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Sturgeon caviar and cardiovascular diseases, Caspian Sea wild and farmed beluga, *Huso huso* caviar and their lipid quality indices

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ABSTRACT

The objective was to investigate the detailed information about proximate, fatty acid compositions and lipid quality indices in the caviar of wild and farmed beluga, *Huso huso* from Iran. The fatty acid composition varied with origin of caviars, although did no differ in proximate compositions. The most notable difference ($P<0.05$) was the higher concentration of linoleic acid (C18:2n-6) in farmed beluga caviar (8.32%) than in wild ones (0.37%). The amounts of docosahexaenoic acid (C22:6n-3) in wild and farmed caviars (23.88% and 23.75% respectively) were not different ($P>0.05$). There were significantly differences between samples in the amount of eicosapentaenoic (C20:5n-3), arachidonic (C20:4n-6) and docosapentaenoic (C22:5n-3) acids ($P<0.05$). The total ω-3 in wild and farmed caviars were 38.42% and 30.42% ($P>0.05$). Total ω-6 was higher in farmed samples ($P<0.05$). The ratio of ω-3/ω-6 was higher in wild (2.90) than in farmed (1.75) samples ($P<0.05$). It was also true for, AI content (0.29 and 0.28) and TI (0.18 and 0.21) and also PI content (1.73 and 1.46) respectively, however the differences were not significant ($P>0.05$). The present study indicated that, fatty acids profile in beluga caviars can be used as an index to determine fish origin and diet. Also farmed beluga caviar has good balanced with lipid quality indices to decrease the potential risk of coronary heart diseases and like wild ones could be considered as a good food sources.

Keywords: Beluga, Caspian Sea, Caviar, Heart disease, Lipid quality.

INTRODUCTION

These days, sturgeon species are in danger due to low water quality, habitat destruction, over-fishing and illegally poaching (Pajand *et al.* 2017). Hence, to accomplish commercial demands, aquaculture of sturgeons has increased rapidly in whole the world and within Iran. Beluga, *Huso huso* is a valuable species for aquaculture due to its fast growth rate and diseases and inappropriate water quality endurance. In addition, beluga produces excellent meat and valuable caviar, so, it is a great candidate among other sturgeons to culture (Falahatkar & Najafi 2019). Fish include specified polyunsaturated fatty acids that have important effects on prostaglandin synthesis regulation and assisting wound treatment (Bowman & Rand 1980; Gibson 1983). One of the salient features of fish is the great amount of unsaturated fatty acids in fat (Hedayatifard & Moeeni 2004). There are several studies on fatty acid profiles in different fishe species including Jorjani *et al.* (2016); Zakipour Rahimabadi *et al.* (2016) and Saffar Shargh *et al.* (2017). Lately, seafood consumption has increased due to its health beneficial, especially because of polyunsaturated fatty acids (PUFAs) that can be valuable for prevention of cardiovascular diseases, Alzheimer (Saliu *et al.* 2017) and cancers (Connor 1997). Due to important effects of fatty acids on health, it is essential to explain the lipid quality index related to the fatty acid profile and their biological functions. The lipid quality index is evaluated by a number of indices of fatty acid compositions; the indices of atherogenicity (AI) and thrombogenicity (TI), according to Turan *et al.* (2007), EPA + DHA according to Nurhan (2007), PUFA/SFA ratio according to Kalogeropoulos *et al.* (2004) and Marques *et al.* (2010), ω-3/ω-6 PUFA ratios according to

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Marques *et al.* (2010) and ultimately ARA/EPA, UFA/SFA ratios according to Larsen *et al.* (2011). Environment of fish has an important role in fatty acid compositions of sturgeon caviars. Different feeding strategies cause interspecies differences in fatty acid compositions of sturgeon lipids (Gessner *et al.* 2002), so, they can be a reflection of their feeding character in the wild or in captivity. Some data on the chemical and biochemical composition of caviar and flesh of sturgeon and other fishes are available in scientific literature. Park *et al.* (2015) worked on "general and biochemical composition of caviar from sturgeon, *Acipenser ruthenus* farmed in Korea". DePeters *et al.* (2013) worked on "fatty acid and mineral composition of sturgeon eggs to distinguish between farm-raised versus wild white sturgeon, *Acipenser transmontanus*". Gong *et al.* (2013) studied "nutritional composition of caviar from three commercially farmed sturgeon species in China". Ovissipour & Rasco (2011) compared "fatty acid and amino acid of domestic and wild beluga roe and impact on fertilization ratio". Bekhit *et al.* (2009) determined the "impact of maturity on the physicochemical and biochemical properties of Chinook salmon, *Oncorhynchus tshawytscha* roe". Gessner *et al.* (2008) used "biochemical composition of caviar as a tool to discriminate between aquaculture and wild origin". Mol & Turan (2008) compared "proximate, fatty acid and amino acid compositions of various types of fish roes". Vaccaro *et al.* (2005) have analyzed "fatty acid composition of a cultured sturgeon hybrid, *Acipenser naccarii* × *Acipenser baerii*". Bledsoe *et al.* (2003) worked on "caviar and fish roe products". Alasalvar *et al.* (2002) studied "differentiation of cultured and wild sea bass, *Dicentrarchus labrax* total lipid content, fatty acid and trace mineral composition". Wirth *et al.* (2002) worked on "chemical and biochemical composition of caviar from different sturgeon species and origins". Gessner *et al.* (2002) investigated the "nutrient composition of sturgeon caviar to provide a farm-raised product that was equivalent to caviar product in wild ". Tamaru *et al.* (1992) studied "fatty acid and amino acid profiles of spawned eggs of stripped mullet, *Mugil cephalus*". Fatty acid compositions in meat and caviar of different sturgeons have been studied previously. However, the objective of present study was to gain detailed information about the fatty acid compositions and lipid quality indices of caviar in the valuable Caspian Sea wild and fresh water farmed beluga sturgeon, *Huso huso* and comparing their effects on cardiovascular improvement indices.

MATERIALS AND METHODS

Sturgeon caviar collection

Wild beluga caviar samples (300 g) were provided by Mazandaran Sturgeon Affairs Office and farmed sturgeon caviars were collected from Sturgeon Hatchery Centers (Commercial Private Estates). In Iran Farmed samples (300 g) were conducted and originated from different three individual female beluga sturgeons. Both caviar samples packed in closed commercial glass cans (each glass can consisted of 50 g caviar) and stored at 0-4 ˚C until delivered to the laboratory where the samples were analyzed. Farmed beluga sturgeons were reared in concrete tanks with freshwater constantly overflowing and the tanks water important parameters were kept relatively constant: temperature; 17-19 ˚C, pH: 6.9-7.5, oxygen level more than 7 mg/L and salinity ≤ 1 ppt. Fish were fed by commercial diet (caviar Coppens, Germany) once a day, 0.3% of their biomass. The proximate compositions of the diet contain (dry matter basis), 50% crude protein, 12% crude fat, 0.6% crude fiber, 7.8% ash, 1.29% P, vitamin A 10000 (IE kg^{-1}),vitamin D 100 (IE kg^{-1}),vitamin E 200 (mg kg^{-1}),vitamin C 1000 (mg kg^{-1}), gross energy 20.4 (MJ kg^{-1}), digestible energy 18.8 (MJ kg^{-1}) and metabolisable energy 16.4 (MJ kg^{-1}).

Proximate composition

Caviar samples were analyzed for proximate composition including crud protein, lipid, moisture and ash using the AOAC (Association of Official Analytical Chemist) standard methods (AOAC 2005). Briefly, crude protein content was measured by determining nitrogen content (× 6.25) using automated Kjeldahl analysis (V50Analyzer, Bakhshi, Iran). Lipid was extracted using an automatic Soxtec system (Soxtec 6CTF, Bakhshi, Iran). Moisture was measured after drying the sample at 105 ˚C to constant weight (SL 901, KTS, Iran). Ash was determined by incineration in a muffle furnace (KLI 14, KTS, Iran) to a constant weight at 550 ˚C.

Fatty acid analysis

After the extraction of total lipids according to the Folch *et al.* (1957) method, fatty acid methyl esters were prepared in n-hexan using MgCl as a catalyst by the AOAC method (AOAC 2005). The gas chromatography analysis of the fatty acid methyl esters were performed on a gas chromatograph (Shimadzu GC14A, Japan) equipped with a capillary column (BPX70, 50 m × 0.25 mm.0.2µm) and flame Ionization Detector. The carrier gas was helium at a pressure of 53.8 psi and the flow rate of 1.5 mL min^{-1}. The thermal gradient was 160 ˚C for

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10 min, then increased by 2°C/min to 180°C and held at 180°C for 85 min. The detector and injector temperature were 250 and 200 °C respectively. The volume of injected samples was 1 µL. Fatty acids were identified by comparing the retention time of each fatty acid versus its respective authentic standard (Merck KGaA, Germany). The results expressed as percentage (%) of total fatty acid.

Lipid quality indices

The lipid quality indices for example, the atherogenic index (AI) and the thrombogenic index (TI) were calculated according to Ulbricht and Southgate (1991), on the basis of fatty acid percentages including saturated, monounsaturated and polyunsaturated fatty acids.

AI = [12:0 + 4(14:0) + 16:0] / [MUFA + *n*-3 PUFA + *n*-6 PUFA]

TI = [14:0 + 16:0 + 18:0] / [0.5MUFA + 0.5(*n*-6PUFA) + 3(*n*-3PUFA) + (*n*-3PUFA/*n*-6PUFA)]

“Atherogenic or hyperlipidemic saturated fatty acid are lauric (C12:0), myristic (C14:0) and palmitic (C16:0) acids, while thrombogenic fatty acid are myristic, palmitic and stearic acids. In the above equations, the myristic acid is considered to be four times more atherogenic than the other fatty acids. Thus the coefficient 4 has been assigned to it. The MUFA have been assigned a coefficient of 0.5 because they are less antitherogenic than the ω-3 fatty acids, which have been assigned a coefficient of 3. Therefore, these indices can indicate if a food is suitable for prevention of human cardiovascular disease” (Ulbricht & Southgate 1991). In the present study lauric acid (C12:0) was not detected in both samples so, it was not included in the calculations.

Polyene index (PI) is a useful index for determination of lipid oxidation and calculated according to Jeong *et al.* (1990).

PI = EPA+DHA/C16:0

Statistical analyses

Analyses were carried out triplicate for each sample of two treatments and the results were presented as mean and standard deviation. To find quantitative relationship, Pearson correlation coefficient and linear regression analysis were used. An unpaired t-test using the Statistical Package for the Social Sciences (SPSS) software release 19.0.0 (SPSS Inc, Chicago, IL., USA) at a significant level of $P < 0.05$ were used.

RESULTS

Proximate composition

The proximate compositions of the beluga caviar, from both wild and farmed are presented in Fig. 1. Results showed that in wild and farmed samples crude protein, crude lipid, moisture and ash were 26.56 ± 0.11% and 26.37 ± 0.65%, 16.06 ± 0.16% and 16.35 ± 0.18%, 51.26 ± 0.21% and 51.40 ± 0.28% and also 5.00 ± 0.95% and 4.85 ± 0.06% respectively. The results showed that there was no significant differences between them ($P>0.05$).

Fatty acid composition and nutritional quality indices

The percentages of the fatty acids of wild and farmed beluga caviar samples are listed in Table 1. Despite the differences in fatty acid composition of the total lipids found in wild and farmed samples including, total ω-6, total ω-9, the ratio of ω-3/ω-6, docosahexaenoic acid/eicosapentaenoic acid (DHA/EPA) and arachidonic acid/ eicosapentaenoic acid (ARA/EPA) ($P < 0.05$), there were no significant differences among saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), highly unsaturated fatty acids (HUFA), unsaturated fatty acids (UFA), total ω-3, EPA+DHA and also atherogenic (AI), thrombogenic (TI) and polyene (PI) indices ($P>0.05$). The PUFAs were found to be the major fatty acids in both caviar samples followed by SFAs and MUFAs. The most abundant saturated fatty acid (SFA) in both samples was palmitic acid (C16:0) comprising 19.52 ± 0.22% and 19.40 ± 2.03% in wild and farmed samples respectively ($P>0.05$). Among monounsaturated fatty acids (MUFA) the oleic acid (C18:1n-9) was the most abundant one, consisting of 16.09 ± 0.02% and 18.76 ± 0.51% in wild and farmed samples respectively ($P > 0.05$). Docosahexaenoic acid (C22:6n-3) by 23.88 ± 0.2% and 23.75 ± 2.22% was the main PUFAs in wild and farmed samples respectively ($P > 0.05$) (Table 1). In wild samples after (DHA) the amount of arachidonic acid (C20:4n-6) followed by eicosapentaenoic acid (C20:5n-3) were the main PUFAs, however, in farmed samples, linoleic (C18:2n-6) and then arachidonic (C20:4n-6) acids were the main PUFAs after (DHA) ($P < 0.05$) (Table 1). Total ω-3 in wild and farmed samples were 38.42 ± 0.31% and 30.42 ± 2.51% respectively with no significant difference ($P>0.05$) between them.

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However, the ω-6 levels were 13.27 ± 0.04 % and 17.39 ± 0.05% which was significantly different (P<0.05) (Table 2). It was also true for the ω-3/ω-6 ratios which were 2.90 ± 0.04 in wild and 1.75 ± 0.14 in farmed samples (P<0.05). The sum of EPA+DHA was not different between two samples, while the DHA/EPA and ARA/EPA ratios were higher in farmed samples (P < 0.05) (Table 3). The AI (0.29 ± 0.01 and 0.28 ± 0.04) and TI (0.18 ± 0 and 0.21 ± 0.03) contents in wild and farmed samples were not significantly different from each other (Tables 3). Also, it was true for PI content (1.73 ± 0.04 and 1.46 ± 0.28) (P>0.05) (Table 2).

Table 1. Fatty acids profile in wild and farmed beluga caviar (g per 100 g of fatty acids)

Fatty acid	Wild beluga	Farmed beluga
C14:0 (Myristic acid) †	0.44 ± 0.05 ᵃ	0.15 ± 0.01 ᵃ
C15:0 (Pentadecanoic acid) †	0.62 ± 0.03 ᵃ	0.09 ± 0.02 ᵇ
C16:0 (Palmitic acid) †	19.52 ± 0.22 ᵃ	19.4 ± 2.03 ᵃ
C17:0 (Heptadecanoic acid) †	0.81 ± 0 ᵃ	0.31 ± 0.02 ᵇ
C18:0 (Stearic acid) †	3.75 ± 0 ᵃ	4.59 ± 0.08 ᵇ
C20:0 (Arachidic acid) †	0 ± 0 ᵃ	1.18 ± 0.04 ᵇ
C21:0 (Heneicosanoic acid) †	0 ± 0 ᵃ	0.23 ± 0.01 ᵇ
C22:0 (Docosanoic acid) †	0 ± 0 ᵃ	0.22 ± 0.01 ᵇ
C23:0 (hexacosanoic acid) †	0.28 ± 0 ᵃ	0.37 ± 0.01 ᵇ
C16:1 (Palmitoleic acid) ‡	2.71 ± 0.06 ᵃ	0.74 ± 0.08 ᵇ
C17:1 (Heptadecanoic acid) ‡	0.41 ± 0.01 ᵃ	0.06 ± 0.01 ᵇ
C18:1n-9 (Oleic acid) ‡	16.09 ± 0.02 ᵃ	18.76±0.51 ᵃ
C20:1 (Eicosenoic acid) ‡	0.32 ± 0.01 ᵃ	1.02 ± 0.04 ᵇ
C24:1n-9 (Nervonic acid) ‡	1.67 ± 0.02 ᵃ	2.25 ± 0.2 ᵃ
C18:2n-6 (Linoleic acid) §	0.37 ± 0.01 ᵃ	8.32 ± 0.23 ᵇ
C20:2 (Eicosadienoic acid) §	0.49 ± 0.03 ᵃ	1.26 ± 0.07 ᵇ
C22:2n-6 (Docosadienoic acid) §	0.77 ± 0 ᵃ	0 ± 0 ᵇ
C18:3n-3 (Linolenic acid) §	0.39 ± 0.02 ᵃ	0.76 ± 0.01 ᵇ
C20:3n-6 (Eicosatrienoic acid) §	0.27 ± 0.02 ᵃ	2.19 ± 0.09 ᵇ
C20:4n-6 (Arachidonic acid) §	11.86 ± 0.07 ᵃ	6.88 ± 0.2 ᵇ
C20:5n-3 (Eicosapentaenoic acid) §	9.85 ± 0.06 ᵃ	4.61 ± 0.16 ᵇ
C22:5n-3 (Docosapentaenoic acid) §	4.3 ± 0.03 ᵃ	1.3 ± 0.14 ᵇ
C22:6n-3 (Docosahexaenoic acid) §	23.88 ± 0.2 ᵃ	23.75 ± 2.22 ᵃ

Values are the Mean ± SD. Within the same row, values with different superscripts are significantly different (P ≤ 0.05).
† SFA: Saturated fatty acids, ‡ MUFA: monounsaturated fatty acids, §PUFA: Polyunsaturated fatty acids.

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 401~413 Received: Jan. 30 2021 Accepted: June 07. 2021
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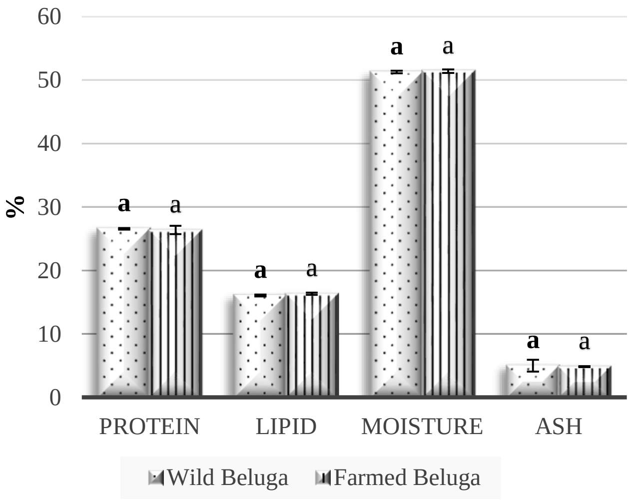

Fig. 1. Proximate composition of wild and farmed beluga caviar (%)Values are the Mean ± SD. Within the columns, values with different superscripts are significantly different ($P \leq 0.05$).

In addition, high correlation coefficient (R^2=0.5716) for linear regression (y = 46.505x + 12.48) was observed between saturated fatty acids (SFA) and atherogenic index (Fig. 2), while correlation coefficient of (R^2 = 0.0293) for linear regression (y = -17.124x + 77.227) between unsaturated fatty acids and atherogenic index (Fig. 3) and correlation coefficient (R^2 = 0.0145) for linear regression (y = -15.625x + 54.88) between polyunsaturated fatty acids and atherogenic index (Fig. 4) in wild and farmed samples were not positive. Similarly, there was high correlation coefficient (R^2 = 0.6499) for linear regression (y = 36.147x + 18.757) between saturated fatty acids (SFA) and thrombogenic index (Fig. 5), while the correlation coefficient of (R^2 = 0.7384) for linear regression (y = -62.687x + 84.478) between unsaturated fatty acids and thrombogenic index (Fig. 6) and correlation coefficient of (R^2 = 0.9019) for linear regression (y = -89.922x + 67.834) between polyunsaturated fatty acids and thrombogenic index (Fig. 7) in wild and farmed beluga caviars were not positive.

Table 2. Comparison of fatty acid series in wild and farmed beluga caviar (%).

Fatty acid series	Wild beluga	Farmed beluga
SFA	25.42 ± 0.3 [a]	26.54 ± 2.2 [a]
MUFA	21.20 ± 0 [a]	22.83 ± 0.36 [a]
PUFA	52.18 ± 0.3 [a]	49.07 ± 2.63 [a]
HUFA	49.89 ± 0.22 [a]	36.54 ± 2.72 [a]
UFA	73.38 ± 0.3 [a]	71.90 ± 2.26 [a]
Total ω-3	38.42 ± 0.31 [a]	30.42 ± 2.51 [a]
Total ω-6	13.27 ± 0.04 [a]	17.39 ± 0.05 [b]
Total ω-9	17.76 ± 0.04 [a]	21.01 ± 0.31 [b]
UFA/SFA	2.89 ± 0.04 [a]	2.71 ± 0.31 [a]
ω-3/ω-6	2.90 ± 0.04 [a]	1.75 ± 0.14 [b]
PI (EPA+DHA/C16:0)	1.73 ± 0.04 [a]	1.46 ± 0.28 [a]

Values are the Mean±SD. Within the same row, values with different superscripts are significantly different ($P \leq 0.05$). SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids, HUFA: highly unsaturated fatty acids, UFA: unsaturated fatty acids, PI: polyene index.

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Table 3. Lipid quality indices (LQI) in wild and farmed beluga caviar

Lipid quality index	Wild beluga	Farmed beluga
PUFA/SFA	2.05 ± 0.04 [a]	1.85 ± 0.25 [a]
UFA/SFA	2.89 ± 0.04 [a]	2.71 ± 0.31 [a]
ω-3/ω-6	2.9 ± 0.04 [a]	1.75 ± 0.14 [b]
ARA/EPA	1.20 ± 0.01 [a]	1.49 ± 0.01 [b]
EPA+DHA	33.73 ± 0.26 [a]	28.36 ± 2.39 [a]
DHA/EPA	2.42 ± 0.01 [a]	5.15 ± 0.3 [b]
AI	0.29 ± 0.01 [a]	0.28 ± 0.04 [a]
TI	0.18 ± 0 [a]	0.21 ± 0.03 [a]

Values are the Mean±SD. Within the same row, values with different superscripts are significantly different ($P \leq 0.05$). SFA: saturated fatty acids, PUFA: polyunsaturated fatty acids, UFA: unsaturated fatty acids, EPA: eicosapentaenoic acid, DHA: docosahexaenoic acid, ARA: arachidonic acid, AI: atherogenic Index, TI: thrombogenic Index. Lauric acid (C12:0) was not detected in both samples so, it was not included in the calculations.

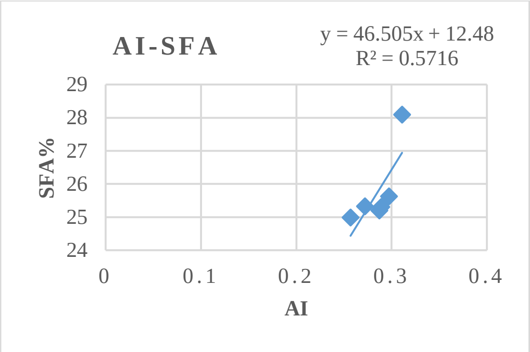

Fig. 2. Correlation between saturated fatty acids and atherogenic index in wild and farmed beluga caviar.

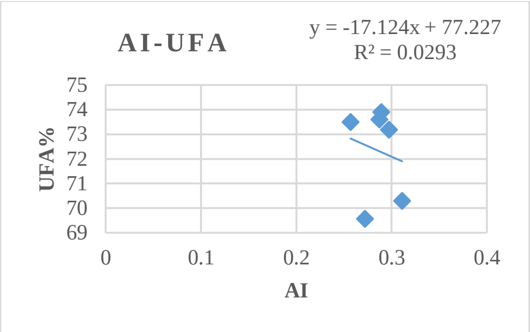

Fig. 3. Correlation between unsaturated fatty acids and atherogenic index in wild and farmed beluga caviar.

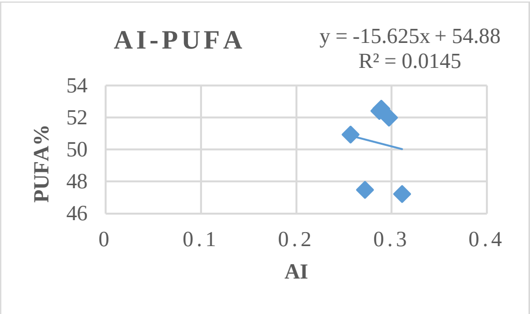

Fig. 4. Correlation between polyunsaturated fatty acids and atherogenic index in wild and farmed beluga caviar.

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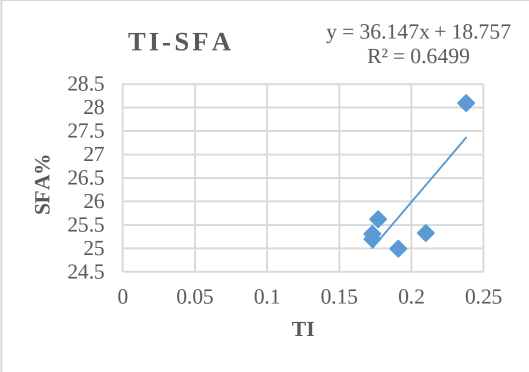

Fig. 5. Correlation between saturated fatty acids and thrombogenic index in wild and farmed beluga caviar.

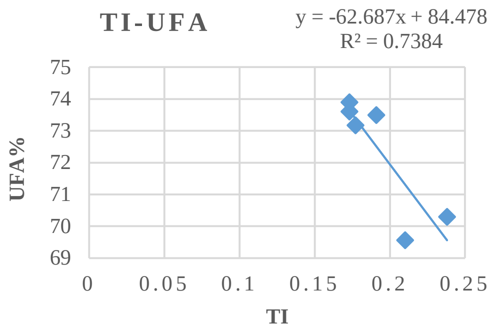

Fig. 6. Correlation between unsaturated fatty acids and thrombogenic index in wild and farmed beluga caviar.

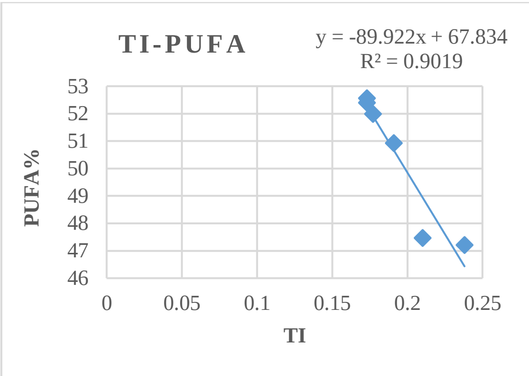

Fig. 7. Correlation between polyunsaturated fatty acids and thrombogenic index in wild and farmed beluga caviar.

DISCUSSION

The proximate compositions of wild and farmed beluga caviars had no significant differences (P>0.05). The results were within the range reported for sturgeon caviars by other authors including Caprino *et al.* (2008); Mol & Turan (2008); Gessner *et al.* (2002); Sternin & Doré (1993) and Rehbein (1985). Ovissipour & Rasco (2011) found no differ between the wild and farmed beluga roes in the protein, lipid, moisture and ash contents which in wild samples were 15.11 ± 0.97, 14.87 ± 1, 64.1± 2.1 and 4.2 ± 0.65 and in farmed ones were 14.56 ± 0.2, 14.55 ± 0.6, 64.83 ± 0.46 and 4.51 ± 0.91 respectively (P > 0.05). The main group among fatty acids in both samples (with 16% total fat) were polyunsaturated followed by saturated and monounsaturated fatty acids (PUFA> SFA > MUFA). The greatest saturated fatty acid (SFA) in both wild and farmed beluga caviars was palmitic acid (C16:0) by 19.52 ± 0.22% and 19.40 ± 2.03% respectively with no significant difference between them (P>0.05). Fatty acid composition of fish lipid extremely depends on some factors, especially fish diets (Fowler *et al.* 1994; Sathivel *et al.* 2002; Şengör *et al.* 2003). Ackman & Eaton (1966) stated that palmitic acid has an important role in several metabolic process in fish and other aquatic animals. Kaya *et al.* (2014) reported that the primary SFA in cultured, *H. huso* is palmitic acid. Mol & Turan (2008) reported that the major SFA in beluga caviar compared

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to other sturgeons was palmitic acid. High contents of palmitic acid (C16:0) in caviar and flesh of sturgeon fish have been reported by Abbas & Hrachya (2015); Li *et al.* (2014); DePeters *et al.* (2013); Gong *et al.* (2013); Ovissipour & Rasco (2011); Abedian Kenari *et al.* (2009); Mol & Turan (2008); Caprino *et al.* (2008); Czesny *et al.* (2000) and Chen *et al.* (1995). Amongst the monounsaturated fatty acids (MUFA) in both caviar samples, oleic acid (C18:1n-9) was the most abundant one. Similar to results obtained by Abbas & Hrachya (2015); Li *et al.* (2014); Ovissipour & Rasco (2011); Caprino *et al.* (2008); Mol & Turan (2008); Czesny *et al.* (2000) and Ashton *et al.* (1993). In the present study, the amount of linoleic acid (C18:2n-6) was higher in farmed beluga caviars than in wild ones ($P<0.05$). Similarly, Ovissipour & Rasco (2011) reported that linoleic acid contents in wild and farmed beluga roes were 0.78 ± 0.05 and 11.42 ± 0.26 % respectively with significant differences with each other ($P<0.05$). Gessner *et al.* (2002), Czesny *et al.* (2000), Silversand *et al.* (1996) and Chen *et al.* (1995) suggested that this reflects fat dietary intake. The same tendency in sturgeon and other fishes was also reported by Gessner *et al.* (2002), Czesny *et al.* (2000), Gallagher *et al.* (1998), Silversand *et al.* (1996) and Chen *et al.* (1995). Freshwater fish species contain much higher contents of C18 fatty acids while low ω-3 EPA and DHA comparision with marine fish (Ackman 1967). The linoleic acid has been used to differentiate the origin of caviars from farmed and wild sturgeons due to its higher content in farm-raised sturgeon caviar than in wild ones. Wirth *et al.* (2000), Wirth *et al.* (2002) and Czesny *et al.* (2000) suggested that, fatty acid analyses can be used to discriminate the origin of sturgeon caviars from wild and farmed fish. The new diets reformulation has led to the similarity of linoleic acid content in farmed caviar to wild ones (Czesny *et al.* 2000).

In marine fish speices the major polyunsaturated fatty acids are eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) (Ackman 1989). EPA is useful in brain disorders and cancer therapy (Fenton *et al.* 2000). DHA is also a major component of brain, eye retina and heart muscle so, it is important for brain and eye development and has important role in cardiovascular health (Ward & Singh 2005). Fish lipids contain a good source of EPA and DHA. Aquatics are well-known to be the major source of PUFAs and humans obtain main part of EPA and DHA from consuming fish, aquatic invertebrates and macro algae (Arts *et al.* 2001). In present study there was not different in the polyunsaturated fatty acids (PUFAs) contents between samples. However, significantly higher levels of eicosapentaenoic (9.85 ± 0.06%), docosapentaenoic (4.30 ± 0.03%) and arachidonic acids (11.86 ± 0.07%) were observed in wild samples than in farmed ones ($P<0.05$). similar to results of Ovissipour &Rasco (2011) and Gessner *et al.* (2002).

DePeters *et al.* (2013) reported that eicosapentaenoic acid (C20:5n-3) was higher in farmed fish eggs ($P<0.05$), while docosahexaenoic (C22:6n-3) and arachidonic (C20:4n-6) acids were not different in farmed white sturgeon, *A. transmontanus* eggs and wild ones. Gong *et al.* (2013) reported that, DHA was significantly higher in *A. baerii* and *A. Schrenckii* than *H. dauricus* ×*A. schrenkii* caviars but EPA did no differ among them.

DHA in the present study was a little lower in farmed than in wild samples, although there was no significant differences between them ($P>0.05$). The sum of EPA+DHA had no differences between two groups. EPA+DHA are known to reduce the risk of cardiovascular disease and inflammation (Breslow 2006; Calder 2006). American Heart Association stated that about 1.0 g/day of EPA+DHA or having two times of fish fatty acids in a week decrease the risk of death from coronary heart disease (Huynh & Kitts 2009). Thus, EPA+DHA is one of the major lipid quality index. Gong *et al.* (2013) found higher EPA+DHA in caviar of *A. baerii* and *A. Schrenckii* than *H. dauricus* ×*A. schrenkii* (Table 4). In present study, the ARA/EPA ratio was significantly higher in farmed than in wild samples ($P<0.05$). Freshwater fish are known to process high contents of ω-6 PUFA, especially linoleic (18:2n-6) and arachidonic (20:4n-6) acids, unlike, these fish contain lower concentration of long-chain ω-3 PUFA than marine fish (Özogul *et al.* 2007). Arachidonic acid is one of the important fatty acids for humans. However, it will be harmful if consume excessively (Farooqui *et al.* 1997). Some authors suggest that the ARA/EPA ratio is a better lipid quality index than the ω-3/ω-6 ratio. High ARA/EPA ratio decreases the lipid nutritional benefits of fish oil (Larsen *et al.* 2011). Unsaturated ω-3 PUFAs help to stop blood platelets from sticking to each other (Trubo & Carroll 1997) and reduce the cholesterol level (Potter & Hotchkiss 1995). In present study there was no significantly difference between the amount of total ω-3 in wild beluga caviars (38.42 ± 0.31) than farmed ones (30.42 ± 2.51). The total ω-6 was significantly higher in farmed samples than wild ones. Ovissipour & Rasco (2011) found higher total ω-3 in wild beluga roe than farmed ones (Table 4), Gessner *et al.* (2002) found greater amount of ω-3 in wild stellate, *A. stellatus* caviars than farmed ones, Ashton *et al.* (1993) reported that wild Chinook salmon, *O. tshawytscha* roe contained more ω-3 than farmed ones and Gong *et al.* (2013) reported that the amount of ω-3 was significantly higher in *A. baerii* and *A. Schrenckii* than in *H. dauricus*

Caspian J. Environ. Sci. Vol. 19 No. 3 pp. 401~413 Received: Jan. 30 2021 Accepted: June 07. 2021
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×*A. schrenkii* caviar and the amount of ω-3 was higher rather than ω-6 in all samples which have been examined by Mol & Turan (2008; Table 4). The higher content of total ω-3 to ω-6 causes more energy accumulation and better health situation in fishes. Also the content of PUFAs, ratio of ω-3/ω-6 acids is well known to have dietetic importance due to their key role in synthesis balancing of eicosanoids in creatures (Steffens 1997). Consequently, the ratio of ω-3/ω-6 in this study was higher in wild beluga samples than farmed beluga caviars (P<0.05). Similarly, Ovissipour & Rasco (2011) stated that, the ω-3/ω-6 ratio was significantly higher in wild beluga roe than farmed one and Gong *et al.* (2013) found no differ in ω-3/ω-6 among the samples (Table 4).

Table 4. Fatty acid series in wild and farmed beluga caviar and other sturgeon caviars as well as bony fishes roes (%)

Fishes	SFA	MUFA	PUFA	UFA	UFA/ SFA	EPA+DHA	DHA/EPA	ω-3	ω-6	ω-3/ ω-6	References
Beluga (*Huso huso)* Wild	25.42	21.20	52.18	73.38	2.89	33.73	2.42	38.42	13.27	2.9	Present study
Beluga (*Huso huso*) Farmed	26.54	22.83	49.07	71.90	2.71	28.36	5.15	30.42	17.39	1.75	Present study
Beluga (*Huso huso)* Wild	33.7	43.45	16.19	59.64	1.76	8.0	1.75	8.82	7.37	1.195	(Ovissipour & Rasco 2011)
Beluga (*Huso huso*) Farmed	32.5	41.68	19.52	61.2	1.88	3.62	1.91	4.64	14.87	0.32	(Ovissipour & Rasco 2011)
Acipenser gueldenstaedti	23.37	41.25	17.93	59.18	2.53	12.22	1.75	12.9	5.03	2.56	(Mol & Turan 2008)
Acipenser persicus	25.45	39.95	21.04	60.99	2.40	15.87	1.95	16.46	4.58	3.59	(Mol & Turan 2008)
Huso huso	23.50	46.50	16.00	62.5	2.65	11.34	2.92	12.10	3.90	3.10	(Mol & Turan 2008)
Acipenser baerii	24.74	38.93	35.61	74.54	3.01	17.41	2.76	18.62	16.40	1.14	(Gong *et al.* 2013)
Acipenser Schrenckii	25.43	42.35	31.27	73.62	2.89	13.21	2.58	14.23	15.83	0.90	(Gong *et al.* 2013)
Huso dauricus ♀×*A. schrenkii* ♂	25.44	43.29	29.52	72.81	2.86	12.87	2.67	14.00	14.89	0.94	(Gong *et al.* 2013)
Acipenser ruthenus	27.87	43.14	28.99	72.13	2.58	16.08	2.42	16.93	11.36	1.49	(Park *et al.* 2015)
Acipenser transmontanus (wild)	24.94	46.9	26.07	72.97	2.92	18.57	3.13	20.66	10.64	1.94	(DePeters *et al.* 2013)
Acipenser transmontanus (farmed)	23.72	37.05	31.35	68.4	2.88	18.01	2.23	20.48	10.49	1.95	(DePeters *et al.* 2013)
Salmo trutta labrax	17.48	24.46	36.73	61.19	3.50	30.08	0.68	32.68	4.05	8.06	(Mol & Turan 2008)
Mugil cephalus	11.26	35.60	20.95	56.55	5.02	15.44	1.53	16.26	4.69	3.47	(Mol & Turan 2008)

EPA: Eicosapentaenoic acid, DHA: Docosahexaenoic acid, ARA: Arachidonic acid, SFA: Saturated fatty acids, MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, UFA: Unsaturated fatty acids.

Ulbricht & Southgate (1991) suggested two indices including AI (atherogenic index) and TI (thrombogenic index) that might better characterize the atherogenic thrombogenic potential of fatty acids than other indices. The atherogenic (AI) and thrombogenic (TI) indices among different fatty acids cause an integrated assessment of dietary lipid on human coronary well-being (Ulbricht & Southgate 1991). In the present study, the AI values in wild and farmed samples were 0.29 and 0.28 while, TI were 0.18 and 0.21 respectively, albeit both with no significantly differences (P > 0.05). The results using the Pearson Correlation Coefficient showed that there was

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a positive significant association between the amount of saturated fatty acids and AI and TI indices. On the contrary, the amount of AI and TI indices decreased due to increase in UFA and PUFA in caviars (Figs. 2, 3, 4, 5, 6 and 7). According to high amount of valuable unsaturated fatty acids in both two groups AI and TI contents are enough for human health and cardiovascular benefits. Higher values of AI and TI (>1.0) are harmful to human health (Bobe *et al*. 2004). Thus, less values of these indices indicate the better nutritional quality. Valfré *et al.* (2003) reported that AI and TI values were 1.35 and 0.45 for anchovy, 0.94 and 0.32 for eel, 0.57 and 0.37 for rainbow trout, 0.45 and 0.25 for sea bass respectively. Rueda *et al.* (1997) also reported that AI and TI values were 0.4 and 0.2 in wild red porgy and 0.2 and 0.5 in farmed red porgy respectively.
The EPA+DHA/C16:0 ratio (polyene index) is a useful index for determination of lipid oxidation (Jeong *et al.* 1990). In the present study PI value in wild and farmed beluga caviar samples were 1.73 and 1.46 respectively (P>0.05). Taheri *et al.* (2012) stated that the PI content in Cobia, *Rachycentron canadum* fillet was 0.27 which decreased to 0.12 during frozen storage, Nazemroaya *et al.* (2009) reported that this ratio has been decreased (55.55 and 46.66%) in mackerel and shark, during frozen storage respectively, suggesting that oxidation is active during freezing. Also, Hedayatifard and Hassani Moghadam (2016) worked on *Cyprinus carpio* and determined that PI ratio was 0.27 in fresh, smoked and 30th days after production.

CONCLUSION
The fatty acids profile of beluga caviars have the potential to distinguish wild caviars versus farmed ones and can be used as an index to determine fish origin and diet. Both samples were good-balanced with unsaturated fatty acids, so, it can be said that, the farmed beluga caviar like wild ones could be considered as a good food sources and has cardiovascular protective benefits due to its proper lipid quality indices.

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