THESES OF DOCTORAL (PhD) DISSERTATION

KAPOSVÁR UNIVERSITY
FACULTY OF ANIMAL SCIENCE
Department of Pig and Small Animal Breeding

Head of the doctoral school:
Dr. Péter Horn
Member of the Hungarian Academy of Sciences

Supervisor:
Dr. Csaba Hancz
CSc

Co-Supervisor:
Dr. Tamás Gergely Molnár
PhD

INVESTIAGATIONS ON MEAT QUALITY AND GROWTH OF PIKEPERCH (*SANDER LUCIOPERCA* L.) AND VOLGA PIKEPERCH (*SANDER VOLGENSIS* GMELIN) FED ARTIFICAL FEEDS WITH DIFFERENT FATTY ACID COMPOSITIONS

Author:
GERGELY SZABÓ

KAPOSVÁR

2009

1. INTRODUCTION

The fish is an exceedingly healthy food of high biological value it is easy to digest. Beside the high amount of protein, the proportion of the fat of the meat is low (1-7%). The proportion of the unsaturated fatty acids is high and the proportion of the omega-3/omega-6 (n-3/n-6) fatty acids (3:1-4:1) might help to develop the ideal level in the human body.

There is a huge demand for fish meat, mainly for the tasteful, boneless predatory species in the developed European countries. The pikeperch (*Sander lucioperca* L.) could also be sold in an almost unlimited amount (PINTÉR, 2002). The predatory species are by-products of the fish farms, where the carp is dominant. The higher production of the predatory species would most probably be realized in intensive systems. The pikeperch is a traditional species of the fish farms, but is a new subject of the professional, intensive fish production. The hybridization with its close relative, the less sensitive Volga pikeperch (*Sander volgensis* Gmelin), might help the domestication of the pikeperch (MÜLLER ET AL., 2004). This result and the fact that it can be better reared among intensive conditions and easily accustomed to artificial feed might focus the attention on the Volga pikeperch.

It is necessary to develop feeding methods and adequate feeds suitable to the demands of the perch species, in order to complete the intensive rearing technology. From point of view of the more economical production, the substitution of the generally used fish oil to vegetable oil might be of great importance. More than 50% of the total fish oil production of the world is used in the aquaculture (XU AND KESTEMONT, 2002). According the prediction of BARLOW (2000) this proportion will be 85% by 2010. The conception of “fish from fish” is unsustainable and the use of alternative protein

and fat sources is becoming an important issue worldwide and also in Hungary.

In most pikeperch experiments trout feed was used. However, the 20-30% fat content is most probably high for the perch species (KESTEMONT ET AL., 2001). The optimal level is most probably around 10-12% fat, 53-58% protein content and 20-21 MJ/kg energy content (SCHULTZ ET AL., 2007).

In the last few years several studies examined the fatty-acid profile of the different fish species when using varying oil sources in the feed mixture. For example, in case of the Atlantic salmon (*Salmo salar* L.), the scientific literature is very abounding in this field. In case of the perch species, however, there are only a few publications in this subject. SHULTZ ET AL. (2005) used feed, containing fish oil, linseed oil or soybean oil to the fish. ZAKES ET AL. (2004) fed the pikeperch with rapeseed oil containing feed.

The intensive rearing of the native predatory fish species has been investigated for more than 10 years at the Kaposvár University. The previous results and the developed infrastructure formed the basis of my examinations.

During my research work, my aim was:

1. to determine how the feeding of the varying fat content feeds, using both vegetable and animal oils, influences the productive parameters of the fish and the fatty acid content of the fish meat,
2. to determine the differences in the consumption, growth rate, body composition and in the fatty acid profile of the fillet of the two species, if the feed mixture contained the same amount of fat, but varying vegetable oils,
3. to examine the growth, the feed conversion ratio and the body composition of the pikeperch and Volga pikeperch using varying amount of feeds containing the optimal amount of fat.

2. MATERIAL AND METHODS

Six experiments are introduced in my dissertation. Three examinations were carried out both in case of pikeperch and Volga pikeperch. The pairs of experiments were made in the same rearing system with similar settings, shifted in time. Pikeperch and Volga pikeperch in the first and second experiment were fed with feeds containing animal and vegetable oils (fish and linseed oil). The effects of the different vegetable oils (soybean, sunflower and rapeseed oil) were evaluated in the third and fourth examination. In the fifth and sixth experiments, the influence of the varying amount of feed on the productive parameters and body composition of the pikeperch and Volga pikeperch were examined.

Table 1 The summarized data of the experiments

Experiments	**Species**	**Period**	**Type of treatment**	**Number of treatment**	**Repeats**	**Parameters**
1.	Pike-perch	6 week	12 or 18% fish or linseed oil +control	5	4	growth, body composition, fatty acid profile
2.	Volga pikeperch	5 week	12 or 18% fish or linseed oil +Trouvit and control	6	4	growth, body composition, fatty acid profile
3.	Pike-perch	6 week	Different vegetable oils	3	4	growth, body composition, fatty acid profile
4.	Volga pikeperch	6 week	Different vegetable oils	3	3	growth, body composition, fatty acid profile
5.	Pike-perch	6 week	Different daily rations	3	4	growth, body composition,
6.	Volga pikeperch	6 week	Different daily rations	3	4	growth, body composition

2.1. The origin and setting of the experimental stocks

The experiments were carried out in the Fish Laboratory of the Faculty of Animal Science of the Kaposvár University. One year old (0+) pikeperch and Volga pikeperch were used. The pikeperch were transported from the Keszthely fish laboratory of the Georgikon Faculty of Agriculture of the University of Pannonia and from the Makkos and Co. Ltd. (Fonyód) to Kaposvár. The Volga pikeperch were fished out from the Lake Balaton in the Keszthely gulf with trawl net several times. The pikeperch that were obtained from Keszthely were already accustomed to the artificial feeds, while the Fonyód prereared fish and the Balaton Volga pikeperch were weaned to the artificial feeds in the laboratory.

The experiments were carried out in recirculation system with a total volume of 2600 l. The experimental block consisted of 30 glass tanks (33×30×60 cm) of 65-litres of volume, three filtering tanks of 200 litres volume, connected to each other and the plastic pipes connecting all operating parts. For mechanical filtering, two containers contained surface increasing material, while the third, the depositing container had no filtering material. The glass tanks were aerated separately and the constant 1.5-2 litre/minute water flow was secured with separate cocks.

2.2. Experimental settings

2.2.1. The effect of the animal and vegetable oil (fish and linseed oil) sources on the growth and body composition of the pikeperch

Eighty one-year-old (0+) pikeperch were introduced into the aquaria (4 fish/aquaria, 3.9 g/l) for the 42-day-long experiment. At the beginning of the experiment, 63.8±15.6 g (mean±SD, n=80) was the body weight, while

178.2±14.1 mm was the standard body length. 1.13±0.26 was the average condition factor of the fish. During the experiment, the proportion of the fat content of the dry feed – containing originally 6% fat (F6%) – was raised with fish and linseed oil to 12% (+6%) or 18% (+12%) (F12%, F18% and L12%, L18%). All the four of the experimental feeds were used in four randomly chosen aquaria (four treatments, four repetitions). The F6% dry feed was used as the control (in four aquaria, as well). At the end of the experiment, after the measuring, 3-3 fish were selected randomly from every group (F6%, F12%, F18%, L12%, and L18%) for chemical analysis. The body composition and fatty acid profile of the fish of the different treatments were determined. Furthermore, the effects of the treatments on the growth, feed conversion ratio and condition factor were also evaluated.

2.2.2. The effect of the animal and vegetable oil (fish and linseed oil) sources on the growth and body composition of the Volga pikeperch

In the 42-day-long experiment 96 one-year old (0+) Volga pikeperch were stocked into the aquaria (4 fish/aquarium, 3.1 g/l). At the beginning of the experiment, 50.2±8.9 g (mean±SD, n=96) was the body weight and 161.2±8.5 mm was the standard body length. 1.15±0.08 was the average conditional factor of the fish. The fat content of the dry feed – containing originally 6% fat (F6%), like in the previous experiment – was raised with fish and linseed oil to 12% (+6%) or 18% (+12%) (F12%, F18% and L12%, L18%). The four experimental dry feed were used in four randomly selected aquaria. The F6% basic feed and the Trouvit trout feed (T, 24% fat content) were fed in 4 aquaria each. The Trouvit had been used previously in pikeperch experiments, but Volga pikeperch had not been fed with it yet. Feed pellets (5 mm) were offered twice a day (at 10 and 17 o'clock) in an amount

of 2% of the fish total weight. The same measuring methods, chemical analysis and parameter evaluation were done like in the first experiment.

2.2.3. The effect of the different vegetable oils (soybean, sunflower and rapeseed oil) on the growth and body composition of the pikeperch

Sixty pikeperch (5 fish/aquarium, 2.1 g/l) were introduced in the same aquarium system for the 6-week-long examination. 27.9±8.0 g (mean±SD; n=60) was the average starting body weight of the pikeperch and 135.8±12.0 mm was the standard body length. 1.08±0.06 was the condition factor of the fish at the beginning of the experiment. In the experiment, the 6% fat content of the base feed was complemented to 11% (+5%) using soybean (SO), rapeseed (RO) and sunflower (NO) oil. Therefore, the feeds did not differ in their fat content only in the source of the fat. Fish were fed 3 mm pellets by hand once a day (at 10 o'clock), according to appetite. At the end of the experiment, the growth and feed conversion ratio indexes were determined and compared the body composition of the fish of the different treatments (3 randomly chosen fish/treatment). Before the beginning of the experiment, from the stock, that were fed with the base feed until then, 3 fish were killed and frozen until the end of the experiment. At the end of the experiment they were sent to chemical analysis with the rest of the samples.

2.2.4. The effect of the different vegetable oils (soybean, sunflower and rapeseed oil) on the growth and body composition of the Volga pikeperch

During the 42-day-long experiment, 63 Volga pikeperch were introduced into the aquaria (7 fish/aquarium, 3.9 g/l). 35.8±8.4 g (mean±SD; n=63) was the average, starting body weight of the fish, while 139.2±9.3 mm was the standard body length. 1.30±0.08 was the condition factor of the

fish at the beginning of the experiment. In the experiment, the 6% fat content of the base feed (complete seabream dry feed) was complemented to 12% (+6%) using soybean (SO), rapeseed (RO) and sunflower (NO) oil. Therefore, the feeds did not differ in their fat content (12%) only in the source of the fat. Fish were fed 3 mm pellets by hand once a day (at 10 o'clock), according to appetite. The same measuring and sampling protocol was applied as in the previous experiment.

2.2.5. The effect of the different amount of feeds on the growth and body composition of the pikeperch

Sixty pikeperch (5/aquarium, 1,2 g/l) were introduced into the aquaria, 15.5±4.7 g (mean±SD, n=60) was their average starting body weight and 109.2±9.0 mm was their body length. 1.18±0.29 was their condition factor. Once a day, the fish were fed with commercial feed (Screttings) with a diameter of 3 mm that contained 45% crude protein and 11.5% crude fat. During the 6-week-long period, the feed was given in three different daily amounts (0.9 g/day (1,2% of the biomass); 1,5 g/day (2% of the biomass) and ad libitum (control)) to the fish. The feed that was left at the bottom of the aquaria was removed after the feeding. Based on the known number of pellets and the average weight of them, the real daily consumption and the waste could be calculated. At the end of the experiment three fish from every treatment were sent to the chemical laboratory in order to determine their body composition. Furthermore, I have calculated the average productive parameters of the different treatments.

2.2.6. The effect of the different amount of feeds on the growth and body composition of the Volga pikeperch

Seven Volga pikeperch were introduced into every aquarium (2.0 g/l). 18.1±4.4 g (mean±SD, n=84) was their average, starting weight and 109.8±8.0 mm was their standard body length. 1.34±0.1 was their condition factor. Once a day, the fish were fed with commercial pelleted feed (Screttings) with a diameter of 3 mm that contained 45% crude protein and 11.5% crude fat. During the 6-week-long period, the feed was given in three different daily amounts (1.3 g/day (1% of the biomass); 2.6 g/day (2% of the biomass) and 3.9 g/day (3% of the biomass)) to the fish in 4 randomly chosen aquaria. Feed was given by hand pellet by pellet. I have removed the feed that was left at the bottom of the aquaria after the feeding. According to the number of pellets and the average weight of them, the daily consumption was calculated. At the end of the experiment, I have sent three fish from every treatment to the chemical laboratory in order to determine their body composition. Furthermore, I have calculated the average productive parameters of the different treatments.

2.3. Sampling, chemical analysis

At the end of the experiments, 3 fish from every treatment were killed. Samples of 4 g were taken from every fish from the *dorso-lateral* part of the right fillet in order to analyse the fatty acid profile, while the remainder of the bodies were homogenized with a grinder. I have not taken any fillet samples during the fifth and sixth experiment since there was no fatty acid profile analysis during these experiments.

The chemical analysis of the total bodies, the fillets and the used dry feeds were carried out in the Research Institute for Animal Breeding and Nutrition

in Herceghalom. The extraction of the fat was done with Folch extraction, the determination of the fatty acid profile was done with gas-chromatographic method.

2.4. Statistical evaluation

Statistical analyses were made with the SPSS for Windows 10.0 software package (1999). The effect of the treatments on the growth, the feed consumption, the feed conversion ratio, the body and the fatty acid composition were evaluated with one-way analysis of variance. In the first and second experiment, where the pikeperch and the Volga pikeperch were fed with different feeds in varying amounts, the parameters were analyzed with multivariate analysis of variance. In case of the one-way analysis of variance I have run the Tukey and the Dunnet (2-sided) post hoc tests at a significance level of 0.05.

3. RESULTS

3.1. The effect of the animal and vegetable oil (fish and linseed oil) sources on the growth and body composition of the pikeperch

The F18% treatment (18% fish oil) showed the best growth (0.48±0.12 mm/day), the best weight gain (0.69±0.20 g/day) and the most favourable S.G.R. value (mean: 0.76-0.88%/day) ($P>0.05$). I found the best feed consumption value (171.4±20.8 g/aquarium) and the best feed waste value (32.6±18.7 g/aquarium) in case of the F6% control group. From the feed conversion ratio's point of view (mean: 1.52-1.68 g/g), there were no significant difference ($P>0.05$) among the treatments (Table 2).

There were no significant differences between the average values of the dry matter, raw protein and raw fat of the different treatments ($P>0.05$). The multivariate analysis of variance (GLM) showed that the amount of fat in the feed had an effect on the crude fat, accumulated in the total body ($P=0.035$) and on the dry matter of the body ($P=0.047$).

The ratio of palmitic acid (C16:0), heptadecanoic acid (C17:0), vaccenic acid (C18:1n-7) and linoleadic acid (C18:2n-6t) were higher in the fish oil fed treatments (F6% and F12%, F18%) than the linseed oil eating groups (L12%, L18%) ($P<0.05$).

11.4±2.5% was the proportion of the linoleic acid (C18:2n-6c) in the L12% group and 11.3±2.4 % in the L18% group, while in the other groups it varied between 6.02% and 9.08% ($P=0.015$). Examining the α-linoleic acid (C18:3n-3), it can be said, that it was in 18-23 times higher proportion of the fat content of the fillet in the L12% and L18% group than in the F6%, F12%, F18% treatments ($P<0.001$). Both essential fatty acids give a signifi-

cant portion (13 and 51%) of the fatty acid composition of the linseed oil, while they are not considerable in the fish oil (4.4 and 1.5%). According to the GLM analysis, it was true for most fatty acids, that the used oil source influenced significantly their proportion in the fillet.

Table 2 The growth and feed consumption parameters in the experiment (n=4)

Parameters	Treatment					Fat %	Fat sources	Interaction (Fat % × Fat sources)
	F6%	F12%	F18%	L12%	L18%			
	mean±SD					P value		
Growth (mm/day)	0.33± 0.09	0.35± 0.08	0.48± 0.12	0.40± 0.02	0.41± 0.28	**NS**	**NS**	**NS**
Weight gain (g/day)	0.62± 0.13	0.57± 0.17	0.69± 0.20	0.58± 0.06	0.66± 0.35	**NS**	**NS**	**NS**
CV final (%)	20.2± 10.3	29.5± 12.7	33.7± 12.1	29.7± 14.9	32.9± 10.4	**NS**	**NS**	**NS**
S.G.R. (%/day)	0.82± 0.15	0.76± 0.19	0.88± 0.19	0.77± 0.06	0.84± 0.36	**NS**	**NS**	**NS**
Feed consumption (g/aquarium)	171.4± 20.8	154.8± 17.5	156.0± 7.31	159.6± 5.52	161.0± 27.5	**NS**	**NS**	**NS**
Feed waste (g/aquarium)	32.6± 18.7	49.2± 20.3	56.3± 20.0	45.4± 5.10	48.4± 14.5	**NS**	**NS**	**NS**
Feed conversion (g/g)	1.54± 0.23	1.68± 0.31	1.52± 0.36	1.64± 0.12	1.58± 0.28	**NS**	**NS**	**NS**

NS: means no significant different (GLM Multivariate);
F6%: basic feed (6% fat); F12%: +6% fish oil (12% fat); F18%: +12% fish oil (18% fat)
L12%: +6% linseed oil (12% fat); L18%: +12% linseed oil (18% fat).

Significant differences ($P<0.05$) were found between the treatments in arachidonic acid (C20:4n-6), EPA (C20:5n-3) and DPA (C22:5n-3) in this experiment. There were no significant differences from the physiologically important, DHA's (C22:6n-3) point of view between the fish oil and the linseed oil groups ($P>0.05$). This phenomenon is interesting, because 12.2-12.9% was the proportion of the DHA in the „F" feeds and it was 1.75-2.53% in the L12% and L18% feeds. Most probably, the pikeperch was able to produce the DHA from shorter carbon chain, less unsaturated fatty acids, which were abundant in the feeds. JANKOWSKA ET AL. (2003) found that pikeperch fed with food of different docosahexaeonic acid contents (fish and Trouvit pellets) did not show significant differences in the fillet DHA content.

The DHA/EPA proportion showed significant differences among the treatments. The F12% group showed the narrowest proportion (average: 2.71), and the F6% showed the widest proportion (average: 5.51) ($P=0.003$). The proportion of the saturated fatty acids was significantly higher in the fish oil treatments than in the L12% or L18% groups ($P=0.001$). The average values of the MUFA and PUFA fatty acids did not show significant differences ($P>0.05$). The excellent n-3/n-6 fatty acid proportion (3:1-4:1) of the pikeperch meat did not deteriorate significantly due to the linseed oil containing feed. There were, however, significant differences in the proportion of the saturated/unsaturated fatty acids between the „F" and „L" groups ($P<0.05$). This proportion was higher in the linseed oil groups, which was due to the higher proportion of the saturated fatty acids.

3.2. The effect of the animal and vegetable oil (fish and linseed oil) sources on the growth and body composition of the Volga pikeperch

During the experiment, only a few of the Volga pikeperch consumed the feed complemented with linseed oil and even those “consumers” ate it only in maintenance level. Basically, the fish of the L12% and L18% groups barely grew and their condition deteriorated during the experiment. The group, that were fed with the Trouvit trout feed, showed the best growth (0.54±0.12 mm/day) and the best weight gain (0.81±0.07 g/day) ($P>0.05$). The S.G.R. index of the L12% and L18% groups (0.02±0.10 and 0.34±0.11%/day) significantly ($P<0.001$) stayed behind the results of the other groups (average: 0.87-1.28%/day).

Considering the feed consumption, the L12% and L18% groups showed the lowest averages among the treatments, they were significantly different from results of the other treatments ($P<0.001$). Examining the feed conversion, favourable values were observed in the F6%, F12%, F18% and the T treatments (average: 0.90-1.99 g/g) unlike the two linseed oil groups, where 16.0±10.6 g/g (L12%) and 3.12±0.92 g/g (L18%) were the values of this parameter.

In case of the total body composition (Figure 1) the T treatment had the highest dry matter content (27.0±1.2%). The fish of the T group had the highest proportion of the crude fat (7.26±1.28%) ($P<0.05$).

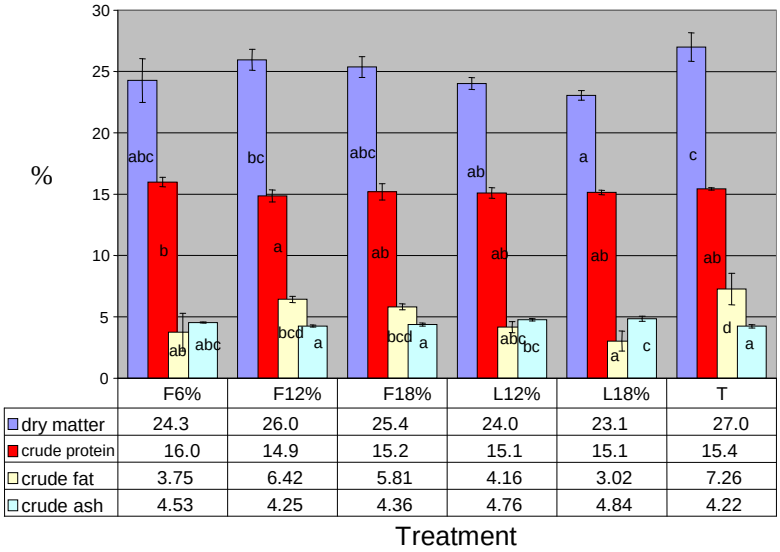

Figure 1 The body composition of the Volga pikeperch in the different treatments (mean±SD, n=3) (the values in the table are average values)

a, b: the different letters show statistically differences (One-Way ANOVA, Tukey post hoc test;
F6%: basic feed (6% fat); F12%: +6% fish oil (12% fat); F18%: +12% fish oil (18% fat); L12%: +6% linseed oil (12% fat); L18%: + 12% linseed oil (18% fat).

The α-linoleic acid (C18:3n-3) content of the linseed oil is significant and this mirrored in the fillet of the Volga pikeperch that were fed with this feed, it accrued in the fish. In spite of the low feed consumption the fillet of the L12% and L18% groups had significantly ($P<0.001$) higher (2.65±1.06% and 4.92±1.75%) linoleic acid content than the other groups (average: 0.50-1.01%). The important hormone precursor and membrane constituent, the arachidonic acid (C20:4n-6) showed significant differences ($P=0.044$) between the linseed oil treatments (mean: 2.42-2.61%) and the Trouvit groups (mean: 1.98%).

In the ratio of the EPA (C20:5n-3) there were significant ($P<0.001$) differences among the L12%, L18% (7.58±0.23% and 7.30±0.70%) and the fish oil treatments (11.1-11.9%). The ratio of the DHA showed no signifi-

cant differences between the treatments, which might not be explained by the fatty acid composition of the feeds, since the proportion of this fatty acid were extremely low (only 1.79-2.53%) in the feeds that were complemented with linseed oil. Whereas 12.2-17.6% was the average proportion of the DHA in the feed complemented with fish oil. In my opinion, this phenomenon might be explained by the *de novo* synthesis of the semi essential DHA.

The multivariate analysis of variance justified, like in case of the pikeperch, that the fatty acid composition of the feed significantly influences the fatty acid profile of the fillet. It is interesting that, oppositely to the pikeperch, the amount of the fat of the feeds influenced significantly the proportion of several fatty acids of the fillet of the Volga pikeperch.

There was not found any significant differences in the proportion of the total saturated fatty acid (SFA) and the MUFA and the PUFA between the treatments ($P>0.05$). It is remarkable, that the exceedingly high n-3 fatty acid proportion of the pikeperch could be observed in case of the Volga pikeperch, as well. The lipid fraction of the fillet of the T group had the highest proportion of the n-3 fatty acids and this same group had the lowest proportion of n-6 fatty acids. It follows from this, that the T group had the highest n-3/n-6 fatty acid ratio (9.72±1.63). This value differed significantly ($P<0.05$) from the average value of all the other treatments (average: 4.51-6.13).

3.3. The effect of the different vegetable oils (soybean, sunflower and rapeseed oil) on the growth and body composition of the pikeperch

In this experiment no significant differences in the growth and feed conversion parameters were observed ($P>0.05$). The consumption of the different groups were similar (average: 39.56-53.27 g/aquarium), but inde-

pendently from the treatments the waste of feed were remarkably high. The RO treatment (rapeseed oil) showed the lowest consumption and highest feed waste values. I have experienced the highest weight gain in the soybean oil groups (0.48±0.27 g/day) (P>0.05) (Table 3).

Table 3 Growth and feed consumptions results in the third experiment (n=4)

Parameters	**Treatment (mean±SD)**			
	RO	**NO**	**SO**	**P value**
Final body weight (g)	30.5±6.70	29.2±10.73	31.7±13.72	NS
Growth (mm/day)	0.62±0.22	0.67±0.11	0.77±0.30	NS
Weight gain (g/day)	0.18±0.18	0.36±0.07	0.48±0.27	NS
CV final (%)	25.4±3.11	42.8±9.60	36.2±15.91	NS
S.G.R. (%/day)	0.12±0.11	0.31±0.16	0.26±0.05	NS
Feed consumption (g/aquarium)	39.6±11.3	50.4±4.60	53.3±9.90	NS
Feed conversion (g/g)	8.20±4.65	3.52±2.34	3.36±0.49	NS

NS: no significant difference (One-Way ANOVA, Tukey post hoc test);
RO: rapeseed oil, NO: sunflower oil, SO: soybean oil eating groups.

The dry matter content of the total body in the control feed groups were lower than the dry matter content of the other treatments (P=0.042). There were no significant differences in the crude protein and crude ash content of the bodies, but there were significant differences in the fat content of the bodies. The control group showed the lowest amounts (average: 1.99%) (P=0.041) and the fish of the sunflower groups were the fattiest (average: 5.49%). BRANSDEN ET AL. (2003) found that Atlantic salmon (*Salmo salar*) fed with sunflower oil had higher fat content in the liver and the fillet than in the fish oil eating fish.

The amount of the palmitic acid (C16:0) decreased in the fish meat, while the amount of the oleic acid (C18:1n-9) increased during the experiment. However, there were significant differences only between the RO and the control group from the mentioned fatty acids' point of view (P=0.024 and P=0.021). It follows from this that the fish of the RO treatments had the lowest amount of palmitic acid (C16:0) and the highest amount of oleic acid (C18:1n-9) in their fat. The accumulation of the latter fatty acid in the fillet might be explained by the high oleic acid content (33.4%) of the feed complemented with rapeseed oil.

The proportion of the linoleic acid (C18:2n-6c) increased in the fat of the fish during the experiment. I have found the highest values (average: 13.1%) in the soybean oil group. The amount of the α-linolenic acid (C18:3n-3) has also increased in the fillet of the fish. From this point of view the rapeseed oil groups gave the highest (average: 1.34%) and the control group the lowest (average: 0.42%) values (P=0.018). However, the proportion of the arachidonic acid (C20:4n-6) decreased in the fillet of the fish of all treatments (P=0.005).

The proportion of the DPA (C22:5n-3) changed significantly in the RO and NO groups during the experiment ($P<0.05$). The SO groups, however, showed no significant differences from the starting values ($P>0.05$). It is an interesting result that neither the EPA (C20:5n-3) nor the DHA (C22:6n-3) showed significant differences between the samples. In this examination it clearly came to light that the fatty acid composition of the feed has significant influence on the fatty acid composition of the fillet (Figure 2).

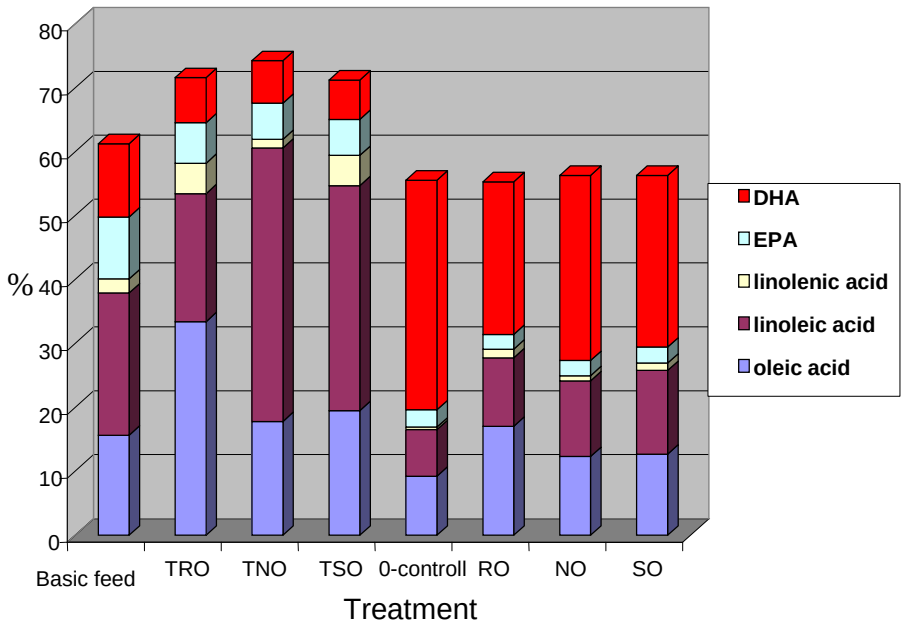

Figure 2: The proportion of some of the fatty acids of the fillet of the pike-perch in w% in the third experiment (average, n=3)

RO: rapeseed oil, NO: sunflower oil, SO: soybean oil eating groups;
Basic feed 6% fat content; TRO: rapeseed oil (+5%), TNO: sunflower oil (+5%), TSO: soybean oil (+5%) feeds.

Examining the sum of the monounsaturated fatty acids (MUFA), the rapeseed oil groups showed the highest value (mean: 28.2) (P>0.05). The samples of the sunflower groups had the most of the total polyunsaturated fatty acids (PUFA) (mean: 54.4) (P>0.05). The MUFA slightly increased, while the PUFA decreased in the fillet during the experiment (P>0.05). The NO group had the highest amount of n-3 fatty acids, while from the n-6 the SO group had the highest amount. The RO group had the lowest amount of the n-3, compared to the starting values (P=0.039). The RO group had the lowest n-3/n-6 proportion compared to the starting values (P=0.045).

3.4. The effect of the different vegetable oils (soybean, sunflower and rapeseed oil) on the growth and body composition of the Volga pike-perch

At the end of the experiment the body weight (mean: 57.3-57.7 g) was 62-63% more than the initial weight (mean: 35.5-36.2 g). This result was higher than the ratio of pikeperch in the third experiment (13-14%). The fish of the RO group showed the best body weight gain out of the three treatments (0.53±0.01 g/day) ($P>0.05$). There was no significant difference in the feed consumption between the treatments (average: 149.9-155.7 g/aquarium). The feed conversion ratio showed favourable values in all treatments. This parameter was 0.97±0.04 g/g in the rapeseed oil group, 1.15±0.36 g/g in the sunflower group and 1.01±0.08 g/g in the soybean group ($P>0.05$).

During the experiment, I did not find any significant differences in the dry matter, raw protein, crude fat and crude ash of the fish ($P>0.05$). In case of the crude fat content, in all three treatments it has increased compared to the control (3.14±1.12%). This difference was significant ($P=0.026$) in the sunflower group (5.20±0.51%).

The RO groups had the highest oleic acid proportion (18.6±2.6%) in the fillet samples. However, in case of this mentioned fatty acid, there were significant differences only between the RO and SO treatments (11.9±2.5%) ($P<0.05$). The high oleic acid proportion of the RO groups is no surprise, since the rapeseed oil contains this fatty acid in high proportion (it might be 45% of the total fatty acids).

In case of the usually essential linoleic (18C:2n-6c) and the α-linolenic acid (C18:3n-3), significant difference was only found in the latter

fatty acid. This significant difference could be observed between the SO and RO groups (P=0.042). The linoleic acid (18C:2n-6c) content of the sunflower oil is remarkably high (20-69%), so its high proportion in the fillet of the NO groups could be explained by this.

The control group had the highest DPA (C22:5n-3) proportion, with 2.81±0.16% (P<0.05). The arachidonic acid (C20:4n-6), the EPA (C20:5n-3) and the DHA (C22:6n-3) are extremely important from the fish' point of view. No significant differences (P>0.05) were found in these fatty acids between the treatments (mean: 1.28-1.45%; 5.47-6.31%; 30.1-33.0% respectively). The particularities of the fatty acid profile of the different vegetable oils clearly mirrored in the fatty acid composition of the fillet of the Volga pikeperch. Some derived indexes were calculated from the results of the fatty acids. These parameters can be found in Table 4.

Table 4: Fatty acid indexes in the fourth experiment (mean±SD, n=3)

Fatty acid (%) (w%. in the proportion of the total fatty acids content)	**Treatment**				
	0-control	**RO**	**NO**	**SO**	**P value**
Σ saturated	24.1±0.2	25.1±0.5	26.2±1.2	26.6±2.4	NS
Σ MUFA	19.9±4.2	23.8±3.3	17.9±3.9	16.2±3.5	NS
Σ PUFA	55.9±4.0	51.1±2.9	55.9±2.8	57.2±2.2	NS
Σ unsaturated/ Σ saturated	3.10±0.03	2.99±0.08	2.82±0.17	2.79±0.35	NS
Σ n-3	43.3±6.8	39.4±4.1	38.2±6.0	43.4±3.9	NS
Σ n-6	13.0±2.8	11.8±1.2	17.7±3.4	13.8±2.1	NS
n-3/n-6	3.62±1.19	3.39±0.71	2.3±0.8	3.2±0.8	NS
DHA/EPA	5.27±1.37	5.41±0.69	5.5±1.0	6.3±0.8	NS
Average chain length	19.0±0.2	18.9±02	18.9±0.3	19.1±0.2	NS
Unsaturation index	295.5±32.6	273.9±19.7	275.5±26.2	296.0±17.9	NS

Unsaturation index: 1 x Σ monen+ 2 x Σ dien + 3 x Σ trien…
NS: no significant difference (One-Way ANOVA);
0-control: starting state, RO: rapeseed oil, NO: sunflower oil, SO: soybean oil eating groups.

3.5. The effect of the different amount of feeds on the growth and body composition of the pikeperch

Low values (0.07-0.14 g/day) of weight gain were observed in this experiment, only 0.5-1 % of the starting weight was the daily growth. Considering the S.G.R. significant differences (P=0.038) were found between the 1.2% (average: 0.44%/day) and the 2% (average: 0.77%/day) groups. In connection with the weight gain and the feed conversion ration, it was observed that the 1.2% and the 2% groups did not differ from the „*ad libitum*" group. On the other hand, the average value of latter two groups differed significantly from each other (P=0.025). The groups that ate more feed grew better than the 1.2% group. The feed conversion ratio showed favourable values in all treatments (mean: 1.07-1.44 g/g). The 2% group showed the best result. The amount of the uneaten feed grew in direct ratio to the growing daily feed portion (Figure 3).

It was found that the amount of the daily ration has no effect on the body composition. It is partly because the fish did not eat significantly (P>0.05) more, even if they could do it.

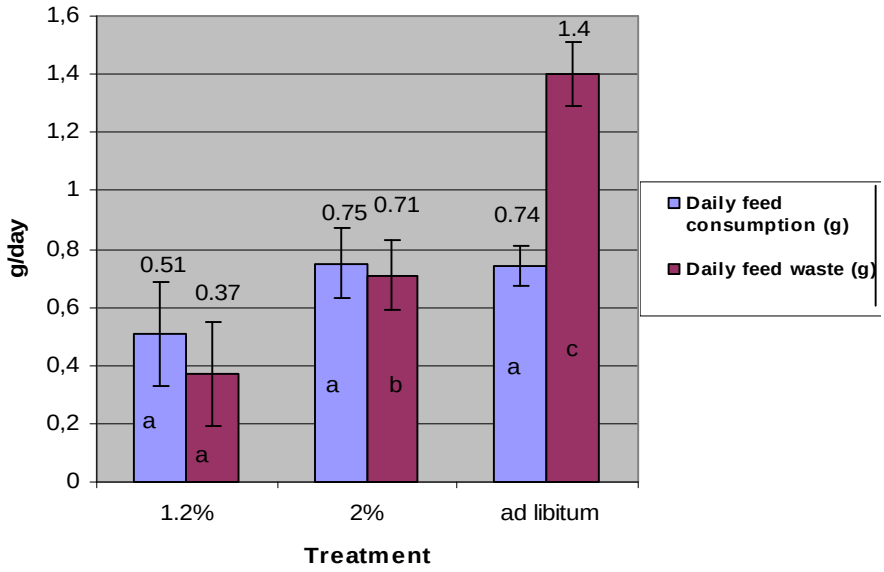

Figure 4: The development of the daily feed consumption and feed waste, according to the treatments (mean±SD; n=4)

a, b, c: the different letters show statistically justifiable differences (P<0.05);
1.2%, 2%, ad libitum: the feeding levels compared to the biomass.

3.6. The effect of the different amount of feeds on the growth and body composition of the Volga pikeperch

Looking at the weight gain and the feed conversion ratio, the 2% groups had the best results which mean that the most intensively fed group showed the best results. Considering the average weight gain values, the difference was significant between the 1% and the 2% groups (P=0.027). I have observed remarkably good S.G.R. values, varying between 0.92 and 1.28 %/day.

The feed conversion ratio results were exceedingly favourable during the examination. According to my observations, the 2% group showed the best results with 0.85 g/g value. However, there were no significant differ-

ences between the average values of the three groups (P>0.05). The feed consumption of the 1% groups differed significantly from the 2% and 3% groups, but this difference was clearly due to the difference in the intensity of the feeding (P=0.013). Daily rations also affected the feed waste (Figure 4). In case of the 1% group, it was 1.8%; in case of the 2% group, it was 29.2% and in case of the 3% group, it was 53.1% of the total amount (P<0.001).

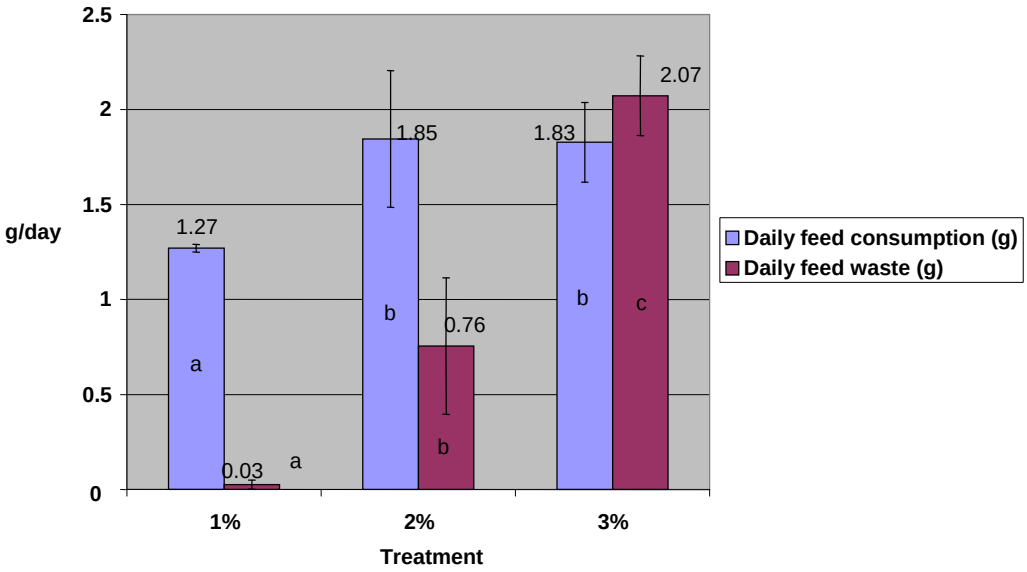

Figure 4 The development of the daily feed consumption and feed waste, deviation (mean±SD; n=4)

a,b,c: the different letters indicate statistically justifiable differences (P<0.05); 1%, 2%, 3%: the feeding levels compared to the biomass.

Looking at the body composition, it can be concluded that the intensity of the feeding had no significant influence on the body composition (P>0.05). The fat content of the body did not differed significantly between the treatments. That is easy to understand since the two more intensively fed groups (2% and 3%) ate the same amount of feed (average: 1.85 and 1.83 g/day).

4. CONCLUSIONS

Concluding from the results of my examinations, it can be said that the 11-12% fat content in the feed is optimal for both the pikeperch and the Volga pikeperch. Although it is true that the higher fat content (18% in case of pikeperch, 18 and 24% in case of Volga pikeperch) results in a somewhat better growth rate and feed conversion ratio, but the differences were usually not significant. At the same time, the fundamentally dry fish fillets were pinguefied by the high lipid content of feed which is clearly unfavourable in case of the perch species.

The use of soybean, sunflower and linseed oils are applicable in case of the pikeperch. Similar results were achieved about the use of soybean, sunflower and rapeseed oil in case of Volga pikeperch. In my opinion, the mentioned oil sources make the partial exchange of the fish oil possible in the feeds of the perch species.

It became apparent during the examinations, that the pikeperch did not tolerate the rapeseed oil, while the Volga pikeperch showed unfavourable results in case of linseed oil. The pikeperch were willing to eat the rapeseed oil feed only in an amount of maintenance level, so their productive parameters stayed behind the other treatments. Most of the Volga pikeperch did not eat the feed complemented with linseed oil. Because of the high importance of this question, these findings should be ascertained in further experiments.

It can be concluded that the fatty acid profile of the oil source significantly influences the fatty acid composition of the fillet of the pikeperch and Volga pikeperch. Although, due to the effect of the vegetable oil complementation, the fatty acid composition of the fillet has changed, but the fatty acids, that are pronouncedly important from a physiological point of

view and their proportion (n-3/n-6; DHA/DPA), which are favourable characteristics of the fish meat, did not deteriorate significantly.

Independently from the degree of supply of the docosahexaenoic acid, the DHA content of the fillet did not decrease significantly in case of the examined perch species. The pikeperch and the Volga pikeperch were able toe hold the 25-30% DHA proportion if DHA poor vegetable oils (especially the linseed oil) were used to supplement the basic feed. From this, it can be concluded that the perch species are able to keep the level of the essential fatty acids from the minimal DHA content of the feed and probably from *de novo* synthesis (very likely from the C18:3n-3 precursor).

We can found many publications about the desirable daily feed ration of the pikeperch suggesting it to be in general between 0,25 and 6% of the fish biomass (JANKOWSKA ET AL.., 2003; SCHULTZ ET AL., 2005; ZAKES, 2003; ZAKES ET AL., 2006; RÓNYAI AND CSENGERI, 2008; BÓDIS AND BERCSÉNYI, 2009). According to my examinations, which aimed the determination of the optimal daily amount of the ideal fat content feed (11.5%), it can be concluded that, in the case of the two examined species, 1.5% of the biomass is the desirable portion for one-year-old (15-18 g) fingerlings. Since the steps were too large in my model experiments, in order to achieve more accurate results, I suggest further examinations within the determined ideal interval with ten percent differences between the treatments.

5. THE NEW SCIENTIFIC RESULTS

1. For the pikeperch and the Volga pikeperch, the feed containing 11-12% fat is the ideal. At this amount of lipid, the productive parameters of the fish are still favourable (the S.G.R. is above 0.8-1.0%; the feed conversion ratio is between 1.0 and 1.4 g/g) and the pinguefying, which could be observed when the feed had higher fat content (6-8%) can be kept around 4-6%.

2. In case of the pikeperch, 50% of the fish oil content of the feed can be replaced with linseed, soybean and sunflower oil; while in case of the Volga pikeperch 50% of the fish oil might be exchanged with soybean, rapeseed and sunflower oil. Although the fatty acid composition of the fillet changes according to the effect of the mentioned oils, the physiologically favourable fatty acid profile of the fish and the meat quality did not change in significant degree.

3. The use of rapeseed oil is not advisable in the feeds of the pikeperch, while in case of the Volga pikeperch, the use of the linseed oil should be avoided. The examined species did not prefer the mentioned oil sources and so their productive parameters significantly stayed behind the other treatments.

4. In case of the examined species, 25-30% was the optimal proportion of the DHA, independently from the amount and the source of the fat in the feed. It was concluded that the favourable DHA level of the fillet remains unchanged if the feed contains enough long chained n-3 fatty acids (α-linolenic acid, EPA), even if the feed does not contain enough DHA.

5. In case of intensive Volga pikeperch rearing I have experienced an outstanding (0.85-0.90 g/g) feed conversion ratio when fish oil was used in the feed but even if vegetable oil was used in the feed, the feed conversion ratio was still remarkably good (0.97-1.15 g/g). In my examinations, the one-year-old Volga pikeperch did not significantly fall behind the pikeperch in growth and weight gain. The technological tolerance of the Volga pikeperch – in the aquarium, amid hand-feeding and normal room light conditions – was better than its larger relative's.

6. RECOMMENDATIONS

I recommend 11-12% fat content in the feed in the intensive rearing of the pikeperch and Volga pikeperch. The use of the higher fat content feed results excessive pinguefying, so I do not recommend their use. Both from economical and from physiological point of view this amount of lipid seems to be ideal in case of both examined species.

During the experiments, it came to light, that the pikeperch did not prefer the rapeseed oil in the feed, while the Volga pikeperch did not prefer the linseed oil in the feed. Therefore, I do not recommend the use of the rapeseed oil in pikeperch feeds and the use of linseed oil in Volga pikeperch feeds. However, the unambiguous justification of my results needs further examinations.

Linseed, soybean and sunflower oils are suitable to substitute 50% of the fish oil of the pikeperch feeds. Soybean, rapeseed and sunflower oils are suitable to replace 50% of the fish oil of the Volga pikeperch feeds. If 50% of the desirable fat content (12%) is exchanged with vegetable oils, it will most probably not cause off flavour and it will not deteriorate significantly the chemical meat quality.

According to my results, in case of the one-year-old pikeperch and Volga pikeperch, the desirable feeding intensity is 1.5% of the fish biomass.

7. PUBLICATIONS CONCERNING OF THE SUBJECT OF THE DISSERTACION

Articles in foreign languages:

Molnár, T., Szabó, A., **Szabó, G**., Szabó, C., Hancz Cs.: Effect of different dietary fat content and fat type on the growth and body composition of intensively reared pikeperch *Sander lucioperca* L. *Aquaculture Nutrition*, 2006. Vol. 12:173-182. pp. (IF: 1,642)

Molnár, T., Müller, T., **Szabó, G**., Hancz, Cs.: Growth and feed conversion of intensively reared Volga perch (*Stizostedion volgensis*). Proceedings of the 14th Internatinal symposium „Animal Science Days". 13-14. October 2006. Lillafüred, Hungary. *Acta Agraria Kaposvariensis*, 2006. 10(2):315-319.pp.

Articles in Hungarian language:

Szabó, G.: A süllő (*Stizostedion lucioperca* L.) intenzív nevelése és takarmányozása. Irodalmi áttekintés. *Állattenyésztés és Takarmányozás*. 2006. 55. 2. 169-179.pp.

Szabó, G., Müller, T., Molnár, T., Sudár, G., Hancz Cs.: Különböző takarmányadagok hatása a kősüllő (*Sander volgensis* Gmelin 1788) növekedésére és testösszetételére. *Acta Agraria Kaposvariensis,* 2009. 13(1) (megjelenés alatt)

Full conference papers in foreign language proceedings:

Szabó, G., Molnár, T., Hancz, Cs.: Effect of dietary fat content on the growth and body composition of pikeperch. *AQUA 2005, European Aquaculture Society*. Trondheim, Norway, 2005. august 9-12. Special Publications. No.35:439-440.pp.

Full conference papers in Hungarian proceedings:

Molnár, T., Stettner, G., Müller, T., **Szabó, G**., Hancz, Cs.: A telepítési sűrűség hatásának vizsgálata az intenzíven nevelt kősüllő *(Stizostedion volgensis*) növekedésére és takarmányértékesítésére. *Halászatfejlesztés.* 2004. 29. 75-81.pp. (XXVIII. Halászati Tudományos Tanácskozás. HAKI, Szarvas, 2004. május 12-13.)

Molnár T., Stettner G., **Szabó G**., Hancz Cs.: A növekedés és a testösszetétel vizsgálata fogassüllőn, azonos fehérje-, de eltérő energiatartalmú tápok etetése mellett. *Halászatfejlesztés.* 2005. 30. 143-146.pp. (XXIX. Halászati Tudományos Tanácskozás. HAKI, Szarvas, 2005. május 4-5.)

Szabó, G., Hancz, Cs., Stettner, G., Bódis, M., Molnár, T.: Eltérő napi takarmányadagok hatása a táppal etetett süllő (*Sander lucioperca* L.) növekedésére és testösszetételére. *Halászatfejlesztés.* 2006. 31. 163-173.pp. (XXX. Halászati Tudományos Tanácskozás, HAKI. Szarvas, 2006. május 24-25.).

Abstracts in foreign language:

Szabó, G., Molnár, T., Hancz, Cs.: Effect of dietary fat content on the growth and body composition of pikeperch. *European Aquaculture Society.* Trondheim, Norway, 2005. august 9-12. Special Publications. No. 35. 439-440.pp.

Szabó, G., Hancz, Cs., Molnár T.: Effect of different dietary fat content and fat sources on the growth and body composition of Volga pikeperch *Sander lucioperca. European Aquaculture Society.* Firenze, Italy, 2006. may 9-13. Special Publications. 1050.p.

Abstracts in Hungarian:

Szabó, G., Molnár, T., Stettner, G., Hancz, Cs., 2007: Intenzív süllő (*Sander lucioperca* L.) és kősüllő (*Stizostedion volgense* G.) nevelési kísérletek a Kaposvári Egyetemen. Eredményeink összefoglalása*. XXXI. Halászati Tudományos Tanácskozás*, HAKI. Szarvas, 2007. május 16-17. Kiadvány kötet: 30.p.

Szabó, G., Molnár, T., Müller, T., Hancz, Cs.: Kősüllő (*Stizostedion volgense* G) intenzív nevelése eltérő zsírforrásokat tartalmazó haltápok etetése mellett. *XXXII. Halászati Tudományos Tanácskozás*, HAKI. Szarvas, 2008. május 14-15. Kiadvány kötet: 53.p.