Effect of the Way of Cooking on Contents of Essential Polyunsaturated Fatty Acids in Filets of Zander

Michail I. GLADYSHEV[1,2], Nadezhda N. SUSHCHIK[1,2], Galina A. GUBANENKO[2], Olesia N. MAKHUTOVA[1], Galina S. KALACHOVA[1], Ekaterina A. RECHKINA[2] and Kseniya K. MALYSHEVSKAYA[2]

[1]Institute of Biophysics of Siberian Branch of Russian Academy of Sciences, Akademgorodok, Russia; [2]Siberian Federal University, Krasnoyarsk, Russia

Abstract

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Fatty acid content of raw and cooked zander (*Sander lucioperca*) was studied. Special attention was paid to long-chain polyunsaturated fatty acids: eicosapentaenoic, 20:5 n-3 (EPA) and docosahexaenoic, 22:6 n-3 (DHA), and also to the n-6/n-3 ratio, which are regarded as indicators of nutritive value. As found, the heat treatments, boiling, stewing and frying, including those in a convection steam oven (CSO), did not significantly decrease the content of EPA and DHA in the products. Boiling and stewing appeared to give products of a higher nutritive value, regarding the above indicators, than frying and cake preparation. Frying of zander in CSO was found to be more beneficial for nutrition compared to pan-frying. The cooked zander had higher EPA and DHA contents than many other popular food fish species, and also had a high nutritive value due to the low n-6/n-3 ratio when boiled and stewed.

Keywords: EPA content; DHA content; n-6/n-3 ratio; fish silets; convection steam oven

Long-chain polyunsaturated fatty acids of n-3 family (PUFA), such as eicosapentaenoic acid (20:5 n-3, EPA) and docosahexaenoic acid (22:6 n-3, DHA), are known to be essential for providing the healthy functioning of neural system, retina and cardiovascular system of humans (Plourde & Cunnane 2007). There are international recommendations for personal daily intakes of EPA+DHA to reduce a risk of cardiovascular disease and psychiatric disorders (Kris-Etherton *et al.* 2009).

Fish are known to be the main source of EPA and DHA in human diet (Usydus & Szlinder-Richert 2012). Since fish species differ in EPA and DHA content, they have different nutritional value for humans. Thereby, the study of PUFA content in diverse food fish species from various locations is essential in order to compare the benefits they offer for the consumer health (Usydus *et al*. 2011; Chuang *et al*. 2012).

Consumption of raw fish is unusual in Western societies, and fish products are prepared by heating and other culinary treatments. However, the long-chain PUFA such as EPA and DHA are especially susceptible to oxidation, and an exposure to high temperatures during processing can cause degradation of these fatty acids in foods (Mnari *et al*. 2010; Zotos *et al*. 2013). Nevertheless, another recent evidence indicated that the EPA and DHA levels remained unchanged in some fish species under certain ways of cooking (Gladyshev *et al*. 2006, 2007; Larsen *et al*. 2010). It is important to emphasise that expressing data from different fish species and products for PUFA in terms of mass weight per weight of tissue is needed if recommendations for human consumption

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levels are attempted (Gladyshev *et al*. 2007, 2012; Huynh & Kitts 2009).

Thus, the aim of our work was to study fatty acid content, mass weight per weight of tissue, in particular contents of EPA and DHA, in the muscle tissue (filets) of zander (*Sander lucioperca*), which is a popular food fish species in many European countries. We aimed to evaluate a possible influence of several common and technological ways of cooking on PUFA contents of this fish species.

MATERIAL AND METHODS

Material. Commercially available zander was purchased in frozen state at a local wholesale market in the city of Krasnoyarsk (Siberia, Russia). The fish were caught in the west of Russia (Kaliningrad Region) and were held at the market prior to being sampled at –18°C. All purchased fishes originated from the same bulk supply and kept at the market for 3 months. Cooking treatments were started immediately after purchasing. Three fishes were used in each analysis, i.e. they were sampled under each treatment: control (raw), boiling, stewing, frying, and cake preparation on a stove and in a convection steam oven (CSO). Thereby, 27 samples from 27 fishes were analysed. Muscle tissues (filets) below the dorsal fin were taken as the samples for subsequent cooking and analyses. All skin was removed from the muscle tissue prior to analyses or cooking. The tissues of raw fish were thawed under room temperature during about an hour prior to analyses. The cooked fish were sampled for the subsequent analyses within an hour after the cooking.

Cooking. We used several common ways of cooking with a stove and several technological ways with a convection steam oven, the latter is nowadays widely used in catering in Russia. Boiling was carried out on a stove at a temperature of 85–90°C during 10 min in an excessive volume of water that fully covered the fish, and boiling in a convection steam oven (Rational, Hamburg, Germany) was done at 90°C and 100% moisture during 5 minutes. Stewing (boiling in a small amount of water accounting for 30% of the raw fish weight) was at 85–90°C during 12 min on the stove, and at 90°C and 70% moisture during 4 min in CSO. Pan-frying in sunflower oil (oil weight was 5% of the raw fish weight) on the stove was at 150–170°C during 9 min, while frying in CSO was carried out at 90°C and 10% moisture during 5 min with oiling, approximately 1% of the raw fish weight. Sunflower oil was used because it is the most common cooking oil in Russia. Fish cakes were prepared by mincing of filets without skin and bones. Cakes were pan-fried using 5% oil of the minced filet weight on the stove at 150–170°C during 16 min, and in CSO they were prepared at 95°C and 70% moisture during 7 minutes.

Analyses. Prior to analyses, cooked fish portions of 100–150 g were homogenised and subsamples for moisture and fatty acid measurements were taken from this mass. Subsamples from raw fish were taken by cutting. To measure the moisture content filet parts from the raw and cooked samples of about 10–15 g of wet weight were taken and dried until constant weight at 105°C. The subsamples for lipid analysis were of about 1–2 g of wet weight (ww). Lipid extraction and subsequent preparation of fatty acid methyl esters (FAMEs) were the same as in our previous works (e.g. Kalachova *et al*. 2011). A gas chromatograph equipped with a mass spectrometer detector (model 6890/5975C; Agilent Technologies, Santa Clara, USA) and with a 30 m long, 0.25 mm internal diameter capillary column HP-FFAP was used. The instrument conditions were as follows: helium as a carrier gas with flow rate of 1 ml/min; injector temperature 220°C; column temperature programming from 100°C to 180°C at a rate of 5°C/min with 10 min of isothermal regime, then the next step from 180°C to 220°C at a rate of 5°C/min with 30 min of isothermal regime; interface and ion source temperatures 230°C; quadrupole temperature 150°C; electron impact at 70 eV; scanning the ion fragments from 50 to 500 atomic units at 0.6 s/scan. Data were collected and analysed using the GC ChemStation program (Agilent Technologies, Santa Clara, USA) as described in Gladyshev *et al.* (2012). The FAMEs were quantified according to the peak area of the internal standard, nonadecanoic acid, the solutions of which were added to samples prior to the lipid extraction.

Statistical analysis. One-linkage cluster analysis was carried out conventionally, using Euclidean distances. Prominent fatty acid contents, mg/g of wet weight, were used as the axes of multidimensional hyperspace. The cluster analysis, standard error (SE) and Fisher's *LSD post-hoc* test were calculated conventionally, using STATISTICA software, Version 9.0 (StatSoft Inc., Tulsa, USA).

RESULTS AND DISCUSSION

The average moisture content varied in all fish samples from about 63.8% in fried zander to 79.7%

Table 1. Moisture content (%) in raw and cooked fish: mean values from three samples ± SE (standard error)

Treatment	Moisture (%)
Raw	79.7 ± 0.4^{A}
Boiled	79.4 ± 0.8^{A}
Boiled in CSO	78.8 ± 0.6^{A}
Stewed	75.6 ± 0.8^{B}
Stewed in CSO	79.1 ± 0.0^{A}
Fried	63.8 ± 1.0^{C}
Fried in CSO	75.7 ± 0.6^{B}
Cake	69.6 ± 1.2^{D}
Cake in CSO	71.4 ± 0.5^{D}

CSO – convection steam oven; means labelled with the same letter are not significantly different at $P < 0.05$ according to Fisher's *LSD post-hoc* test

in raw fish (Table 1). Besides the fried product, fish cakes also had comparatively low values of moisture, while the values of the other products were close to that of the raw fish (Table 1). The moisture loss during frying in vegetable oils, like in our present study, was reported for some other fish species (Gladyshev *et al.* 2006, 2007; Mnari *et al.* 2010; Zhang *et al.* 2013; Zotos *et al.* 2013).

In all samples 106 fatty acids (FA) were identified. Quantitatively prominent FAs are given in Table 2.

Cluster analysis revealed two large clusters, separated due to differences in FA contents: the

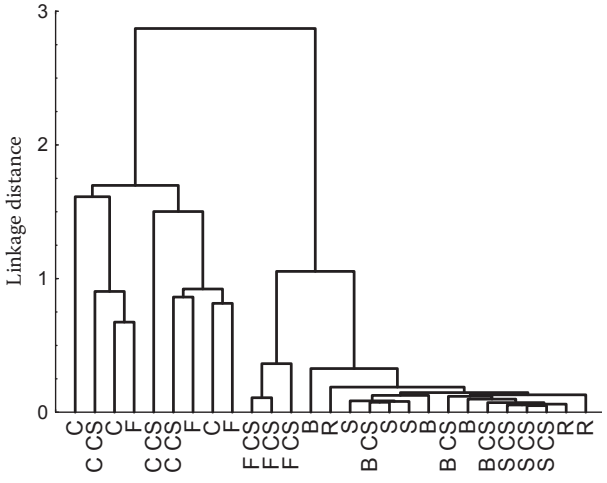

Figure 1. Dendrogram of the cluster analysis of the contents (mg/g of wet weight) of 24 prominent fatty acids (see Table 2) in fish products

R – raw; B – boiled; B CS – boiled in convection steam oven; F – fried; F CS – fried in convection steam oven; S – stewed; S CS – stewed in convection steam oven; C – cakes; C CS – cakes prepared in convection steam oven; the ordinate axis represents Euclidean distances in 24-dimension hyperspace

Table 2. Prominent fatty acid (FA) content in zander after different ways of cooking: mean values (mg/g of wet weight) from nine samples ± SE (standard error)

FA	Raw	Boiled	Boiled in CSO	Stewed	Stewed in CSO	Fried	Fried in CSO	Cake	Cake in CSO
16:0	0.49 ± 0.04^{A}	0.65 ± 0.07^{A}	0.64 ± 0.02^{A}	0.68 ± 0.01^{A}	0.55 ± 0.01^{A}	1.42 ± 0.12^{B}	0.61 ± 0.04^{A}	1.76 ± 0.17^{BC}	1.89 ± 0.36^{C}
18:0	0.21 ± 0.02^{A}	0.29 ± 0.02^{A}	0.27 ± 0.01^{A}	0.31 ± 0.00^{A}	0.23 ± 0.00^{A}	0.75 ± 0.06^{B}	0.29 ± 0.02^{A}	0.78 ± 0.13^{B}	0.68 ± 0.12^{B}
18:1 n-9	0.22 ± 0.03^{A}	0.29 ± 0.03^{A}	0.30 ± 0.03^{A}	0.30 ± 0.02^{A}	0.25 ± 0.01^{A}	2.41 ± 0.27^{B}	0.58 ± 0.04^{A}	3.06 ± 0.42^{B}	2.64 ± 0.53^{B}
18:2 n-6	0.03 ± 0.00^{A}	0.07 ± 0.01^{A}	0.04 ± 0.00^{A}	0.04 ± 0.00^{A}	0.04 ± 0.01^{A}	6.25 ± 0.78^{B}	1.14 ± 0.03^{A}	7.23 ± 1.10^{B}	5.64 ± 1.10^{B}
18:3 n-3	0.01 ± 0.00^{A}	0.01 ± 0.00^{A}	0.01 ± 0.00^{A}	0.01 ± 0.00^{A}	0.01 ± 0.00^{A}	0.03 ± 0.00^{B}	0.01 ± 0.00^{A}	0.06 ± 0.00^{C}	0.06 ± 0.01^{C}
20:4 n-6	0.23 ± 0.02^{AD}	0.31 ± 0.03^{BC}	0.26 ± 0.02^{AB}	0.28 ± 0.01^{AC}	0.23 ± 0.01^{AD}	0.33 ± 0.02^{C}	0.19 ± 0.02^{DE}	0.17 ± 0.01^{D}	0.23 ± 0.04^{AE}
20:5 n-3	0.12 ± 0.01^{AC}	0.17 ± 0.02^{B}	0.14 ± 0.01^{ABC}	0.14 ± 0.01^{AB}	0.12 ± 0.01^{ACD}	0.17 ± 0.02^{B}	0.09 ± 0.01^{CD}	0.09 ± 0.00^{D}	0.14 ± 0.03^{AB}
22:4 n-6	0.01 ± 0.00^{AB}	0.01 ± 0.00^{AB}	0.02 ± 0.01^{A}	0.02 ± 0.00^{AC}	0.00 ± 0.00^{B}	0.02 ± 0.00^{AC}	0.01 ± 0.00^{BC}	0.01 ± 0.00^{BC}	0.01 ± 0.00^{AC}
22:5 n-6	0.09 ± 0.01^{ABC}	0.12 ± 0.01^{A}	0.07 ± 0.03^{CD}	0.10 ± 0.01^{ABC}	0.09 ± 0.00^{AC}	0.12 ± 0.01^{A}	0.08 ± 0.01^{BC}	0.06 ± 0.00^{C}	0.09 ± 0.02^{ABD}
22:6 n-3	0.75 ± 0.07^{ACD}	1.03 ± 0.12^{B}	0.78 ± 0.07^{ACD}	0.92 ± 0.03^{AB}	0.74 ± 0.01^{ACD}	1.05 ± 0.03^{B}	0.63 ± 0.10^{CD}	0.56 ± 0.04^{D}	0.82 ± 0.15^{BC}
Total FA	2.64 ± 0.22^{A}	3.68 ± 0.33^{A}	3.15 ± 0.17^{A}	3.42 ± 0.03^{A}	2.81 ± 0.06^{A}	13.58 ± 1.19^{B}	4.17 ± 0.04^{A}	14.75 ± 1.97^{B}	13.17 ± 2.44^{B}
n-6/n-3	0.40 ± 0.01^{A}	0.42 ± 0.03^{A}	0.42 ± 0.00^{A}	0.41 ± 0.02^{A}	0.40 ± 0.00^{A}	5.20 ± 0.78^{B}	1.94 ± 0.31^{C}	9.85 ± 0.93^{D}	5.72 ± 0.76^{B}

CSO – convection steam oven; means labelled with the same letter are not significantly different at $P < 0.05$ according to Fisher's *LSD post-hoc* test

first cluster included fried products and fish cakes, and the other samples joined in the second cluster (Figure 1). The separation was evidently caused first of all by significantly higher average contents of oleic acid (OA, 18:1 n-9) and linoleic acid (LA, 18:2 n-6) in the fried fish and cakes compared to those in the other products and in the raw fish (Table 2).

According to the above differences in 18:2 n-6 contents, the n-6/n-3 ratio had nearly similar low values in raw, boiled and stewed fish, 0.40–0.42, while the products fried in CSO had an intermediate value, 1.94, and fried products and fish cakes had higher values, 5.20–9.85 (Table 2). As known, the n-6/n-3 ratio is an important indicator of nutritive quality. Healthy values of this ratio for human diet are believed not to be higher than 3, while the current Western diet has n-6/n-3 from 10 to 25 (Wall *et al.* 2010). Zander from Swedish lakes had the n-6/n-3 ratio of about 0.53 (Ahlgren *et al.* 1994), and in Turkish lakes this ratio in filets of zander varied from 0.26 to 1.39 (Celik *et al.* 2006; Guler *et al*. 2011), thereby on average it was close to that of the raw zander studied in our work (Table 2). Boiling and stewing did not evidently affect this ratio, while in the fried zander and in the fish cakes the n-6/n-3 value increased dramatically, more than 10 and 20 times, respectively, compared to that of the raw fish (Table 2). A similar increase of the n-6/n-3 ratio during frying in vegetable oils was reported for many other fish species (Gladyshev *et al.* 2006, 2007; Ansorena *et al.* 2010; Mnari *et al.* 2010; Zhang *et al.* 2013). The mechanism for the changes is the absorption of cooking oil that is rich in 18:2 n-6 (Mnari *et al.* 2010; Maulvault *et al.* 2012; Zotos *et al*. 2013). It is important to note that frying in the convection steam oven, which needs a lower quantity of cooking oil, gave a significantly lower n-6/n-3 ratio than the pan-frying (Table 2). Thus, frying of zander in CSO appeared to be more beneficial for the nutritive value of fish concerning the n-6/n-3 ratio, compared to the pan-frying. In general, boiling and stewing appeared to be healthier ways of culinary treatment of the zander than frying and cake preparation, since they provided the n-6/n-3 ratio lower than 1 in the fish products.

Sum contents of the two physiologically important PUFAs, 20:5 n-3 (EPA) and 22:6 n-3 (DHA), are depicted in Figure 2. Boiled and fried fish had significantly higher average values of EPA+DHA than raw fish and fish boiled in CSO, stewed in CSO, fried in CSO and fish cakes (Figure 2). Products fried in CSO and fish cakes had significantly lower EPA+DHA contents compared to those in raw fish, boiled, stewed and fried products (Figure 2).

In contrast to the general tendency of absence of a statistically significant decrease in EPA and DHA content between the raw and cooked zander, there were significant differences between the fish products prepared by some ways of cooking. For instance, boiled and fried zander had significantly higher EPA+DHA contents than those boiled in SCO, stewed in SCO, fried in SCO and cakes (Figure 2). Moreover, boiled and fried zander had a significantly higher PUFA content than the raw fish. This increase in EPA and DHA content in the fried zander was evidently caused by the moisture loss of around 15% (Table 1). It should be noted that boiling, stewing, and frying in the convection steam oven gave lower EPA and DHA content in the fish products than the same culinary treatments in a traditional way, while cakes, prepared in CSO, had a significantly higher content of these PUFA compared to pan-fried cakes (Figure 2).

Raw zander had an average content of EPA+DHA, 0.86 mg/g ww (Figure 2), which was higher than that of many wild freshwater species, such as redbelly tilapia, Nile tilapia, Nile perch, sharptooth catfish, marbled lungfish (Kwetegyeka *et al.* 2008), and even higher than the content in some marine species, e.g. shad, mullet, brown meager, bonito, whiting (Chuang *et al.* 2012), European sole, cod (Usydus & Szlinder-Richert 2012) and in some farmed species, tilapia and sutchi catfish (Usydus *et al.* 2011).

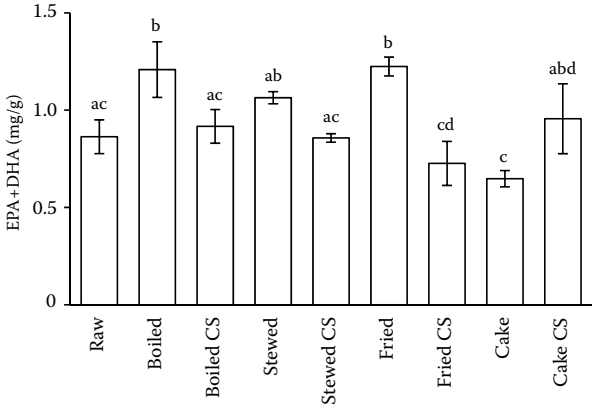

Figure 2. Sum of eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acid contents in raw and cooked fish: mean values (mg/g of wet weight) from 3 samples

Bars represent standard errors; means labelled with the same letter are not significantly different at $P < 0.05$ according to Fisher's *LSD post-hoc* test; fish products: R – raw, B – boiled, B CS – boiled in convection steam oven, F – fried, F CS – fried in convection steam oven, S – stewed, S CS – stewed in convection steam oven, C – cakes, C CS – cakes, prepared in convection steam oven

However, zander evidently is a lean fish. EPA+DHA content in cooked zander was significantly lower than that in many products, prepared from other fish species, such as salmon (Gladyshev *et al.* 2006; Ansorena *et al.* 2010; Larsen *et al.* 2010;), cod (Gladyshev *et al.* 2007), black scabbard (Maulvault *et al.* 2012), trout, herring and rock sole (Gladyshev *et al.* 2007), mackerel, sardine and tuna (Usydus & Szlinder-Richert 2012). Nevertheless, the EPA+DHA content of the fried zander, 1.22 mg/g ww (Figure 2), was significantly higher than that of the fried wild gilthead sea bream (Mnari *et al.* 2010) and cod (Ansorena *et al*. 2010).

CONCLUSIONS

Although zander is the lean fish species, it had a higher EPA+DHA content than many other popular fish species, including tilapia, shad, mullet, and cod. Heat treatments did not decrease significantly the content of EPA and DHA in zander. Boiling and stewing did not change the n-6/n-3 ratio compared to raw fish. However, pan-frying in sunflower oil and cake preparation increased the n-6/n-3 ratio more than 10 and 20 times, respectively. Since the use of the convection steam oven for frying gave a significantly lower n-6/n-3 ratio compared to the pan-frying, this type of fish product, prepared in CSO, appeared to have higher nutritive quality.

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Corresponding author:

Prof Michail I. Gladyshev, Institute of Biophysics of Siberian Branch of Russian Academy of Sciences, Akademgorodok, Krasnoyarsk 660036, Russia; E-mail: glad@ibp.ru