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Research Paper

Assessment of the relationship between nutritional quality indices of beluga sturgeon (*Huso huso*) fillets and frying with different vegetable oils

Ali Hasanpour Ardekanizadeh[1] • Seyed Vali Hosseini[1]* • Reza Tahergorabi[2]* • Zahra Hoseinabadi[3] • Xesus Feas Sanchez[4]

[1]Department of Fisheries, Faulty of Natural Resources, University of Tehran, Karaj, Iran.
[2]Department of Family and Consumer Sciences, Food and Nutritional Sciences, North Carolina A&T State University, Greensboro, NC 27411.
[3]Health and Food Safety, Faculty of Health, Qazvin University of Medical Sciences, Iran.
[4]Academy of Veterinary Sciences of Galicia, Edificio EGAP, Santiago de Compostela (A Coruña), Spain.

*Corresponding author. E-mail: hosseinisv@ut.ac.ir; rtahergo@ncat.edu

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Abstract. The influences of frying on fatty and amino acids profile and nutritional quality indices of Beluga sturgeon fillets were investigated by using four different vegetable oils (canola, sunflower, soybean, and olive oil). The fatty acid composition of the fillets is affected by the type of frying oil. Oleic acid, palmitic acid, and docosahexaenoic acid were the most abundant fatty acid in raw Beluga sturgeon. After frying, the oleic acid content in fillets fried with olive oil was higher than in other vegetable oils ($p < 0.05$). Fillets that were fried in olive and canola oil had a significantly higher content of MUFA in comparison with the others. Fillets that were fried in sunflower and soybean oils had the highest amount of PUFA. The DHA/EPA and n6/n3 ratios of sunflower oil were higher than in the other samples. Frying reduced the total amino acid contents, with the lowest values obtained in samples fried in sunflower oil. The content of essential amino acids was reduced in all samples, but in olive oil, this reduction was lower than in the others. Finally, the content of PUFA in sunflower oil makes it suitable for consumption, but it is also desirable to use olive oil by considering the difference in total amino acid reduction.

Keywords: Amino acids, fatty acids, fish, frying, *Huso huso*, vegetable oils.

INTRODUCTION

Fish and fishery products are considered important food due to the high content of long-chain polyunsaturated fatty acids (PUFA), such as eicosapentaenoic (EPA) and docosahexaenoic acids (DHA), (Abou-Taleb *et al*., 20121; Genç and Diler, 2019; Kaya *et al*., 2008; Ying *et al.*, 2017). Polyunsaturated fatty acids are valuable sources of healthy oils that are beneficial in the prevention of many health conditions including cardiovascular diseases (Nikoo and Ghomi, 2013). Additionally, seafood products are good sources of essential amino acids (EAA), vitamins, and minerals. However, cooking methods and storage conditions influence the nutritional values of the fish including EAA contents and EPA, DHA levels (Kaya *et al*., 2008; García *et al.*, 2022). Goswami and Manna (2020) reported that boiled fish (*T. ilisha*) had less protein, fat, moisture, and mineral contents as well as amino acid and fatty acid contents than fried samples of fresh and salted fish which indicated the importance of cooking method.

Frying is a simple and quick method of cooking in which the food is heated in a frying medium above the boiling points of water. Although, frying is a popular method of cooking due to its irresistible taste and textural properties,

this method of cooking change the lipid composition of fried product. At the same time, oil is taken up by food which increases its calorie. Additionally, some studies suggest that during frying, oxidation damage occurs in unsaturated fatty acids, but when the oil is heated to a temperature of 100°C or more, saturated fatty acids can also be oxidized. Oxidation in frying at 200°C causes damage more easily to oils with a high degree of unsaturation, while hydrolysis is easy to occur in oils with long-chain saturated fatty acids. The oils and fats are used as a means of heat transfer from the fryer to the food. Hydrogenated oils have two certain drawbacks: a. high amounts of trans fatty acids and b. low sensory scores of fried products in comparison to vegetable oils, because of an unpleasant taste and smell (Nieva-Echevarria *et al*., 2016).

Susceptibility to lipid oxidation, hydrolysis and polymerization in oils during the frying process depends upon the fatty acid unsaturation levels, as well as antioxidant components of that respective oil, the temperature and time of frying, type of cooking oil, and the type of frying pan used (Abou-Taleb *et al*., 20121; Nikoo and Ghomi, 2013). For instance, most vegetable oils are rich in mono and polyunsaturated whereas foods fried in animal fats will be enriched in saturated fatty acids (Chiou and Kalogeropoul, 2017; Ekiz and Oz, 2019). Therefore, the use of different fat sources for frying, results in different effects on the oxidative stability of the treated products, especially under household conditions (Genç and Diler, 2019).

There have been many studies on the nutritional properties of vegetable oils. For example, Kocatepe *et al*. (2019) reported nutritional information for the fried mussels in sunflower oil used by the local restaurant, the MUFA content increased with the effect of frying oils and the content of EPA and DHA in the mussel was significantly reduced by the effect of frying. Also, Oluwaniyi *et al*. (2017), in another study, evaluated the proximate composition, amino acid, and fatty acid contents of the fried Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) fillet in the palm, groundnut, soybean, and refined palm oil and their results indicated that only samples fried in palm oil had significantly lower essential amino acid compared to other samples fried in different vegetable oils (Oluwaniyi *et al.*, 2017).

Beluga sturgeon (*Huso huso*) is one of the largest farmed sturgeon species which grow fast. Their major habitat is the Caspian Sea. They have tasty meat rich in protein with high biological value and with medium fat content. However, they are good sources of minerals and vitamins, and Caviar is extracted from them (Badiani *et al*., 1996).

Although there is little published literature on the effects of cooking methods on the fatty acid and mineral composition of several fish species (Gladyshev *et al.*, 2006; Weber *et al.*, 2008), there is little information about the effects of different cooking vegetable oils on fried fishes. Hence, the main objective of this study was to investigate the effects of different vegetable oils (canola oil, sunflower oil, soybean oil, and olive oil) on the fatty acid and amino acid profiles of Beluga sturgeon.

MATERIALS AND METHODS

Sample preparation

About 5 kg of frozen Beluga sturgeon fillet was bought from Mazandaran sturgeon fishery station, located in Babolsar (Mazandaran province, Iran) in March 2021. The unfrozen and fresh fish (~37.9 kg) had been caught using Gill nets and then gutted, washed, and cut into pieces under hygienic conditions. After receiving the samples in the laboratory (within 1.5 h in chilled condition), fillets were washed with cold water and then sliced with a clean knife.

Frying with different vegetable oils and analysis

In this study, canola, soybean, sunflower, and olive oil were used for the frying fish fillets. A fryer machine (Model FR-2012, Pars Khazar Co., Iran) was used for frying the samples. For each treatment, the oil temperature was adjusted to 150°C in the fryer and then a sliced fillet (with a thickness of 20 ± 2 mm) was put in the fryer and cooked (deep frying method) for up to 5-6 min. To separate the excess oils from the samples and also to reduce to sample temperature to ambient temperature (approximately 23°C), the samples were placed on a clean plate in the laboratory for 20 min. Then samples were packed and kept at -24°C before proximate analysis and at -80°C before fatty and amino acid analysis (Nalan *et al.*, 2004).

The AOAC method (2005), was used for the determination of proximate composition (moisture, protein, lipid and ash). Moisture was determined by drying the samples in an electric oven (Parmehr, Iran) at 105°C to constant weight; protein was determined by the Kjeldahl method (N × 6.25) and lipids were extracted with hexane (hexane extracted lipid) using an automatic Kjeldahl and Soxtec system, respectively. Samples were incinerated in a muffle furnace at 550°C for 4 h for ash determination.

The fatty acid composition and amino acid profile were assayed by methods described by Fritsche and Johnston (1990) and Deng *et al*. (2004), respectively, and explained in our previous work (Abedian-Kenari *et al*., 2009). Briefly, total lipids of each sample were extracted by using chloroform: methanol (2:1, v/v) as a lipid solvent (Folch *et al*., 1957). Then and for the preparation of fatty acid methyl esters (FAMEs), lipids from each treatment were transmethylated by using 20% methanolic boron trifluoride (BF3, Merck, Darmstadt, Germany). Afterward, FAMEs were analyzed using a Phillips GC-PU4400 (Phillips Scientific, Cambridge, UK) equipped with a fused silica capillary polar column (BPX70, 60 m × 0.32 mm ID, 0.25-

Table 1. Proximate composition (% wet weight) of raw and fried Beluga sturgeon (*Huso huso*) fillet with different vegetable oil[1&2].

Sample	Moisture	Protein	Lipid	Ash
Raw	70.6 ± 1.31[a]	18.6 ± 0.42[b]	8.75 ± 0.41[b]	1.24 ± 0.04[b]
COF	62.1 ± 1.21[b]	22.8 ± 0.9[a]	14.3 ± 1.52[a]	1.79 ± 0.08[a]
SfOF	61.6 ± 2.03[b]	23.2 ± 1.04[a]	15.2 ± 1.64[a]	1.83 ± 0.13[a]
SbOF	61.4 ± 2.41[b]	23.5 ± 0.79[a]	15.5 ± 1.08[a]	1.64 ± 0.07[a]
OOF	62.2 ± 1.89[b]	22.9 ± 1.42[a]	13.4 ± 1.47[a]	1.68 ± 0.11[a]

[1] Mean weight of experimental fish was ~37.9 kg and each value represents the mean of six replication.
[2] COF: Beluga sturgeon fillet fried in canola oil, SfOF: Beluga sturgeon fillet fried in sunflower oil, SbOF: Beluga sturgeon fillet fried in soybean oil, OOF: Beluga sturgeon fillet fried in olive oil.

µm film thickness, SGM, Victoria, Australia) and a flame ionization detector (FID).

For the determination of amino acid (AA) content in the experimental samples, a de-lipidation stage in 2:1 chloroform: methanol solution was done before the beginning of the analysis (Abedian-Kenari *et al*., 2009). In this investigation, the Pico Tag method was used for determining amino acid content (Deng *et al*., 2004). Briefly, experimental samples were hydrolyzed in evacuated sealed ampoules with 6 M hydrochloric acid for 22 h at 110°C, then dried in vacuum condition. Dried samples were derivatized with phenylisothiocyanate (PITC) to produce phenylthiocarbamide (PTC) amino acids. The resulting PTC amino acid was dissolved in a 250-*µ*L solution of acetonitrile: water (7:2). Afterward, 20 *µ*L of the solution was analyzed using a reverse-phase HPLC (Perkin-Elmer Co., Seri 200, USA) equipped with a C_{18} core-shell column (Kinetex 5u EVO C18 150×4.6 mm; Phenomenex Co, USA) at a constant wave-length (338 nm).

Statistical analysis

In this study, a one-way analysis of variance (ANOVA) was used for the mean comparison of obtained data. First, all the data were evaluated for homogeneity of variances at a significant level of $P < 0.05$, and probability values <0.05 were considered statistically significant. Microsoft Excel (version 2016) and SPSS (version 15) computer programs were used for statistical analysis.

RESULTS AND DISCUSSION

Proximate compositions of slices of fried Huso huso in different vegetable oils

Frying causes many chemical and physical changes to the oil as well as the fried food (Chiou and Kalogeropoulos, 2017; Delfieh *et al.*, 2013; Nalan *et al.*, 2004). Table 1 shows the effect of different frying vegetable oils on *Huso huso* fillets' proximate compositions. The moisture contents of Beluga fillets range from 70.6% in raw fish to 61.4% in the sample fried in soybean oil. The moisture content of raw Beluga sturgeon dropped significantly ($P < 0.05$) after frying in all treatments that relate to the denaturation of protein structure and evaporation of water within frying (Delfieh *et al*., 2013), but the protein and lipid contents of fried fillets elevated significantly ($P<0.05$) due to the oil permeation after evaporating water within frying, the total lipid content of the fillet samples was reversely pertaining to the moisture content (Koubaa *et al*., 2012). Due to over-frying, plenty of moisture is lost, and the proportion of protein is increased. This is important since fish are a great source of food protein and the cooking method should not have an adverse effect on the protein content or the quality of the product (García *et al.*, 2022). The cooking method that was used in this study did not reduce the protein content of the fish. There was no significant difference in the ash content among raw and frying samples. Albeit, there were no significant differences found between other samples with various vegetable oils. These results are in agreement with those reported by Golgolipour *et al.* (2019) for grass carp (*Ctenopharyngodon idella*) and Hosseini *et al.* (2014) for Kutum roach (*Rutilus frisii kutum*).

Fatty acid composition and nutritional quality indices of slices fried in different vegetable oils

Many factors including nutrition, geographical region, season, body length, environmental temperature, and lipid content may impact the fatty acid profile of the fish and shellfish (Abou-Taleb *et al*., 20121; Delfieh *et al*., 2013) The fatty acid profile of the Beluga sturgeon fillet was significantly affected by the type of vegetable oil treatment. Prominent fatty acid content (% of total fatty acids), and contents of the fatty acid groups, and nutritional quality indices in raw and Beluga sturgeon fried in different vegetable oils are shown in Tables 2 and 3, respectively. The major fatty acids found in raw fillets were oleic acid (24.7%), Palmitic acid (19.2%), DHA (11.7%), and calculated for 55.6% of total fatty acids. EPA and DHA contents were reduced after frying with vegetable oils. The DHA/EPA ratio in raw fish was 2.26 (Table 3). Kocatepe *et al.* (2019) also reported that the content of EPA and DHA

Table 2. Prominent fatty acid content (% of total fatty acids) in raw and fried Beluga sturgeon (*Huso huso*) in different vegetable oils[1].

Fatty acid (%)	Raw fish	COF	SfOF	SbOF	OOF
C14:0	3.13 ± 0.12^{a}	3.01 ± 0.42^{a}	1.38 ± 0.03^{c}	2.09 ± 0.01^{b}	2.11 ± 0.07^{b}
C15:0	0.61 ± 0.01^{a}	0.35 ± 0.03^{b}	0.64 ± 0.02^{a}	0.27 ± 0.03^{c}	0.00^{d}
C16:0	19.19 ± 0.55^{a}	8.31 ± 0.18^{d}	8.64 ± 0.10^{d}	11.35 ± 0.3^{c}	13.82 ± 0.09^{b}
C18:0	8.42 ± 0.25^{a}	6.68 ± 0.17^{c}	4.79 ± 0.22^{d}	7.21 ± 0.07^{b}	6.17 ± 0.06^{c}
C20:0	0.40 ± 0.02^{b}	0.62 ± 0.04^{a}	0.34 ± 0.02^{c}	0.21 ± 0.04^{d}	0.36 ± 0.02^{bc}
C22:0	1.36 ± 0.25^{a}	1.21 ± 0.34^{a}	0.86 ± 0.04^{b}	1.41 ± 0.04^{a}	0.10 ± 0.01^{c}
C16:1	2.79 ± 0.26^{a}	1.86 ± 0.15^{b}	1.06 ± 0.04^{c}	1.93 ± 0.08^{b}	2.41 ± 0.39^{a}
C18:1n-9	24.68 ± 0.44^{e}	47.32 ± 0.17^{b}	29.69 ± 0.23^{c}	28.41 ± 0.16^{d}	54.78 ± 0.4^{a}
C20:1n-9	1.68 ± 0.17^{a}	0.89 ± 0.04^{d}	0.79 ± 0.05^{d}	1.21 ± 0.08^{b}	1.03 ± 0.02^{c}
C18:2n-6	5.03 ± 0.04^{d}	17.79 ± 0.4^{c}	42.04 ± 0.18^{a}	36.64 ± 0.08^{b}	3.17 ± 0.32^{e}
C18:3n-3	5.57 ± 0.21^{a}	3.43 ± 0.07^{c}	1.42 ± 0.07^{e}	3.03 ± 0.09^{d}	4.02 ± 0.02^{b}
C20:3n-3	0.81 ± 0.06^{a}	0.000^{c}	0.41 ± 0.07^{b}	0.000^{c}	0.75 ± 0.03^{a}
C20:4n-6 (Arachidonic acid)	2.06 ± 0.03^{a}	0.63 ± 0.04^{c}	1.06 ± 0.03^{b}	0.000^{d}	0.72 ± 0.04^{c}
C20:5n-3 (Eicosapentanoic acid)	5.17 ± 0.01^{a}	1.65 ± 0.05^{b}	0.89 ± 0.05^{d}	1.46 ± 0.09^{c}	1.45 ± 0.04^{c}
C22:6n-3 (Decosahexanoic acid)	11.73 ± 0.14^{a}	2.09 ± 0.03^{d}	2.27 ± 0.02^{c}	2.35 ± 0.07^{c}	3.11 ± 0.16^{b}
Total	94.64 ± 0.68^{c}	95.84 ± 0.28^{b}	96.28 ± 0.31^{b}	97.57 ± 0.34^{a}	93.9 ± 1.08^{b}

[1]For abbreviations see Table 1

in the mussel was significantly decreased by the effect of frying. All vegetable oils significantly reduced the content of total n-3. It seems that the frying method has the most determinantal effect on reducing the total n-3 content. The effect of frying with different vegetable oils on the reduction of n-3 depends on the fatty acid combination and their susceptibility to oxidation (Halvorsen and Blomhoff, 2011; Idun-Acquah *et al.*, 2016). A high amount of PI (peroxidisability index) implies a higher sensitivity of fatty acids to oxidation. The PI index value of 151.6 was obtained in this study. This index was significantly degraded to 50.6 in fried fillets in olive oil and also PI values for Hosseini *et al.* (2014) study were 170.8. Saturated fatty acids (SFAs) were the main type of fatty acids followed by PUFAs and monounsaturated fatty acids (MUFAs), respectively. The SFA content after frying with vegetable oils decreased, MUFA has a useful effect on health by enhancing high-density lipoprotein cholesterol (HDLC). MUFAs are chiefly existing in vegetable oils, consisting of peanut, mustard, olive, and canola, and are also found in high ratios in animal fats. The MUFAs content increased significantly ($p < 0.05$), especially in olive oil and canola oil; This increase is due to the higher content of oleic acid (C18:1 n-9) in olive and canola oil. In other words, olive oil is rich in MUFA, C18:1 n-9 containing 798 g kg^{-1} total fatty acids. No significant increase was observed in the content of MUFA when fish fillets were fried with sunflower and soybean oil. Enhancement in the content of oleic acid in fried fillets in olive and canola oil as a consequence of frying is described, by the much lower oxidation rate of oleic acid than that of linoleic and linolenic acids and by the exchange of PUFA to oleic acid, which is more stable. In addition, the increased content of oleic and linoleic fatty acids after the frying process probably can be caused by the mixing of oleic and linoleic acids from the oil and the decrease in water content (Ekiz and Oz, 2019). The content of PUFA in olive oil was even lower than the other vegetable oils (Table 3). Moreover, the content of omega-3 PUFAs in total fatty acids was 23.3%, offering a good source of omega-3 PUFAs for Beluga sturgeon.

Sunflower which is a good source of linoleic acid is a very popular oil in Iran. Frying in sunflower oil made a higher increase of PUFA n-6 content in comparison with other vegetable oil due to the higher content of n-6 in sunflower oil. Because of oil absorption during frying, the high level of linoleic acid in the fried fillets was related to the fatty acid composition of sunflower oil. Also, the fatty acid composition of soybean oil was dominated by linoleic acid and the amount of this fatty acid showed a significant increase after frying and reached 36.6% of the total fatty acids (Table 2). Meanwhile, when canola oil was used, the amount of this fatty acid decreased significantly and reached 17.8% of the total fatty acids. Frying caused a significant reduction of arachidonic acid. This can be caused by oxidative decomposition of unsaturated fatty acids during the heating process at high temperatures, which is more prone to occur because the double bonds are more susceptible to attack by oxygen. These results are supported by Nikoo and Ghomi (2013), who reported the same results about MUFA and PUFA content of farmed great sturgeon.

In humans, every chronic illness and disorder is nearly relevant to high levels of hazardous factors, including C-reactive protein, tumor necrosis factor, thromboxane A2, leukotriene B4, and many others (Nikoo and Ghomi, 2013). Consumption of omega-6 fatty acids enhances these factors, while omega-3 intake has a preventive effect. The omega-6 to omega-3 ratio is a substantial

Table 3. Contents of the fatty acid groups (as percentage) and nutritional quality indices (NQI) of raw and fried Beluga sturgeon fillets in different vegetable oils[1].

Fatty acid (%)[2]	Raw fish	COF	SfOF	SbOF	OOF
∑SFA	33.12 ± 0.21[a]	20.18 ± 0.34[b]	16.65 ± 0.11[c]	22.54 ± 0.43[b]	22.46 ± 0.71[b]
∑PUFA	30.37 ± 0.05[c]	25.59 ± 0.01[d]	48.09 ± 0.03[a]	43.48 ± 0.1[b]	13.22 ± 0.23[e]
∑MUFA	29.15 ± 0.7c	50.07 ± 0.31[b]	31.54 ± 0.43[c]	31.55 ± 0.1[c]	58.22 ± 0.6[a]
∑PUFA-n3	23.28 ± 0.14[a]	7.17 ± 0.03[b]	4.99 ± 0.01[c]	6.84 ± 0.1[bc]	9.33 ± 0.19[b]
∑PUFA-n6	7.09 ± 0.01[d]	18.42 ± 0.21[c]	43.1 ± 0.65[a]	36.64 ± 0.5[b]	3.89 ± 0.03[e]
n6/n3	0.3 ± 0.01[d]	2.56 ± 0.09[c]	8.63 ± 0.2[a]	5.35 ± 0.1[b]	0.41 ± 0.03[d]
n3/n6	3.28 ± 0.05[a]	0.38 ± 0.02[b]	0.11 ± 0.3[b]	0.18 ± 0.06[b]	2.39 ± 0.5[a]
TUFA	59.52 ± 0.81[d]	75.66 ± 0.45[b]	79.63 ± 0.31[a]	75.03 ± 0.61[b]	71.44 ± 0.48[c]
SFA/TUFA	0.55 ± 0.1[a]	0.26 ± 0.07[c]	0.2 ± 0.04[c]	0.3 ± 0.06[b]	0.31 ± 0.01[b]
DHA/EPA	2.26 ± 0.39[b]	1.26 ± 0.19[c]	2.55 ± 0.3[a]	1.61 ± 0.31[c]	2.14 ± 0.11[b]
ARA/EPA ratio	0.39 ± 0.01[b]	0.38 ± 0.6[b]	1.19 ± 0.17[a]	0.000	0.49 ± 0.02[b]
PI (Peroxidisability index)	151.61 ± 0.5[a]	55.04 ± 0.14[c]	74.22 ± 0.21[b]	71.04 ± 0.03[b]	50.62 ± 0.4[c]
HH (Hypocholesterolaemic/hypercholesterolaemic ratio)	2.42 ± 0.4[c]	6.44 ± 0.71[a]	7.72 ± 0.34[a]	5.34 ± 0.17[b]	4.22 ± 0.67[b]
AI (Atherogenic Index)	0.53 ± 0.08[a]	0.26 ± 0.03[b]	0.17 ± 0.01[b]	0.26 ± 0.05[b]	0.31 ± 0.04[b]
TI (Thrombogenicity Index)	0.33 ± 0.01[a]	0.32 ± 0.1[a]	0.28 ± 0.14[a]	0.37 ± 0.01[a]	0.36 ± 0.06[a]

[1]For abbreviations see Table 1.
[2]SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; TUFA, total unsaturated fatty acids; ARA, arachidonic acid; EPA, Eicosapentanoic acid; DHA, Decosahexanoic acid.

determinant of health and a lower ratio is favorable for decreasing the risks of chronic illness. The omega-6 to the omega-3 fatty acid ratio in the raw Beluga sturgeon fillets was 0.3. After frying, levels of this ratio increased significantly and reached 2.56, 8.63, 5.35, and 0.41 in fried fillets with canola, sunflower, soybean, and olive oil, respectively (Table 3). An increase in C18:2 fatty acids and a decrease in the levels of n-3 fatty acids in fried Beluga sturgeon slices resulted in an increase in *n*6/*n*3 ratio after frying. The variations in this ratio can also be associated with the basic fat content in raw fish. The *n*-3/*n*-6 ratio in raw Beluga sturgeon was 3.28 (Table 3). The *n*-3/*n*-6 ratio of the fried samples decreased significantly. Despite the decrease in this ratio within frying in various vegetable oils, all samples had an *n*-3/*n*-6 ratio according to the WHO recommended range (Gladyshev *et al.*, 2006; Koubaa *et al.*, 2012; Weber *et al.*, 2008). According to current WHO recommendations, the daily ratio of *n*3/*n*6 in the total human diet should not be more than 1:5, i.e., 0.2. In tissues of marine fish, the *n*3/*n*6 ratio on average varies from 5 to 10, and in freshwater fish from 1 to 4. Some investigators proposed that the ARA/EPA ratio is the best nutritional quality index than the n-3/ n-6 ratio (Delfieh *et al*., 2013; Garcیa *et al.*, 2022). The increase in ARA/EPA ratio decreases the nutritional value of fish oil (Larsen *et al.*, 2011). The frying in different vegetable oils except for sunflower oil had no significant effect on this index. The results are in agreement with the reports of Karimian *et al.* (2016), who reported similar results. Weber *et al.* (2008) indicated that frying in soybean oil resulted in a higher increase of n-6 content in comparison with hydrogenated vegetable oil and canola oil due to the higher total content of n-6 in soybean oil.

In this study, the hypocholesterolemic/hypercholesterolaemic fatty acid ratio (HH) was 2.42 in raw Beluga sturgeon. Frying increased it significantly ($P < 0.05$). In other studies, the ratio of HH was found to range from 0.25 to 3.23 for some other species (Ulbricht and Southgate, 1991). Higher amounts of HH ratio are the most favorable. Ulbricht and Southgate (1991), suggested two indices containing AI (atherogenic index) and TI (thrombogenic index) which might better identify the atherogenic thrombogenic potential of fatty acids than other nutritional quality indices. The lower values of AI and TI indices illustrate the better nutritional quality of fatty acids; therefore, diets with less AI and TI values could decrease the possible risk of coronary heart disease (CHD). In this study, the AI and TI indices of raw fish were 0.53 and 0.33, respectively (Table 3). Frying in different vegetable oils had no significant effect on TI. On the other hand, frying decreased AI significantly. These results of AI and TI were similar to the findings of Rosa *et al.* (2007) in African catfish (*Clarias gariepinus*). They found the lowest AI values in fried samples and TI values of all samples were similar to the raw sample. The results indicated that most of the fatty acids of the fried slices were similar to those of the frying oils. In fact, during the frying technique, a replacement of oil between the food and the frying oil is happening, therefore changing the fat composition of fried foods, becoming resemble the oil used. Furthermore, some literature states that the frying process causes the product to turn golden brown. The

Table 4. Amino acid profile of raw and fried Beluga sturgeon (*Huso huso*) in different vegetable oil.

Amino acid[1]	Raw fish	COF	SfOF	SbOF	OOF
Threonine[2]	4.8 ± 0.14[a]	4.18 ± 0.06[b]	3.04 ± 0.03[c]	4.36 ± 0.26[b]	4.39 ± 0.09[b]
Valine[2]	5.57 ± 0.46[a]	3.84 ± 0.06[c]	2.8 ± 0.29[d]	4.4 ± .07[b]	4.82 ± .04[b]
Methionine[2]	2.47 ± 0.2[a]	1.57 ± .08[c]	1.46 ± 0.28[c]	1.71 ± 0.03[c]	2.08 ± 0.04[b]
Cysteine[2]	0.52 ± 0.04[a]	0.37 ± 0.06b[c]	0.36 ± 0.03[c]	0.53 ± 0.06[a]	0.45 ± 0.04[ab]
Isoleucine[2]	4.99 ± 0.1[a]	3.84 ± 0.09[c]	2.67 ± 0.18[d]	3.67 ± 0.04[c]	4.04 ± 0.03[b]
Leucine[2]	9.22 ± 0.08[a]	7.41 ± 0.22[c]	6.73 ± 0.16[d]	7.56 ± 0.35[c]	8.09 ± 0.1[b]
Phenylalanine[2]	5.05 ± 0.05[a]	4.56 ± 0.14[b]	2.79 ± 0.21[c]	5.04 ± 0.05[a]	4.6 ± 0.17[b]
Lysine[2]	8.23 ± 0.1[a]	6.74 ± 0.07[c]	6.7 ± 0.23[c]	7.25 ± 0.16[b]	7.33 ± 0.13[b]
Tyrosine[3]	2.72 ± 0.15[c]	2.62 ± 0.09[c]	1.28 ± 0.16[d]	4.44 ± 0.25[a]	3.25 ± 0.08[b]
Aspartate[3]	8.48 ± 0.11[c]	10.51 ± 0.12[ab]	8.56 ± 0.41[c]	10.27 ± 0.08[b]	10.71 ± 0.09[a]
Glutamate[3]	15.38 ± 0.09[b]	14.66 ± 0.17[c]	16.58 ± 0.17[a]	14.66 ± 0.05[c]	15.3 ± 0.11[b]
Serine[3]	2.69 ± 0.19[b]	2.02 ± 0.04[c]	1.58 ± 0.12[d]	2.74 ± 0.04[b]	3.37 ± 0.03[a]
Glycine[3]	5.47 ± 0.08[c]	7.25 ± 0.02[a]	5.32 ± 0.36[c]	7.26 ± 0.33[a]	6.79 ± 0.18[b]
Histidine[3]	2.67 ± 0.08[a]	1.49 ± 0.08[c]	0.92 ± 0.05[d]	1.95 ± 0.02[b]	2.05 ± 0.04[b]
Arginine[3]	3.86 ± 0.09[a]	2.43 ± 0.03[d]	1.66 ± 0.05[e]	3.23 ± 0.32[b]	2.85 ± 0.05[c]
Alanine[3]	7.07 ± 0.09[c]	7.51 ± 0.12[b]	7.38 ± 0.23[b]	8.41 ± 0.16[a]	8.24 ± 0.09[a]
Proline[3]	1.92 ± 0.05[a]	1.46 ± 0.12[b]	1.08 ± 0.02[c]	1.44 ± 0.09[b]	1.51 ± 0.09[b]
Total amino acid	91.15 ± 0.65[a]	82.5 ± 0.73[c]	70.96 ± 0.12[d]	89 ± 1.41[b]	89.93 ± 0.53[ab]
% Difference	-	-9.61[b]	-21.3[a]	-3.36[c]	-1.18[d]
Σ EAA[2]	42.9 ± 0.5[a]	34.8 ± 0.57[b]	28.1 ± 0.48[c]	37.9 ± 0.71[b]	38.7 ± 0.49[ab]
% EAA	47.5 ± 0.91[a]	42.6 ± 0.47[b]	39.5 ± 0.8[c]	43.4 ± 0.47[b]	43.4 ± 0.47[b]
Σ NEAA[3]	47.5 ± 0.21[ab]	46.9 ± 0.53[ab]	43 ± 0.11[c]	49.4 ± 0.39[a]	50.6 ± 0.33[a]
%NEAA	52.5 ± 0.84[c]	57.4 ± 64[b]	60.5 ± 0.94[a]	56.6 ± 0.49[b]	56.6 ± 0.19[b]
P-PER	3.4 ± 0.46[a]	2.55 ± 0.12[b]	2.52 ± 0.33[b]	2.35 ± 0.67[c]	2.83 ± 0.17[a]

[1]Tryptophan was not determined. Values (g 100^{-1} g protein) in each row with the same superscripts are not significantly different (Duncan significance level is defined as $P<0.05$). For abbreviations see Table 1.
[2] Essential amino acids for humans
[3] Non-essential amino acids for humans

appearance of this color is due to the Maillard reaction. The intensity level of this color depends on the time, frying temperature, and chemical composition of the outer surface of the food, while the type of fat used has very little effect on the surface color of the food. The main purpose of frying is to obtain the characteristic color, flavor, aroma, and crust characteristics of food ingredients. This characteristic is obtained from the combination of the Maillard reaction with volatile components that are absorbed by the oil (Nieva-Echevarria *et al.*, 2016).

Amino acid composition of slices fried in different vegetable oils

Since fish are considered an important source of protein, it is very critical that the amino acid contents should not be compromised within multiple food processing methods such as frying. It was perceived that frying commonly led to a decline in the total amino acid (TAA) (Oluwaniyi *et al.*, 2010). Generally, the lack of one type of amino acid in food can be covered with similar amino acids in other foods so that the quality of the protein will increase. Protein quality is determined by the type and proportion of amino acids it contains. High-quality protein is a protein that contains all types of essential amino acids in proportions suitable for growth.

As stated, different kinds of frying oils were used in frying the fish fillets and the findings indicated that typically, regardless of the oil type, frying leads to the TAA reduction. Burger and Walters (1973) had previously presented that heat processing is accountable for reductions in protein value in muscle foods as a consequence of the degradation or unavailability of the constituent amino acids. This may explain why the heat treatment also contributed to the change in amino acid contents of the fish samples. The number of amino acids in raw and fried Beluga sturgeon is shown in Table 4. The amino acid composition of raw fillets is like those observed by Erkan *et al.* (2010) for Horse Mackerel. In the raw Beluga sturgeon, Glutamate, Leucine, and Aspartate were the major amino acids, with a content of 15.4, 9.22 and 8.48 (g/100 g protein), respectively. Their contents were significantly ($p < 0.05$) higher than the other amino acids in this study. Badiani *et al.* (1996) also reported that the basic amino acids were glutamic acid, aspartic acid, and leucine

in raw cultured sturgeon (*Acipenser* spp.).

Eight amino acids are commonly considered essential for humans: lysine, cysteine, methionine, threonine, isoleucine, leucine, phenylalanine, and valine. Essential amino acid contents of fried samples in four vegetable oils were significantly ($p < 0.05$) lower than those found in raw fillets. The leucine contents of fried Beluga fillets ranged from 6.73 to 8.09 g/100 g. The fried fillets in olive and sunflower oil had the highest and lowest leucine concentration, respectively. The maximum threonine, valine, methionine, isoleucine, leucine, and lysine level was observed in fried samples in olive oil. The content of lysine in Beluga sturgeon decreased from 8.23 to 6.7 g/100 g after frying as reported by Fillion and Henry (1998), and this suggested that losses were because of the formation of bonds among the amino groups of the protein and oxidation products of the fat (Fillion and Henry, 1998).

Histidine, serine, arginine, aspartate, glutamate, glycine, alanine, proline, and tyrosine are non-essential amino acids. The content of these amino acids (except proline, arginine, and histidine) in fried samples in four vegetable oils was significantly ($p < 0.05$) higher than those found in raw fishes. The aspartate contents of fried Beluga sturgeon fillets varied from 8.48 to 10.71 g/100 g. Also, Oluwaniyi *et al.* (2010), reported a similar result for aspartate amount in fried *Urophycis tenuis* (white hake) with soybean oil, who reported 10.61 g/100g protein. Some amino acids, alanine, glutamic acid, and glycine are accountable for the odor and taste of seafood and seafood products (Erkan *et al.*, 2010). Glycine and alanine contents of raw Beluga sturgeon were significantly ($p < 0.05$) lower than those found in fried fillets, these results coincided with those observed by Erkan *et al.* (2010).

The highest aspartate and serine values of fried fillets were identified in olive oil, also the maximum content of alanine, glycine, and tyrosine were in fillets fried in soybean oil. Furthermore, the highest glutamate was observed in fried fillets in sunflower oil. Generally, frying in the four vegetable oils alleviates some essential amino acids for humans; while, non-essential amino acids for humans, only in fried fillets in olive oil and soybean oil have been increased. The reduction in the TAA amount of fried samples ranged from 1.18% in olive oil to 21.3% in sunflower oil. It is recommended to increase the usage of olive oil for frying of fishes. Our results are consistent with the Oluwaniyi *et al.* (2010) research, which reported the reduction in total essential amino acid (%TEAA) in the fried fish samples with soybean and palm oil.

According to Burger and Walters (1973), three main kinds of reactions are accountable for the nutritional changes that happen in processed foods. One of these is the Maillard reaction in that amino groups (especially the ε-amino group of lysine) react with aldehyde groups of reducing sugars or carbonyls from oxidized fat, therefore making those amino acids metabolically unavailable; cross-linkage reactions, i.e. protein-protein interactions, an example of which is the constitute of =CH–N= links (instead of normal peptide bonds) that are resistant to enzymic hydrolysis in the gut; and damage to sulfur amino acids (like methionine, cysteine, etc.) by oxidation or desulphydration (Burger and Walters, 1973). The reductions observed in the amino acid composition, particularly of our fried samples, are considered to be a consequence of these reactions and they are more pronounced in some types of oil than others because the different oils have varying frying temperatures. The predicted protein efficiency ratios of the fish fillets varied from 2.35 in fried fillets in soybean oil to 2.83 in olive oil. The P-PER of fried fillets is lower than the P- PER of the corresponding raw samples. The standard reference for the PER is based on casein, a cow's milk protein, that has a PER of 2.5 (FAO/WHO/UNU, 1985), the amount obtained for the raw fish, fried fillets in canola oil, sunflower oil, and olive oil are larger than or equal to 2.5, while the values for fried fillets in soybean oil is slightly less than 2.5. Commonly, a PER below 1.5 nearly explains a protein of low or poor quality (Friedman, 1996), but none of the samples were in this range.

CONCLUSION

In general, there were significant effects of different vegetable oil on protein, fat, moisture, amino acid, and fatty acid contents of fried Beluga sturgeon fillets. The moisture content of raw Beluga decreased but the protein and lipid contents of fried slices increased significantly after frying. during the frying, oil was taken up and increased the fat content of the fillets. The fatty acid profile of the filets was also influenced by the oil uptake. the n-6/n-3 ratio was also changed post-frying. Frying of Beluga fillets caused a reduction in fatty acid total SFA content. Frying significantly enhanced the MUFA amount of fish fillets, especially in canola and olive oils. Frying generally had the most deteriorative effect on the total amino acids, total essential amino acids, and protein efficiency ratio. These results show that different amino acids undergo different changes. Frying could also significantly reduce the contents of total amino acids. Also, the decline of essential amino acids for humans by frying is adverse. In this situation using the sunflower oil due to PUFA content is preferred but by considering the difference in total amino acid reduction of olive oil as minimum difference, this oil is more favorable.

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