not enough to significantly contribute to the increase in the level of oxidation (Table 4). Low level of oxidation was confirmed by the amount of dienes that remained virtually unchanged, and even slightly decreased, after heat treatment (Table 4). During the oxidation of PUFAs containing methylene substituted dienes and

Table 4. Oxidation level of raw and cooked fish fillets

Weat treat-ment	PV mEq/kg lipids	AsV	Totox	CD %	AV mg KOH/g lipids
R	1.35 ±0.11^{a}	0.81 ±0.08^{a}	3.51 ±0.14^{a}	0.48 ±0.01^{c}	6.45 ±0.06^{a}
B	2.45 ±0.15^{bc}	1.10 ±0.09^{ab}	6.00 ±0.28^{bc}	0.54 ±0.01^{d}	5.34 ±0.05^{a}
Bs	21.87 ±1.51^{d}	3.52 ±0.21^{d}	47.26 ±2.29^{d}	1.23 ±0.02^{e}	11.32 ±0.08^{a}
Mw	2.68 ±0.19^{c}	1.42 ±0.14^{c}	6.78 ±0.31^{c}	0.46 ±0.01^{c}	5.04±0.05^{a}
M	2.16 ±0.13^{b}	1.16 ±0.12^{bc}	5.48 ±0.21^{b}	0.33 ±0.01^{b}	5.86 ±0.06^{a}
F	2.59 ±0.12^{c}	1.33 ±0.15^{bc}	6.51 ±0.30^{c}	0.23 ±0.01^{a}	0.25 ±0.14^{a}

Explanations as in Table 1.

polyenes, there is a shift in the position of the double bond due to isomerisation and conjugate bond formation (conjugated dienes) [Zuta et al. 2007]. This is accompanied by increased UV absorption at 234 nm. It is an indicator of autooxidation and is reported to increase with uptake of oxygen and formation of peroxides, during the early stages of oxidation [Farmer 1946]. Low level of striped catfish lipid oxidation is presumably a result of low amounts of PUFA, high amounts of SFA and antioxidant properties of polyphosphates present in meat [Kołakowski 1986, Molins 1991]. The research by Jayasingh and Cornforth [2004] demonstrated that minced pork with the addition of polyphosphates contained less secondary oxidation products after cooking and during storage than the control sample, without the addition of polyphosphates.

It is worth noting that the temperature also affected the observed lipid oxidation level. Although the temperature was often 100°C, and during frying as high as 170--180°C, it was never higher than 77°C in the centre of the mass of the sample. According to Sioen et al. [2006] oxidation products are formed at a temperature of 150°C and in presence of oxygen.

The methods of heat treatment that were applied caused also an overall decrease in the amount of acid value (AV) of between 10 and 20% (Table 4). Higher amount of AV in raw samples than in the same samples after heat treatment can be a result of evaporation of volatile FFA during heating [Bimbo and Crowther 1991, Weber et al. 2008] and deactivation of enzymes during processing, making evaporation of FFA more difficult [Weber et al. 2008].

A decrease in the oxidation level and the amount of free fatty acids was also observed during heating of the following fish: wels catfish [Weber et al. 2008], salmon fillets Al-Saghir et al. [2004], and during heating of tuna heads [Chantachum et al. 2000]. The research by Kołakowska et al. [2001] on herring and sprat also showed that the methods of heat treatment such as conventional boiling, microwave cooking and

frying causes a decrease in both primary and secondary oxidation products. The only observed irregularity involved microwave cooking herring with water that resulted in a 2-3 times increase of AsV. In case of trout, samples exposed to high temperatures (frying, roasting) contained less oxidation products than samples cooked at a temperature of 100°C and those that were microwave cooked and exposed to high temperatures for a shorter period of time. It can be concluded therefore that decomposition of oxidation products outbalances their formation in high temperatures [Kołakowska et al. 2006]. Low amounts of oxidation products and FFA, despite the applied temperature of 180°C during frying (Table 4), is a consequence of a transfer of oil into tissue what contributed to the dilution of oxidation products and FFA. Similar processes were observed by Aro et al. [2000] in fried herring, by Kołakowska et al. [2001] in fried sprat and herring, and by Weber et al. [2008] in fried wels catfish.

As mentioned above, the dependencies observed in this research did not apply to conventional boiling with the addition of salt – this method of heat treatment resulted in more than 16-fold increase in the amount of peroxides and a 4-fold increase in the amount of secondary oxidation products (Table 4). High lipid oxidation level was further confirmed by a nearly 3-fold increase in the content of dienes (Table 4).

This high level of oxidation after boiling can be attributed to the presence of salt, which is a strong oxidizing agent [Yanar et al. 2006, Andersen et al. 2007]. Relatively high oxidation level was the more unexpected given that striped catfish fillets contain low amounts polyunsaturated fatty acids and there were phosphates in the meat, that act as antioxidants even in the presence of NaCl in concentrations between 0.25-2% [Molins 1991]. An increased amount of peroxides after heat treatment of fish with an addition of salt than without it was also observed by Kołakowska et al. [2006] when conventionally boiling trout, and Kong et al. [2008] in the first 10 minutes of heating salmon fillets. High level of lipid oxidation can be, to some extent, a result of the presence of free fatty acids (FFA), whose amount increased nearly 2-fold after conditional boiling with the addition of salt (Table 4). FFA oxidize at a higher rate than fatty acids incorporated into acylglycerol compounds [Guillen and Cabo 1997], therefore the presence of free fatty acids formed during hydrolysis intensifies the process of developing oxidative rancidity [Ziemlański and Budzyńska-Topolowska 1991].

CONCLUSIONS

A 100 g portion of fillet, depending on the applied method of heat treatment delivers between 12 and 23 mg of the EPA + DHA sum, which is as little as 2.5 to 5% of daily the recommended amount for these acids. Taking into account that n-3 PUFA deficiency involves mainly long-chain acids, striped catfish fillets are not a valuable source of these acids, however, due to low fat content and a proper n-6/n-3 PUFA ratio they can be alternative to products such as pork. Moreover, striped catfish lipids, after heat treatment, maintaining low level of oxidation and hydrolysis. When cooking striped catfish fillets in salted water it is worth bearing in mind that their oxidation level will greatly increase.

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WPŁYW OBRÓBEK CIEPLNYCH NA JAKOŚĆ LIPIDÓW PANGI (*PANGASIUS HYPOPHTHALMUS*)

Wstęp. Dzięki stosunkowo niskiej cenie i akceptacji konsumenckiej cały czas rośnie produkcja i sprzedaż filetów z pangi. Ze względu na białe mięso i brak rybiego zapachu mogą one być alternatywą takich ryb, jak dorsz czy morszczuk. W pracy zbadano wpływ czterech obróbek cieplnych (gotowania z dodatkiem i bez dodatku soli, smażenia, goto-

wania mikrofalowego z wodą, gotowania mikrofalowego bez wody) na skład kwasów tłuszczowych oraz poziom utlenienia i hydrolizy lipidów pangi.

Materiał i metody. Badania przeprowadzono na filetach z pangi, kupionych w jednym z lokalnych sklepów. Materiał analizowano około 1 rok przed wygaśnięciem terminu przydatności do spożycia. Jakość lipidów pangi oznaczono za pomocą następujących wskaźników: liczby nadtlenkowej (PV), liczby anizydynowej (AsV), wskaźnika Totox, zawartości dienów (CD), liczby kwasowej (AV) oraz składu kwasów tłuszczowych metodą chromatografii gazowej.

Wyniki. Wykazano, że gotowanie zarówno konwencjonalne, jak i mikrofalowe filetów z pangi nie wpływa istotnie na zmiany w udziale procentowym SFA oraz MUFA. Powoduje natomiast ok. 10% zmian w PUFA, w tym EPA i DHA. Zawartość sumy EPA oraz DHA w 100 g surowych filetów wynosiła 16,5 mg, natomiast po gotowaniu konwencjonalnym, mikrofalowym i smażeniu – odpowiednio ok. 12, 22 i 23 mg. Stwierdzono, że po zastosowaniu gotowania konwencjonalnego następują średnio 10-procentowe straty tłuszczu, czego nie obserwowano podczas ogrzewania mikrofalowego. Mimo istotnego wpływu obróbek cieplnych na zawartość pierwotnych i wtórnych produktów utlenienia, lipidy pangi wykazały się jakością dobrą. W żadnej bowiem z prób liczba nadtlenkowa nie przekroczyła 3 meq O_2/kg, anizydynowa zaś – 1,5. Dodatek soli podczas gotowania wpłynął na 16-krotny wzrost zawartości nadtlenków i czterokrotne zwiększenie zawartości wtórnych produktów utlenienia.

Wnioski. Porcja 100 g filetów z pangi, w zależności od zastosowanej obróbki cieplnej, dostarcza jedynie od 12 do 23 mg sumy EPA + DHA, co stanowi tylko od 2,5 do 5% dziennego zapotrzebowania na wymienione kwasy. Ponieważ niedobory n-3 PUFA dotyczą przede wszystkim kwasów długołańcuchowych, filety z pangi nie są ich cennym źródłem. Ze względu na małą zawartość tłuszczu i odpowiedni stosunek n-6 do n-3 PUFA, panga może być alternatywą na przykład dań z wieprzowiny. Gotując filety w osolonej wodzie, należy się liczyć z gwałtownym wzrostem produktów utlenienia.

Słowa kluczowe: akwakultura, panga, obróbki cieplne, kwasy tłuszczowe, utlenienie lipidów

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