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Short communication

Fatty acid composition in tissues of the farmed Siberian sturgeon (*Acipenser baerii*)

Petteri Nieminen[a,b,*], Eini Westenius[a], Toivo Halonen[c], Anne-Mari Mustonen[a,b]

[a] *University of Eastern Finland, Faculty of Health Sciences, School of Medicine, Institute of Biomedicine/Anatomy, P.O. Box 1627, FI-70211 Kuopio, Finland*
[b] *University of Eastern Finland, Faculty of Science and Forestry, Department of Biology, P.O. Box 111, FI-80101 Joensuu, Finland*
[c] *Eastern Finland Laboratory Centre Joint Authority Enterprise (ISLAB), P.O. Box 1700, FI-70211 Kuopio, Finland*

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ABSTRACT

The fatty acid (FA) compositions of the diet and diverse tissues of the farmed Siberian sturgeon (*Acipenser baerii*) were analyzed in detail to assess their nutritional quality. Twelve male fish were sampled for muscle, fat, liver, brain, gill, kidney and gonad and the tissue FA measured by gas–liquid chromatography. The FA profile of the diet diverged from the FA signatures of the tissues, where the sturgeons accumulated particular highly-unsaturated FA (HUFA). They were probably derived from the diet but, as previous studies have shown that fish can also have desaturase enzymes, endogenous synthesis of these FA cannot be excluded. The sturgeon muscle tissue contained HUFA in proportions comparable to those of other fish species that are considered good sources of n-3 polyunsaturated FA. The indices of atherogenicity and thrombogenicity were also within the values considered to be health-promoting.

1. Introduction

Fish is considered an excellent source of long-chain n-3 polyunsaturated fatty acids (PUFA) (Mozaffarian & Wu, 2012). They have been rigorously investigated due to their potential benefits in health promotion and in the prevention of cardiovascular diseases. The most effective PUFA in this respect seem to be the highly-unsaturated fatty acids (HUFA) 20:5n-3 and 22:6n-3. The possible beneficial effects of n-3 PUFA include decreased circulating triacylglycerol concentrations and reductions in the occurrence of cardiac arrhythmias. A decrease in the tissue proportions of n-3 PUFA or in the n-3/n-6 PUFA ratio can predispose the body to a pro-inflammatory state and, e.g., non-alcoholic fatty liver disease associated with obesity (Anstee, Targher, & Day, 2013; El-Badry, Graf, & Clavien, 2007).

Generally, the proportions of different fatty acids (FA) and the most beneficial PUFA vary considerably between different fish species, depending on the diet (Ackman, 2008). For example, the wt% of particular FA of interest in some Mediterranean marine fish varied as follows: 18:1 10.3–32.4%, 18:2n-6 1.0–3.3%, 18:3n-3 0.2–0.8%, 20:5n-3 4.9–16.5% and 22:6n-3 1.9–31.0%. The values for freshwater fish derived from approximately the same geographical area were as follows: 18:1 14.2–32.6%, 18:2n-6 1.4–14.3%, 18:3n-3 0.06–0.62%, 20:5n-3 2.0–11.3% and 22:6n-3 2.1–18.6%. Thus, the FA signatures cannot be deduced by extrapolating from existing data on the FA compositions of fish in a known habitat, but they have to be determined, one at a time, to gain information on the potential health benefits of a fish species marketed for human consumption. The muscle FA compositions in some sturgeon species and hybrids (*Acipenser baerii*, *A. naccarii*, *A. transmontanus*, *Huso huso*, *A. naccarii* × *A. baerii*) were investigated previously and the percentages of FA of principal interest were highly variable as follows: 18:1n-9 18.6–34.6%, 18:2n-6 2.6–26.8%, 18:3n-3 0.6–7.9%, 20:5n-3 3.9–9.4% and 22:6n-3 5.4–15.0% (Badiani, Stipa, Nanni, Gatta, & Manfredini, 1997; Hosseini et al., 2010; Vaccaro, Buffa, Messina, Santulli, & Mazzola, 2005).

The Siberian sturgeon (*A. baerii*) is a freshwater fish inhabiting large Siberian rivers, such as the Ob, Yenisei, Lena and Kolyma, of which the Ob River is the most important (Ruban & Zhu, 2010). According to the International Union for Conservation of Nature, the Siberian sturgeon is endangered because the species matures late, the intervals between spawns are long and the productivity of northern water ecosystems is generally low. Other risk factors for wild Siberian sturgeons include overfishing, poaching, damming and pollution of water caused by the mining industry. In nature, Siberian sturgeons do not reach puberty until 9–22 years of age; females mature later than males. To preserve natural resources and threatened species, fish farming allows the

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* Corresponding author at: University of Eastern Finland, Faculty of Health Sciences, School of Medicine, Institute of Biomedicine/Anatomy, P.O. Box 1627, FI-70211 Kuopio, Finland. Tel.: +358 207 872211.

E-mail address: petteri.nieminen@uef.fi (P. Nieminen).

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protection of natural populations of species that are, however, in demand by customers. While sturgeon meat and especially caviar can be considered luxury food items, their nutritional value is of importance as sturgeon farming is increasing at the moment. In fact, the Siberian sturgeon is farmed actively in, e.g., Russia, China, France, Poland, Germany, Italy and some other countries to be marketed to the general population (Williot et al., 2005).

It can be hypothesized that, like other fish species, the Siberian sturgeon would contain relatively high proportions of potentially beneficial FA, especially HUFA. It is important to assess the FA composition of each farmed fish species due to the great variations in FA composition caused by differences in diet. The aims of this study were, thus, (i) to assess the FA composition of various tissues of farmed Siberian sturgeon and (ii) to investigate how the FA profile of the diet is reflected in the FA profiles of fish tissues.

2. Materials and methods

The Siberian sturgeons sampled for this study were reared at Carelian Caviar, Huutokoski, Finland (62.20304785N, 27.72615320E). The fish were male sturgeons [$n = 12$; hatched in April 2006; body mass 2.53 ± 0.12 (1.99–3.51) kg, body length 67.5 ± 1.1 (61.5–75.0) cm] kept initially at closed water cycle plants and transferred into outside pools (100 m^3, 40–60 kg fish/m^3) in June 2009. The fish were fed with commercial diets (0.5%/biomass/day; Ecolife 15 until August 2009; Ecogen 15 No. 9 until sampling; BioMar SAS, Nersac, France). Before sampling on October 12, 2009, the sturgeons were fasted for 9 days. They were stunned with a blow on the head and killed by exsanguination. The tissues that were sampled were as follows: ventral muscle, ventral fat, liver, kidney, gonad, brain and gills. The samples were taken (into Eppendorf tubes) and snap-frozen in liquid nitrogen.

The FA were analyzed from total lipids. Subsamples of different tissues and representative diet samples (Ecogen 15 No. 9, as it was the diet the fish received for approximately 8 weeks until sampling) were transmethylated according to Christie (1993) by heating with 1% H_2SO_4 in methanol under nitrogen atmosphere. The FA methyl esters were extracted with hexane and analyzed by the Agilent 6850 gas–liquid chromatograph (Agilent Technologies, Santa Clara, CA, USA), using previously established methods (Mustonen et al., 2012). The peak areas of the chromatograms were converted to mol% by using the theoretical response factors (Ackman, 1992). The FA were marked by using the abbreviations: [carbon number]:[number of double bonds]:n-[position of the first double bond calculated from the methyl end]. Fractionation coefficients (FC) were calculated by dividing the mol% of a FA in a tissue by the corresponding value in the diet. The indices of atherogenicity (IA) and thrombogenicity (IT)—measures of lipid quality for human health and cardiovascular disease prevention—were calculated according to Ulbricht and Southgate (1991).

The FA values of the different tissues were compared by the Kruskal–Wallis analysis of variance (ANOVA) and the Dunn's *post hoc* test (SigmaPlot *v*.11.0, Systat Software, Chicago, IL, USA). The data were also subjected to a multivariate principal component analysis (PCA) to describe the general relationships of the FA compositions in different tissues by using the Sirius *v*.6.5 software package (Pattern Recognition Systems AS, Bergen, Norway) (Kvalheim & Karstang, 1987). A P value less than 0.05 was considered to be statistically significant. The results are presented as means ± SE.

3. Results

The most abundant FA in the diet were as follows: 16:0, 20:5n-3, 18:1n-9, 16:1n-7, 14:0, 22:6n-3, 18:2n-6, 18:0 and 18:1n-7 (Table 1). In the tissues, 18:1n-9 dominated (except in brain and kidney with 16:0 as the most abundant FA), followed by 16:0, 22:6n-3, 18:2n-6, 20:5n-3, 16:1n-7, 18:0, 18:1n-7 and 14:0. According to the PCA (Fig. 1), the diet diverged from the studied tissues and also the FA compositions of liver and brain were distinctive. The FA profiles of kidney and gills were relatively similar, while muscle, fat and gonad resembled one another. The FA that classified the tissues most clearly included 22:6n-3, 20:5n-3, 18:0 and 18:1n-9. The most abundant n-6 PUFA was 18:2n-6 with the highest proportions in fat $\geqslant$ gonad $\geqslant$ muscle $\geqslant$ liver $\geqslant$ kidney $\geqslant$ gill $\geqslant$ brain. The highest n-3 PUFA sums were observed in kidney (almost one third of total FA) and gills and the lowest (11.1 mol%) in liver. All tissues had n-3/n-6 PUFA ratios >1, the highest being in brain tissue. The average IA varied from 0.28 to 0.55 (0.46 ± 0.01), the lowest being in gills, brain and kidney, and the values of IT were between 0.25 and 0.37 (0.30 ± 0.01) with the lowest values in kidney, gills and muscle.

Regarding the FC, saturated FA (SFA) were mostly present in higher proportions in the diet than in the tissues, with some exceptions (Suppl. 1). In the case of monounsaturated FA, all tissues accumulated 18:1n-9 and 16:1n-9 in excess of that in the diet. The FC values of the essential FA (EFA) varied as follows: the proportions of 18:2n-6 were higher in liver, muscle, gonad and fat tissue than in the diet, while the percentages of 18:3n-3 were higher in gonad, fat and muscle. Regarding the n-6 PUFA derivatives, 20:4n-6 accumulated in brain, kidney, gills and gonad. For the n-3 PUFA derivatives, the percentages of 20:5n-3 were lower in all tissues than in the diet, but brain, gills, kidney and muscle had elevated proportions of 22:6n-3 compared to the dietary values.

4. Discussion

Although the precise benefits of consuming a diet rich in long-chain n-3 PUFA remain controversial, there is quite a widespread consensus that they can be useful in the prevention of deaths related to cardiovascular diseases (Ackman, 2008). The FA composition of fish varies greatly according to their diet but, generally, fish are considered a good source of n-3 PUFA. It was suggested that it is too simplistic to compare only the SFA and PUFA proportions of food items to assess their health benefits. Thus, the IA and IT developed by Ulbricht and Southgate (1991) can be used to compare the FA profile of the Siberian sturgeon to those of other fish species and sources of dietary fat. From the viewpoint of health benefits, the muscle of the Siberian sturgeon proved to be comparable to other good sources of n-3 PUFA, confirming our hypothesis. Also, the sturgeon tissues showed significant differences in their FA compositions. While a few reports, such as by Xu, Hung, and German (1993), have assessed the FA profiles of sturgeon feeds and selected tissue types, this is, to our knowledge the first study describing the detailed FA composition of several tissues in relation to the diet.

Compared to previously studied sturgeon species, the proportions of the dietarily significant FA were mostly within the range of values that had been determined earlier (Badiani et al., 1997; Hosseini et al., 2010; Vaccaro et al., 2005). Thus, the general FA profile of the Siberian sturgeon was quite as expected and the muscle proportions of important HUFA, 20:5n-3 (6.8% in the present study) and 22:6n-3 (8.0%), were at a similar level or slightly lower but comparable to those of previously studied sturgeons (*ibid.*). As the FA profiles of fish show large variations (Ackman, 2008), it is still important to test new, actively-farmed species to assess their usefulness for human nutrition. In this respect, the Siberian sturgeon does not seem to be inferior to its relatives. Also the IA and IT were clearly <1. With IA, the values (average for the Siberian sturgeon = 0.46) were comparable to those for PUFA-enriched