

Influence of frying oil type and chill storage on the nutritional quality of farmed great sturgeon (*Huso huso*)

Influência do tipo de óleo de fritura e armazenamento a frio na qualidade nutricional do esturjão branco (Huso huso) de cativeiro

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ABSTRACT

Objective

The objective of this study was to investigate the effect of frying oils (canola, hydrogenated sunflower and soybean oils) available commercially and chill storage on the proximate and fatty acid composition of fried slices of farmed great sturgeon (*Huso huso*).

Methods

Slices of farmed great sturgeon were fried for four minutes at 160°C in a deep-fryer using different frying oils (canola, hydrogenated sunflower and soybean oils). The oil-to-slice ratio was 2:1. After frying, the slices were allowed to be air cooled for two minutes prior to analysis. For performing the analysis, each of the abovementioned batches was divided into two groups: one group was analysed immediately after frying and the second group was chill-stored at 4°C for three days and then analysed.

Results

After frying, the moisture content decreased while that of fat increased. Fatty acid composition of the slices is affected by type of frying oil. Frying increased the omega-6-to-omega-3 (n-6:n-3) fatty acid ratio while decreased Eicosapentaenoic Acid (C20:5 n-3) and Docosahexaenoic Acid (C22:6 n-3) contents. Proximate and fatty acid composition of raw slices did not change after chill storage. However, in fried- and chill-stored slices, Eicosapentaenoic Acid and Docosahexaenoic Acid contents decreased, while linoleic acid content increased.

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Conclusion

The fatty acid composition of the fried slices tended to resemble that of the frying oils, indicating fatty-acid equilibrium between oils and slices and, during chill storage, it is influenced by the type of frying oil. Slices fried with canola oil had omega-6-to-omega-3 ratios in the ranges recommended for human health.

Indexing terms: Beluga Whale. Centesimal composition. Lipids. Oels.

RESUMO

Objetivo

O objetivo deste estudo foi investigar o efeito de óleos de fritura (canola, girassol hidrogenado e soja) disponíveis comercialmente e do armazenamento a frio em postas fritas de beluga (*Huso huso*), e na composição centesimal e lipídica.

Métodos

Postas de beluga de cativado foram fritas por imersão durante quatro minutos a 160°C utilizando-se óleos de fritura diferentes (canola, girassol hidrogenado e soja). A razão entre óleo e postas foi de 2:1. Após a fritura, permitiu-se que as postas esfriassem a temperatura ambiente por dois minutos antes da análise. Para a análise, cada um dos grupos acima foi dividido em dois subgrupos: um subgrupo foi analisado imediatamente após a fritura e o segundo subgrupo foi armazenado resfriado a uma temperatura de 4°C por três dias e então analisado.

Resultados

Após a fritura, o conteúdo da umidade diminuiu enquanto que da gordura aumentou. A composição dos ácidos graxos das postas foi afetada pelo tipo de óleo utilizado na fritura. A fritura aumentou a razão omega-6 para omega-3 e diminuiu os conteúdos dos Ácidos Eicosapentaenoico (C20:5 n-3) e Docosahexaenoico (C22:6 n-3). As composições centesimal e lipídica das postas cruas não se alteraram após o armazenamento a frio. Porém, os conteúdos de Ácidos Eicosapentaenoico e Docosahexaenoico nas postas fritas e resfriadas diminuíram, enquanto que de ácido linoleico aumentou.

Conclusão

A composição lipídica das postas fritas tendeu à semelhança do óleo utilizado para a fritura, indicando um equilíbrio de ácidos graxos entre os óleos e as postas. A composição lipídica das postas durante o armazenamento a frio é influenciada pelo tipo de óleo de fritura. Postas fritas com óleo de canola continham uma razão de ômega-6 para ômega-3 dentro do intervalo recomendado para a saúde humana.

Termos de indexação: Beluga. Composição centesimal. Lipídeos. Óleos.

INTRODUCTION

The best sources of long chain Polyunsaturated Fatty Acids (PUFA), such as Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acids (DHA) are seafood¹. PUFAs are highly appreciated in human foods as these fatty acids have beneficial roles on reducing atherosclerosis, and preventing and treating numerous disorders, like cardiovascular disease and others². Aquatic ecosystems are the main source of omega-3 fatty acids and humans obtain most of it by consuming seafood³. PUFA are very susceptible to lipid oxidation, which not only affects the sensory

attributes of the food, but also contributes to many diseases in humans⁴.

Frying is the most common practice in food preparation. It gives unique organoleptic characteristics to foods such as flavor, texture and appearance, which can improve the palatability of foods⁵. During frying, water in food is replaced by the frying oil and as a consequence, the oil becomes an important component of the fried food⁶. However, different oils are used to prepare foods. The effects of different cooking oils on the nutritional quality of fish based on their fatty acid profiles have been studied^{7,8}. Moreover, chill

storage of fried foods is also a common practice⁹ and may influence their nutritional quality.

The great sturgeon or beluga (*Huso huso*) is among farmed sturgeon species. They are large, tasty and grow fast^{10,11}. Their natural range is diverse habitats of the Northern Hemisphere and the most famous luxury food product comes from them: caviar^{12,13}. Sturgeons are not only important because of their valuable caviar, but also for their meat of excellent quality and taste. Sturgeon meat is rich in proteins of good biological value. Fat content is average but contents of essential ions and vitamins are high¹⁴. This species is commonly cultivated in concrete tanks supplied with well water. Males are sold (usually to restaurants) after being sexed by biopsy at the age of 3. Chill storage of fried great sturgeon flesh using different oils is common; however, the effect of chill storage on the nutritional quality of the slices with reference to its essential PUFA content is not well known. Therefore, the aim of the present study was to investigate the effect of frying with different oils and chill storage on the proximate and fatty acid compositions of fried slices of farmed great sturgeon.

METHODS

Fish samples

Farmed great sturgeon with an average weight of 5kg (n=3) were purchased from a local sturgeon farm (Sari, Iran). The fish were reared in concrete circular tanks (8m diameter, 1.5m depth) at 30kg/m³ in density and fed 2.0% of their body weight with commercial diets for trout containing 40.00% protein and 15.00% fat. The major fatty acids of the diet were C16:0 (18.83%), C18:0 (5.04%), C16:1 (3.17%), C18:1 (27.78%), C18:2 (27.27%), C18:3 (8.99%), C20:5 (0.59%) and C22:6 (3.47%). At the farm, the fish were beheaded, eviscerated, washed and then placed in coolers with a fish-to-ice ratio of approximately 1:2 (w/w) and transported to the laboratory during

the morning, arriving within the hour. Upon arrival, the fish were skinned and rinsed with tap water several times to remove the blood and slime. The fish were then cut into 1cm slices. All slices were divided randomly into four batches, namely: soybean oil, canola oil, hydrogenated sunflower oil (solid fat), and raw.

Frying and chill storage

Each of the abovementioned batches was then divided into two groups: in Group 1, the samples were analysed after filleting and frying or not (day 0); and in Group 2, the samples were chill-stored at 4°C for three days and then analysed (day 3). All slices (except the raw group) were fried for four minutes at 160°C in a deep-fryer (Hamilton, HDF-510, Iran). The oil-to-slice ratio was 2:1. After frying, the slices were allowed to cool at room temperature for two minutes before the analysis. Table 1 shows the fatty acid composition of the oils.

Proximate composition

Moisture was determined by drying the samples in an oven (Heraeus, D-63450, Hanau, Germany) at 105°C to a constant weight¹⁵. Fats were extracted as recommended by Bligh & Dyer¹⁶. Ash was determined by incineration in a muffle furnace (Isuzu, Tokyo, Japan) at 550°C for three hours¹⁵; crude protein was determined by the Kjeldahl method (N×6.25) using an automatic Kjeldahl system (230-Hjeltec Analyzer, Foss Tecator, Höganäs, Sweden)¹⁵.

Fat extraction

Fats were extracted according to the method developed by Bligh & Dyer¹⁶. Fifty grams of the sample were homogenized in a blender for two minutes with a mixture of 50mL chloroform and 100mL methanol. Then 50mL of chloroform were added and further homogenized

Table 1. Fatty acid composition (g/100g of total fatty acids) of frying oils used for frying farmed great sturgeon slices. Sari, Iran, 2011.

Fatty acids	Canola	Frying oils Hydrogenated sunflower oil	Soybean
C16:0	3.86	19.21	9.58
C18:0	1.80	4.56	3.81
C18:1	63.65	29.56	21.13
C18:2 n-6	17.52	40.76	56.02
C18:3 n-3	6.71	3.89	6.82
C20:1	1.52	0.33	0.31
C20:5 n-3	0.36	0.15	0.14
C22:6 n-3	0.69	0.31	0.40
SFA	5.66	23.77	13.39
MUFA	65.17	29.37	21.44
PUFA	25.28	45.11	63.38
n-3	7.76	4.35	7.36
n-6	17.52	40.76	56.02
n-6/n-3	2.26	9.37	7.61

SFA: Total Saturated Fatty Acids; MUFA: Total Monounsaturated Fatty Acids; PUFA: Total Polyunsaturated Fatty Acids; n-3: Total omega-3 fatty acids; n-6: Total omega-6 fatty acids; n-6/n-3: omega-6 to omega-3 ratio.

for 30 seconds. Finally, 50mL of distilled water were added to the mixture and blended for 30 seconds. The homogenate was centrifuged (Avanti J-E, Beckman Coulter, Inc., USA) at 3000rpm for 15 minutes at 4°C. The supernatant was then transferred into a separating flask and the lower phase (chloroform phase) was drained off into a 250mL Erlenmeyer flask containing 4g of anhydrous sodium sulfate and shaken vigorously. The solution was then filtered through a Whatman number 4 filter paper into a round-bottom flask. A rotary evaporator (Rotavapor R-114, Büchi, Flawil, Switzerland) was used for solvent evaporation at 25°C.

Fatty acid analysis

Fatty acid methyl ester was prepared as follows: fat samples (1g) were diluted with 2mL of 2M potassium hydroxide in methanol followed by the addition of 7mL n-hexane in a sealed tube. The mixture was then shaken using a vortex for one minutes and left in a water bath (temperature 50°C -55°C) for about 20 minutes until it separated into two phases. Fatty acid methyl ester was then taken from the top layer for analysis by trace gas

chromatography (GC) (Thermo Finnigan, Italy). The GC settings were as follows: capillary column (Bpx-70, 60m, 0.32mm, i.d. 0.25µm); split ratio of 90:1; injection port temperature of 250°C; flame ionization detector temperature of 270°C. The oven temperature was set at 195°C for 75 minutes. Flow rate of carrier gas (helium) was 1mL min⁻¹ and the makeup gas was nitrogen (N₂) (30mL/min). The sample size injected for each analysis was 1µL. The data are expressed as g/100g of total fatty acids.

Statistical analysis

Data were analyzed by one-way Analysis of Variance (Anova) and Duncan's multiple range test ($p < 0.05$) by the software Statistical Package for the Social Sciences 16 (SPSS).

RESULTS AND DISCUSSION

Proximate composition

Table 2 shows the proximate composition of farmed great sturgeon slices. Roughly, 70.0%

of the slices consisted of moisture, 6-7.0% fat, 18.0% protein and 2.0% ash. The protein content in cultivated beluga sturgeon was similar to that of cultivated white sturgeon (*Acipenser transmontanus*) with 18-19.0% protein¹⁷, cultivated *Acipenser* spp. with 17.6-21.0% protein¹⁴, Gulf of Mexico sturgeon (*A. oxyrinchus desotoi*) with 17.4-19.5% protein¹⁸ and Russian sturgeon (*A. guldenstaedtii*) with 16.4-17.6% protein¹⁹. Sturgeon fish are medium-fat fish with fat content between 5-15.0%^{14,19-21} and the amounts of fat in farmed beluga was within this range. After frying, the moisture content decreased while that of fat increased ($p < 0.05$). Similar results were reported by Garcia-Arias²² for sardine (*Sardina pilchardus*), Gokoglu²³ for rainbow trout (*Oncorhynchus mykiss*), Weber *et al.*⁸ for silver catfish (*Rhamdia quelen*) and Ersoy & Özeren²⁴ for African catfish (*Clarias gariepinus*). Fat increase after frying is due to oil penetration on the food after water is partially lost by evaporation²⁵.

Fatty acid composition of raw slices

The main fatty acids of farmed great sturgeon flesh in this study were oleic acid (C18:1), linoleic acid (C18:2) and palmitic acid (C16:0), representing about 76.14g/100g of the total fatty acids (Table 3). Polyunsaturated fatty acids constituted the most dominant class of fatty acids (37.85g/100g of total fatty acids) followed by monounsaturated (33.89g/100g of total fatty acids) and saturated (23.28g/100g of total fatty acids) fatty acids, respectively (Table 4). The EPA and DHA contents in cultivated beluga flesh (0.90 and 3.52g/100g of total fatty acids, respectively) were lower than those of other cultivated sturgeon species, such as Siberian sturgeon (*Acipenser baerii*), Adriatic sturgeon (*A. naccarii*) and white sturgeon (*A. transmontanus*), with 4.8-6.54g/100g EPA and 8.7-9.7g/100g DHA²⁶. Lower EPA and DHA contents in cultivated beluga

Table 2. Proximate composition (%) of raw and fried slices of farmed great sturgeon with different oils. Sari, Iran, 2011.

Fatty acids	Fresh		Canola oil		Hydrogenated sunflower oil		Soybean oil	
	Day 0	Day 3	Day 0	Day 3	Day 0	Day 3	Day 0	Day 3
Fat	6.00 ± 1.31 ^c	6.90 ± 1.41 ^c	12.41 ± 4.08 ^{abc}	11.60 ± 1.41 ^{abc}	13.65 ± 4.67 ^{ab}	13.30 ± 2.12 ^{ab}	17.15 ± 2.75 ^a	12.50 ± 2.68 ^{abc}
Protein	18.85 ± 0.49	18.65 ± 0.63	17.90 ± 1.27	18.05 ± 0.07	17.78 ± 0.63	18.55 ± 0.35	18.60 ± 0.70	18.35 ± 0.63
Ash	2.10 ± 0.14	2.20 ± 0.00	2.05 ± 0.07	1.90 ± 0.28	2.07 ± 0.17	1.95 ± 0.21	2.00 ± 0.14	2.20 ± 0.28
Moisture	71.35 ± 1.48 ^a	71.90 ± 0.84 ^a	62.40 ± 0.84 ^{bc}	63.20 ± 1.41 ^{bc}	60.70 ± 3.81 ^{bc}	62.90 ± 0.14 ^{bc}	59.90 ± 0.56 ^c	64.25 ± 0.91 ^b

* Means with the same superscript letters within the same row were not significantly different ($p > 0.05$).

Table 3. Fatty acid composition (g/100g of total fatty acids) of raw and fried slices of farmed great sturgeon with different oils. Sari, Iran, 2011.

Fatty acids	Fresh		Canola oil		Hydrogenated sunflower oil		Soybean oil	
	Day 0	Day 3	Day 0	Day 3	Day 0	Day 3	Day 0	Day 3
C14:0	0.41 ± 0.03 ^c	0.48 ± 0.04 ^{bc}	0.57 ± 0.25 ^{abc}	0.61 ± 0.07 ^{abc}	0.81 ± 0.02 ^a	0.77 ± 0.02 ^a	0.68 ± 0.07 ^{ab}	0.63 ± 0.00 ^{abc}
C16:0	18.20 ± 0.56 ^{ab}	18.15 ± 1.34 ^{ab}	10.68 ± 3.41 ^d	12.15 ± 0.91 ^{cd}	18.25 ± 0.07 ^{ab}	18.65 ± 0.49 ^a	14.90 ± 0.14 ^{bc}	14.55 ± 0.07 ^c
C16:1	3.05 ± 0.09 ^a	3.19 ± 0.08 ^a	1.37 ± 0.77 ^b	1.61 ± 0.14 ^b	1.78 ± 0.07 ^b	1.66 ± 0.00 ^b	1.70 ± 0.20 ^b	1.52 ± 0.02 ^b
C18:0	4.67 ± 0.32 ^a	4.95 ± 0.12 ^a	2.61 ± 0.08 ^e	2.67 ± 0.12 ^e	3.95 ± 0.04 ^{bc}	4.12 ± 0.03 ^b	3.42 ± 0.21 ^d	3.63 ± 0.11 ^{cd}
C18:1	30.17 ± 1.34 ^b	29.47 ± 1.46 ^b	48.96 ± 1.12 ^a	47.93 ± 0.89 ^a	33.84 ± 0.51 ^b	34.60 ± 0.39 ^b	32.30 ± 1.50 ^b	31.31 ± 0.10 ^b
C18:2n-6	27.77 ± 0.94 ^b	27.43 ± 0.91 ^b	19.88 ± 1.66 ^c	19.82 ± 0.10 ^c	28.07 ± 0.65 ^b	28.59 ± 0.13 ^b	33.28 ± 2.35 ^a	35.42 ± 0.65 ^a
C18:3n-3	5.66 ± 0.12 ^a	5.05 ± 0.07 ^b	2.38 ± 0.03 ^e	2.35 ± 0.09 ^e	2.74 ± 0.06 ^d	2.66 ± 0.08 ^d	3.59 ± 0.24 ^c	3.75 ± 0.07 ^c
C20:1	0.67 ± 0.10 ^a	0.70 ± 0.15 ^a	0.41 ± 0.02 ^b	0.54 ± 0.10 ^{ab}	0.46 ± 0.07 ^b	0.34 ± 0.04 ^b	0.41 ± 0.04 ^b	0.37 ± 0.04 ^b
C20:5n-3	0.90 ± 0.02 ^a	1.01 ± 0.0 ^a	1.02 ± 0.06 ^a	0.95 ± 0.07 ^a	0.93 ± 0.04 ^a	0.73 ± 0.02 ^b	0.93 ± 0.12 ^a	0.71 ± 0.00 ^b
C22:6n-3	3.52 ± 0.45 ^a	3.69 ± 0.33 ^a	2.00 ± 0.50 ^c	2.45 ± 0.21 ^{bc}	2.99 ± 0.17 ^{ab}	2.26 ± 0.24 ^{bc}	2.48 ± 0.33 ^{bc}	2.00 ± 0.41 ^c

* Means with the same superscript letters within the same row were not significantly different ($p > 0.05$).

coincided with the lower content of these fatty acids in the diet (0.59 and 3.47g/100g of total fatty acids, respectively).

Fatty acid composition of slices fried with different oils

Tables 3 and 4 show the effect of frying on the fatty acid composition of farmed great sturgeon slices with different types of cooking oil. When the slices were fried with canola oil, the Monounsaturated Fatty Acids (MUFA) content increased significantly ($p < 0.05$). The increase is due to the higher amounts of oleic acid (63.65g/100g of total fatty acids) in canola oil. No changes in the content of MUFA were seen when slices were fried with other oils. Fatty acid composition of soybean oil was dominated by linoleic acid (56g/100g of total fatty acids) and the content of this fatty acid exhibited significant increase after frying and reached 33.28g/100g of the total fatty acids (Table 3). Meanwhile, when canola oil was used, the content of this fatty acid decreased significantly ($p < 0.05$) and reached 19.88g/100g of the total fatty acids. The Saturated Fatty Acid (SFA) content after frying with canola and soybean oils decreased, which coincided with the low amounts of this class of fatty acids in the oils used (Table 4). When hydrogenated sunflower oil was used, SFA did not change.

In humans, many chronic diseases and disorders are closely associated with high levels

of risk factors, such as C-reactive protein, tumor necrosis factor, thromboxane A_2 , leukotriene B_4 and many others. Intake of omega-6 fatty acids increases these factors, while omega-3 intake has a suppressive effect. The omega-6-to-omega-3 ratio is an important determinant of health and a lower ratio is desirable for reducing the risks of chronic diseases. Fish are the best sources of omega-3 essential fatty acids, such as EPA and DHA, which are very effective in lowering the abovementioned risk factors³. The omega-6-to-omega-3 fatty acid ratio in the raw slices of cultivated beluga was 2.75 (Table 4). After frying, this ratio increased significantly, reaching 4.22:1 and 4.75:1 in slices fried with hydrogenated sunflower oil and soybean oil, respectively. This is higher than the recommended ratio range (2:1-4:1) for human health suggested by Pepping²⁷. In Indo-Pacific king mackerel (*Scomberomorous guttatus*), frying resulted in an increased proportion of C18:2 and omega-6-to-omega-3 ratio (from 0.54 in raw flesh to 1.2 in fried samples) and instead EPA and DHA contents decreased⁹. When sardine (*Sardina pilchardus*) fillets were fried, omega-6-to-omega-3 ratio increased significantly, with consequent decrease in the proportions of EPA and DHA²². The results indicated that most of the fatty acids of the fried slices resemble those of the frying oils. In fact, during the frying process, an exchange of oil between the food and the cooking oil takes place, thereby changing the fat composition of fried foods, becoming similar to the oil used^{6,7,28}.

Table 4. Major class of fatty acids (g/100g of total fatty acids) of raw and fried slices of farmed great sturgeon with different oils. Sari, Iran, 2011.

Fatty acids	Fresh		Canola oil		Hydrogenated sunflower oil		Soybean oil	
	Day 0	Day 3	Day 0	Day 3	Day 0	Day 3	Day 0	Day 3
SFA	23.28	23.58	13.86	15.43	23.01	23.54	19.00	18.81
MUFA	33.89	33.36	50.74	50.08	36.08	36.60	34.41	33.20
PUFA	37.85	37.18	25.28	25.60	34.73	34.24	40.28	41.88
n-3	10.08	9.75	5.40	5.75	6.66	5.65	7.00	6.46
n-6	27.77	27.43	19.88	19.82	28.07	28.59	33.28	35.42
n-6/n-3	2.75	2.81	3.68	3.45	4.22	5.06	4.75	5.48

SFA: Total Saturated Fatty Acids; MUFA: Total Monounsaturated Fatty Acids; PUFA: Total Polyunsaturated Fatty Acids; n-3: Total omega-3 fatty acids; n-6: Total omega-6 fatty acids; n-6/n-3: omega-6 to omega-3 ratio.

The effects of chill storage on proximate and fatty acid composition of fried great sturgeon slices

Tables 2-4 show the proximate and fatty acid composition of fried and chill-stored slices of farmed great sturgeon. There were no changes in the proximate composition of raw slices after three days of chill storage. In the slices fried with different oils, protein and ash contents remained stable during the chill storage. In the slices fried with soybean oil, the moisture content increased and fat content decreased after chill storage. Similar to the proximate composition of raw slices, fatty acid composition remained stable and did not change after 3 days of chill storage. The result is in agreement with those of Pirini *et al.*²⁹ for sea bass (*Dicentrarchus labrax*) and Senso *et al.*² for farmed gilthead sea bream (*Sparus aurata*), who reported that fatty acid composition of the fillets did not change significantly during chill storage. However, in slices fried with hydrogenated sunflower oil and soybean oil, the omega-6-to-omega-3 ratio increased after chill storage and reached 5.06:1, and 5.48:1 respectively, higher than the recommended ratio range for human health. This increase is due to the slight increase in C18:2 fatty acid content and decrease in EPA and DHA contents after chill storage (Table 3).

CONCLUSION

The fatty acid composition of farmed great sturgeon slices tended to resemble that of the frying oils used, indicating fatty acid equilibrium between the oil and slices. Chill-stored raw slices had proximate and fatty acid compositions similar to fresh slices. The fatty acid composition of fried slices during chill storage is influenced by the type of frying oil. Fried slices by canola oil had an omega-6-to-omega-3 ratio in the range recommended for human health.

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