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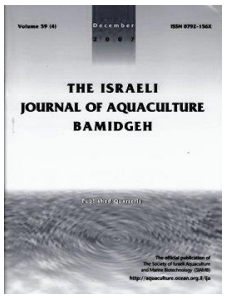

Effects of Canola and Safflower Oil Supplementation in Diets, on Growth Performance and Fatty Acid Composition of Russian Sturgeon (*Acipenser gueldenstaedtii* Brandt, 1833)

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Key words: *Acipenser gueldenstaedtii,* feed, canola oil, safflower oil, growth performance, fatty acid composition

Abstract

The aim of this study was to determine the impact on growth performance and muscle fatty acid composition, of replacement of 50% fish oil (FO) with canola oil (CO) and safflower oil (SFO) in the diets of Russian sturgeon (*Acipenser gueldenstaedtii*). Two isoproteic (48%) and isolipidic (12%) diets were formulated combining two oil sources (50% fish oil + 50% canola oil or 50% fish oil + 50% safflower oil). The diets were fed to apparent satiation to triplicate groups for 15 weeks, twice a day. No significant differences were observed between the experimental groups fed CO and SFO diets in terms of weight gain, specific growth rate, feed conversion ratio, and protein efficiency ratio. The experimental groups fed CO and SFO diets did not show significant differences in terms of protein, lipid, ash, and moisture content in their muscle. There were no significant differences in muscle between total n-3 fatty acids but total n-6 fatty acids were significantly higher in SFO group (24.90%) than in CO group (21.30%). Total n-6 fatty acids were also higher than (20.43%) at the start. In conclusion, 50% replacement of FO by CO or SFO in Russian sturgeon diets had no negative effect on growth performance, feed efficiency and fatty acid composition in the muscle of this species.

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Introduction

Marine fish meal and oil are the major ingredients used as protein and lipid sources in commercial aquaculture feeds. The aquaculture feed industry uses about 90% of the global supply of fish oil (Turchini et al., 2011). There is a growing demand for fish meal and oil in both the aquaculture and traditional farm animal feed sectors and with the decline in global production due to quota restrictions, prices rose in 2013 to record high levels (Globefish, 2014). Therefore, it is imperative for the aquaculture industry that suitable alternatives to fish oil be found.

A number of studies have shown that some vegetable oils (soybean, rapeseed, linseed oils) can partially or totally replace fish oil in diets for several fish species such as Atlantic salmon, rainbow trout, turbot, seabass, and common carp without affecting growth performance and feed efficiency (Yildirim et al., 2013; Bell et al., 2001; Bell et al., 2003a; Richard et al., 2006). However some results have shown altered fatty acid composition in the body of fish fed substitutes, compared with fish fed diets containing FO (Bell et al., 2001; Caballero et al., 2002; Montero et al., 2005; Pettersson et al., 2009). In some studies, replacing fish oil with vegetable oils, has resulted in a change in fatty acid profiles with lowered levels of eicosapentaenoic acid, 20:5n-3 (EPA) and docosahexaenoic acid, 22:6n-3 (DHA) and higher levels of 18C fatty acids, such as oleic acid, 18:1n-9 (OA), linoleic acid, 18:2n-6 (LA), and α-linolenic acid, 18:3n-3 (ALA) in muscle tissue and liver composition of Atlantic salmon (Torstensen et al., 2004a,b). Salmonids have the ability to endogenously convert ALA and LA to EPA, DHA and AA (arachidonic acid, 20:4n-6), by enzymatic pathways of desaturation and elongation (Bell et al., 2001), but these pathways might not be efficient enough for optimal growth and health of the fish without adding some dietary EPA and DHA (Pettersson et al., 2009).

Canola and other monounsaturated fatty acid (MUFA)-rich oils are considered to be good candidates to partially replace the fish oil included in aquaculture feeds. MUFA are easily digestible and are a good source of available energy, and their deposition in fish flesh is considered to be less detrimental than other fatty acids, from a human nutritional viewpoint. Among the vegetable oil sources used in fish oil replacement in aquaculture feeds, canola oil is the most studied and is utilized as MUFA-rich vegetable oil (Turchini and Mailer, 2011). Canola oil has an excellent balance between OA, LA and ALA (Huang et al., 2007). Several studies have investigated the effects of partial or total replacement of fish oil with canola oil, on growth performance and fatty acid composition in Atlantic salmon (Bell et al., 2001; 2003a,b; Rosenlund et al., 2001), in rainbow trout (Pettersson et al., 2009), in sea bass (Montero et al., 2005) but there are few studies on the effects of vegetable oils such as canola oil on growth performance and fatty acid composition in sturgeon species (Sener et al., 2005; Palmegiano et al., 2008). There is no study on the replacement of fish oil with safflower oil in sturgeon species.

The aim of this study was to determine the effects of 50% FO replacement by CO or SFO in diets on growth performance, feed efficiency, and fatty acid composition of Russian sturgeon.

Materials and Methods

Fish and maintenance. The 15 week experiment was conducted in an indoor facility at Sinop University Fisheries Faculty in Sinop (Turkey). The fish for the experiment (Russian sturgeon) were obtained from a state-owned farm in Amasya-Turkey and acclimated for two months prior to the experiment. During the acclimation period, the fish were fed a commercial trout diet [Black Sea Feed; 53% protein, 16% lipid, 10% ash, 1.5% fiber, 19.5% Nitrogen-Free Extract (NFE)] twice a day to apparent satiation. At the start of the experiment, the fish (mean weight 200±0.48 g) were fasted for a day, individually weighed to the nearest 1 g, and randomly distributed in six circular fiberglass tanks (water volume of 300 L) at 10 fish per tank with three replicates. Water inflow was adjusted to 4 L/min and supplemental aeration was provided via airstone diffusers. Average temperature and water quality parameters were monitored daily. Dissolved oxygen and pH were 18.4±0.2°C, 6.7±0.1 mg/L and 7.6, respectively. From each tank, 10 fish from the initial stock, at the beginning of the experiment, and 5 fish at the end of the experiment were sampled, homogenized, and analyzed, for muscle composition.

Canola and safflower oil supplementation in diets of Russian sturgeon

Experimental diets and feeding. Diet ingredients were obtained from local feed and feed ingredient manufacturers (SIBAL Inc. Sinop-Turkey; Sungur Pazarlama,Vital Inc., Sivas-Turkey; Gülce Yag, Kurtulus Yag Inc., Manisa-Turkey). Two iso-nitrogenous and iso-lipidic diets (48% protein and 12% lipid) were formulated combining two oil sources (50% fish oil + 50% canola oil-Diet I and 50% fish oil + 50% safflower oil-Diet II). Formulation and chemical composition of the experimental diets are shown in Table 1. The ingredients were thoroughly mixed, homogenized, moistened by the addition of 35% boiling water, and pelleted (3.0 mm) in a mincer. The pellets were dried at 70°C for 18 h and stored in plastic bags in a refrigerator. Fish were fed by hand to apparent satiation twice a day (at 09:00 and 15:00).

Table 1. Formulation and chemical composition (wet weight basis) of the diets

	CO Diet	*SFO Diet*
Ingredients (g/kg)		
Fish meal([a])	375	375
Extracted soybean meal	272.5	272.5
Wheat flour	150	150
Corn protein	125	125
Fish oil([b])	36.75	36.75
Safflower oil	-	36.75
Canola oil	36.75	-
Vitamin premix([*])	2.0	2.0
Mineral premix([*])	2.0	2.0
Proximate Composition(%)		
Moisture	9.26	5.87
Protein	48.42	48.30
Lipid	12.32	12.24
Ash	6.04	7.21
NFE[1]+Crude fiber	23.96	26.38
Gross energy (kJ/g)	20.37	20.72

[a] Anchovy meal
[b]Anchovy oil
CO= Canola oil, SFO=Safflower oil
* Per kg feed: 12,500 IU vitamin A; 2,500 IU vitamin D3; 10 mg vitamin K3; 10 mg vitamin B1; 20 mg vitamin B2; 15 mg vitamin B6; 0.03 mg vitamin B12; 250 mg vitamin C; 200 mg niacin; 1 mg biotin; 10 mg folic acid; 60 mg pantothenic acid;
1,000 mg Ca; 600 mg magnesium; 450 mg potassium; 90 mg zinc;
12 mg manganese; 5 mg Cu
[1]NFE=100-(%protein+ %lipid+ %ash+ %moisture)

Chemical analyses. Chemical composition of samples of fish and experimental diets were analyzed by standard methods (AOAC 1995) in laboratories of University of Sinop, Faculty of Fisheries (Sinop-Turkey). Moisture was determined gravimetrically after drying at 105◦C to constant weight, crude protein (Nx6.25) by the Kjeldahl method after acid digestion; crude lipid by petroleum ether extraction in a Soxhlet apparatus, and ash by incineration in a muffle furnace at 550°C for 6h. All analyses were performed in triplicate.

Preparation of Fatty Acid Methyl Esters. Lipid determination of the fish and diet samples was carried out by a modified Bligh and Dyer Method (Hanson and Olley 1963). Approximately 30 mg of lipid was placed in the reaction tubes and saponified with 1.5 ml of 0.5 N methanolic NaOH for 7 min/115°C. After cooling, 2 ml of Boron trifluoride (14% BF_3) was added and heated for another 5 min. at the same temperature as above. Then reaction tubes were cooled, 2 ml of iso-octane and 3 ml of saturated NaCl solution were added, and mixed for 30 seconds until the separation of the organic phases. Fatty Acid Methyl Esters (FAME) were extracted from the top layer, and transferred into an amber vial for further gas chromatography (GC) analysis. FAME extracts were kept at the freezer at -20°C until GC analysis (Oksuz and Ozyilmaz 2010).

Chromatographic Conditions. Fatty acids were analyzed using Gas Chromatography-Mass Spectrometry (GC-MS) with a Hewlett Packard GC (model 6890)

coupled with Hewlett Packard (model 5972A, HP 6890 system) MS detector. Separation of fatty acids was performed with HP-INNOWAX Polyethylene Glycol Capillary Column (Model number HP 19091N-133, 0.25 mm * 30m * 0.25 µm), and use of HP 6890 automatic injection system. Injection and detector temperatures were set at 250°C and 270°C, respectively. Split ratio was 1:20 with a total injection volume of 1 µl. Injector was washed three times with iso-octane and with the FAME containing isooctane prior to injection. Post injection, injector program was also set to triple wash the injector before next injection. Initially, oven temperature was programmed at 120°C and held for 3 minutes. Then, the temperature was increased to 180°C, held for 5 minutes, and further increased to 250°C with a 10°C per minute ramp rate and held at this temperature for four minutes. Total separation was achieved in 30 minutes. Identification of individual fatty acids was carried out by comparing the retention time of FAME standard (Supelco 47085U PUFA No: 3) and Supelco 37 component Fame mix (Supelco 47885-U). Confirmation of fatty acid methyl esters was also performed using an MS data base library (FAMEDBWAX) (Oksuz and Ozyilmaz 2010).

Statistical analysis. Anderson-Darling and Levene tests were used for homogeneity of variances and equality of variance of groups, respectively. Arcsine square root transformation of percentage data was conducted to achieve homogeneity of variances before statistical analysis. All the data was statistically analyzed using one-way ANOVA, and Tukey's test at $p<0.05$ and applied as a multiple sample comparison analysis using Minitab 13.0 for Windows**.** A significance level of 5 % was determined for all tests.

Results

Proximate diet and fatty acid composition. Proximate composition of all experimental diets was similar containing 48.30% to 48.42% crude protein and 12.24% to 12.32% crude lipid, respectively (Table 1). The safflower oil diet (SFO) contained high levels of saturated fatty acids (SFA), particularly myristic acid (14:0, MA), palmitic acid (16:0, PA) and stearic acid (18:0, SA), accounting for 2.30, 15.82 and 4.75% lipid, respectively (Table 2). The fatty acid composition of the canola oil diet (CO) was characterized by high levels of OA (31.18% lipid) and the fatty acid composition of the SFO diet was characterized by high levels of LA (31.99% lipid). CO diet had the highest concentrations of ALA and MUFA. SFO diet had the highest concentrations of EPA, DHA, SFA and PUFA (polyunsaturated fatty acids) with values of 4.42, 7.89, 24.58 and 47.56% lipid, respectively. The n-3/n-6 and DHA/EPA ratios were 0.60 and 0.43% lipid, 1.99 and 2.31% lipid for the CO and SFO diets, respectively.

Table 2. Fatty acid composition of the experimental diets (% of total fatty acids)

	Diets	
Fatty Acids	*CO*	*SFO*
C14:0	2.27	2.30
C15:0	0.34	0.34
C16:0	15.39	15.82
C18:0	4.42	4. 75
C20:0	0.78	0.65
C22:0	0.45	0.42
C24:0	0.33	0.28
C16:1 n-7	2.71	2.68
C18:1 n-7	2.71	2.03
C18:1 n-9	31.18	21.37
C20:1 n-9	1.27	0.90
C22:1 n-9	0.53	0.87
C18:3 n-3	3.44	1.92
C18:4 n-3	0.44	0.46
C20:3 n-3	0.22	0.23
C20:5 n-3	3.22	3.42
C22:5 n-3	0.42	0.44
C22:6n-3	6.40	7.89
C18:2 n-6	23.04	31.99
C20:2 n-6	nd	0.30
C20:4 n-6	0.45	0.91
ΣSFA	**23.98**	**24.58**
ΣMUFA	**38.40**	**27.86**
ΣPUFA	**37.62**	**47.56**
Σn-3 PUFA	**14.13**	**14.36**
Σn-6 PUFA	**23.49**	**33.21**
n-3/n-6	**0.60**	**0.43**
DHA/EPA	**1.99**	**2.31**

Different superscripts within the row denote significant differences.
nd (not detected)

Growth performance. The diets were well accepted by the experimental fish and no mortality was observed during the experimental period. No significant differences in weight gain (WG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER) and hepatosomatic index (HIS) were found between the groups at the end of the experiment ($p>0.05$) (Table 3).

Table 3. Growth performance and feed efficiency in fish fed the experimental diets*

	Acipenser gueldenstaedtii (Russian sturgeon)	
	CO	*SFO*
Initial weight (g)	200.03±0.38	199.77±0.59
Final weight (g)	296.10±7.17	281.33±12.05
Weight gain (g)	96.07±7.02	81.57±12.53
FCR[1]	1.05±0.04	1.21±0.21
SGR (%)[2]	0.52±0.03	0.45±0.06
PER[3]	1.98±0.15	1.69±0.26
HSI (%)[4]	1.87±0.06	2.09±0.22

*Values are the mean ± SEM of triplicate groups (10 fish for each replicates)
CO, canola oil
SFO, safflower oil
[1]FCR, Feed Conversion Ratio = Total feed intake (g)/Weight gain (g)
[2]SGR, Specific Growth Rate = [(ln final body weight - ln initial body weight)/days] x 100
[3]PER, Protein Efficiency Ratio = Weight gain (g)/Protein intake (g)
[4]HSI, Hepatosomatic Index (%) = (Liver weight / Body weight) x 100

Proximate composition of muscle. Chemical composition (% wet weight) of muscle of experimental fish after 15 weeks feeding trial is shown in Table 4. There were no significant differences in the crude protein, lipid, ash, or moisture content among groups fed the experimental diets. But, the results were significantly different from the initial values ($p<0.05$).

Table 4. Chemical composition (% wet weight) of muscle in Russian sturgeon fed the experimental diets*

Proximate Composition	*Initial*	*CO*	*SFO*
Moisture	74.72±0.10[a]	78.03±0.46[b]	78.18±0.23[b]
Crude Protein	18.44±1.53[a]	20.78±0.24[a]	18.99±0.16[a]
Crude Lipid	6.64±0.42[a]	4.07±0.06[b]	3.41±0.21[b]
Ash	1.01±0.01[a]	1.07±0.01[a]	1.05±0.01[a]

Different superscripts within the row denote significant differences.

*Values are the mean ± SEM of three replicates (Ten fish from the initial stock and five fish at the end of the experiment per tank were pooled.)

Fatty acid composition of muscle. The fatty acid composition of muscle of Russian sturgeon fed experimental diets is shown in Table 5. Highest LA (21.83%) was observed in SFO group and the highest OA level (32.89%) was found in CO group. The initial ALA, AA, EPA, and DHA were the highest in CO and SFO groups. SFA was the highest in the muscle of the fish at the start of the experiment and the lowest in CO group at the end of the experiment. Dominant fatty acids among the saturated fatty acid were MA, PA and SA. MUFA was the highest in CO group and the highest PUFA was observed in SFO group. While there were no significant differences between Σn-3 fatty acids of fish fed experimental diets, n-6 fatty acids were significantly different ($p<0.05$). In the groups fed with SFO, the ratio of total n-6 fatty acids was higher (21.30 and 24.90%) than that in the fish at the start of the experiment (20.43%). The DHA/ EPA ratios were higher in fish fed the experimental diets than at the beginning of the experiment ($p<0.05$).

Table 5. Fatty acid composition of muscle in Russian sturgeon (*Acipenser gueldenstaedtii)* fed the experimental diets (% of total fatty acids)

		Diets	
Fatty Acids	*Initial*	*CO*	*SFO*
C14:0	3.39±0.12[a]	2.19±0.29[b]	2.37±0.11[b]
C15:0	0.52±0.01[ac]	0.35±0.04[bc]	0.40±0.02[c]
C16:0	19.54±0.15[a]	16.41±2.12[b]	17.76±1.28[b]
C18:0	3.32±0.05[a]	3.54±0.31[a]	3.83±0.21[a]
C20:0	0.29±0.01[a]	0.25±0.02[a]	0.27±0.01[a]
C16:1 n-7	5.37±0.27[a]	3.20±0.23[b]	3.35±0.21[b]
C18:1 n-7	3.02±0.00[a]	2.68±0.18[a]	2.75±0.20[a]
C18:1 n-9	27.01±0.99[a]	32.89±4.40[b]	28.20±1.15[a]
C20:1 n-9	1.88±0.22[a]	1.85±0.29[a]	1.73±0.08[a]
C22:1 n-9	0.72±0.06[a]	0.39±0.09[b]	0.35±0.10[b]
C18:3 n-3	2.44±0.13[a]	1.91±0.05[b]	1.83±0.08[b]
C18:4 n-3	0.65±0.01[a]	0.37±0.01[b]	0.37±0.01[b]
C20:3 n-3	0.63±0.02[a]	0.46±0.06[b]	0.45±0.02[b]
C20:5 n-3	3.59±0.11[a]	2.76±0.37[b]	2.57±0.08[b]
C22:5 n-3	0.93±0.04[a]	0.94±0.14[a]	0.91±0.02[a]
C22:6 n-3	7.29±0.71[a]	8.50±1.23[b]	7.97±0.32[b]
C18:2 n-6	18.02±0.24[a]	18.64±1.04[a]	21.83±0.27[b]
C18:3 n-6	0.44±0.06[ab]	0.31±0.02[a]	0.53±0.03[b]
C20:2 n-6	0.75±0.05[a]	0.81±0.11[a]	0.94±0.03[a]
C20:3 n-6	0.36±0.10[a]	0.32±0.07[a]	0.59±0.04[b]
C20:4 n-6	0.66±0.04[a]	0.90±0.05[b]	0.82±0.03[b]
C22:5 n-6	0.48±0.15[a]	0.32±0.06[a]	0.30±0.00[a]
ΣSFA	**27.06±0.27[a]**	**22.74±2.68[b]**	**24.62±1.04[c]**
ΣMUFA	**36.99±0.53[a]**	**41.01±3.81[b]**	**36.38±1.20[a]**
ΣPUFA	**35.95±0.79[a]**	**36.25±1.15[a]**	**39.00±0.36[b]**
Σn-3 PUFA	**15.52±0.77[a]**	**14.96±1.86[a]**	**14.10±0.34[a]**
Σn-6 PUFA	**20.43±0.44[a]**	**21.30±0.76[b]**	**24.90±0.16[c]**
n-3/n-6	**0.76±0.04[a]**	**0.71±0.11[a]**	**0.57±0.01[b]**
DHA/EPA	**2.02±0.13[a]**	**3.07±0.05[b]**	**3.10±0.03[b]**

Different superscripts within the row denote significant differences.

Discussion

In this study none of the experimental diets were detrimental to Russian sturgeon. There was no difference in growth, feed efficiency, and chemical body composition compared to diets containing only dietary fish oil. Similar results were reported when several other plant oils (soybean, sunflower, canola, corn, peanut or olive oils) were tested for *A. transmontanus* (Palmegiano et al., 2008), *A. persicus* (Imanpoor et al., 2011), *Huso huso* (Hassankiadeh et al., 2013), and some other fish species (*Dicentrarchus labrax*, Martins et al., 2006; *Salmo salar,* Rosenlund et al., 2001; *Oncorhynchus mykiss*, Martins et al., 2006; *Pagrus major*, Huang et al., 2007; *Perca fluviatilis*, Blanchard et al., 2008; *Cyprinus carpio*, Yildirim et al., 2013). The use of blends of vegetable oils and fish oils were as acceptable as digestible lipids as fish oil, in rainbow trout, and vegetable oils such as soybean, safflower, olive and palm oils could constitute 80-90% of the added oil in diets without affecting growth performance (Caballero et al. 2002). The replacement of 50% dietary fish oil with unrefined peanut oil had no adverse effect on the growth performance of common carp (Yildirim et al. 2013). There were no significant effects on weight gain in White sturgeon (Xu et al. 1993) and no negative effects on growth of turbot fed diets containing SFO (Bell et al., 1994; Altundag et al. 2014). Partial replacement of cod liver oil with either linseed or SFO did not have a negative effect on growth performance in juvenile Eurasian perch (Blanchard et al. 2008). However, growth performance was significantly lower in rainbow trout fed a diet containing 100% SFO as the sole lipid source compared to fish fed diets containing 100% pollock liver oil or linseed oil as the sole lipid source (Kiron et al. 2004). In this study, the use of FO in combination with CO or SFO did not have adverse effects on the growth performance of Russian sturgeon. Body composition in terms of crude protein, lipid, ash, or moisture in fish was also not significantly affected by the supplemented lipid sources (CO or SFO). Similar results were obtained using several vegetable oils in diets for white sturgeon (Xu et al., 1993) and Iranian sturgeon (Imanpoor et al., 2011).

In some studies where level of vegetable oil inclusion in diets was 50% and above, a significant accumulation of LA and reduction of EPA and DHA was found in the flesh of salmon, although dietary vegetable oil inclusion does not result in reduced growth performance and feed conversion (Bell et al., 2001, 2003a, b). In the present study, the SFO diet contained more LA (31.99%) compared to the CO diet (23.04%) and the SFO group contained more LA (21.83%) in muscle than the CO group (18.64%). This result is probably because safflower oil contains more LA compared to the canola oil. Safflower oil contains 11% of fatty acids as OA; 79% as LA; and 0.5% as ALA, however, canola oil provides 60% of fatty acids as OA; 21% as LA; and 10% as ALA (Kwon et al. 1991).

Diets containing canola oil showed higher levels of OA (31.18%) and MUFAs (38.40%) and lower levels of n-6 PUFA (23.49%) than SFO group (21.37%, 27.86; 33.21% respectively). After 15 weeks of rearing, most fatty acids in the muscle of Russian sturgeon reflected the fatty acid profile of the diet. The group fed CO diet showed higher levels of OA (32.89%) and MUFAs (41.01%) and lower levels of n-6 PUFA (21.30%) than SFO group (28.20%, 36.38%, 24.90% respectively) with no difference in growth performance and feed efficiency.

Our results also indicate some reduction in the levels of EPA and DHA in the muscle of CO group (2.76% and 8.50%) and SFO group (2.57% and 7.97%) compared to the initial value (3.59% and 7.29% respectively) ($p<0.05$), but the difference between CO and SFO groups was not significant ($p>0.05$). The results confirm that fatty acid composition of tissue lipids in Russian sturgeon reflects dietary fatty acid composition.

It is known that freshwater fish species require both the n-3 and n-6 series of fatty acids, especially LA and ALA, in their diets for optimal growth and health (Martino et al., 2002; Tocher, 2003). Sturgeon, as with other fresh water fish, typically require the n-3 and n-6 series of fatty acids and need these fatty acids in their diet (Sener et al., 2005; Glencross, 2009). Sturgeon require both n-3 and n-6 fatty acids and sturgeon can elongate and desaturate LA to AA and ALA to DHA, respectively (Deng et al. (1998). In the present study, Russian sturgeon demonstrated the ability to better retain DHA in muscle tissue compared to ALA and EPA because the levels of DHA in muscle were higher

than the levels of DHA in the diets, while levels of ALA and EPA followed the opposite trend. Selective retention of DHA could to be related to the preferential use of ALA and EPA, as described for white sturgeon (Palmegiano et al., 2008; Hassankiadeh et al., 2013), rainbow trout (Caballero et al., 2002) and European sea bass (Montero et al., 2005). Many freshwater fish and also sturgeon are able to synthesize and store DHA and EPA from ALA, AA from LA, and are able to both synthesize and store DHA (Palmegiano et al. (2008). These researchers suggested that vegetable oils (e.g. soybean oil or corn oil) could be used in diets for most of the rearing period of sturgeons while high levels of inclusion of FO in diets could only be used in the last two months.

Conclusion

It is well known that n-3 HUFA (particularly EPA and DHA) which are abundant in FO, are useful for growth, health and flesh quality in fish. However, vegetable oils can partially replace them and this is an advantage due of their availability and relatively stable price. The partial replacement of FO with several vegetable oils or their blends in the feeds can provide optimal levels of EFAs and thereby reduce fish production costs. The results of this study indicated that it is possible to replace 50% of FO with CO or SFO in Russian sturgeon diets without any negative effect on growth, feed utilization, and fatty acid composition.

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References

Altundag M.S., Ustaoglu Tiril S. and A. Ozdemir, 2014. Effects of safflower oil supplementation in diet on growth performance and body fatty acid composition of turbot (*Psetta maxima*). *Aquacult. Int.*, 22:597–605.

AOAC, 1995. Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Arlington, VA.

Bell J.G., Tocher D.R., MacDonald F.M. and J.R. Sargent, 1994. Effects of diets rich in linoleic (18:2n-6) and α-linolenic (18:3n-3) acids on growth, lipid class and fatty acid compositions and eicosanoid production in juvenile turbot (*Scophthalmus maximus* L.). *Fish Physiol. Biochem.*, 13:105–118.

Bell J.G., McEvoy J., Tocher D.R., McGhee F., Campbell P.J. and J.R. Sargent, 2001. Replacement of fish oil with rapeseed oil in diets of Atlantic salmon (*Salmo salar*) affects tissue lipid compositions and hepatocyte fatty acid metabolism. *J. Nutr.,* 131: 1535-1543.

Bell J.G., McGhee F., Campbell P.J. and J.R. Sargent, 2003a. Rapeseed oil as an alternative to marine fish oil in diets of post-smolt Atlantic salmon (*Salmo salar*): changes in flesh fatty acid composition and effectiveness of subsequent fish oil "wash out". *Aquaculture*, 218: 515-528.

Bell J.G., Tocher D.R., Henderson R.J., Dick J.R. and V.O. Crampton, 2003b. Altered fatty acid compositions in Atlantic salmon (*Salmo salar*) fed diets containing linseed and rapeseed oils can be partially restored by a subsequent fish oil finishing diet. *J Nutr*, 133: 2793–2801.

Blanchard G., Makombu J.G. and P. Kestemont, 2008. Influence of different dietary 18:3n-3/18:2n-6 ratio on growth performance, fatty acid composition and hepatic ultrastructure in Eurasian perch, *Perca fluviatilis*. *Aquaculture*, 284: 144-150.

Caballero M.J., Obach A., Rosenlund G., Montero D., Gisvold M. and M.S. Izquierdo, 2002. Impact of different dietary lipid sources on growth, lipid digestibility, tissue fatty acid composition and histology of rainbow trout, *Oncorhynchus mykiss*. *Aquaculture*, 214: 253–271.

Deng D.F., Hung S.S.O. and D.E. Conklin, 1998. White sturgeon (*Acipencer transmontanus*) require both n-3 and n-6 fatty acids. *Aquaculture (Abstracts Lipids and*

Fatty Acids), 161: 333-335.
Glencross B.D., 2009. Exploring the nutritional demand for essential fatty acids by aquaculture species. *Reviews in Aquaculture*, 1: 71–124.
Globefish, 2014. Fishmeal and fish oil – June 2014. http://www.globefish.org/fishmeal-and-fish-oil-june-2014.html
Hanson S.W.F. and J. Olley, 1963. Application of the Bligh and Dyer method of lipid extraction to tissue homogenates. *Biochem. J.*, 89: 101-102.
Hassankiadeh M.N., Khara H., Sadati M.A.Y. and H. Parandavar, 2013. Effects of dietary fish oil substitution with mixed vegetable oils on growth and fillet fatty acid composition of juvenile Caspian great sturgeon (*Huso huso*). *Aquacult. Int.*, 21:143-155.
Huang S.S.Y., Oo A.N. Higgs D.A., Brauner C.J. and S. Satoh, 2007. Effect of dietary canola oil level on the growth performance and fatty acid composition of juvenile red sea bream, *Pagrus major*. *Aquaculture*, 271: 420–431.
Imanpoor M.R., Asghari M. and R. Asadi, 2011. Requirements for n-3 highly unsaturated fatty acids in feding juvenile Iranian sturgeon (*Acipenser persicus*) and its effects on growth, carcass quality and fatty acid composition. *Aquacult. Int.*, 19: 1035-1046.
Kiron V., Puangkaew J., Ishizaka K., Satoh S. and T. Watanabe, 2004. Antioxidant status and nonspecific immune responses in rainbow trout (*Oncorhynchus mykiss*) fed two levels of vitamin E along with three lipid sources. *Aquaculture*, 234: 361-379.
Kwon J.S., Snok J.T., Wardlaw G.M., D. H. Hwang, 1991. Efects of diets high in saturated faty acids, canola oil, or saflower oil on platelet function, thromboxane B_2 formation, and faty acid compositon of platelet phospholipids. *Am. J. Clin. Nutr.*, 54: 351-358.
Martino R.C., Cyrino J.E.P., Portz L. and L.C. Trugo, 2002. Performance and fatty acid composition of surubim *(Pseudoplatystoma coruscans)* fed diets with animal and plant lipids. *Aquaculture,* 209: 233-246.
Martins D., Gomes E., Rema P., Dias J., Ozo´rio R.O.A., and L.M.P. Valente, 2006. Growth, digestibility and nutrient utilization of rainbow trout (*Oncorhynchus mykiss*) and European sea bass (*Dicentrarchus labrax*) juveniles fed different dietary soybean oil levels. *Aquacult. Int.*, 14: 285–295.
Montero D., Robaina L., Caballero M.J. Gines R. and M.S. Izquierdo, 2005. Growth, feed utilization and flesh quality of European sea bass (*Dicentrarchus labrax*) fed diets containing vegetable oils: A time course study on the effect of a re-feeding period with 100% fish oil diet. *Aquaculture*, 248: 121-134.
Oksuz, A. and A. Ozyilmaz, 2010. Changes in fatty acid compositions of Black Sea anchovy (*Engraulis encrasicolus* L. 1758) during catching season. *Turk. J. Fish. Aquat. Sci.*, 10: 381-385.
Palmegiano G.B., Gai F., Daprà F., Gasco L., Pazzaglia M. and Peiretti P.G., 2008. Effects of Spirulina and plant oil on the growth and lipid traits of white sturgeon (*Acipenser transmontanus*) fingerlings. *Aquacult. Res.*, 39: 587-595.
Pettersson A., Johnsson L., Brännäs E. and J. Pickova, 2009. Effects of rapeseed oil replacement in fish feed on lipid composition and self-selection by rainbow trout **(Oncorhynchus mykiss).** *Aquacult. Nutr.*, 15: 577–586.
Richard N., Kaushik S., Larroquet L., Panserat S. and G. Corraze, 2006. Replacing dietary fish oil by vegetable oils has little effect on lipogenesis, lipid transport and tissue lipid uptake in rainbow trout (*Oncorhynchus mykiss*). *Brit J. Nutr.*, 96: 299-309.
Rosenlund G., Obach A., Sandberg M.G., Standal H. and K. Tveit, 2001. Effect of alternative lipid sources on long-term growth performance and quality of Atlantic salmon (*Salmo salar* L.). *Aquacult. Res.***,** 32: 323–328.
Sener E., Yildiz M. and E. Savas, 2005. Effects of dietary lipids on growth and fatty acid composition in Russian sturgeon (*Acipenser gueldenstaedtii*) juveniles. *Turk. J. Vet. Anim. Sci.*, 29: 1101–1107.
Tocher D. R., 2003. Metabolism and functions of lipids and fatty acids in teleost fish. *Rev. Fish. Sci.*, 11: 107-184.

Torstensen B.E., Froyland L. and O. Lie, 2004a. Replacing dietary fish oil with increasing levels of rapeseed oil and olive oil – effects on Atlantic salmon (*Salmo salar* L.) tissue and lipoprotein lipid composition and lipogenic enzyme activities. *Aquacult. Nutr.*, 10: 175–192.

Torstensen B.E., Froyland L., Ornsrud R. and O. Lie, 2004b. Tailoring of a cardioprotective muscle fatty acid composition of Atlantic salmon (*Salmo salar*) fed vegetable oils. *Food Chem.*, 87: 567–580.

Turchini G.M., Ng W.K., Tocher D.R., 2011. Fish oil replacement and alternative lipid sources in aquaculture feeds. CRC Press, Taylor & Francis Group, Boca Raton, FL, USA, 533 pp.

Turchini G.M. and R.J. Mailer, 2011. Rapeseed (Canola) oil and other monounsaturated fatty acid-rich vegetable oils. In: *Fish oil replacement and alternative lipid sources in aquaculture feeds.* (Turchini, G.M., Ng, W.K. & Tocher, D.R. eds), pp. 161-208. CRC Press, Taylor & Francis Group, Boca Raton, FL, USA.

Yildirim O., Acar, U., Turker, A., Sunar, M.C. and S Yilmaz, 2013. The effects of partial or total replacement of fish oil by unrefined peanut oil on growth performance and body chemical composition of Common carp (*Cyprinus carpio*). *Isr. J. Aquacult. - Bamidgeh,* IJA_65.2013.919, 5 pages.

Xu R., Hung S.S.O. and J.B. German, 1993. White sturgeon tissue fatty acid compositions are affected by dietary lipids. *J Nutr.*, 123: 1685-1692.