Effect of different vegetable oils on the body composition of pikeperch (*Sander lucioperca* (L.)) under intensive culture conditions

T. Molnár[1], G. Szabó[2], A. Szabó[3], A. Csuvár[1], Cs. Hancz[1]

[1]Kaposvár University, Faculty of Agricultural and Environmental Sciences, Institute of Environmental and Natural Conservation Sciences
H-7400 Kaposvár, Guba Sándor u. 40.

[2]Agricultural and Rural Development Agency
Budapest, PO Box 62.

[3]Kaposvár University, Faculty of Agricultural and Environmental Sciences, Institute of Food and Agricultural Product Qualification
H-7400 Kaposvár, Guba Sándor u. 40.

ABSTRACT

The aim of this study was to evaluate the effects of the different vegetable oils on the body composition of pikeperch (Sander lucioperca (L.)). Fish of 27.88±7.97 g body weight and 135.83±11.99 mm (mean±SD; n=60) standard body length were introduced into 65 L aquaria, working in a recirculation system. Three experimental diets containing different vegetable oils were fed. Basic feed (60 g kg^{-1} lipid content) was complemented with vegetable oils (soybean oil (So), rapeseed oil (Ra), and sunflower oil (Su)) that resulted 110 g kg^{-1} crude fat content, in average. Body composition and the fillet fatty acid profile were determined at the end of the 6 weeks experimental period. Control group fed on the basic feed had significantly lower dry matter and lipid content than fish consuming oil complemented feeds. Fatty acid profile of the fish fillets changed according to the lipid composition of the experimental diets. The proportion of palmitic acid (C16:0) decreased, while the ratio of oleic acid (C18:1n-9) has increased significantly in the fish fillets in group Ra compared to the control group. The ratio of linoleic acid (C18:2n-6; feed Ra) and α-linolenic acid (C18:3n-3; feed Ra and So) showed also significant increases while the level of arachidonic acid (C20:4n-6) decreased significantly in all of the treated groups. The ratio of DPA (C22:5n-3) changed in groups Ra and Su significantly. The ratio of n3 fatty acids was found to be the highest in the Su group while group So had the highest n6 levels. Rapeseed oil induced the highest n9 fatty acid ratio in the fish fillet. As compared to the initial value all of the treatments produced a decreased n3/n6 values.

(Keywords: fatty acid profile, fillet composition, pikeperch, *Sander lucioperca* (L.), vegetable oil)

ÖSSZEFOGLALÁS

Az eltérő növényi olajok hatása az intenzíven nevelt süllő (*Sander lucioperca* (L.)) testösszetételére

[1]Molnár T., [2]Szabó G., [3]Szabó A., [1]Csuvár A., [1]Hancz Cs.
[1]Kaposvári Egyetem, Agrár- és Környezettudományi Kar, Környezettudományi és Természetvédelmi Intézet
7400 Kaposvár, Guba Sándor u. 40.
[2]Mezőgazdasági és Vidékfejlesztési Hivatal
1385 Budapest, Pf. 62.
[3]Kaposvári Egyetem, Agrár- és Környezettudományi Kar, Élelmiszer- és Mezőgazdasági Termék Minősítő Intézet
7400 Kaposvár, Guba Sándor u. 40.

A kísérlet célja a különféle növényi olajok süllő (Sander lucioperca (L.)) testösszetételére kifejtett hatásának vizsgálata volt. A 27,88±7,97 g tömegű és 135,83±11,99 mm (átlag±SD; n=60) standard testhosszú halakat 65 literes recirkulációs rendszerben működő akváriumokba telepítettük fel és három különböző növényi olajokat tartalmazó kísérleti tápot fogyasztottak. Ezek egy alaptakarmány (6%-os zsírtartalommal) növényi olajos (szója olaj (So), repce olaj (Ra), és napraforgó olaj (Su)) kiegészítésével készültek (11%-os átlagos nyerszsír tartalommal). A 6 hetes kísérlet végén meghatároztuk a testösszetételt és a zsírsavösszetételt. A kontrol csoport mely az alaptakarmányt fogyasztotta jelentősen alacsonyabb szárazanyag és zsírtartalmat mutatott, mint a kezelt csoportok. A hal filé zsírsav összetétele a kísérleti takarmányok zsírsavösszetételének megfelelően alakult. A palmitinsav (C16:0) részaránya csökkent, míg az olajsavé (C18:1n-9) szignifikánsan nőtt a repce olajos (Ra) csoport filéjében a kontrolhoz viszonyítva. A linolsav (C18:2n-6; repceolajos takarmány Ra) és α-linolénsav (C18:3n-3; repce és szójaolajos, Ra és So takarmányok) aránya szintén növekedést mutatott, míg az arachidonsav (C20:4n-6) jelentősen csökkent az összes kezelt csoportban. A DPA (C22:5n-3) aránya a repceolajos (Ra) és napraforgó-olajos (Su) csoportokban változott szignifikánsan. Az n3 zsírsavak aránya a legmagasabb a napraforgó-olajos (Su), míg az n6 zsírsavak aránya a szójaolajos (So) csoportban volt. A legmagasabb n9 zsírsav arányt a repceolaj alakította ki a filében. A kezdeti értékhez képest az összes kezelés csökkentette az n3/n6 arányt a filében.
(Kulcsszavak: zsírsav profil, file összetétel, süllő, *Sander lucioperca* (L.), növényi olaj)

INTRODUCTION

Pikeperch, *Sander lucioperca* (L.) is a well-known and highly evaluated predator fish of the European pond fish culture. This species can be sold at high prices on the markets but increasing of its production is hindered by the lack of an effective intensive breeding and ongrowing technology. Former investigations (*Ruuhijarvi et al.*, 1991; *Baer et al.*, 2001) proved that pikeperch fingerlings can be trained to accept formulated feed by gradual substitution of natural food sources with artificial diets. In most cases trout pellet with 200–300 g kg^{-1} fat content was used (*Alsted et al.*, 1995). This fat content proved to be high (*Kestemont et al.*, 2001) and the optimal level could be determined between 100–120 g kg^{-1} (*Zakes et al.*, 2004). *Zakes* (2003) also demonstrated that the level of daily feed ration affects the body composition of pikeperch. The highest body fat content was found in the group fed the highest daily ration.

Examining several predator fishes *Nettleton* (2000) concluded that the cultured and wild fish show differences in the ratio of polyunsaturated fatty acids and also in the

n3 fatty acid levels. *Farkas and Herodek* (1967) defined that the fatty acid composition of the lipids is determined by the production of the polyunsaturated fatty acids in the lower level of the food chain, and also the "dilution" with endogenous fatty acids affects the profile. The fatty acid composition of the fish body never corresponds to the feed FA composition since it contains the fatty acids *de novo* synthetized or modified in the liver by desaturation or elongation. This latter modification is especially characteristic to the phospholipids fraction, which generally contains higher proportion of the PUFA than the triglycerides (*Henderson and Tocher,* 1987). Radioisotope examinations determined the way of the elongation and desaturation in the n9, n3, n6 fatty acids originated from the feed (*Greene and Selivonchick,* 1987).

In the last decade several studies were carried out to examine the fatty acid profile of the fish fillet using different oil sources in the formulated feeds. In case of the most investigated fish, the Atlantic salmon (*Salmo salar* (L.)), the oil sources were sunflower oil (*Brandsen et al.,* 2003), rapeseed oil (*Rennie et al.,* 2005) and linseed oil (*Bell et al.,* 2004). The body composition of pikeperch was studied by *Schulz et al.* (2005) using fish oil, linseed oil and soybean oil in the feeds and by *Molnár et al.* (2006) who compared the fish oil to the linseed oil in the diet.

Generally, the fat content of the fish feeds originates from fish oil; however, this fat source is getting more and more expensive and has more limited availability than the vegetable oils. The aim of our investigation was to determine the changes in the body composition, especially in the fatty acid profile of the juvenile pikeperch fed formulated feeds with vegetable oil replacements.

MATERIALS AND METHODS

Experimental fish

The training of the pikeperch to accept formulated feed was carried out in the Fish Laboratory of the Agricultural Faculty of the Pannon University (Keszthely, Hungary) where the fish was reared in an aquaria-system working in recirculation system. At this period the fish was feeding with trout pellet containing 450 g kg^{-1} crude protein and 115 g kg^{-1} crude fat. Fish at the age of 6 months were transported to the Fish Laboratory of the Kaposvár University and introduced to aquaria working in a recirculation system. Due to the handling stress at transport and the transition to the basic feed (containing no added oil), a period of four weeks was introduced before the feeding trial. The average initial bodyweight of the pikeperch was 27.88±7.97 g (mean±SD; n=60), and the standard body length was 135.83±11.99 mm (mean±SD; n=60). The average fish biomass $aquarium^{-1}$ was 139.38±4.22 g (mean±SD, n=12). The initial condition factor was 1.08±0.06.

Experimental conditions and measurements

The experiment lasted for 6 weeks. Altogether 60 fish were introduced to 65 l (33 x 30 x 60 cm) aquaria, stocking 5 fish $aquarium^{-1}$. The mean stocking density was 2.1 g l^{-1} in the experiment. Individually aerated aquaria worked in a recirculation system. This system had a total volume of 2500 l attached to a simple bio filter unit and a 200-l settling tank from where the water is pumped back to the fish-keeping units. The daily water replacement rate was about 5% of the total volume. The water flow rate was adjusted to 1.5 l min^{-1} in aquaria. Water temperature was measured daily over the 42-day rearing interval with laboratory thermometer (±0.1 ^{o}C). Dissolved oxygen (HI 93732 N Spectrophotometer, Instruments Deutschland GmbH., Germany), pH (Watercheck pH

and EC Meter, Hanna Instruments Deutschland GmbH., Germany). Nitrite, nitrate, total ammonia nitrogen (TAN) and phosphate levels were measured weekly photometric method (Filter Photometer pF-10, Macherey-Nagel GmbH. & Co., Germany). The temperature was 19.95±1.07 ºC (means±SD, n=42) and the pH changed between 7.7–7.9 during the experiment. The O_2, NO_2-N, NO_3-N, TAN and PO_4-P content of the water in the rearing system (average of the inflow and outflow water) were 8.2±0.97 mg l^{-1}, 0.09±0.02 mg l^{-1}, 6.39±1.73 mg l^{-1}, 0.26±0.65 mg l^{-1} and 2.68±0.75 mg l^{-1} (n=6), respectively. The photoperiod was as follows: 12 hours low light intensity (25 lux at the water surface) and 12 hours of total darkness.

Four aquariums were randomly assigned to each treatment. A basic feed containing 60 g kg^{-1} fat (originated from the components; mainly fish oil) was completed with the following vegetable oils: soybean-oil (So), rapeseed-oil (Ra), sunflower-oil (Su) that resulted approximately 110 g fat kg^{-1} feed. All of the feed used in our experiment were prepared in a fish feed producer factory. The chemical composition of the experimental feeds is shown in *Table 1*. The 3 mm pellets were offered once a day manually, always at the same time (10 a.m.) until satiation. Daily feed consumption was later calculated and proved to be around 2% of the fish biomass.

Table 1

Chemical and fatty acid composition of the experimental diets

Parameters (1)	**Treatment (2)**			
	Basic (control)(3)	**Ra**	**Su**	**So**
Dry matter (g kg^{-1}) (4)	891.9	897.8	894.4	898.2
Crude protein (g kg^{-1}) (5)	419.4	399.4	406.3	409.8
Crude fat (g kg^{-1}) (6)	59.3	102.3	106.9	107.9
Crude fiber (g kg^{-1}) (7)	20.4	19.9	20.8	18.1
Crude ash (g kg^{-1}) (8)	93.0	90.0	90.4	89.4
Fatty acid composition (g kg^{-1}) of the total fatty acids (9)				
C10:0	0.2	0.1	0.0	0.1
C12:0	0.5	0.3	0.3	0.3
C14:0	24.4	15.5	13.9	14.2
C14:1n-5	0.2	0.1	0.1	0.1
C15:0	2.3	1.5	1.3	1.3
C16:0	166.6	112.9	111.3	130.8
C16:1n-7	37.4	23.2	20.8	21.5
C17:0	3.2	2.2	1.9	2.2
C17:1n-7	5.6	3.3	2.9	3.1
C18:0	50.4	33.8	43.7	46.8
C18:1n-9	156.6	333.9	178.1	195.1
C18:1n-7	24.6	29.4	14.8	19.6
C18:2n-6t	1.1	0.7	0.8	0.6
C18:2n-6c	222.2	200.5	427.5	352.0
C18:3n-6	1.0	0.6	0.6	0.6
C18:3n-3	22.2	47.4	13.6	47.0
C20:0	2.6	4.4	2.8	3.9
C20:1n-9c	20.7	22.6	11.2	12.0
C20:2	3.3	2.4	1.7	2.0
C20:3n-3	1.3	0.9	0.7	0.7
C20:3n-6	1.7	1.1	0.9	1.0

Table 1 (continued)

C20:4n-6 (AA)	9.2	5.7	5.0	4.9
C20:5n-3 (EPA)	97.0	63.3	56.6	56.2
C22:0	2.9	3.4	5.5	4.4
C22:1n-9	3.2	3.2	1.6	1.9
C22:5 (DPA)	13.7	8.5	7.9	7.6
C22:6n-3 (DHA)	114.5	70.7	66.5	61.9
C24:0	3.1	2.4	2.9	2.4
C24:1n-9	8.3	5.9	5.0	5.8
Σ SFA	256.2	183.6	176.6	275.5
Σ MUFA	256.6	234.5	421.5	245.2
Σ PUFA	487.1	581.8	401.8	479.1
Σ n3	235.0	182.3	137.4	165.8
Σ n6	226.0	202.9	429.8	354.2
Σ n9	188.8	365.6	195.9	214.8
n3/n6	1.03	0.90	0.32	0.47
DHA/DPA	8.36	8.32	8.42	8.14
DHA/EPA	1.18	1.12	1.17	1.10
DHA/ C18:3n-6c	114.5	117.8	110.8	103.2
AA/ C18:2n-6c	0.04	0.03	0.01	0.01
Chain length (10)	18.35	18.24	18.19	18.14
Unsaturation index* (11)	206.6	159.8	207.0	181.2

*Unsaturation index: 1 x Σ monoenoic + 2 x Σ dienoic + 3 x Σ trienoic … (12)

1. táblázat: A kísérleti takarmányok kémiai és zsírsav összetétele

Paraméter (1), Kezelés (2), Alap (Kontrol)(3), Szárazanyag (4), nyers fehérje (5), nyerszsír (6), nyers rost (7), hamu (8), zsírsav összetétel a teljes zsírsav százalékában (9), lánchossz (10), Telítettlenségi Index (11), Telítettlenségi Index: *1 x Σ monoén + 2 x Σ dién + 3 x Σ trién … (12)*

Fish measurements

At the beginning and at the end of the experiment standard body length (±1 mm) and live body weight (±0.01 g) was measured individually. Condition factor was calculated as $K = W L^{-3} \times 100$ where W is live weight (g) and L is standard length (cm). Daily feed consumption was measured per aquarium and feed conversion ratio was calculated by dividing the weight of dry food fed by the gain as wet fish weight for the total period. The leftover feed was siphoned out, filtered, blotted and weighed before the next feeding.

Sampling and chemical analysis

Three randomly chosen fish (fed for four weeks with the basal diet containing 60 g kg^{-1} crude fat) were sacrificed in the beginning of experiment and served as controls for body and fillet composition investigations. At the end of the trial three fish in each treatment were over-anaesthetised with clove oil (dose 0.025 mL L^{-1}, 2 min). Fish were dissected and approximately 3 g fillet samples originated from the dorsal part of the fish were taken for the analysis of fatty acid composition. Samples were immediately frozen to –70 ^{o}C and stored until analysis. The remaining part of the body was homogenized and subjected to chemical body analysis. Dry matter content was determined after drying

samples in a vacuum oven at 50 ºC and a vacuum of 13.3 kPa, using anhydrous calcium chloride as the drying agent. After 16 h, the vacuum was changed to 0.2 kPa and the samples were weighed every 4 h until they reached constant weight. Nitrogen content was determined in the fresh samples by Kjeldahl analysis according to ISO 5983 (*ISO,* 1997). The crude fat content was determined by extraction of freeze-dried samples with petroleum-ether and drying the extract at 103 ºC to a constant weight according to ISO 6492 (*ISO,* 1985). Ash was analysed by burning oven-dried samples in a muffle furnace at 550 ºC according to ISO 5984 (*ISO* 1978). The crude fibre content of the feeds was determined as the loss in mass resulting from ashing of the residue obtained after acid and alkaline digestion of the sample according to ISO 6865 (*ISO* 2000). Tissue fat content was extracted according to *Folch et al.* (1957). Total lipids were transmethylated by boron trifluoride (BF_3) and methanol. Gas liquid chromatography was performed on a Shimadzu 2100 apparatus (Shimadzu, Kioto, Japan) equipped with an SP-2380 (Supelco, Bellefonte, PA, USA) type capillary column (30 m x 0.25 mm ID, 0.20 µm film, cat. No.:24110-U) and flame ionization detector (2 x 10^{-11}). Characteristic operating conditions were: injector temperature: 270 ºC, detector temperature: 300 ºC, helium flow: 28 cm s^{-1}. The oven temperature was graded: from 80 to 205 ºC: 2.5 ºC min^{-1}, 5 min at 205 ºC; from 205 to 250 ºC: 10 ºC min^{-1}, 5 min at 250 ºC. To identify individual FAs, an authentic FA standard (Mixture Me100, cat. No.:90-1100; Larodan Fine Chemicals AB, Malmö, Sweden) was used.

Statistical analysis

Statistical analyses were carried out with SPSS® For Window™ (Version 10. 1999). The analysis of variance (one-way ANOVA) procedure was used to test main effects. Treatment means were compared using alpha of 0.05 for significance in Tukey and Dunnett post hoc tests. Analysis of variance was carried out on aquarium means for growth, feed consumption and feed loss traits. Body composition and fillet fatty acid profile data were obtained by randomly chosen three fish per treatment.

RESULTS AND DISCUSSION

During the experiment no losses have occurred. All of the groups showed acceptable growth but the condition factor of group Ra tended to be lower, without statistically significant difference. The effect of the different vegetable oil contents was not significant on the growth and feed utilization parameters (*Table 2*). Independently from the treatments the feed losses were high. However, the Ra group showed an increased feed loss and a lower weight gain; but the difference was significant only in the feed consumption: feed loss ratio compared to the other treatments. The highest weight gain value was measured in the group So.

Table 2

Growth and feed conversion of fish

Parameters (1)	Treatment (means±SD) (2)			
	Ra	Su	So	P value
Final body weight (g) (3)	30.54±6.68	29.24±10.71	31.72±13.72	NS
Final body length (mm) (4)	142.90±9.12	139.70±14.59	141.35±17.54	NS
Fish biomass (g)* (5)	150.80±9.54	160.48±15.33	149.19±3.69	NS
Condition factor (6)	1.06±0.006	1.11±0.06	1.09±0.02	NS
Growth (mm day^{-1}) (7)	0.62±0.22	0.67±0.11	0.77±0.30	NS
Weight gain(g day^{-1}) (8)	0.18±0.18	0.36±0.07	0.48±0.27	NS
Total used feed amount (g/aquarium)** (9)	102.81±15.91	102.64±4.65	106.55±18.53	NS
Feed consumption (g/aquarium)** (10)	39.56±11.29	50.40±4.58	53.27±9.93	NS
Feed loss (g/aquarium)** (11)	63.25±4.69	52.24±9.14	53.28±8.63	NS
Feed consumption/feed loss (12)	0.62±0.13a	1.00±0.29b	1.00±0.08b	0.024

*Total weight of five fish in an aquarium. (13),**Calculated for five fish/aquarium (14), NS means: not significantly different (Tukey's post hoc test) (15)

2. táblázat: A halak növekedése és takarmányértékesítése

Paraméter (1), Kezelés (átlag±SD) *(2), Befejező tömeg (g) (3), Befejező hossz (mm) (4), hal biomassza (g) (5), Kondíció faktor (6), Növekedés (mm/nap) (7), tömeggyarapodás (g/nap)(8), összes beadott takarmány (g/akvárium) (9), összes elfogyasztott takarmány (g/akvárium) (10) takarmány pazarlás (g/akvárium)(11), takarmányfogyasztás/pazarlás (12), Öt hal teljes tömege egy akváriumban (13), öthal/akváriumra számítva (14), NS:nem szignifikáns,* Tukey Post Hoc teszt

Regarding the growth parameters of the pikeperch fingerlings, all vegetable oil complementation seemed to be adequate for intensive rearing. However, the feed consumption data show that the rapeseed oil possibly had an unpleasant taste. This theory seems to be also confirmed by the condition decay and the higher level of the feed losses. However, the alteration of the latter parameter could derive from the feeding method (until satiation, but once a day). It was also observed fish captured the pellets but instead of swallowing released them. The daily weight gain corresponded to the values measured in similar experimental settings. *Molnár et al.* (2006) fed pikeperch fingerlings (22.1 g) with pellet containing 120 g kg^{-1} fish oil, resulting a weight gain of 0.28 g day^{-1} similar to the 0.18 (Ra), 0.36 (Su), 0.48 (So) g day^{-1} values measured in this experiment. In contrast, the condition factor (K=1.11) was lower than the value (K=1.22) in the above-mentioned publication.

The chemical composition of the fish samples is shown in *Table 3*. The body composition of the fish fed various vegetable oils did not differ significantly. Although, compared to the control, the dry matter of all treated groups has increased (P=0.015) due

to the increment of the crude fat content which was significant in the groups Ra and Su (P=0.041).

Table 3

The effects of different dietary fat sources on the total body composition (n=3)

Treatments (means±SD) (1)					
Chemical composition (2)	**Control (7)**	**Ra**	**Su**	**So**	**P value (8)**
Dry matter (g kg^{-1}) (3)	227.80±6.29a	269.77±13.50b	270.47±13.79b	261.17±18.16b	0.015
Crude protein (g kg^{-1}) (4)	169.73±6.60	179.23±6.97	180.00±4.95	176.07±0.65	NS
Crude fat (g kg^{-1}) (5)	19.93±2.91a	53.80±16.65b	54.90±12.93b	46.93±16.40ab	0.041
Crude ash (g kg^{-1}) (6)	43.67±1.06	45.20±0.35	42.93±1.27	43.53±2.91	NS

NS means: not significantly different, a,b means significantly different (Dunnett (2-sided) and Tukey Post Hoc tests) (9)

3. táblázat: Az eltérő olajforrások hatása a teljes test összetételére (n=3)

Kezelés (1), Kémiai összetétel (2), Szárazanyag (3), nyers fehérje (4), nyerszsír (5), hamu (6), Kontrol (7), P-érték (8), NS:nem szignifikáns, a,b: szignifikáns különbség (Dunnett t (2-sided) és Tukey Post Hoc teszt) (9)

The fillet fat content of the pellet fed pikeperch generally ranges between 70 g kg^{-1} (*Schulz et al.*, 2005) and 107 g kg^{-1} (*Zakes et al.*, 2004). *Schulz et al.* (2005) achieved the 70 g kg^{-1} level with soybean oil replacement, while Zakes fed 100 g kg^{-1} fat content with a mixed oil source, containing also rapeseed oil. These are higher in both cases than the results of our experiment (53.80 g kg^{-1} rapeseed oil, 46.93 g kg^{-1} soybean oil). *Molnár et al.* (2006) found also higher fat content with vegetable oil feeding (linseed oil, 80.2 g kg^{-1} body fat content) but the fish oil source resulted similar body fat content (54.1±7.1 g kg^{-1}) to our present results. The dry matter contents and the protein contents of body were also lower than the values published by *Zakes et al.* (2004) (336 and 191 g kg^{-1} dry matter and crude protein content, respectively). *Molnár et al.* (2006) found similar dry matter (283 g kg^{-1}) but lower protein levels (154 g kg^{-1}) in the fish body.

The fatty acid composition of the fish fillet is shown in *Table 4*. The ratio of palmitic acid (C16:0) in the fish fillet was decreasing compared to the control value, however the difference was significant only in group Ra, the other two treated groups showed a medial level. Reverse tendency was detectable in the ratio of oleic acid (C18:1n-9) resulting a significantly different high level in group Ra. The ratio of linoleic acid (C18:2n-6c) and α-linolenic acid (C18:3n-3) was increasing in all treated groups, but the differences were significant in the So group in both fatty acids and in the Ra group in the α-linolenic acid compared to the control. The arachidonic acid (ARA; C20:4n-6) level decreased in the fish fillet during the trial. The three vegetable oil groups did not differ significantly, but the control level was significantly higher. The docosapentaenoic acid, DPA (C22:5n-3) level changed also in all of the groups, but the difference was significant only in the groups Ra and Su. The vegetable oil treatment had

no significant effect on the EPA (C20:5n-3), and DHA (C22:6n-3) levels and also on the EPA: DHA ratio; however both fatty acid showed a decreasing value.

The ratio of the saturated fatty acids decreased in all groups but it was significant only in the group So. The MUFA did not change significantly, although the level in group Ra increased 1.5 times compared to the control. This resulted a reverse change in the PUFA level; the Ra group showed a decrease in the PUFA but the difference was not significant. The total n3 fatty acid ratio was the lowest in the Ra group, and this group had the highest n9 level. Both changes were significant. The highest n6 level was measured in the So group, however, the difference between the treated groups was not significant. The n3/n6 ratio decreased during the experiment, the difference was significant in the groups Ra and So.

The calculated Δ5 desaturase index value decreased significantly in group Ra. The Δ9 index value increased significantly also in group Ra. The Δ6 index differed significantly in the group So, as compared to the control value. In the biosynthesis of n6 the fatty acids ARA is an end-product, while linoleic acid (C18:2n-6) is the precursor. Regarding the ratio of the two fatty acids all the treatments differed significantly from the control value (P=0.008). The calculated unsaturation index changed between 256.3±29.7 and 281.5±15.6. Although the treated groups were similar, compared to the initial value (317.2±23.8) a decrease was detected, being significant in group Ra (P=0.088).

Table 4

The effects of different dietary fat sources on the fatty acid composition of fillets (n=3)

Fatty acid composition (g kg^{-1}) of the total fatty acids (1)	Treatments (means±SD) (2)				
	Control (3)	Ra	Su	So	P value (4)
C10:0	0.2±0.3	0.1±0.1	0.2±0.4	0.1±0.1	NS
C12:0	0.3±0.1	0.4±0.02	0.3±0.1	0.4±0.3	NS
C14:0	13.1±4.6	29.0±5.1	23.5±12.7	24.2±12.3	NS
C14:1n-5	0.4±0.4	1.3±0.4	1.1±0.7	1.0±0.6	NS
C15:0	2.4±0.3	2.9±0.3	2.7±0.7	2.6±0.7	NS
C16:0	183.9±7.2a	159.2±2.5b	167.1±11.3ab	168.4±11.6ab	0.05
C16:1n-7	25.6±8.1	51.5±9.7	42.2±22.3	42.2±21.4	NS
C17:0	4.0±0.5	3.8±0.3	3.6±0.6	3.6±0.6	NS
C17:1n-7	3.3±1.0	5.2±1.0	4.0±2.2	4.6±2.6	NS
C18:0	49.0±3.4	32.9±7.1	40.0±12.6	40.9±13.8	NS
C18:1n-9	92.5±21.2a	170.4±34.1b	123.1±24.0ab	126.8±29.0ab	0.05
C18:1n-7	23.7±0.9	26.4±0.6	23.2±3.9	24.2±2.5	NS
C18:2n-6t	1.2±0.7	4.1±0.9	3.1±1.7	3.5±2.0	NS
C18:2n-6c	72.5±21.8a	107.1±16.8ab	118.5±32.4ab	131.0±20.1b	0.072
C18:3n-6	1.4±0.3	1.7±0.3	2.2±0.4	2.0±0.3	NS

Table 4 (continued)

C18:3n-3	4.2±1.4a	13.4±3.5b	7.8±3.7ab	11.6±2.3b	0.018
C20:0	2.7±0.1	2.9±0.3	2.7±0.8	2.5±0.3	NS
C20:1n-9	13.1±4.6	23.2±3.6	18.7±6.4	16.2±4.9	NS
C20:2n-6	2.5±0.2	3.2±0.6	2.9±0.7	2.4±0.7	NS
C20:3n-3	1.6±0.1	1.6±0.1	2.0±1.1	1.6±0.2	NS
C20:4n-6 (AA)	19.5±1.3a	11.3±2.0b	13.7±1.2b	12.7±3.0b	0.005
C20:5n-3(EPA)	93.8±5.4	81.3±3.6	80.8±14.4	80.4±6.4	NS
C22:5n-3 (DPA)	27.0±0.5a	23.1±1.3b	24.0±0.1b	24.8±1.8ab	0.014
C22:6n-3 (DHA)	359.3±51.2	239.0±61.3	289.4±37.4	269.0±62.6	NS
C24:0	0.9±0.3	0.8±0.1	0.7±0.1	0.5±0.2	NS
C24:1n-9	2.0±0.2a	4.2±0.7b	2.7±0.8ab	2.8±0.7ab	0.017
Σ SFA	256.4±5.5a	232.0±1.3b	240.8±9.6ab	243.2±11.4ab	0.034
Σ MUFA	160.5±36.1	282.2±48.4	214.9±60.1	217.7±60.1	NS
Σ PUFA	583.1±31.0	485.9±47.2	544.3±52.8	539.1±48.8	NS
Σ n3	485.8±52.1a	358.4±62.6b	404.0±22.6ab	387.4±58.1ab	0.074
Σ n6	97.3±21.7	127.4±15.6	140.3±32.8	151.7±20.2	NS
Σ n9	107.6±25.9a	197.8±37.0b	144.6±31.1ab	145.8±33.2ab	0.052
n3/n6	5.22±1.51a	2.88±0.89b	2.96±0.53ab	2.60±0.61b	0.035
Δ5 (C20:4n-6/ C20:3n-3)	12.2±1.8a	7.0±1.4b	7.8±3.0ab	8.0±1.4ab	0.047
Δ6 (C18:3n-6/ C18:2n-6)	0.02±0.001a	0.02±0.001ab	0.02±0.003ab	0.01±0.001b	0.027
Δ9 (C18:1n-9/ C18:0)	1.9±0.6a	5.5±1.9b	3.4±1.5ab	3.5±1.6ab	0.106
DHA/DPA	13.3±2.1	10.3±2.0	12.1±1.6	10.8±1.7	NS
DHA/EPA	3.8±0.5	2.9±0.6	3.7±1.2	3.4±1.0	NS
DHA/C18:3n-6	271.2±91.0	148.2±73.0	136.5±24.4	141.6±50.7	NS
AA/C18:2n-6	0.29±0.09a	0.11±0.04b	0.12±0.02b	0.10±0.03b	0.008
Chain length (5)	19.3±0.2	19.0±0.3	19.0±0.2	18.9±0.3	NS
Unsaturation index (6)	317.2±23.8a	256.3±29.7b	281.5±15.6ab	272.8±28.3ab	0.088

NS means: not significant, a,b means: significant different (Dunnett t (2-sided) and Tukey Post Hoc tests) (7)
Unsaturation index: 1 x Σ monoenoic + 2 x Σ dienoic + 3 x Σ trienoic …(8)

4. táblázat: Az eltérő olajforrások hatása a filé zsírsav összetételére (n=3)

Zsírsav összetétel a teljes zsírsav százalékában (1), Kezelés (2), Kontrol (3), P-érték (4), lánchossz (5), Telítettlenségi Index (6), NS:nem szignifikáns, a,b: szignifikáns különbség (Dunnett t (2-sided) és Tukey Post Hoc teszt), Telítettlenségi Index: 1 x Σ monoén + 2 x Σ dién + 3 x Σ trién …(8)

The palmitic acid proportion of the fillet decreased, while the level of oleic acid increased. These changes in the fillet fatty acid composition were correlative with the differences in the experimental feeds. Oleic acid was dominant in the fillet of the rapeseed oil fed group, which can be explained with the high oleic acid content of the rapeseed oil in the feed. Similarly, the higher α-linolenic acid (C18:3n-3), and linoleic acid (C18:2n-6) content of the vegetable oil groups may be attributed to the dietary fatty acid levels. *Regost et al.* (2003) reported that the flesh of turbots (*Psetta maxima*) fed on pellets with high soybean oil content was rich in linoleic acid (C18:2n-6). Our results confirmed this, since the fillet of the soybean oil group contained higher ratio of this fatty acid than the control value.

The control EPA, DPA, and DHA levels were higher than the final levels, as measured in the treated groups. Regost et al. (2003) published a similar tendency in turbot (*Psetta maxima*) fed pellets with high soybean and linseed oil replacement; the mentioned fatty acids had lower levels than it was measured in the control (fish oil) group. In pikeperch, the difference was detectable in all of the three fatty acids but was only significant by DPA. Although vegetable oils are poor in long chain PUFA, the fish fillet showed acceptable values. *Jankowska et al.* (2003) detected 74.9 g kg^{-1} fatty acids EPA, 24.0 g kg^{-1} fatty acids DPA (C22:5n-3) and 245.0 g kg^{-1} fatty acids DHA (C22:6n-3) in the fillet fat content of wild pikeperch. In our investigation the lowest levels were found in the rapeseed oil group (81.3 g kg^{-1} fatty acids EPA, 23.1 DPA, and 239.0 DHA). Pikeperch is able to compensate these low levels both by the elongation and desaturation of C18 fatty acids (*Jankowska et al.*, 2003). By arachidonic acid (C20:4n-6), the significant reduction emerged correspondently to the ratio in the actual feeds.

The saturated fatty acid proportion decreased in all treated groups. The soybean oil feed contained higher amounts of saturated fatty acids, but the level in the fish fillet of this group did not differ significantly from the other two groups. Although, the highest MUFA content was detected in the sunflower oil feed, there was no surplus in the fish fillet of this group, moreover, the MUFA content in the rapeseed oil group was higher. Regarding the control value, the vegetable oil replacements have generally increased the MUFA ratio. The PUFA ratio changed contrary to MUFA; it showed a decrease due to the vegetable oil feeding. However, the divergent vegetable oils had the same effect on the PUFA ratio, the differences in the feed fatty acid contents did not manifest in the fish fillet; the fish metabolism likewise equalized the differences.

The n3/n6 ratio decreased in the three vegetable oil groups during the experiment. *Jankowska et al.* (2003) fed pikeperch with a pellet containing similarly 110 g kg^{-1} fat (TROUVIT, Classic 7) and found that the n3/n6 ratio was 4.40 which was higher than the best vegetable oil group (Su, 2.96) in our experiment. The higher control value was due to the lower n6 level (76.0 g kg^{-1} fatty acids) together with a similar n3 level (334.6 g kg^{-1} fatty acids). Consequently the higher n6 ratio in the fed pellets had an effect on the fillet n6 ratio. Schulz et al. (2005) published 174 g kg^{-1} fatty acids n6 level, and 321 g kg^{-1} fatty acids n3 level in the fillet of pikeperch fed soybean oil resulting 1.8 n3/n6 ratio. In this experiment these parameters were as follows: 151.7, g kg^{-1} fatty acids, 387.4±58.1 g kg^{-1} fatty acids, and 2.60, respectively. It can be established that the fillet n3/n6 ratio is mainly determined by the pellet n3/n6 ratio in the pikeperch, as it was described also in perch (*Perca fluviatilis*) by *Xu et al.* (2002).

The unsaturation index found in all of the treated groups (especially the control value) was high. *Molnár et al.* (2006) obtained similar value (267.1) in pikeperch fed pellets containing 120 g kg^{-1} fat partially replaced with linseed oil. The highest value in

our experiment was 281.5 found in the sunflower oil group. The high level was primarily resulted by the high ratio of DHA in the fish fillet.

CONCLUSIONS

Based on our results it can be concluded that the investigated performance traits were similarly affected by the different vegetable fat sources applied. The fatty acid profile of the fillet was slightly poorer in its PUFA levels as compared to the fish oil based control diet, however the three vegetable oils induced largely similar changes in this aspect.

ACKNOWLEDGEMENT

This work was supported by the Hungarian Scientific Research Fund (OTKA D048498).

REFERENCES

Alsted N., Due T., Hjermitsley N., Andreasen N. (1995). Practical experience with high energy diets, FCR, growth and quality. J. Appl. Ichthyol., 11. 329-335.

Baer J., Zienert S., Wedekind H. (2001). Neue Erkentnisse zur Umstellung von Natur- auf Trockenfutter bei der Aufzucht von Zandern (*Sander lucioperca L.*). Fischer und Teichwirt., 7. 243-244.

Bransden M.P., Carter C.G., Nichols P.D. (2003). Replacement of fish oil with sunflower oil in feeds for Atlantic salmon (*Salmo salar* L.): effect on growth performance, tissue fatty acid composition and disease resistance. Comp. Biohcem. Physiol. B, 135. 611-625.

Bell J.G., Henderson R.J., Tocher D.R., Sargent J.R (2004). Replacement of dietary fish oil with increasing levels of linseed oil: Modification of flesh fatty acid composition in atlantic salmon (*Salmo salar* L.) using a fish oil finishing diet. Lipids, 39. 223-231.

Farkas T., Herodek S. (1967). Investigations of the fatty acid composition of fishes from Lake Balaton. Annal. Biol. Tihany, 34. 3-13.

Folch J. M., Leeas M., Sloane-Stanley G.H. (1975). A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem., 226. 495-509.

Greene D.H.S., Selivonchik D.P. (1987). Lipid metabolism in fish. Prog. Lipid Research., 26. 53-85.

Henderson R.J., Tocher D.R. (1987). The lipid-composition and biochemistry of fresh-water fish. Prog. Lipid Research, 26. 281-347.

ISO (1978). Animal Feeding Stuffs – Determination of Crude Ash. ISO 5984. International Organization for Standardization

ISO (1985). Animal Feeding Stuffs – Determination of Fat Content. ISO 6492. International Organization for Standardization

ISO (1997). Animal Feeding Stuffs – Determination of Nitrogen Content and Calculation of Crude Protein Content – Kjeldahl Method. ISO 5983. International Organization for Standardization

ISO (2000). Animal Feeding Stuffs – Determination of Crude Fibre Content. ISO 6865. International Organization for Standardization

Jankowska B., Zakes Z., Zmijewski T., Szczepkowski M. (2003). Fatty acid and meat utility of wild and cultured zander, S*ander lucioperca* (L.). EJPAU, 6. Issue:1 Series: Fisheries

Kestemont P., Vandeloise E., Mélard C., Fontaine P., Brown P.B. (2001). Growth and nutritional status of Eurasian perch *Perca fluviatilis* fed graded levels of dietary lipids with or without added ethoxyquin. Aquaculture, 203.85-99.

Molnár T., Szabó A., Szabó G., Szabó C., Hancz C. (2006). Effect of different dietary fat content and fat type ont he growth and body composition of intensively reared pikeperch, *Sander lucioperca* (L.). Aquacult. Nutr., 12. 173-182.

Nettleton J. A. (2000). Fatty Acid in Cultivated and Wild Fish. Proceedings of the International Institute of Fisheries Economics and Trade. July 10-14. Oregon State University, Cavallis, OR.

Regost C., Arzel J., Cardinal M., Rosenlund G., Kaushik S.J. (2003). Total replaement of fish oil by soybean or linseed oil with a return to fish oil in Turbot (*Psetta maxima*) 2. flesh quality properties. Aquaculture, 220. 737-747.

Rennie S., Huntingford F.A., Loeland A.L., Rimbach M. (2005). Long term partial replacement of dietary fish oil with rapeseed oil; effects on egg quality of Atlantic salmon *Salmo salar.* Aquaculture, 248. 135-146.

Ruuhijarvi J., Virtanen E., Saimainen M., Muyunda M. (1991). The growth and survival of pike-perch, *Stizostedion lucioperca L.* larvae fed on formulated feeds. European Aquaculture Society, Special Production No. 15, Gent. Belgium

Schulz C., Knaus U., Wirth M., Rennert B. (2005). Effects of varying dietary fatty acid profile on growth performance, fatty acid, body and tissue composition of juvenile pike perch (*Sander lucioperca*). Aquacult. Nutr., 114. 403-413.

SPSS® For Window™ (1999). Version 10., Copyright SPSS Inc., Chicago, IL.

Xu X., Kestemont P. (2002**).** Lipid metabolism and FA composition in tissues of Eurasian Perch *Perca fluviatilis* as influenced by dietary fats. Lipids, 37. 297-304.

Zakes Z. (2003). Pikeperch, *Sander lucioperca* (L.) production in recirculating systems (in Czech with English summary). Bulletin VURH Vodnany ½, 136-140.

Zakes Z., Przybyl A., Wozniak M., Szczepkowski M., Mazurkiewicz J. (2004). Growth performance of juvenile pikeperch, *Sander lucioperca* (L.) fed graded of dietary lipids. Czech J. Anim. Sci., 49. 156-163.

Corresponding author (*levelezési cím*):

Tamás Molnár
Kaposvár University, Faculty of Agricultural and Environmental Sciences, Institute of Environmental and Natural Conservation Sciences
H-7400 Kaposvár, Guba Sándor u. 40.
Kaposvári Egyetem, Agrár- és Környezettudományi Kar, Környezettudományi és Természetvédelmi Intézet
Tel.: 06 82/505-800, Fax: 36-82-320-175
e-mail: molnar.tamas.gergely@ke.hu