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Food Chemistry 93 (2005) 627–631
Food Chemistry
www.elsevier.com/locate/foodchem

Fatty acid composition of a cultured sturgeon hybrid (*Acipenser naccarii* × *A. baerii*)

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Received 9 August 2004; received in revised form 28 September 2004; accepted 28 September 2004

Abstract

Analyses of fatty acids from the dorsal muscle of *Acipenser naccarii* × *A. baerii* sturgeon hybrid were carried out. The data were compared with those reported in the literature for other sturgeons reared for human consumption. This hybrid would seem to be of great nutritional interest, its flesh being more beneficial for human health than those of other cultured sturgeons. In fact, the level of polyunsaturated fatty acids (PUFAs) was very high (34.7 ± 0.67%), being similar to that of monounsaturated fatty acids (37.9 ± 0.83%). Moreover, the PUFAs-*n*3/PUFAs-*n*6 ratio (6.74) was noticeably higher in this hybrid than in the other cultured sturgeon species. There were also high contents of EPA (C20:5*n*3) and DHA (C22:6*n*3), the two most important essential fatty acids for human health. The linolenic acid (C18:3*n*3) is the metabolic precursor of the PUFAs-*n*3, and it is important also in human metabolism. In *A. naccarii* × *A. baerii* hybrid we found higher C18:3*n*3 values than in other sturgeon species cultured for commercial purposes.

Keywords: Sturgeon; Aquaculture; Fatty acids; Muscle

1. Introduction

In human health, the importance of polyunsaturated fatty acids (PUFAs) is well known, in particular for the prevention of cardiovascular diseases. In regard to this, the most beneficial fatty acids are the PUFAs-*n*3 (Arts, Ackman, & Holub, 2001; Chow, 1992; Connor, 2000; Lees & Karel, 1990; Simopoulos, 1989; Steffens, 1997; Terano et al., 1983; von Schacky, Fisher, & Weber, 1985). Consequently, the healthy effects of fish, the main source of PUFAs-*n*3 for humans, are well documented (Greene & Selivonchick, 1987; Henderson & Tocher, 1987). However, some species of farm-reared fish are low in PUFAs-*n*3 compared with wild fish (Pigott, 1989; van Vliet & Katan, 1990). For this reason, it is of great interest to highlight the composition of fatty acids in cultured fish.

In recent years, the intensive culture of certain sturgeon species has developed as an alternative to that of other more traditional fish species (namely, salmonids, cyprinids and others) (Garcia-Gallego, Sanz, Domezain, & De la Higuera, 1999). Sturgeon fish farming has been practised in Russia since 1875 (Rosenthal & Gessner, 1992). However, until recently, such farming was exclusively concerned with fingerling production for restocking natural habitats to support declining wild sturgeon populations (Rosenthal & Gessner, 1992; Williot et al., 2001). To date, sturgeon fishes are among the most promising temperate freshwater species for aquaculture

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0308-8146/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2004.09.042

in Western Europe (Williot et al., 2001), and most cultured sturgeons are produced for sale as whole fresh fish. *Acipenser transmontanus*, *A. naccarii*, *A. baerii* and *A. gueldenstaedti* are the most common sturgeon species reared for human consumption in Western Europe (Williot et al., 2001). Furthermore, in the last decade, many sturgeon hybrids have been cultured, since they generally show better growth performance than their parental species (Bronzi, Rosenthal, Arlati, & Williot, 1999; Steffens, Jähnichen, & Fredrich, 1990; Williot et al., 2001). The hybrid between *A. naccarii* (Bonaparte) and *A. baerii* (Brandt) was first obtained in an Italian sturgeon fish farm in 1993 (Arlati, Hernando, Poliakova-Belysceva, & Soriguer, 1999). Currently, this hybrid is cultivated in Italy for ongrowing (Williot et al., 2001), while the parental species *A. naccarii*, due to specific Italian programmes, is reared only for restocking activities in natural environments (Bronzi et al., 1999; Williot et al., 2001).

At present, there are some studies available on lipid composition of cultured sturgeons (Ackman, Eaton, & Linke, 1975; Agradi et al., 1993; Badiani et al., 1996; Badiani, Stipa, Nanni, Gatta, & Manfredini, 1997; Chen, Chapman, Wei, Portier, & O'Keefe, 1995; Garcia-Gallego et al., 1999; McKenzie et al., 1997; Naruse, Oyaizu, & Hirota, 1989; Paleari & Grimaldi, 1994; Paleari, Beretta, Grimaldi, & Vaini, 1997; Shimma & Shimma, 1968; Xu, Hung, & German, 1993; Xu & Hung, 1996), but none of these was focused on the *A. naccarii* × *A. baerii* hybrid. The main aims of our study were to present the first data on the fatty acid profile of *A. naccarii* × *A. baerii* hybrid obtained in an experimental rearing trial (Vaccaro, 2003; Vaccaro, Buffa, Mirto, Sarà, & Mazzola, 2004) and to compare the results with data reported in the literature for other sturgeons reared for human consumption.

2. Materials and methods

The experimental rearing of *A. naccarii* × *A. baerii* hybrid (hereafter referred to as "AL") was performed from December 2000 to November 2001 as described in Vaccaro (2003) and in Vaccaro et al. (2004). During the growth trials, fish were fed automatically with pelleted food (Hendrix s.p.a., Europa HD; 48.0% crude protein, 20.0% crude lipid, 8.5% ash and 1.7% crude cellulose; pellet size was 2 mm) for 11 months. The feeding rate was maintained at 2.5% of the reared biomass.

Samples of dorsal muscle were collected from 20 specimens randomly sampled in November 2001, when the sturgeons were 18 months old. Muscular samples were minced and analysed in triplicate for moisture, total lipid content, and fatty acids profile analysis. Data were reported as means calculated from the 20 specimens ± standard error.

Moisture was determined according to AOAC (1995) and total lipids were extracted from the homogenised samples as described by Folch, Less, and Stanley (1957) and determined gravimetrically.

Fatty acid methyl esters (FAMEs) were obtained by direct transesterification (Lepage & Roy, 1984), and analysed by gas chromatography using a Perkin Elmer autosystem XL equipped with a silica capillary column (30 m × 0.32 mm × 0.25 μm Omegawax 320, Supelco, Bellefonte, PA, USA) and a flame ionisation detector (FID). Helium was used as carrier gas. The column temperature was programmed at 200 °C; injector and detector were maintained at 250 and 300 °C, respectively. Individual FAMEs were identified by comparison with a known standard (mixed PUFA of fish oil, Supelco, Bellefonte, PA, USA) and were quantified as the area percentage of each FAME.

The same fatty acid analyses were carried out on three samples of the diet fed to the sturgeons.

3. Results

Body measurements and water and lipid contents of edible portions of the sturgeons are listed in Table 1. In November 2001, the sturgeons had a total wet weight of 1779.7 ± 414.4 g and a standard length of 59.5 ± 4.2 cm. The muscle of the assayed fish had a water content of 73.33 ± 4.66% and a lipid content of 9.24 ± 1.16%.

In Table 2, the fatty acid composition of the sturgeon diet is shown. Only four fatty acids (C16:0, C22:6*n*3, C18:1*n*9, C20:5*n*3) were particularly abundant, contributing to 63% of the total fatty acids. When the fatty acids of the diet were grouped by their saturation index, PUFAs represented the most dominant class (44.5 ± 2.21%), whereas the percent composition of saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) were less and in similar amounts

Table 1
Body measurements and lipid and water contents of the dorsal muscle of *Acipenser naccarii* × *A. baerii* sturgeon hybrid at the end of the experimental rearing

	Body measurements			Proximate composition	
	Total weight (g)	Total length (cm)	Standard length (cm)	Water (%)[a]	Total lipid (%)[a]
Mean	1779.7	69.6	59.5	73.33	9.24
SD	414.4	4.4	4.2	4.66	1.16

[a] % of total wet weight.

Table 2
Fatty acid profiles of the diet and of the dorsal muscle of *Acipenser naccarii* × *A. baerii* sturgeon hybrid at the end of the experimental trial

Fatty acid (% of total fatty acids)	Diet		AL muscle	
	Mean	±SD	Mean	±SD
14:0	5.76	0.36	4.91	0.05
16:0	18.83	0.07	20.12	0.13
16:1*n*7	6.76	0.06	7.29	0.21
16:2*n*4	0.75	0.03	0.62	0.06
18:0	4.12	0.12	1.73	0.17
16:3*n*4	0.78	0.11	0.04	0.05
18:1*n*9	15.31	0.11	25.95	0.82
18:1*n*7	2.85	0.25	3.10	0.09
18:2*n*6	4.77	0.00	3.36	0.08
18:3*n*6	0.23	0.01	0.18	0.01
20:1*n*9	1.27	0.16	0.97	0.07
18:3*n*3	2.47	0.35	1.11	0.30
18:4*n*3	1.92	0.03	1.20	0.06
22:1*n*9	–	–	0.15	0.01
22:1*n*11	0.74	0.01	0.28	0.03
20:3*n*3	0.25	0.01	0.20	0.07
20:4*n*6	1.37	0.05	0.84	0.05
20:4*n*3	0.60	0.03	0.75	0.07
20:5*n*3	12.54	0.22	9.40	0.33
24:1*n*9	–	–	0.17	0.03
22:4*n*6	0.26	0.02	0.10	0.01
22:5*n*3	2.30	0.76	2.21	0.07
22:6*n*3	16.23	0.57	15.01	0.36
∑SFA[a]	28.71	0.54	26.76	0.16
∑MUFA[b]	26.93	0.59	37.92	0.83
∑PUFA[c]	44.49	2.21	34.70	0.67
∑PUFA-*n*3	36.32	1.98	30.19	0.44
∑PUFA-*n*6	6.64	0.09	4.48	0.14
*n*3/*n*6[d]	5.74	0.10	6.74	0.14

[a] 14:0 + 16:0 + 18:0.
[b] 16:1*n*7 + 18:1*n*9 + 18:1*n*7 + 20:1*n*9 + 22:1*n*9 + 22:1*n*11 + 24:1*n*9.
[c] 16:2*n*4 + 16:3*n*4 + 18:2*n*6 + 18:3*n*6 + 18:3*n*3 + 18:4*n*3 + 20:3*n*3 + 20:4*n*6 + 20:4*n*3 + 20:5*n*3 + 22:4*n*6 + 22:5*n*3 + 22:6*n*3.
[d] ∑PUFA-*n*3/∑PUFA-*n*6.

(28.7 ± 0.54% and 26.9 ± 0.59%, respectively). PUFAs-*n*3 were represented more than PUFAs-*n*6, exhibiting a PUFAs-*n*3/PUFAs-*n*6 ratio of around 5.

The fatty acid composition of AL sturgeon flesh is shown in Table 2. The fatty acid profile shows a clear dominance of the two classes of unsaturated fatty acids, MUFAs and PUFAs, respectively with 37.9 ± 0.83% and 34.7 ± 0.67% of total fatty acids. The amount of SFAs was appreciably lower (26.76 ± 0.16%). A higher proportion of PUFAs-*n*3 than PUFAs-*n*6 was observed, the PUFAs-*n*3/PUFAs-*n*6 ratio being 6.74.

The most abundant fatty acids in AL muscle were, in decreasing order: oleic (C18:1*n*9), palmitic (C16:0), docosahexaenoic (C22:6*n*3, DHA), and eicosapentaenoic (C20:5*n*3, EPA), respectively at 26.0 ± 0.82%, 20.1 ± 0.13%, 15.0 ± 0.36%, and 9.40 ± 0.33%. These four fatty acids represented about the 70% of total fatty acids.

Oleic acid was the most represented MUFAs, accounting for slightly more than 68% of total MUFAs.

Among the polyenoic acids, C22:6*n*3 was the most abundant accounting for about 43% of total PUFAs. The PUFAs acids were also characterised by a high proportion of 20:5*n*3, which represented about 24% of total PUFAs. EPA and DHA were about 80% of the PUFAs-*n*3 series. Linoleic acid (C18:2n6) was clearly prevalent in the PUFAs-*n*6 series (around 75%), in which 18.7% was provided by arachidonic acid (C20:4*n*6).

Saturated fatty acids were noticeably dominated by C16:0, which contributed more than 75% of total SFAs.

4. Discussion

This study reports, for the first time, data on flesh lipid composition of AL sturgeon hybrid. This fish showed a fairly high muscular lipid content (9.24 ± 1.16%) when compared with data on *A. baerii, A. naccarii* and *A. transmontanus* reared in Italy for commercial purposes and provided with a fish oil enriched diet (Badiani et al., 1996, 1997; Paleari et al., 1997). Indeed, these authors found mean lipid contents in the range of 2.54–7.76% of total muscle weight, except in only one case reported by Badiani et al. (1996), which referred to a mean fat content around 10% in *A. naccarii* flesh. According to the scale proposed by Stansby (1976), AL sturgeon can be classified as a medium-fat fish, because its fat content ranges between 5% and 15%.

Dietary lipids very likely affected the fatty acids composition of AL sturgeon muscle. This agrees with observations on other fish species (Henderson & Tocher, 1987; Steffens, 1997; Watanabe, 1982) and recently also noticed in the white sturgeon *A. transmontanus* (Xu & Hung, 1996). Our data demonstrate that the most abundant fatty acids in the AL flesh (C16:0, C18:1*n*9, 20:5*n*3 and 22:6*n*3) coincided with the four fatty acids mainly present in the sturgeons' diet. Moreover, oleic (C18:1*n*9) and palmitic (C16:0) acids were the two most abundant fatty acids. This is in agreement with Standsy's findings (1982), according to which oleic and palmitic totalled >30% in fish edible tissues.

In AL sturgeon muscle, the level of PUFAs was very high (34.7 ± 0.67%), being similar to that of MUFAs (37.9 ± 0.83%). These data contrast with the findings for other sturgeons reared in Italy (Badiani et al., 1996, 1997; Paleari et al., 1997) and with *A. oxyrinchus desotoi* cultured in the USA (Chen et al., 1995) or *A. naccarii* reared in Spain (Garcia-Gallego et al., 1999). Indeed, these authors reported a higher content of MUFAs, in spite of PUFAs, in muscular tissues of the sturgeons studied. On the contrary, the level of SFAs in AL flesh (26.8 ± 0.16%) is similar to that revealed in the sturgeons of the aforesaid studies.

Another relevant consideration emerging from the fatty acid profile of AL flesh is the elevated PUFAs-*n*3/PUFAs-*n*6 ratio (6.74), noticeably higher in this

hybrid than in the other cultured sturgeon species (Badiani et al., 1996, 1997; Chen et al., 1995; Garcia-Gallego et al., 1999; Paleari et al., 1997). This is of great interest regarding human consumption. Indeed, it is evident that high levels of PUFAs-*n*6 in the human diet could be related to many health disorders (Sargent & Tacon, 1999). For this reason, PUFAs-*n*3 may modulate the undesirable effects of PUFAs-*n*6.

Concerning the single fatty acids, AL hybrid muscle showed high contents of C20:5*n*3 (9.40 ± 0.33%) and C22:6*n*3 (15.0 ± 0.36%). These amounts are clearly higher than C20:5*n*3 values (in the range 4.55–8.28%) and C22:6*n*3 values (in the range 6.75–12.2%) found for muscle of farmed *A. baerii, A. naccarii, A. transmontanus* and *A. oxyrinchus desotoi* (Badiani et al., 1996, 1997; Chen et al., 1995; Paleari et al., 1997), provided with a diet with a similar composition to that employed in the present study. This is an interesting result, since several studies suggested that EPA and DHA are the two most important essential fatty acids for human health (Arts et al., 2001; Chow, 1992; Connor, 2000; Lees & Karel, 1990; Simopoulos, 1989; Steffens, 1997; Terano et al., 1983; von Schacky et al., 1985).

Linolenic acid (C18:3*n*3) is the metabolic precursor of the PUFAs-*n*3, also in the human organism. Here, for AL muscle we found values of C18:3*n*3 higher than in others sturgeon species cultured for commercial purposes. Only *A. transmontanus*, analysed by Paleari et al. (1997), had values of C18:3*n*3 (in the range 4.25–6.40%) higher than that in AL sturgeon (1.11 ± 0.30%).

Among the PUFAs-*n*6 series, the levels of arachidonic acid (C20:4*n*6) (0.84 ± 0.05%) seemed to be very similar between AL hybrid and the two parental species, *A. baerii* (Badiani et al., 1996, 1997) and *A. naccarii* (Garcia-Gallego et al., 1999). On the other hand, this fatty acid was more abundant in cultured *A. transmontanus* (2.05–4.00%) (Paleari et al., 1997) and in *A. oxyrinchus desotoi* (2.50%) (Chen et al., 1995). The C20:4*n*6 is one of the essential fatty acids for humans; however, it is harmful for health if present in excessive quantity in our diet (Farooqui, Rosenberg, & Horrocks, 1997; Steffens, 1997). Concerning the metabolic precursor of the PUFAs-*n*6 series, the level of C18:2*n*6 did not show any relevant differences between the AL hybrid and the other species reared for human consumption (Badiani et al., 1996, 1997; Chen et al., 1995).

In conclusion, our findings on the fatty acid profile of muscle show how the AL hybrid might be of great nutritional interest, its flesh being more beneficial for human health than those of other cultured sturgeons. Consumption of the AL hybrid would be of particular interest for citizens of Western countries. Indeed, in Western diets the content of SFAs is typically very high and the main source of PUFAs is the linoleic acid (C18:2*n*6), a PUFA-*n*6 abundant in most seeds. On the contrary, the dietary content of PUFAs-*n*3 is low. To balance the high content of SFAs and PUFAs-*n*6 in typical Western diets, a beneficial fish diet should contain high amounts of PUFAs-*n*3 and should simultaneously have low levels of SFAs and a relatively high PUFAs-*n*3/PUFAs-*n*6 ratio (Ahlgren, Blomqvist, Boberg, & Gustafsson, 1994). This is what we have found in AL flesh.

Future research should be addressed to understanding whether a good fatty acid profile is maintained in the flesh of 3^+ and 4^+ AL specimens, which are more exploited for commercial purposes than those reported in the present study (i.e. 1^+). However, recent studies (Garcia-Gallego et al., 1999) reported that the fatty acid profile is already established in six-month-old *A. naccarii*. This is particularly true if evident changes in diet composition, feeding regime, and environmental factors do not occur.

Acknowledgements

The authors would like to thank Giuseppe Di Carlo (PhD) and Dr Marco Milazzo (PhD) for their useful suggestions during the revision of the MS.

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