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Effect of alive weight on body composition and fatty acid content of farmed beluga sturgeon (*Huso huso*)

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Abstract

The correlation between alive weight of farmed beluga (*Huso huso*) (ranging from 1 to 89 kg) and body composition and fatty acid content was examined for the first time. In all weight groups, the content of protein, fat, moisture, and ash varied as follows: protein 11.2% to 18.63%, fat 1.40% to 6.0%, moisture 65.77% to 80.4%, and ash 0.54% to 1.4%. Monounsaturated fatty acids (MUFAs) were the most predominant fatty acids (43.11%) followed by polyunsaturated fatty acids (PUFAs; 28.02%) and saturated fatty acids (SFAs; 20.72%). The content of protein, SFAs (C16:0, C18:0, and C20:0), and PUFAs (C18:2 n-6, C18:3 n-3, eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA)) and the n-3/n-6 ratio showed a significant correlation ($P < 0.01$) with body weight. The content of n-3 (ranging from 6.99% to 11.72%) and n-6 (ranging from 10.82% to 28.21%) fatty acids, EPA (ranging from 0.85% to 2.66%), and DHA (ranging from 3.18% to 7.58%) and the n-3/n-6 ratio (ranging from 0.24 to 1.04) increased significantly with increasing body weight of beluga ($P < 0.01$), while MUFA and the DHA/EPA ratio were not correlated with the body weight of the fish. The results of this study indicated that protein content and essential n-3 PUFA were influenced by body weight.

Keywords: Body composition, Fatty acid content, Body weight, Farmed beluga sturgeon

Background

Seafood is a good source of high-quality protein with well-balanced essential amino acids. It is rich in n-3 polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and contains low cholesterol level (Barrento et al. 2010). N-3 are not synthesized in the human body (Simopoulos 2002), and seafood is reported to be the only main source of n-3 PUFA in the human diet which plays an important role in human nutrition and health promotion. This is the reason why an increased consumption of seafood is recommended by dietary guidelines (Jacobsen et al. 2008). Seafood consumption also has an effect on healthy balance between n-3 and n-6 PUFAs in the diet (Orban et al. 2011). With the growing emphasis on the importance of n-3 PUFA on human health and nutrition, it is important to determine the n-3 content of fish and fish products.

Sturgeons are one of the most valuable wildlife commodities on earth. Twenty-seven species of sturgeon exist in the diverse habitats of the northern hemisphere including rivers, estuaries, near-shore oceanic environments, and inland seas. The Caspian Sea is the largest inland water body in the world. The greatest abundance of sturgeon inhabits in the Caspian Sea which is the largest and most important sturgeon fisheries (Ovissipour and Rasco 2012). Six species of sturgeon occur in the Caspian Sea basin (beluga, Russian, Persian, sterlet, stellate, ship; Pikitch et al. 2005). Fuelled by the lucrative international caviar market, the stocks of many sturgeon species have faced rapid declines (Bronzi et al. 2011). In response to the declining sturgeon stocks, commercial sturgeon production in farms has been undertaken by many countries. The Siberian sturgeon (*Acipenser baerii*), Russian sturgeon (*Acipenser gueldenstaedtii*), Adriatic sturgeon (*Acipenser naccarii*), white sturgeon (*Acipenser transmontanus*), beluga sturgeon (*Huso huso*), and several hybrids are the main cultured sturgeon species (Badiani et al. 1997; Ercan 2011; Oliveira et al. 2006; Vaccaro et al. 2005).

Commercial catches of the beluga sturgeon in the Caspian Sea basin declined rapidly due to excessive fishing and habitat deterioration (Ruban and Khodorevskaya 2011). The beluga sturgeon is an important species for sturgeon aquaculture in Iran. This fish grows fast, has big size, and is highly appreciated for its tasty and boneless flesh (Ghomi et al. 2012b; Pourshamsian et al. 2012). Beluga is cultured in concrete indoor tanks using well water (Ghomi et al. 2012c). At the age of 3 years old, males and females are sexed to indentify males for meat production, while females are reserved for caviar production (Masoudifard et al. 2011; Ovissipour and Rasco 2011). Recently, caviar from farmed beluga females was successfully obtained in Iran, and the meat was being sold to the market. The objective of this study was to investigate the effect of body weight (from 1 to 89 kg) on the body composition and fatty acid content of farmed beluga used for caviar production.

Methods

Fish samples

Beluga ($n = 20$) with body weight ranging from 1 to 89 kg was cultured in a local beluga farm (Sari, Iran). The fish from different weight categories were raised in concrete circular tanks (8-m diameter, 1.5-m depth) at a stocking density of 30 kg/m^3 and fed 2% of body weight with a commercial diet containing 40% protein and 15% lipid. The fatty acid composition of the diet was composed of 23.87% saturated fatty acid (SFA), 30.95% monounsaturated fatty acid (MUFA), 40.71% PUFA, 13.44% n-3 fatty acid, and 27.27% n-6 fatty acid. Fish with body weight higher than 50 kg were used for caviar production. After removing caviar, the obtained meat was used to analyze proximate and fatty acid composition. In total, 20 specimens of beluga were analyzed.

Proximate composition

Moisture was determined by drying the samples in an oven (D-63450, Heraeus, Hanau, Germany) at 105°C to a constant weight (AOAC 2005). Ash was determined by incineration in a muffle furnace (Isuzu, Tokyo, Japan) at 600°C for 3 h (AOAC 2005). Crude protein was determined by the Kjeldahl method ($N \times 6.25$) using an automatic Kjeldahl system (230-Hjeltec Analyzer, Foss Tecator, Höganäs, Sweden) (AOAC 2005).

Lipid extraction

Lipid was extracted according to the method of Bligh and Dyer (1959). Fifty grams of sample was homogenized in a blender for 2 min with a mixture of 50 ml chloroform and 100 ml methanol. Then 50 ml of chloroform was added and further homogenized for 30 s. Finally, 50 ml of distilled water was added to the mixture and blended for 30 s. The homogenate was centrifuged (Avanti J-E, BECKMAN COULTER, Inc., Fullerton, CA, USA) at 4,000 rpm for 15 min at 4°C. The supernatant was then transferred into a separating flask, and the lower phase (chloroform phase) was drained off into a 250-ml Erlenmeyer flask containing 4 g anhydrous sodium sulfate and shaken vigorously. The solution was then filtered through a Whatman No. 4 filter paper into a round-bottom flask. A rotary evaporator was used for solvent evaporation at 25°C.

Fatty acid analysis

Fatty acid composition was determined on the oils extracted by the method of Bligh and Dyer (1959). Fatty acid methyl ester was prepared as follows: Lipid samples (1 g) were diluted with 2 ml of 2 M potassium hydroxide in methanol followed by the addition of 7 ml *n*-hexane in a sealed tube. The mixture was then shaken using a vortex for 1 min and left for about 20 min in a water bath (temperature 50°C to 55°C) until it was separated into two phases. From the top layer, fatty acid methyl ester was then taken for analysis using Trace GC (Thermo Finnigan, Rodano, Italy). The GC conditions were as follows: capillary column (Bpx-70, 60 m, 0.32 mm, i.d. 0.25 μm), split ratio of 90:1, injection port temperature of 250°C, and flame ionization detector temperature of 270°C. The oven temperature was set at 195°C for 75 min. The flow rate of carrier gas (helium) was 1 ml/min, and the makeup gas was N_2 (30 ml/min). The sample size injected for each analysis was 1 μl. The data are expressed as grams/100 grams of total fatty acids.

Statistical analysis

Pearson's correlation coefficient with a significance level of $P < 0.05$ was used to test for linear correlations. Data are expressed as mean ± standard deviation (SD).

Results and discussion

Proximate composition

The protein, fat, moisture, and ash content of farmed beluga sturgeon are shown in Table 1. The content of protein, fat, moisture, and ash were 14.73%, 3.92%, 74.97%, and 0.81%, respectively. The protein content in beluga was lower than that in other farmed sturgeon species such as white sturgeon (*A. transmontanus*) with 18% to 19% protein (Paleari et al. 1997), *Acipenser* spp. with 17.6% to 21% protein (Badiani et al. 1996), Gulf of Mexico sturgeon (*A. oxyrynchus desotoi*) with 17.4% to 19.5% protein (Oliveira et al. 2006), Siberian sturgeon (*A. baerii*) with 17.8% to 19.6% protein, and Russian sturgeon

Table 1 Correlation between farmed beluga weight and proximate composition

Composition	*r*	*P* value	Range	Mean	SD
Protein	0.504	0.045*	11.2 to 18.63	14.73	2.18
Fat	0.376	0.102	1.40 to 6.0	3.92	1.39
Ash	−0.124	0.601	0.54 to 1.4	0.81	0.26
Moisture	−0.409	0.073	65.77 to 80.4	74.97	4.05

*Significant at $P < 0.05$.

(*A. gueldenstaedtii*) with 16.4% to 17.6% protein (Chapman et al. 2005). On the other hand, farmed beluga contained lower fat than other farmed sturgeon species (Badiani et al. 1996; Chapman et al. 2005), but its fat content is higher than the fat content of the Gulf of Mexico sturgeon (Oliveira et al. 2006). According to fat content, fish are usually classified into lean (fat content <2%), low-fat (fat content 2% to 4%), medium-fat (fat content 4% to 8%), and high-fat (fat content >8%) (Haard 1992). The present study indicated that the farmed beluga with a fat content lower than 4% could be placed amongst those fish with low fat content. A significant correlation between fish weight and protein content was observed ($r = 0.504$, $P < 0.05$; Figure 1). Palmeri et al. (2007) analyzed the proximate composition of Murray cod of different sizes and reported a lower fat content in smaller fish, more likely due to the utilization of fat at a faster rate during early growth stages. However, in this study, a correlation between body fat and fish weight was not found.

Fatty acid composition

The fatty acid composition of farmed beluga sturgeon fillet is shown in Table 2. MUFAs were the most predominant fatty acids (43.11%) followed by PUFAs (28.02%) and SFAs (20.72%). MUFAs also represented the major fatty acids in several farmed sturgeon species including the white sturgeon (45.39%), Adriatic sturgeon (47.70%), and Siberian sturgeon (44.89%) (Badiani et al. 1997) and the sturgeon hybrid *A. baerii* × (*A. baerii* × *A. medirostris*) (46.21%) (Jankowska et al. 2005). Oleic acid (C18:1) was the major MUFA (40.12% of total fatty acid (TFA)). Palmitic acid (C16:0) was the main SFA (16.6% of TFA). Docosahexaenoic acid (C22:6) was the main n-3 fatty acid (5.20% of TFA), while linoleic acid (C18:2) was the major n-6 fatty acid (17.30% of TFA). The EPA and DHA content of beluga (Figure 2) were lower than those of other cultured sturgeon species such as the Siberian sturgeon (*A. baerii*) with 6.54% EPA and 9.7% DHA, Adriatic sturgeon (*A. naccarii*) with 4.81% EPA and 8.77% DHA, and white sturgeon (*A. transmontanus*) with 5.55% EPA and 9.06% DHA (Badiani et al. 1997). Fatty acid composition could be influenced by the diet the fish consumed (Vaccaro et al.

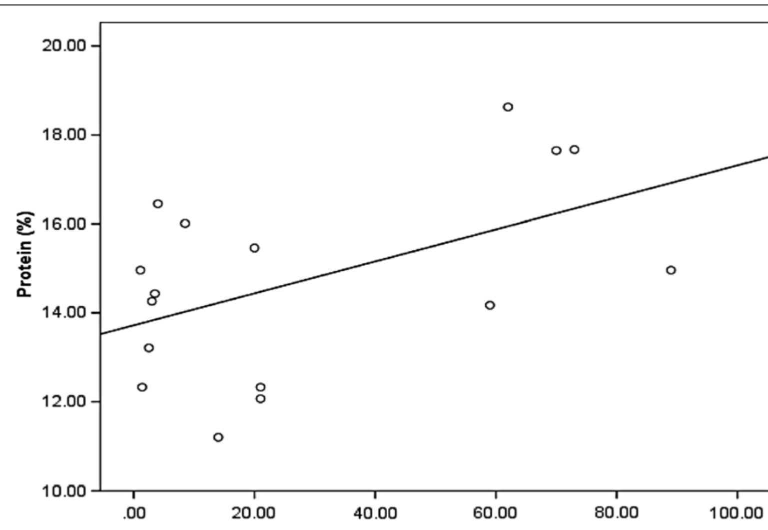

Figure 1 Correlation scatterplot for protein and body weight in farmed beluga.

Table 2 Correlation between farmed beluga weight and fatty acid composition (% of total fatty acids)

Fatty acids	*r*	*P* value	Range	Mean	SD
C14:0	0.455	0.055	0.89 to 2.0	1.40	0.37
C16:0	0.922	0.000*	13.35 to 20.33	16.60	2.41
C16:1	0.886	0.000*	1.59 to 4.17	2.98	0.76
C18:0	−0.590	0.006*	2.23 to 3.31	2.75	0.32
C18:1	0.016	0.947	36.9 to 44.9	40.12	1.94
C18:2 n-6	−0.802	0.000*	10.2 to 27.68	17.30	5.00
C18:3 n-3	−0.896	0.000*	1.48 to 4.27	2.76	0.94
C20:0	−0.907	0.000*	0.14 to 0.24	0.18	0.02
C20:4 n-6	0.210	0.375	0.33 to 1.06	0.59	0.17
C20:5 n-3 (EPA)	0.709	0.000*	0.85 to 2.66	1.71	0.63
C22:6 n-3 (DHA)	0.848	0.000*	3.18 to 7.58	5.20	1.20
∑SFA	0.884	0.000*	17.32 to 24.81	20.72	2.34
∑MUFA	0.247	0.295	38.49 to 47.02	43.11	2.17
∑PUFA	−0.677	0.001*	21.45 to 46.55	28.02	5.73
∑n-3	0.439	0.053	6.99 to 11.72	9.67	1.42
∑n-6	−0.791	0.000*	10.82 to 28.21	17.89	5.02
∑n-3/n-6	0.828	0.000*	0.24 to 1.04	0.60	0.25
DHA/EPA	−0.351	0.129	2.14 to 4.29	3.24	0.70

*Significant at $P < 0.01$.

2005). A significant correlation ($P < 0.01$) between SFAs (C16:0, C18:0, and C20:0), PUFAs (C18:2 n-6, C18:3 n-3, EPA, and DHA), and n-3/n-6 ratio and body weight was found (Table 2). The percentage content of n-3 (ranging from 6.99 to 11.72) and n-6 (ranging from 10.82 to 28.21) fatty acids, EPA (ranging from 0.85 to 2.66), and DHA (ranging from 3.18 to 7.58) and the n-3/n-6 ratio (ranging from 0.24 to 1.04) increased significantly with increasing fish weight ($P < 0.01$). Similarly, among some commercial

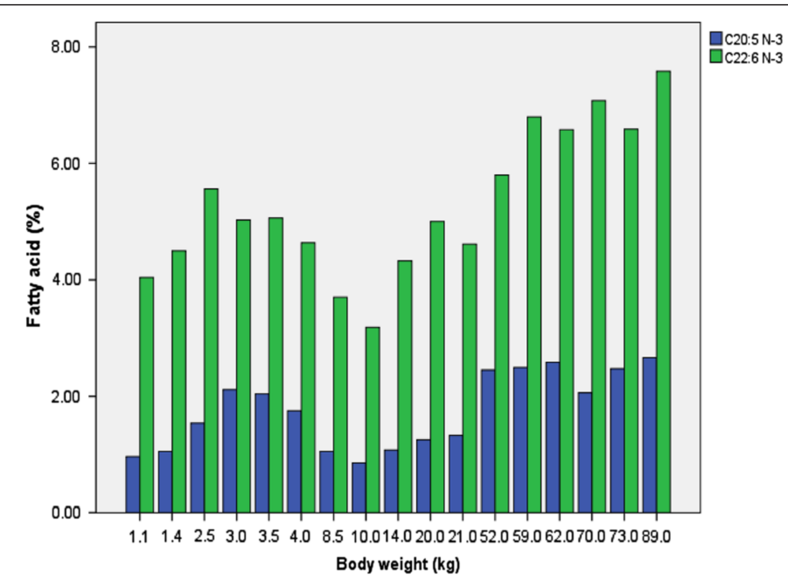

Figure 2 **Fatty acid (EPA, C20:5 n-3; DHA, C22:6 n-3) amount in different body weight of farmed beluga.**

studied species by Ghomi and Dezhabad (2012), n-3 polyunsaturated fatty acids significantly increased ($P = 0.032$) with the increase of fish weight in silver carp, while n-6 fatty acids decreased ($P = 0.013$). However, MUFA and the DHA/EPA ratio were not correlated with body weight.

Essential polyunsaturated fatty acids such as EPA and DHA are not synthesized in the human body; therefore, their inclusion in diets is essential (Ghomi et al. 2012a). A higher DHA/EPA ratio is more beneficial to health as DHA is more efficient than EPA in reducing the risk of coronary heart disease (Simopoulos 2002). The fatty acid composition of farmed Atlantic salmon (Refsgaard et al. 1998); farmed sea bass, gilthead sea bream, and rainbow trout (Testi et al. 2006); carp, walleye Pollock, cod, and Baltic salmon (Usydus et al. 2011); Siberian sturgeon, Adriatic sturgeon, and white sturgeon (Badiani et al. 1997); and sturgeon hybrid (Adriatic sturgeon × Siberian sturgeon) (Vaccaro et al. 2005) also contained a higher percentage of DHA than EPA. On the other hand, a significant positive correlation was found for EPA ($r = 0.709$, $P = 0.000$) and DHA ($r = 0.848$, $P = 0.000$) with fish weight (Table 2, Figure 3).

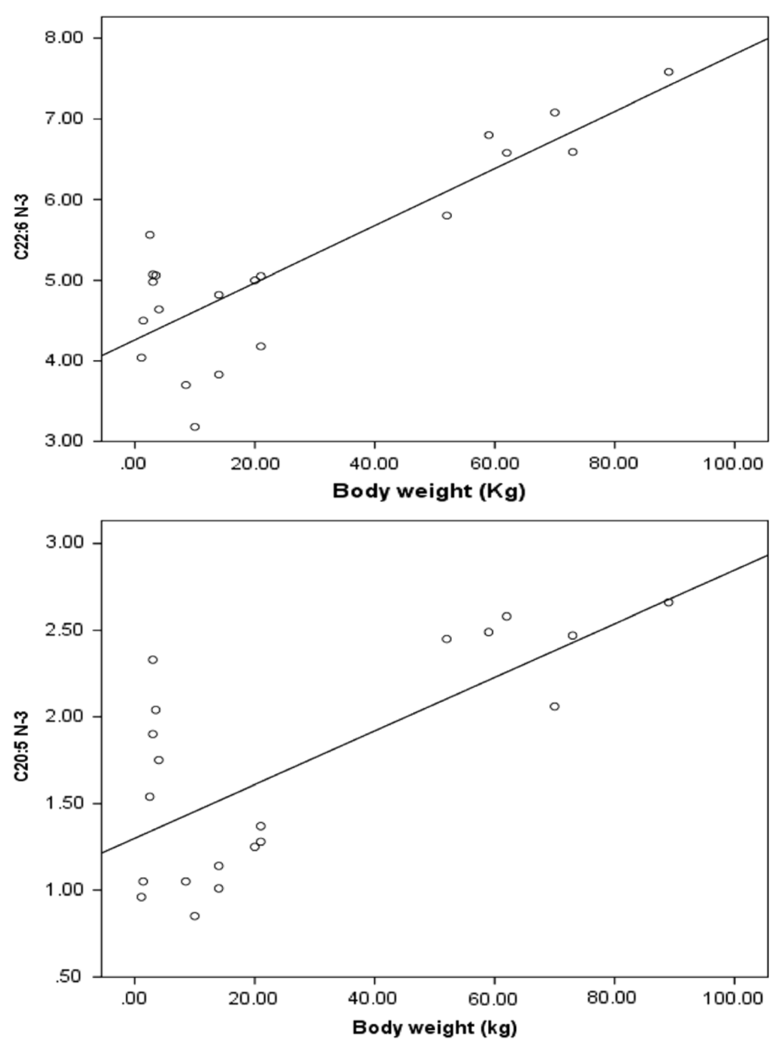

Figure 3 Correlation scatterplot for fatty acid (EPA, C20:5 n-3; DHA, C22:6 n-3) and body weight in farmed beluga.

The n-3/n-6 ratio is an important nutritional index of lipid quality. The n-3 PUFA is important in the prevention of human chronic inflammatory and cardiovascular diseases and prevention of cancer. Seafood is the only significant source of n-3 PUFA, predominantly EPA and DHA (Orban et al. 2011). The n-3/n-6 ratio in farmed beluga was 0.6 (ranging from 0.24 to 1.04). The optimal ratio of n-3/n-6 fatty acids is 1:5 (0.2; Sargent 1997). The n-3/n-6 ratios observed for other sturgeon species were 6.74 in farmed sturgeon hybrid (*A. naccarii* × *A. baerii*) (Vaccaro et al. 2005), 3.83 in farmed Siberian sturgeon (*A. baerii*), and 4.21 in farmed white sturgeon (*A. transmontanus*). In general, the n-3/n-6 ratio in seafood is higher than the recommended value (1:5), and from a nutritional viewpoint, this is highly beneficial and desirable for the daily human diet (Usydus et al. 2011). The correlation between n-3/n-6 ratio and body weight was highly significant ($r = 0.828$, $P = 0.000$). Larger farmed beluga contained a significantly higher n-3/n-6 ratio when compared to smaller fish which could indicate the beneficial health effect of larger farmed beluga fillets.

Conclusions

The nutritional value of farmed beluga used for caviar production in Iran based on fatty acid traits was established for the first time. A significant correlation between the body weight of farmed beluga and protein, PUFA, n-3 and n-6 fatty acids, and n-3/n-6 ratio was observed. The content of essential n-3 PUFA such as EPA and DHA increased with increasing body weight. As all cultured fish were fed with the same source of food, the present study indicates that the body weight could alter the rate of fatty acids established in the body; consequently, the body's fatty acids are dependent to fish body size.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MRG and MN participated in the design of the study. MRG and MS carried out the experiment and performed the statistical analysis. MRG and MN participated in the discussion and corrected the manuscript. All authors read and approved the final manuscript.

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