Fatty acid composition of *Acipenseridae* – sturgeon fish

M Pelic¹, S Vidakovic Knezevic¹, M Zivkov Balos¹, N Popov¹, N Novakov², M Cirkovic¹ and D Ljubojevic Pelic¹

¹ Scientific Veterinary Institute Novi Sad, Rumenački put 20, 21000 Novi Sad, Serbia
² Faculty of Agriculture, University of Novi Sad 8, Trg Dositeja Obradovića, 21000 Novi Sad, Serbia

E-mail: dragana@niv.ns.ac.rs

Abstract. Fish meat is considered to have a beneficial nutritional composition and a favorable effect on human health. Fish meat is a significant source of highly unsaturated fatty acids with beneficial effects on health of consumers. Therefore, knowledge of the fat, protein and especially quality of lipids in fish is very important. The objective of this summary is to synthesize data on the fatty acid composition of different sturgeon species, the meats of which could become more common in Serbia. Sturgeon, due to their favorable sensory properties, are of increasing interest to consumers. These fish are also interesting to fish farms because they are relatively easy to breed, grow fast, and are relatively resistant to diseases. Quality parameters of sturgeon meat are not well studied and there are few data to date.

1. Introduction

Siberian sturgeon and other sturgeon species are food fish of commercial significance in many countries. Recently, it has been recognized that sturgeon farming seems promising due to the fish’s excellent meat quality and relatively high market prices. Sturgeon are increasingly consumed and their meat is well accepted by consumers due to their sensory properties, high concentrations of unsaturated fatty acids and other nutritional properties. Consumption of sturgeon meat has increased recently. According to Gisbert and Williot [1] sturgeon are suitable for aquaculture due to the fish’s relatively good acceptance of formulated feed, rapid growth rate and adaptation to rearing systems. The quality of reared fish is influenced by several factors including nutrition, genetics, water quality, environmental conditions, health conditions, and management practices on the fish farm. The new technologies of sturgeon breeding are mainly based on intensive culture systems and have enabled increased amounts of sturgeon meat to be released on the EU and international markets in recent decades [2].

Sturgeon meat is appreciated by consumers due to its sensory properties and nutritive value. The meat has high contents of highly unsaturated fatty acids (HUFA), which could play an important role in protection of humans from cardiovascular diseases. Essential polyunsaturated fatty acids (PUFA) are not synthesized in the human body but are efficiently synthesized by some aquatic organisms; therefore, a good source of essential PUFA is marine and freshwater fish [3,4]. Docosahexanoic acid (DHA) and eicosapentaenoic acid (EPA) have a positive effects in preventing hypertension and cardiovascular diseases and also have beneficial effects by improving the immunological system [5]. The fatty acid composition of the lipids in sturgeon meat has been relatively little studied in comparison with other fish species. However, knowledge of the fatty acid composition of sturgeon meat is required...
to properly assess the value of these fish. The objective of this summary was to synthesize data on the fatty acid composition of sturgeon meat, and compare the content of fatty acids in the meat of different sturgeon species, some of which could become more common in Serbia.

2. The effect of sturgeon species on chemical composition and fatty acid profile

Sturgeon is a common name of 27 species of fish belonging to the family Acipenseridae. The chemical and fatty acid composition of muscle tissue in some sturgeon species and hybrids (Russian sturgeon (Acipenser gueldenstaedtii), Siberian sturgeon (Acipenser baerii), hybrid (Acipenser baerii Br × Acipenser medirostris Ayres) [6-8] have been examined so far. The chemical composition (Table 1) and percentages of fatty acids (Table 2) were highly variable among the different sturgeon species but also within the same species [9].

Table 1 shows the varied contents of lipids and water in all studies. A negative correlation between lipid and water contents in sturgeon meat was observed in all studies, which is in agreement with the results obtained for other fish species [10]. The lipid content in the meat of different cultured sturgeon species varied, and reported percentages ranged from 5 to 15% [11].

The water content of wild sterlet examined by Ljubojević et al. [10] was slightly lower (75.38 g/100g vs 77.5-77.2), protein content was higher (17.54 g/100g vs 13.1-13.8), and lipid content was within the same range 4.8-6.1 g/100 g as was reported [12] for cultured sterlet. Significant differences in the content of ash in examined sturgeon meats (Table 1) could be due to the presence of small bones in fish fillets. Namely, the calcium, released during bone demineralization, can contribute to a greater mass fraction of ash in the total chemical composition of fish meat. Sturgeon are carnivores and require a high protein feed for optimal health.

| Proximate composition | Stellate sturgeon (Acipenser ruthenus) | Beluga sturgeon | Sterlet (Acipenser ruthenus) | Russian sturgeon (Acipenser gueldenstaedtii, Siberian sturgeon (Acipenser baerii), hybrid (Acipenser baerii Br × Acipenser medirostris Ayres) | Hybrid (SSZ) Siberian sturgeon × (Siberian sturgeon × green sturgeon) – Acipenser baerii Br × (Acipenser baeri × Acipenser medirostris Ayres) |
|-----------------------|--------------------------------------|----------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Fish weight g         | 652.5                                | 201.5          | 1320 g                   | 27.23±0.98 g                                                                                                                    | 1 527± 158                                                                                                                    |
| Moisture %            | 77.8                                 | 83.0           | 75.38±0.35               | 78.24±0.05                                                                                                                      | 73.52±0.55                                                                                                                    |
| Proteins %            | 16.7                                 | 14.9           | 17.54±0.23               | 10.71±0.04                                                                                                                      | 16.51±0.38                                                                                                                    |
| Fat %                 | 3.9                                  | 1.1            | 5.39±0.14                | 6.05±0.07                                                                                                                      | 8.9±0.5                                                                                                                        |
| Ash%                  | 1.6                                  | 1.0            | 0.93±0.09                | 2.36±0.02                                                                                                                      | 0.98±0.05                                                                                                                     |
| Cholesterol content, mg/100g |                         |                |                          | 73.59±0.11a                                                                                                                   | 73.59±0.11a                                                                                                                   |

Reference

Paltenea et al. [14] Jankowska et al. [8] Ljubojević Sener et al. [6] Jankowska et al. [8]

Table 2. Fatty acid profiles of different sturgeon species

| Fatty acids | Wild Stelet sterlet (Acipenser ruthenus) | The farmed Siberian sturgeon (Acipenser baerii) | Reciprocal hybrid (SSZ) Siberian sturgeon × (Siberian sturgeon × green sturgeon) – Acipenser baerii Br × (Acipenser baeri × Acipenser medirostris Ayres) | Russian sturgeon (Acipenser gueldenstaedtii) |
|-------------|------------------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|

2
| C14:0 | 3.31±0.27b | 4.08±0.187 | 4.47±0.36 | 4.14±0.1 |
|-------|------------|------------|------------|------------|
| C15:0 | 0.66±0.05ab |            |            |            |
| C16:0 | 25.09±0.14b | 19.2±0.271 | 19.79±1.92 |            |
| C16:1 | 13.27±0.12 | 0.352±0.012 | 8.18±0.68 |            |
|       |            |            | 6.24±0.121 |            |
| C17:0 | 1.09±0.14  |            |            |            |
| C18:0 | 2.38±0.12e | 1.91±0.104 | 1.91±0.15  | 2.68±0.1  |
| C18:1 cis-9 | 24.87±0.15 | 25.1±0.47 | 27.77±1.48 | 21.57±0.5 |
| C18:1 cis-11 | 7.05±0.16  |            | 2.80±0.14  |            |
| C18:2, n6 | 2.8±0.19  | 7.59±0.301 |            | 11.24±0.3 |
| C18:3, n6 | 0.69±0.51 | 0.410±0.013 | 5.63±0.19 | 0.29±0.1  |
| C18:3, n3 | 4.34±0.1 | 1.49±0.059 | 1.22±0.88  | 1.48±0.2  |
| C20:0 | 0.1±0.04   |            | 0.13±0.1   |            |
| C20:1 | 0.77±0.11  | 1.50±0.063 | 3.97±0.25  | 1.60±0.2  |
| C20:2 | 0.47±0.07  | 0.421±0.013 |            |            |
| C20:3, n6 | 0.2±0.11 |            |            |            |
| C20:3, n3 | 0.55±0.05 |            | 0.24±0.1  |            |
| C20:4, n6 | 1.54±0.08 | 0.898±0.050 | 0.63±0.07 | 0.86±0.1  |
| C20:5, n3 | 4.93±0.09 | 6.83±0.129 | 5.46±0.38  | 6.43±0.3  |
| C22:5, n3 | 2.86±0.04 | 1.84±0.024 | 1.45±0.07  |            |
| C22:6, n3 | 3.79±0.09 | 7.95±0.343 b, 9.34±0.72 | 11.06±0.9 |
| SFA    | 32.67±0.34 | 27.0±0.226 a, | 26.71±1.92 |            |
| MUFA   | 45.97±0.15 | 39.9±0.459 | 46.21±1.27 | 23.29±0.8 |
| PUFA   | 22.17±0.37 | 32.9±0.382 | 27.08±1.68 |            |
| n-3    | 16.47±0.05 | 20.2±0.354 b,c | 19.58±0.68 | 19.21±0.8 |
| n-6    | 5.74±0.36 | 9.99±0.263 | 6.59±0.12  | 12.39±0.4 |
| N3/n6  | 2.9±0.19a | 2.04±0.076 b, 2.97±0.11 |            |            |
| N6/n3  | 0.35±0.02 |            |            |            |
| PUFA/SFA | 0.68±0.01 |            |            |            |
| USFA/SFA | 2.09±0.03 | 2.70±0.031 |            |            |

Reference: Ljubojevic et al. [10] Nieminen et al. [7] Jankowska et al. [8] Sener et al. [6]

Data are means±S.E.M. (n = 8). Different superscripts within the same rows differ (P < 0.01). USFA – unsaturated fatty acids, SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids.

3. The effect of nutrition on chemical composition and fatty acid profile of sturgeon

Bieniarz et al. [13] found freshwater carnivorous fish can be characterized by higher n-3/n-6 fatty acid ratios than phytophagous and benthophagous fish. The fatty acid composition of muscle lipids in fish is greatly influenced by dietary fatty acids, and linear correlations exist between individual fatty acids in muscle tissue, total lipids and their concentrations in dietary lipid. Nieminen et al. [7] reported the fatty acid profile of the diet diverged from the fatty acid profile of the tissues, where the sturgeons accumulated particular HUFA. According to Sener et al. [6], whole body lipid contents in juvenile Russian sturgeon (*Acipenser gueldenstaedtii*) fed on feeds including fish oil, soybean oil and sunflower oil were 4.65%, 4.73% and 5.19%, respectively. The total n-3 and n-6 fatty acids (in the total fatty acid content) of the fish differed significantly, as the percentage of total n-6 fatty acids was higher (22.58% and 22.98%) in fish fed vegetable oils than in the fish oil group (11.39%), while the percentage of n-3 fatty acids was higher (21.57%) in the group fed fish oil than that in the vegetable oil groups (13.15% and 15.00%). The content of DHA was higher in fish fed a diet containing soybean and sunflower oil, and similar findings were reported for white sturgeon (*Acipenser transmontanus R.* ) [15]. Russian sturgeon (*Acipenser gueldenstaedtii*) [16, 17], juvenile Iranian sturgeon (*Acipenser persicus*) [18] and juvenile Beluga sturgeon (*Huso huso*) [19] showed the selectivity and requirement of DHA in sturgeon species. Generally, sturgeon fed diets supplemented with vegetable oils accumulated n-3 PUFA (EPA and DHA). Furthermore, sturgeon species are able to elongate linoleic acid and α-linolenic acid to arachidonic acid (AA), EPA and DHA [6, 18, 19]. Sturgeon species appear to require both n-3 and n-6 fatty acids in their nutrition, and accumulation of these fatty acids in the meat was affected by the fatty...
acids in fish diets. Knowledge of the cholesterol content in food is also very important, especially in fish meat, consumption of which is increasing based on the recommendations of healthy nutrition. Kopicova and Vavreinova [20] reported total cholesterol in starlet as being 61 mg/100g.

4. Recommended ratio of n-6/n-3 essential fatty acids
Fish meat should be included in human nutrition for at least three reasons: as a general source of nutritional components; as low fat, high protein food; and as a source of polyunsaturated fatty acids. The recommended ratio of PUFA to saturated fatty acids (PUFA/SFA) should be increased to >0.4 [21]. Wood et al. [22] reported that all examined fish species have favorable (from 0.63 to 0.92) PUFA/SFA ratios. The n-6/n-3 ratio in all examined fishes was in the optimal range of 2.0-4.0 for human health as suggested by Pepping [23]. From the data shown in Table 2, n-6/n-3 ratios of different sturgeon species were <4.0, which is in accordance with the recommendation of Simopoulos [24] for human nutrition. Moreover, the European Food Safety Authority recommends daily intake amounts of 250 mg of EPA and DHA [25]. Meat of terrestrial farm animals has been implicated as a main cause of the imbalanced fatty acid intake of today’s consumers, due to the fact that some meats naturally have a PUFA/SFA ratio of around 0.1 [22]. Sturgeon lipids are particularly rich of polyunsaturated fatty acids (PUFA) that are only slowly synthesized in humans, which is the major difference between fish meat and meat of farmed terrestrial animals [26]. Knowledge of the chemical and fatty acid composition of freshwater fish including sturgeon is important to nutritionists, who are interested in finding sources of low fat, high protein food with desirable fatty acid composition and favorable amounts of total cholesterol. Sturgeon meat contains biologically active protein that is characterized by a good composition of amino acids, HUFAs including EPA and DHA, and fat-soluble vitamins. Additionally, sturgeon meat is a good source of micro- and macro-elements [27, 28].

5. Conclusion
In conclusion, all sturgeon species likely have potential to become a desirable fish in terms of their fat content and composition. Higher contents of PUFA mostly originate from the feed, so appropriate nutrition of farmed sturgeon might be a solution for obtaining optimal fatty acid composition of sturgeon meat from the nutritional standpoint. The potential to exploit the presently insufficiently used sturgeon species as high-protein foods and to introduce new sturgeon species in Serbian aquaculture underscore the need for reliable analytical data.

Acknowledgements
This work was supported by grants from the Ministry of Education, Science, and Technological Development of the Republic of Serbia (project no. TR31011).

References
[1] Gisbert E and Williot P 2002 J. Fish Biol. 60 1071–92
[2] Williot P, Sabeau L, Gessner J, Arlati G, Bronzi P, Gulyas T and Berni P 2001 Aquat. Living Resour. 14 367–74
[3] Fotuhi M, Mohassel P and Yaffe K 2009 Nat. Rev. Neurol. 5 140
[4] Welch A A, Shakya-Shrestha S, Lentjes M A, Wareham N J and Khaw K T 2010 Am. J. Clin. Nutr. 92 1040–51
[5] Wall R, Ross R P, Fitzgerald G F and Stanton C 2010 Nutr. Rev. 68 280–9
[6] Şener E, Yildiz M and Savaş E 2005 Turk. J. Vet. Anim. Sci. 29 1101–7
[7] Nieminen P, Westenius E, Halonen T and Mustonen A M 2014 Food Chem. 159 80–4
[8] Jankowska B, Kolman R, Szczechkowski M and Zmijewski T 2005 Czech. J. Anim. Sci. 50 220–5
[9] Badiani A, Anfossi P, Fiorentini L, Gatta P P, Manfredini M, Nanni N, Stipa S and Tolomelli B 1996 J. Food Compos. Anal. 9 171–90
[10] Ljubojevic D, Trbović D, Luijić J, Bjelić-Čabriolo O, Kostić D, Novakov N and Ćirković M 2013 Bulg. J. Agric. Sci. 19 62–71
[11] Badiani A, Stipa S, Nanni N, Gatta P P and Manfredini M 1997 *J. Sci. Food Agric.* 74 257–64
[12] Lee D H, Ra C S, Song Y H, Sung K I and Kim J D 2012 *Asian-Australas. J. Anim. Sci.* 25 577–83
[13] Bieniarz K, Kołdras M, Kamiński J and Mejza T 2000 *Folia Univ. Agric. Stetin.* 27 21–44
[14] Paltecea E, Talpeș M, Ionescu A, Zara M, Vasile A and Mocanu E 2007 *J. Anim. Sci. Biotechno.* 40 433–43
[15] Gawlicka A, Herold M A, Barrows F T, De La Noüe J and Hung S S O 2002 *J. Appl. Ichthyol.* 18 673–81
[16] Li Q, Zhu H Y, Wei J J, Zhang F, Li E C, Du Z Y, Qin J G and Chen L Q 2017 *Aquac. Nutr.* 23 500–10
[17] Şener E, Yıldız M and Savaş E 2006 *Turk. J. Fish Aquat. Sci.* 6 23–7
[18] Imanpoor M R, Asghari M and Asadi R 2011 *Aquacult. Int.* 19 1035–46
[19] Hosseini S V, Kenari A A, Regenstein J M, Rezaei M, Nazari R M, Moghaddasi M, Kaboli S A and Grant A A 2010 *J. World Aquac. Soc.* 41 471–89
[20] Kopícová Z and S Vavreinová 2007 *Czech J. Food Sci.* 25 195–201
[21] Wood J D, Richardson R I, Nute G R, Fisher A V, Campo M M, Kasapidou E, Sheard P R and Enser M 2003 *Meat Sci.* 66 21–32
[22] Wood J D, Enser M, Fisher A V, Nute G R, Sheard P R, Richardson R I, Hugès S I and Whittington F M 2008 *Meat Sci.* 78 343–58
[23] Pepping J 1999 *Am. J. Health Syst. Pharm.* 56 719–24
[24] Simopoulos A P 2008 *Exp. Biol. Med.* 233 674–88
[25] EFSA 2009 *EFSA Journal* 1176 1–11
[26] Vladau V V, Bud I and Stefan R 2008 *Bulletin UASVM Animal Science and Biotechnologies* 65 301–5
[27] Kenari A A, Regenstein J M, Hosseini S V, Rezaei M, Tahergorabi R, Nazari R M, Mogaddasi M and Kaboli S A 2009 *J. Aquat. Food Prod. Technol.* 18 245–65
[28] Kaya Y, Turan H and Emin Erdem M 2008 *Int. J. Food Sci. Nutr.* 59 635–42