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Research Article

Effects of Dietary Lipids on Growth and Fatty Acid Composition in Russian Sturgeon (*Acipenser gueldenstaedtii*) Juveniles*

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Abstract: Juvenile Russian sturgeon (*Acipenser gueldenstaedtii*) fed feeds including fish oil, soybean oil and sunflower oil were researched and the effects of the feeds on the growth performance and fatty acid composition of the fish were studied. In the Sapanca Inland Waters Research and Experiment Department of İstanbul University's Faculty of Fisheries, sturgeon juveniles having an approximate initial weight of 27.23 ± 0.98 g were fed experimental feeds containing different kinds of oil for 63 days. Weight gain was 36.83 ± 1.84 g in the fish oil group, 37.63 ± 1.76 g in the sunflower oil group and 32.91 ± 1.93 g in the soybean oil group. Feed conversion ratios were 1.30, 1.30 and 1.45, respectively. The experimental feeds contained 43.79% crude protein and 13.98% crude lipid. At the end of the feeding trials, whole body fat was found 4.65% in the fish oil group, 5.19% in the sunflower oil group and 4.73% in the soybean oil group. Growth performance parameters (HSI, VSI, FCR and SGR) varied significantly among the groups ($P \leq 0.05$). The fatty acid composition analyses showed that total n-3 and n-6 in the whole body fatty acids and the liver fatty acid contents of fish fed feeds contain different kinds of oil were significantly different ($P \leq 0.05$). Naturally, in the groups fed vegetable oil, the ratio of total n-6 fatty acids was higher (22.58 and 22.98) than that in the fish oil group (11.39), and in the group fed fish oil, the n-3 fatty acid ratio was higher (21.57) than that in the vegetable oil groups (13.15 and 15.00). Similar results were found for the values of liver fatty acid composition. These results suggest that sturgeon require both n-3 and n-6 fatty acids and accumulation of these fatty acids in the flesh and liver was affected by fatty acids in the feeds. Therefore, it is possible to use a certain amount of soybean oil or sunflower oil instead of fish oil in sturgeon diets.

Key Words: *Acipenser gueldenstaedtii,* dietary lipids, fatty acid composition

Diyet Lipidlerinin Rus Mersini (*Acipenser gueldenstaedtii*) Yavrularında Büyüme ve Yağ Asidi Kompozisyonuna Etkisi

Özet: Bu araştırmada balık yağı, soya yağı ve ayçiçek yağı ilave edilen yemlerle beslenen Rus mersini (*Acipenser gueldenstaedtii*) yavrularında büyüme performansı ve yağ asidi kompozisyonuna etkisi incelenmiştir. 63 gün süresince başlangıç ağırlıkları 27,23 ± 0,98 g olan mersin yavruları İstanbul Üniversitesi Sapanca İçsu Ürünleri Üretimi Uygulama ve Araştırma Birimi'nde farklı yağlar içeren deney yemleri ile beslenmiştir. Deneyler sonunda canlı ağırlık artışı balık yağı grubunda 36,83 ± 1,84 g, ayçiçek yağı grubunda 37,63 ± 1,76 g ve soya yağı grubunda 32,91 ± 1,93 g bulunmuştur. Yemden yararlanma oranları sırasıyla 1,30; 1,30 ve 1,45 olarak hesaplanmıştır. Deney yemi % 43,79 ham protein ve % 13,98 ham yağ değerine sahiptir. Yemleme deneylerinin sonunda tüm vücut yağı balık yağı grubunda % 4,65, ayçiçek yağı grubunda % 5,19 ve soya yağı grubunda % 4,73 bulunmuştur. Büyüme performansı (HSI, VSI, FCR ve SGR) değerleri gruplar arasında önemli derecede farklı bulunmuştur ($P \leq 0,05$). Yağ asidi kompozisyonu analizlerine göre, farklı yağlar ilave edilen yemlerle beslenen balıkların tüm vücudunda ve karaciğerindeki yağ asitleri içinde toplam n-3 ve n-6 yağ asitleri önemli derecede farklı bulunmuştur ($P \leq 0,05$). Doğal olarak bitkisel yağlarla beslenen gruplarda balık etindeki toplam n-6 yağ asitleri (% 22,58 ve % 22,98) balık yağı grubundan (% 11,39) daha yüksek ve balık yağı ile beslenen grupta da n-3 yağ asitleri (% 21,57) bitkisel yağla beslenen gruplardan (% 13,15 ve % 15,00) daha yüksek bulunmuştur. Benzer sonuçlar balık karaciğerindeki yağ asitleri kompozisyonunda da elde edilmiştir. Bu sonuçlar mersin balıklarının hem n-3 hem de n-6 yağ asitlerine gereksinim duyduğunu ve yemlerdeki bu yağ asitlerinin balık etinde ve karaciğerindeki birikimini etkilediği anlaşılmaktadır. Bunun dışında mersin diyetlerinde soya ve ayçiçek yağının balık yağı yerine belirli miktarlarda kullanılabileceği görülmüştür.

Anahtar Sözcükler: *Acipenser gueldenstaedtii,* diyet lipitleri, yağ asidi kompozisyonu

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Introduction

The sturgeon is the largest freshwater fish and lives the longest in nature. Sturgeon culture is a very old aquaculture practice in Russia. In 1969, a Russian scientist succeeded in artificially fertilizing sturgeon (*Acipenser ruthenus*) eggs from the Volga River and in the rearing of larvae. During the first half of the 20th century, most studies were being conducted on the systematics and biology of sturgeons but rearing of sturgeons in fish farms for meat consumption was less successful. In the 1970s, *A. transmontanus* and *A. ruthenus* were successfully reproduced and culture of *A. baerii* was fully established in the USSR and later exported to other countries such as France, the USA, Italy, Japan, Germany and Poland. Sturgeon farming in western countries began during the 1980s mainly as a consequence of conservation efforts for threatened wild populations. In 1999 the dominant species reared for production in Western Europe was the white sturgeon (*A. transmontanus*). The Russian sturgeon (*A. gueldenstaedtii*) was reared at low levels in some European countries such as Austria, Hungary, Poland and the Netherlands (1,2). In Turkey the first experimental trials on the Russian sturgeon (*A. gueldenstaedtii*) were begun for restocking rivers in the Marmara region in 2002.

The white sturgeon (*A. transmontanus*) and the Siberian sturgeon (*A. baerii*) are 2 major species of sturgeon being cultured commercially outside Russia. The relative importance of the Siberian sturgeon and the Russian sturgeon will increase because they are the most widespread species. There is considerable information available on the growth of the white sturgeon and other sturgeon species. However, information on Russian sturgeon farming is limited (3). The optimum temperature for sturgeon growth appears to be close to 23 ºC and the optimum feeding rates at 23 ºC were 2.0-2.5% body weight/day (4). Protein and carbohydrate requirements and utilization by these fish have been studied (2,5-7) as well as dietary lipids in farmed *A. transmontanus* (5,8,9). Dietary lipids and retention of lipids, particularly in fillets, are parameters often discussed in connection with quality. For farmed fish the relationship between dietary lipids and deposition of fat in fillets has been studied in several species. In a study on the white sturgeon (*A. transmontanus*) Hung et al. (10) reported that dietary lipid levels between 26% and 36% gave good growth without major effects on body composition, whereas 40% dietary lipids lowered the specific growth rate and increased levels of liver lipids. Fish is unique as a food in that it provides long-chain n-3 polyunsaturated fatty acids. In farmed fish the fatty acids as well as other fillet lipids may be altered by feeding (11). There is, however, little information on lipid utilization and fatty acid composition in sturgeon (*A. gueldenstaedtii)*. The objective of the present study was to determine the effects of different dietary lipids on the growth and fatty acid composition of the Russian sturgeon *A. gueldenstaedtii*. Hung et al. (4) reported that the feed, protein, and energy intake required for maintenance at 23 ºC and 26 ºC was below 2.0% body weight/day when the fish were fed a diet with 41% protein and 3.2 kcal/ME/g. Body lipid content was significantly elevated when the feeding rate was increased from 2.5% to 3.0% body weight/day at 23 ºC and from 3.0% to 3.5% body weight/day at 26 ºC. The aim of this study was to investigate the effect of dietary lipids on the growth and fatty acid composition of the Russian sturgeon.

Materials and Methods

Supply of sturgeon

Eyed Russian sturgeon (*Acipenser gueldenstaedtii*) ova were obtained from the Institute of Krasnodor in the Russian Federation in 2001. The fry were hatched in early February and the fish were grown at the Sapanca Inland Waters Research Center of the Fisheries Faculty of İstanbul University. The fish were fed a commercial feed during this period and most of the sturgeon fingerlings were released into the Sakarya River (Marmara region, Turkey) in the early summer of the same year. One hundred eighty sturgeon juveniles were selected and distributed randomly in each tank for the feeding trial.

Feeding trials

Feeding trials were conducted at the İstanbul University, Fisheries Faculty, Sapanca Inland Waters Research Center from, 15 June to 21 August 2001. Sturgeon juveniles, with an average initial weight of 27.23 ± 0.98 g (mean ± SEM, n = 180) were randomly allocated to 280 l of water (30 fish per tank) in 6 duplicate fiberglass tanks. During the feeding trial the fish were fed 1.5% of their body weight per day. Water

was supplied by aerated well water at a rate of 5 l min^{-1} $tank^{-1}$. Water temperature, pH, and dissolved oxygen of the water in the experimental tanks were measured and recorded daily. During the rearing period, water temperature, pH and dissolved oxygen were 16 ± 1 ºC, 7.1 ± 0.7 and 8.5 mg/l, respectively. Three groups of fish were fed the experimental diets twice a day. The experimental diet's formulation is shown in Table 1.

Table 1. Composition of the diet used in the experiments[1].

Ingredients	%
Fish meal	50
Soybean meal	20
Sunflower meal	8
Wheat grain	10
Oil[2]	10
Vitamin and mineral mixture	2
Total	100
Proximate analysis	% (on dry basis)
Moisture	8.75 ± 0.05
Crude protein	43.79 ± 0.42
Crude lipid	13.98 ± 0.18
Crude fiber	3.06 ± 0.06
Ash	10.33 ± 0.19
Nitrogen free extract	19.96 ± 0.38
Gross energy KJ/g	19.27 KJ/g

[1] = Values are mean ± SEM n = 10

[2] = Fish oil, sunflower oil and soybean oil were added to the experimental feeds.

Chemical analyses

The proximate compositions of nutrients in the experimental feed and fish samples (n = 10) collected at the beginning and end of the feeding trial were analyzed according to the AOAC (12). Moisture, crude protein, ether extract, crude cellulose and ash in the experimental feed were analyzed and gross energy was calculated as described by Halver (13). Dry matter, crude protein, ether extract, ash and total fat content of the liver were analyzed in homogenized fish samples obtained at the start and at the end of the feeding trials (12,14).

Growth performance

During the feeding trials, the fish were weighed every 2 weeks according to the experimental groups. Live weight gain was recorded according to the difference between the final weight and initial weight of the fish. The feed conversion ratio (FCR) was calculated by the equation FCR = feed intake (dry weight) (g)/live weight gain (g). The specific growth rate (SGR) was calculated according to the equation SGR = (ln final weight–ln initial weight) x 100/time in days. The condition factor (CF) was determined by the formula: (final body weight (g)/final total body length $(cm)^3$) x 100. Hepatosomatic index (HSI) = [liver weight (g)/body weight (g)] x 100) and viscerosomatic index (VSI = [viscera weight (g)/body weight (g)] x 100) values were determined to observe fat accumulation in the whole body and liver of the fish (15).

Fatty acid analysis

Crude lipid analysis was conducted by ether extraction, and total lipids were extracted after homogenization in chloroform/methanol (2/1 v/v) containing 0.01% butylated hydroxyl toluene as antioxidant basically according to Folch et al. (16), and crude lipid extracts were subsequently separated into polar and non-polar fractions by means of silica Sep Pack cartridges using chloroform and methanol as the solvent system. Fatty acid mixtures were prepared by esterification with 1% sulfuric acid in methanol (17) and the fatty acid analyses of the feed and fish samples were analyzed by capillary gas chromatography with a Perkin Elmer Auto System XL capillary gas chromatograph (column 30 x 0.25 mm, FID detector, CP-2330 Supelco). The flame-ionization detection temperature was 220 ºC. Helium was used as the carrier gas, split rate 1/50, and the oven temperature was programmed for a rise from 120 ºC/2 min to 220 ºC/15min at a rate of 5 ºC/min. Injector temperature was 240 ºC and the detector temperature was 250 ºC. Individual fatty acid methyl esters were identified by reference to known standards (Sigma).

Statistical Analyses

Difference between the growth performances of the groups were tested by one-way analyses of variance (ANOVA) and differences between the means were compared by Duncan's multiple range test at a 95% confidence interval at the end of the feeding trials (18). Effects with $P \leq 0.05$ were deemed statistically significant.

Results

There was no mortality in the Russian sturgeon feeding trials in this study. The oils had no significant effect on the CF levels. HSI values were similar in the fish oil and sunflower oil groups (2.89, 2.97) but different in the soybean oil group (2.75). VSI values were significantly different in the soybean oil, fish oil and sunflower oil groups (10.91, 11.62, 14.24), respectively. Live weight gain, FCR and SGR values were similar in the fish oil and sunflower oil groups but significantly different in the soybean oil group.

Moisture contents of the fish bodies were similar in all groups but crude protein and ash contents were slightly different between before and after the feeding trials in the 3 oil groups. Xu et al. (5) reported that body composition was not significantly affected by dietary lipids. Lipid composition in the whole body and liver in the 3 different oil groups was significantly affected by diet ($P < 0.05$). Initial crude lipid content was higher than lipid content at the end of the feeding trials (Table 2).

The fatty acid composition analyses showed that different dietary lipids affected the whole body and liver fatty acid contents of the fish (Tables 3 -5). Both in the feeds and the whole body or liver of the fish; 18:1n-9 was highest and there was no significant difference in total n-9 in the whole body of the fish. However, 18:1n-9 and total n-9 fatty acids in the liver were similar in fish fed feeds containing fish oil and sunflower oil but higher in those fed feed containing soybean oil. Naturally, n-6 and total n-6 fatty acids were higher in feeds containing vegetable oil (soybean oil and sunflower oil) and in the muscle and liver of fish. 18:1n-9 and 18:2n-6 were the most abundant n-9 and n-6 fatty acids in fish before and after being fed feeds with 3 different oils added.

Discussion

Technologies for the commercial culture of various sturgeon species have been established over the last 20-30 years and are now available to fish farmers. The production of sturgeon meat for human consumption has

Table 2. Growth performance and whole body composition of sturgeon (*Acipenser gueldenstaedtii*) fed experimental diets[1].

Groups	Initial	Group I (Fish oil)	Group II (Sunflower oil)	Group III (Soybean oil)
Body composition (%)				
Moisture	78.24 ± 0.05^{b}	76.27 ± 0.15^{a}	76.21 ± 0.09^{a}	76.78 ± 0.11^{a}
Crude protein	10.71 ± 0.04^{a}	11.63 ± 0.02^{b}	11.19 ± 0.05^{ab}	11.71 ± 0.01^{b}
Crude lipid	6.05 ± 0.07^{c}	4.65 ± 0.03^{a}	5.19 ± 0.05^{b}	4.73 ± 0.02^{a}
Ash	2.36 ± 0.02^{a}	2.83 ± 0.03^{ab}	2.97 ± 0.04^{b}	2.46 ± 0.02^{a}
Liver oil (%)	21.19 ± 0.09d	18.66 ± 0.11^{c}	14.22 ± 0.05^{a}	15.65 ± 0.06^{b}
Growth performance				
HSI	3.16 ± 0.34^{c}	2.89 ± 0.19^{bc}	2.97 ± 0.35^{bc}	2.75 ± 0.42^{a}
VSI	15.78 ± 0.11^{d}	11.62 ± 0.14^{b}	14.24 ± 0.06^{c}	10.91 ± 0.08^{a}
CF	0.36 ± 0.02^{a}	0.35 ± 0.4^{a}	0.35 ± 0.3^{a}	0.36 ± 0.02^{a}
Live weight (g)	27.23 ± 0.98	64.06 ± 2.48^{b}	64.84 ± 3.12^{b}	60.14 ± 3.73^{a}
Live weight gain (g)	-	36.83 ± 1.84^{b}	37.63 ± 1.76^{b}	32.91±1.93^{a}
FCR	-	1.30 ± 0.21^{a}	1.30 ± 0.12^{a}	1.45 ± 0.17^{b}
SGR	-	1.36 ± 0.03^{b}	1.36 ± 0.04^{b}	1.27 ± 0.07^{a}

[1] Values are means ± SEM n = 10. Values in each row with a different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

Table 3. Fatty acid composition of feeds used in the experiments (%).

Fatty acids[2]	Diets[1]		
	FO	SFO	SBO
Saturated			
14:0	5.74 ± 0.2[b]	1.86 ± 0.4[a]	1.83 ± 0.0[a]
18:0	3.87 ± 0.1[a]	3.99 ± 0.3[a]	3.94 ± 0.5[a]
n-9			
18:1n-9	17.58 ± 0.3[a]	20.78 ± 0.2[b]	18.05 ± 0.6[a]
22:1n-9	0.87 ± 0.3[b]	0.39 ± 0.1[a]	0.40 ± 0.4[a]
20:1n-9	1.21 ± 0.1[b]	0.59 ± 0.2[a]	0.64 ± 0.1[a]
24:1n-9	0.67 ± 0.2[b]	0.26 ± 0.1[a]	0.25 ± 0.2[a]
n-6			
18:2n-6	5.00 ± 0.6[a]	45.73 ± 0.8[b]	40.87 ± 1.1[b]
18:3n-6	0.16 ± 0.1	-	-
20:3n-6	0.19 ± 0.1[a]	0.54 ± 0.2[b]	0.39 ± 0.1[ab]
20:4n-6	0.87 ± 0.3[b]	0.24 ± 0.0[a]	0.24 ± 0.2[a]
n-3			
18:3n-3	1.07 ± 0.1[b]	0.47 ± 0.1[a]	3.85 ± 0.3[c]
20:3n-3	0.15 ± 0.0	-	-
20:5n-3	10.23 ± 0.6[b]	3.90 ± 0.5[a]	4.02 ± 0.7[a]
22:6n-3	14.40 ± 0.5[b]	4.03 ± 0.7[a]	4.01 ± 0.1[a]
Total n-3	25.85 ± 1.0[c]	8.40 ± 0.7[a]	11.88 ± 0.3[b]
Total n-6	6.22 ± 0.4[a]	46.51 ± 1.3[c]	41.50 ± 0.9[b]
Total n-9	20.33 ± 0.8[b]	22.02 ± 0.5[a]	19.34 ± 0.5[a]
DHA/EPA	1.41 ± 0.1[b]	1.03 ± 0.1[a]	1.00 ± 0.2[a]

[1] Abbrevations for diets: FO, Fish Oil; SFO, Sunflower Oil; SBO, Soybean Oil.
[2] Values are means ± SEM n = 10. Values in each row with a different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

Table 4. Whole body fatty acid composition of the fish fed feeds containing different oils (%).

Fatty acids[2]	Initial	Diets[1]		
		FO	SFO	SBO
Saturated				
14:0	4.14 ± 0.1[b]	4.39 ± 0.0[b]	2.71 ± 0.4[a]	2.93 ± 0.2[a]
18:0	2.68 ± 0.1[b]	2.37 ± 0.3[a]	2.70 ± 0.2[b]	2.70 ± 0.1[b]
20:0	0.13 ± 0.1[b]	0.02 ± 0.0[a]	0.03 ± 0.1[a]	0.10 ± 0.0[b]
n-9				
18:1n-9	21.57 ± 0.5[a]	22.04 ± 0.7[ab]	22.66 ± 0.3[b]	22.52 ± 0.6[b]
20:1n-9	1.60 ± 0.2[b]	1.30 ± 0.1[a]	1.09 ± 0.1[a]	1.29 ± 0.2[a]
22:1n-9	0.02 ± 0.1[b]	0.02 ± 0.0[b]	0.01 ± 0.0[a]	0.01 ± 0.0[a]
24:1n-9	0.08 ± 0.0[ab]	0.10 ± 0.0[b]	0.07 ± 0.0[a]	0.10 ± 0.0[b]
n-6				
18:2n-6	11.24 ± 0.3[a]	10.44 ± 0.4[a]	26.79 ± 0.8[c]	21.74 ± 0.5[b]
18:3n-6	0.29 ± 0.1[b]	0.03 ± 0.0[a]	0.07 ± 0.0[a]	0.48 ± 0.1[c]
20:4n-6	0.86 ± 0.1[a]	0.86 ± 0.1[a]	0.72 ± 0.0[a]	0.76 ± 0.0[a]
n-3				
18:3n-3	1.48 ± 0.2[b]	1.34 ± 0.1[b]	0.91 ± 0.1[a]	2.03 ± 0.2[c]
20:3n-3	0.24 ± 0.1[a]	0.23 ± 0.0[a]	0.43 ± 0.1[b]	0.35 ± 0.0[ab]
20:5n-3	6.43 ± 0.3[b]	6.55 ± 0.6[b]	4.01 ± 0.5[a]	4.31 ± 0.3[a]
22:6n-3	11.06 ± 0.9[b]	12.22 ± 0.7[b]	7.80 ± 0.5[a]	8.31 ± 0.4[a]
Total n-3	19.21 ± 0.8[c]	20.57 ± 0.5d	13.15 ± 0.3[a]	15.00 ± 0.6[b]
Total n-6	12.39 ± 0.4[a]	11.33 ± 0.2[a]	27.58 ± 0.7[c]	22.98 ± 0.5[b]
Total n-9	23.29 ± 0.8[a]	23.46 ± 0.5[a]	23.83 ± 0.5[a]	23.92 ± 0.6[a]

[1] Abbrevations for diets: FO, Fish Oil; SFO, Sunflower Oil; SBO, Soybean Oil.
[2] Values are means ± SEM n=10. Values in each row with a different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

Table 5. Whole liver fatty acid composition of the fish fed feeds containing different oils (%).

Fatty acids[2]	Initial	Diets[1]		
		FO	SFO	SBO
Saturated				
14:0	4.92 ± 0.3^{c}	4.02 ± 0.2^{b}	2.70 ± 0.1^{a}	3.01 ± 0.1^{a}
18:0	2.32 ± 0.1^{a}	2.43 ± 0.2^{a}	2.67 ± 0.0^{b}	2.72 ± 0.3^{b}
20:0	0.13 ± 0.0^{a}	0.15 ± 0.0^{a}	0.12 ± 0.0^{a}	0.11 ± 0.0^{a}
n-9				
18:1n-9	27.50 ± 0.4^{b}	27.80 ± 0.7^{b}	28.0 ± 0.6^{b}	21.90 ± 0.4^{a}
20:1n-9	1.44 ± 0.3^{b}	1.28 ± 0.2^{ab}	1.05 ± 0.2^{a}	1.26 ± 0.1^{ab}
22:1n-9	0.84 ± 0.3^{c}	0.40 ± 0.1^{b}	0.26 ± 0.0^{a}	0.30 ± 0.0^{ab}
24:1n-9	0.05 ± 0.0^{a}	0.44 ± 0.1^{b}	0.03 ± 0.0^{a}	0.05 ± 0.0^{a}
n-6				
18:2n-6	10.60 ± 0.7^{a}	10.0 ± 0.4^{a}	25.80 ± 1.2^{c}	20.97 ± 0.9^{b}
18:3n-6	0.51 ± 0.3^{ab}	0.27 ± 0.0^{a}	0.65 ± 0.2^{b}	0.03 ± 0.0^{a}
20:4n-6	0.74 ± 0.1^{b}	1.05 ± 0.1^{c}	0.04 ± 0.0^{a}	0.47 ± 0.0^{ab}
n-3				
18:3n-3	1.11 ± 0.3^{ab}	1.28 ± 0.1^{b}	0.90 ± 0.2^{a}	1.96 ± 0.1^{c}
20:3n-3	0.42 ± 0.1^{ab}	0.25 ± 0.0^{a}	0.46 ± 0.2^{b}	0.41 ± 0.1^{ab}
20:5n-3	3.77 ± 0.2^{a}	6.28 ± 0.5^{b}	3.98 ± 0.4^{a}	4.07 ± 0.2^{a}
22:6n-3	9.40 ± 0.5^{b}	13.0 ± 0.7^{c}	7.82 ± 0.2^{a}	8.21 ± 0.4^{a}
Total n-3	14.72 ± 0.8^{b}	20.81 ± 0.4^{c}	13.16 ± 0.7^{a}	14.65 ± 0.3^{b}
Total n-6	11.85 ± 0.4^{b}	10.32 ± 0.3^{a}	26.49 ± 0.8d	21.47 ± 0.6^{c}
Total n-9	29.83 ± 1.0^{b}	29.96 ± 0.6^{b}	29.34 ± 0.8^{b}	23.51 ± 0.7^{a}

[1] Abbrevations for diets: FO, Fish Oil; SFO, Sunflower Oil; SBO, Soybean Oil
[2] Values are means ± SEM n = 10. Values in each row with a different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

begun more recently. The white sturgeon (*A. transmontanus*) and Russian sturgeon (*A. gueldenstaedtii*) and various sturgeon hybrids showed an increase in weight between 1 and 2 kg and 100% survival. At 21-23 °C, market size (0.1-1.3 kg) was attained in 12 months (1).

Water temperature, feeding rate and fish size are the 3 most important factors for feed intake and growth of fish. These factors, especially water temperature (16 ± 1 ºC), affected the growth performance of the fish (4).

In the group fed feed containing fish oil n-3 and total n-3 fatty acids in the whole body and liver were higher than those in the groups fed feed containing vegetable oil (Tables 4, 5). However, 22:6n-3 fatty acid was higher than the feed values in both the whole body and liver of fish fed feed containing sunflower and soybean oil. Similar results were reported for the white sturgeon (*A. transmontanus.*) (5,7), and rainbow trout (19). These suggest the selectivity of 22:6n-3 and its essentiality in this fish. In particular, fish given feeds supplemented with vegetable oil accumulated long chain n-3 PUFA (20:5n-3 and 22:6n-3) in the whole body and liver. Feeding sturgeon diets rich in 18:2n-6 (SFO, SBO) resulted in relatively high levels of 20:5n-3 and 22:6n-3. These results showed that the sturgeon has the ability to elongate 18:2n-6 and 18:3n-3 to 20:4n-6, 20:5n-3 and 22:6n-3 fatty acids because these fatty acids were found in the whole body and liver of fish samples (5,7,9-19). According to these results, the Russian sturgeon can utilize different kinds of oil in diets equally well. Especially n-3 HUFA have a very important effect on human health and total levels of n-3 HUFA in the whole body of fish fed different oils were high and the relationship with dietary lipids of n-3 HUFA was affected by dietary lipids. This result is very important for the formulation of sturgeon diets.

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