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THE EFFECT OF DIET ON THE FATTY ACID COMPOSITION AND LIVER HISTOLOGY OF PIKEPERCH (*SANDER LUCIOPERCA* (L.)) LARVAE

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ABSTRACT. The present study was an attempt to determine the effect various types of diets had on growth, survival, and the content of fatty acids (FA) in pikeperch, *Sander lucioperca* (L.), larvae. During larval development (from day 5 to day 47 post-hatch), the fish were fed two commercial feeds – Bio Kyowa (BK group) and Aglo Norse (AN group) – and Artemia nauplii (A group). A separate group was comprised of larvae which developed under natural conditions (Z group). The results obtained show that the composition of fatty acids of both commercial feeds and Artemia nauplii satisfied the nutritional requirements of pikeperch larvae during their development, which was indicated by high survival and satisfactory growth rates (survival – 50.8-54.4%; final body weight – 0.481-0.575 g; total length – 37.85-48.31 mm). The A group larvae had a two-fold higher content of C 18:1 acid in comparison to the fish in the BK and AN groups. In the A group, polyunsaturated fatty acids comprised 26.07% of total FA content, while in the BK, AN, and Z groups it was 40%. Based on histological observations, it was found that the larvae fed the AN diet had the greatest capacity of hepatocytes and the greatest relative capacity of cytoplasm occupied by lipids.

Key words: PIKEPERCH (*SANDER LUCIOPERCA*), FEEDING OF LARVAE, FATTY ACIDS, LIVER HISTOLOGY

INTRODUCTION

The industrial management of the highly sensitive larvae of many quickly developing marine and freshwater fish is one of the toughest challenges facing aquaculture. Solving this problem requires supplying the larvae with optimum nutrients to ensure fast growth and development rates and high survival. Fatty acids play an important role in fish nutrition as they are the main energy source and a constituent of cellular struc-

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tures. The feeding requirements of fish larvae in the natural environment are reflected by the composition of the zooplankton consumed. The nutritional value of zooplankton changes, and alterations in the composition and content of lipids are related to developmental stage and the seasons of the year (Sargent and Henderson 1986). The food that fish larvae consume under natural conditions varies and is dependent on the species, age, and availability of zooplankton. Artemia nauplii are mainly used as the first natural food during the rearing of fish larvae under experimental conditions and in commercial aquaculture. However, Artemia does not meet the feeding requirements of fish larvae due to the insufficient content of polyunsaturated fatty acids (PUFA), particularly n-3 highly unsaturated fatty acids (HUFA) (Lavens et al. 1995). It was demonstrated that enriching Artemia nauplii before their administration to fish larvae improved the concentration of essential nutrients (Watanabe et al. 1983). The feeding value of Artemia depends on the content and composition of fatty acids (FA), especially of n-3 HUFA. Freshwater fish larvae are less sensitive to variable fatty acid levels in Artemia nauplii, but the FA composition in Artemia may also affect growth in these species, and thus its value as an optimum diet (Bengtson et al. 1991). PUFA linoleic C 18:2 n-6 (LA) and linolenic C 18:3 n-3 (LNA) acids cannot be synthesized *de novo* by animals, including fish; therefore, they are referred to as essential fatty acids (EFA) (Holman 1986). The quantitative and qualitative requirements of EFA in fish differ depending on the species and age. Fatty acids, LA, and/or LNA may satisfy the EFA requirements of freshwater fish, whereas marine fish require long-chained HUFA, eicosapentaenoic C 20:5 n-3 (EPA) and docosahexaenoic C 22:6 n-3 (DHA) in diets for optimum growth (Sargent et al. 1999). The incidence of LA conversion to arachidonic acid C 20:4 n-6 (AA) and LNA to EPA and DHA has been observed in many species of freshwater fish (Sargent et al. 1995). However, it has been demonstrated that the freshwater predatory fish northern pike, *Esox lucius* L., cannot convert C 18:3 n-3 to EPA, or C 18:2 n-6 to AA (Henderson et al. 1995). Studies focusing on determining the optimum content of lipids and fatty acid composition in diets for pikeperch, *Sander lucioperca* (L.), larvae have not been conducted to date.

The aim of the present study was to compare the effect of FA composition in natural feed and commercial diets on growth, survival, and FA content in pikeperch larvae fish tissues and on liver histology.

MATERIAL AND METHODS

FISH AND EXPERIMENTAL DIETS

The experiment was conducted at the Laboratory of Ichthyology and Fisheries of Warsaw Agricultural University (SGGW), Poland. Pikeperch larvae (mean body weight: 5.0 ± 0.3 mg; total mean length: 5.9 ± 0.4 mm n = 50) were obtained five days post-hatch from the Kołoniec Fish Farm (Poland). The larvae were obtained from artificial spawning under controlled conditions. The remaining fish from this spawning were reared in ponds at the Kołoniec Fish Farm. After being transported to the laboratory, the larvae were randomly divided into experimental groups and placed in 20 dm^3 glass aquaria with a water recirculating system, at a density of 200 ind. $aquarium^{-1}$ (3 treatments × 5 replicates). The recirculated and aerated water was pumped through a bio-filter and UV filter. The water flow rate was 2 dm^3 min^{-1} in each aquarium, and additional aeration was applied. The larvae were reared in darkness (L0:D24), excluding breaks for cleaning the aquaria and the administration of feed. Water quality as well as temperature, pH, dissolved oxygen, and ammonia and nitrite content were monitored daily. The mean values of these parameters were as follows: water temperature – 19 ± 0.12°C; pH – 8.59 ± 0.13; oxygen concentration – 8.6 ± 0.16 mg O_2 dm^{-3}; total ammonia nitrogen (TAN = NH_4^+-N +NH_3 –N) – 0.34 ± 0.25 mg TAN dm^{-3}; nitrite (NO_2-N) – 0.097 ± 0.05 mg NO_2-N dm^{-3}. The aquaria were cleaned daily, and dead larvae were removed and counted. The larvae were fed from day 5 post-hatch (day 0 of the experiment) with Artemia nauplii (1000-1500 ind. dm^{-3}, 4 times a day; group A) or one of two commercial feeds: Aglo Norse (group AN) (Larvae Feed Ewos – Bergen, Norway) and Bio Kyowa (group BK) (Kyowa Hakko Koygo, Tokyo, Japan). The fish were fed the artificial feeds every two hours from 08:00 to 22:00 (Table 1). The initial daily feeding rate was 50% of the fish biomass and was gradually reduced down to 5% in the last week of the experiment.

To determine wet body weight and total length and for histological tests, five larvae from each aquarium were sampled on day 42 of the experiment (25 larvae from each feeding group). On the same day, 25 larvae that had been reared from hatching in the ponds of the Kołoniec Fish Farm were also harvested. The collected larvae were anesthetized (MS-222 tricaine methane sulphonate). Total body length was measured using a stereoscopic microscope to the nearest 0.01 mm, and the larvae were weighed to the

nearest 0.01 mg. Final survival rates were calculated from daily mortality and the final number of surviving larvae recorded in each aquarium.

TABLE 1

Chemical composition (%) of diets (data provided by the manufacturer)

	Diets		
Specification	Bio Kyowa (BK)	Aglo Norse (AN)	Artemia nauplii (A)
Protein	54	59	50
Lipids	10	21	10
Ash	13	10	5

HISTOLOGICAL STUDIES

The samples (15 larvae from each feeding group; 3 fish from each aquarium) were subjected to standard histological procedure and the whole fishes were immersed in paraffin, cut longitudinally with a microtome into sections of a thickness of 4-6 μm and stained with hematoxylin and eosin (for general observation), Alcian blue, and periodic acid – Schiff reagent (AB/PAS) at pH 2.5, 1.0, and 0.5. Schiff periodic acid was used to stain glycogen with diastase as a control. Sudan III was employed to detect lipids in the samples preserved in Ciacco liquid (Martoja and Martoja-Pierson 1970, Pearse 1985). A Nikon-Alphaphot-2YS2 microscope with a Nikon 4300 digital camera was used to measure the cells, and the computer analysis of the images was done with the MicroScan (v.1.5) and Lucia 4.21 programs. Morphometric evaluation (hepatocyte volume) and image analysis (relative volume of intracellular lipid deposition) were done for 20 measurements of preparations of five central sections of each fish (n = 20 × 5) (day 42 of the experiment) at a magnification of 400x. In total, 100 measurements of each fish (n = 100 × 5 fish) and each feeding group were done.

FEED COMPOSITION AND FATTY ACID CONTENT

The nutritional value of the feeds was provided by the manufacturer (Table 1). The fatty acid composition was analyzed at the laboratory of the Department of Animal Rearing and Breeding of the Warsaw Agriculture University. The nutritional value of the Artemia nauplii was also determined at the same laboratory (Table 2).

TABLE 2

Fatty acids composition (% of total fatty acids) in diets

Fatty acids (%)	Diets		
	Bio Kyowa (BK)	Aglo Norse (AN)	Artemia nauplii (A)
SFA			
C 10:0	0.1	0.1	nd
C 12:0	0.1	0.1	nd
C 14:0	3.8	5.5	0.8
C 15:0	0.3	0.4	nd
C 16:0	21.4	14.2	10.4
C 17:0	0.3	0.2	1.5
C 18:0	4.7	2.1	5.2
C 20:0	0.2	0.2	nd
C 22:0	0.1	0.1	nd
C 24:0	0.1	0.1	nd
Σ SFA	31.1	23.0	17.9
MUFA			
C 14:1	0.2	0.2	nd
C 16:1	4.2	3.9	13.2
C 17:1	0.5	0.3	nd
C 18:1	25.3	12.4	28.5
C 20:1	2.4	11.1	nd
C 22:1	1.8	15.3	3.0
C 24:1	0.2	0.6	nd
Σ MUFA	34.6	43.8	41.7
PUFA			
C 18:3	1.6	1.9	3.8
C 18:4	0.7	1.0	0.7
C 20:5	7.8	6.6	13.1
C 22:5	0.7	0.6	nd
C 22:6	8.4	8.8	nd
n-3 total	19.1	18.8	17.2
C 16:2	0.3	0.4	nd
C 16:3	0.2	0.3	1.9
C 16:4	0.1	0.4	nd
C 18:2	12.4	12.1	9.6
C 20:2	0.2	0.2	nd
C 20:3	0.1	0.1	nd
C 20:4	1.1	0.3	2.4
C 22:4	0.2	0.2	nd
n-6 total	14.7	14.1	14.3
Σ PUFA	33.8	32.9	31.5
SFA/PUFA	0.92	0.70	0.57
n-3/n-6	1.30	1.33	1.20

nd – not detected; SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids

The fatty acid content was determined by extracting fat from the fish larvae with the modified Washburn and Nix (1974) method. For each feeding group, FA composition was analyzed in mixed samples, in three replicates, and at the same laboratory. The separation and determination of FA content was conducted in an HP 6890 gas chromatograph with a BPX70 column. The methyl esters of fatty acids were separated, and the content of individual FA was expressed as a percentage of the sum of the determined FA. Methyl esters of the following FA were determined: saturated (SFA) – C 16:0, C 18:0; monounsaturated (MUFA) – C 16:1, C 18:1, C 22:1; polyunsaturated (PUFA), PUFA n-3 – C 18:3, C 20:5, C 22:5, C 22:6; PUFA n-6 – C18:2, C 20:3, C 20:4.

STATISTICAL ANALYSES

The means and standard deviations were calculated within the feeding groups for survival, body weight, and total length. The significance of differences among the experimental groups was tested using one-way analysis of variance (ANOVA). Statistical analysis was done using SPSS 12. The results of morphometric measurements were analyzed using one-way hierarchical ANOVA, taking into consideration the effect of feeding and individual variability within groups. The means were compared using the LSD test. The results shown in the figures and tables are expressed as means, and the significance of differences is indicated by a different superscript letter ($P < 0.05$). The FA composition was analyzed by reading the surface areas under peaks for each FA in the chromatographic column.

RESULTS

SURVIVAL, GROWTH, AND FATTY ACIDS COMPOSITION

No significant differences in survival, final body weight, or specific growth rate (SGR) were detected among the feeding groups; only the body length of the pond-reared pikeperch was significantly higher in comparison to the laboratory-reared groups ($P \leq 0.05$) (Table 3).

The diets contained a similar protein level (from 50 to 59%), but the content of lipids in the A and BK diets was 10%, while in the AN diet it was 21% (Table 1). The comparative analysis of FA composition showed that the lowest level of SFA occurred in A and the highest in the BK diet, which contained 21.4% of C 16:0. The highest levels

of long-chain C 20:1 and C 22:1 (cetoleinic acid) was noted in the AN diet, and small quantities of them were noted in the BK diet. The A and AN diets contained 10% more MUFA as compared to the BK diet. Although the natural feed did not contain DPA and DHA, it contained more EPA and AA in comparison to the commercial feeds.

TABLE 3

Survival, body weight, total length, and specific growth rate of pikeperch larvae fed different diets

	Diet treatments							
	Bio Kyowa (BK)		Aglo Norse (AN)		Artemia nauplii (A)		Zooplankton (Z)	
Parameter	mean	SD	mean	SD	mean	SD	mean	SD
Survival (%)	50.80	6.72	52.40	7.67	54.40	8.29	na	na
Body weight (g)	0.48	0.11	0.51	0.07	0.49	0.11	0.575	0.09
Total length (mm)	37.85^{a}	3.89	39.55^{a}	2.72	38.87^{a}	3.72	48.31^{b}	4.23
SGR	10.87	0.08	11.00	0.11	10.89	0.09	11.29	0.07

Values in the same rows with different letters differ significantly $P \leq 0.05$
SGR – Specific Growth Rate (% day^{-1}) : 100 × (ln final body weight (g) – ln initial body weight (g))/time(days)
na – not analyzed

The SFA content in the pikeperch larvae was similar in all feeding groups. In larvae fed the BK diet, the SFA level reflected the lipids in the diet (Table 4). However, the SFA level in the fish fed the AN and A diets was similar to that found in the pikeperch reared under natural conditions. The level of MUFA was considerably lower in the larvae than in the diets. Only in the fish fed Artemia nauplii was there no reduction of MUFA content in the larvae. The analysis of the FA composition in the pikeperch larvae indicated that the application of the A diet resulted in an increase in the share of MUFA in total fatty acid content in comparison with the BK and AN commercial feeds. The content of acid C 18:1 (30.72%) was two-fold higher in the larvae fed Artemia nauplii in comparison with the remaining feeding groups. The percentages of the PUFA acids linoleic C 18:2 n-6 (LA) and C 22:6 n-3 (DHA) were also reduced. The highest level of acid C 18:2 n-6 in larvae was noted in the AN group. The level of acid C 20:4 n-6 (AA) increased proportionally in the larvae in relation to its content in the feed. The lowest quantities of this acid were observed in the larvae fed the AN diet. The level of EPA in the larvae decreased in relation to their content in the feed, whereas the level of DPA and DHA increased. A higher DPA level was found in larvae fed the natural food (A and Z diets) as compared to the larvae fed the commercial feeds. The application of Artemia nauplii in the rearing of pikeperch had an influence on the low level of PUFA (26.07%) and particularly on the very low content of valuable DHA acid (9.89% of the sum of the FA determined).

TABLE 4

Fatty acids composition of pikeperch larvae (% of total fatty acids content)

Fatty acids	Diet treatments			
	Bio Kyowa (BK)	Aglo Norse (AN)	Artemia nauplii (A)	Zooplankton (Z)
SFA				
C 16:0	22.43	22.27	21.62	22.22
C 18:0	7.14	5.77	9,24	8.20
Σ SFA	29.57	28.04	30.86	30.42
MUFA				
C 16:1	1.87	1.51	2.82	1.57
C 18:1	16.62	12.85	30.72	14.15
C 22:1	9.54	12.24	9.53	8.14
Σ MUFA	28.03	26.60	43.07	23.86
PUFA				
C 18:3	0.68	0.37	1.05	0.50
C 20:5	0.75	0.55	0.81	0.49
C 22:5	1.58	0.93	2.16	5.04
C 22:6	29.99	34.11	9.89	28.35
n-3 total	33.00	35.96	13.91	34.38
C 18:2	5.85	7.77	5.25	5.20
C 20:3	0.49	0.39	1.41	0.60
C 20:4	3.06	1.24	5.50	5.54
n-6 total	9.40	9.40	12.16	11.34
Σ PUFA	42.40	45.36	26.07	45.72
SFA/PUFA	0.70	0.62	1.18	0.67
n-3/n-6	3.51	3.83	1.14	3.03

Description as in Table 2

The differences in FA composition found in the larvae fed Artemia nauplii resulted from the reduction of the n-3/n-6 acid ratio (1.14) (in all remaining groups it exceeded 3). In the group of larvae fed the A diet, it was noted that SFA dominated PUFA in the total fatty acid content; this is considerably different from the results obtained in the remaining feeding groups, including the larvae reared in ponds.

The commercial BK and AN feeds applied in the current study affected the contents of the particular groups of FA in fish larvae similarly to the natural feed of the pond-reared pikeperch. Only when the pikeperch larvae were fed with Artemia nauplii was there a reduction in the PUFA content as compared to the other feeding groups.

HISTOLOGICAL OBSERVATIONS AND MORPHOMETRIC DATA

The livers of pikeperch fed the BK diet consisted of hepatocytes of regular shape with centrally situated nuclei. In the cytoplasm, mainly the deposition of glycogen was observed (areas stained positively with PAS) (Photo 1a). On the contrary, in the case of fish fed the AN diet, lipid vacuoles occupied a larger area of cytoplasm in comparison to that occupied by glycogen (Photo 1b), and the nuclei of the hepatocytes were situated at the cell peripheries. The areas of cytoplasm containing glycogen and lipids were similar in the pikeperch fed Artemia nauplii (Photo 1c). The livers of pikeperch which developed under natural conditions had regularly-shaped hepatocytes with centrally situated nuclei (Photo 1d). The highest volume of hepatocytes and the greatest relative volume of cytoplasm occupied by lipids was noted in the larvae fed the AN diet (Figs. 1 and 2). The smallest volume of hepatocytes and the smallest volume of cytoplasm occupied by lipids were observed in the fish fed the BK diet (Figs. 1 and 2). The differences were statistically significant ($P \leq 0.05$).

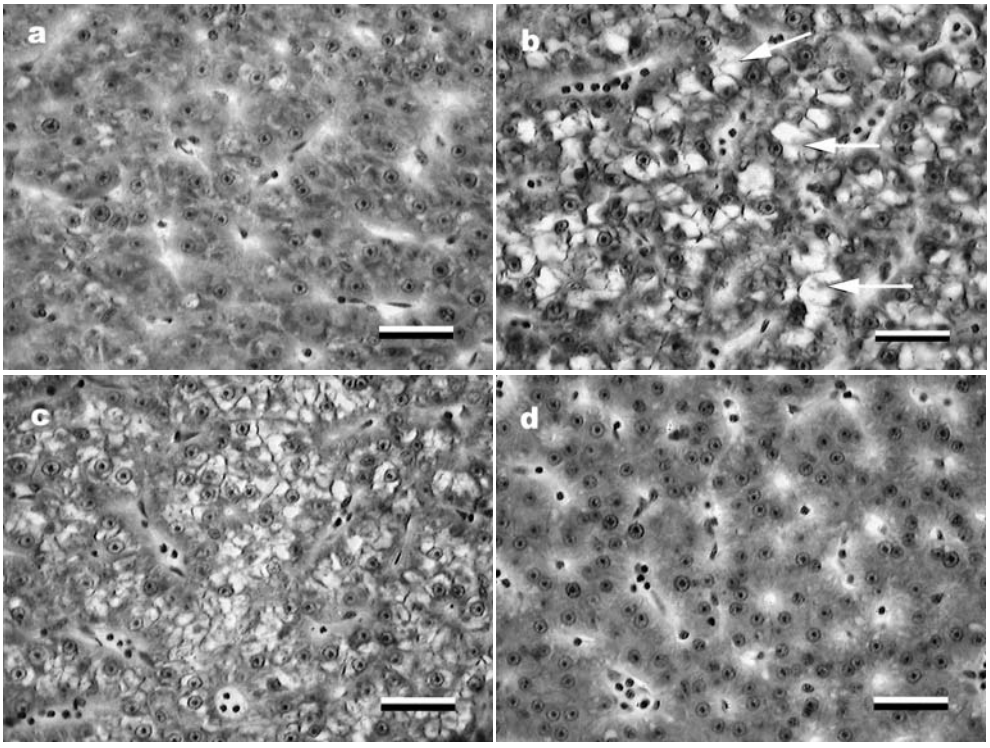

Photo 1. Cross-section of a liver from a pikeperch fed: BK diet (a), AN diet (b) (arrows – lipid vacuoles), A diet (c), Z diet (d), AB/PAS staining; Bar = 25 μm.

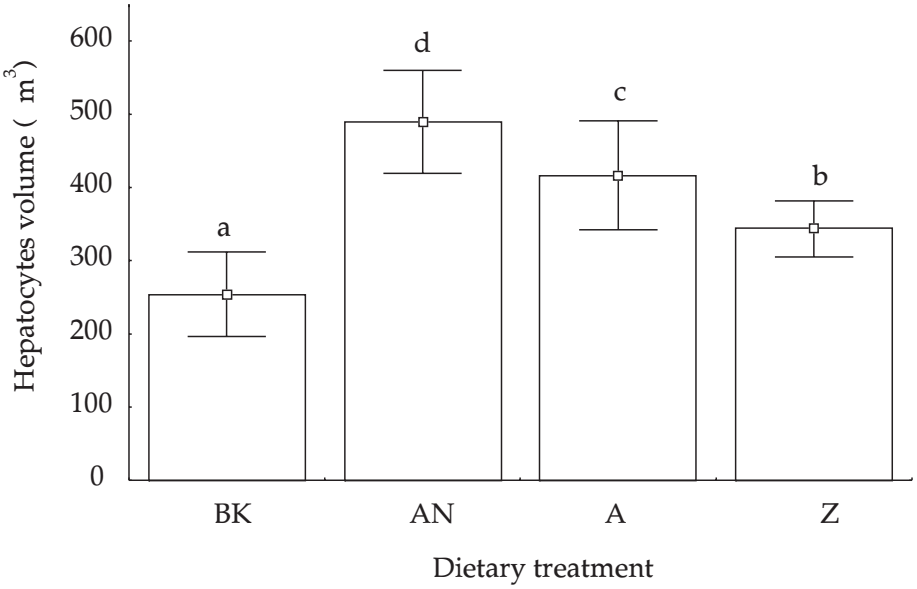

Fig. 1. Comparison of hepatocyte volume of pikeperch (mean ± SD, n = 500). Values marked with different letters differ significantly ($P \leq 0.05$).

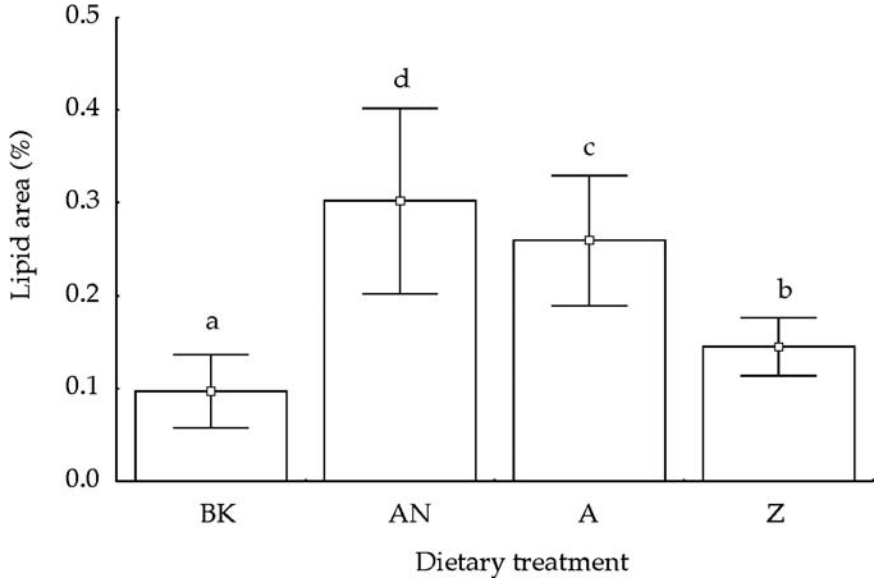

Fig. 2. Mean relative volume (mean ± SD, n = 500) of intracellular lipid deposition in the hepatocytes of pikeperch. Values marked with different letters differ significantly ($P \leq 0.05$).

DISCUSSION

The results obtained indicate that the fatty acid composition in the commercial feeds and Artemia nauplii satisfied the nutritional requirements of the fish. Therefore, these diets can be employed as the first feed in the rearing of pikeperch larvae, as is also indicated by their high survival and growth rates. The FA profile in the larvae reflected the acids profile in the feed, as is the case with other fish species (Arzel et al. 1994, Lanari et al. 1999). Like those reported by Jankowska et al. (2003), the current results suggest that fish are able to elongate and desaturate n-3 fatty acids. The ability to elongate and desaturate is species specific, and it is commonly accepted that freshwater fish have these abilities, while marine fish do not (Yamada et al. 1980). However, rainbow trout, *Oncorhynchus mykiss* (Walbaum), larvae were not able to convert C 18:3 n-3 or C 18:4 n-3 to C 22:6 n-3, which indicates that C 22:6 n-3 may be the essential fatty acid (EFA) for trout larvae (Wirth et al. 1997).

It should be emphasized that DHA content was high in fish fed the commercial feeds and zooplankton, which indicates the role of DHA in the proper growth and development of pikeperch larvae (Montero et al. 2001). The lower level of C 20:5 n-3 and the higher level of C 22:6 n-3 in the tissues as compared to the percentage content in the diets was also observed in rainbow trout (Caballero et al. 2002). It is possible that DHA biosynthesis in pikeperch requires the involvement of the enzymatic complex, including Δ 6 saturase and other elongation-shortening enzymes, allowing DHA synthesis from EPA by 24:6 n-3 and peroxisomal β-oxidation (Buzzi et al. 1996) similarly as in Eurasian perch, *Perca fluviatilis* L. (Kestemont et al. 2001).

The increased content of lipid vacuoles in hepatocytes of fish fed Artemia nauplii and the AN diet probably resulted from the excessive quantity of MUFA, the surplus of which was not utilized as an energy source and was accumulated in the liver. In studies concerning mitochondrial β-oxidation, it was suggested that SFA and MUFA have the priority over PUFA with regard to energy production in fish (Henderson 1996). The present study demonstrated that the high level of C 18:1 in the BK diet was not accumulated in the liver (as confirmed by histological observations) but was utilized as an energy source, which contradicts the observations of Spisni et al. (1998). The metabolism of lipids is regulated mainly by the liver through synthesis as well as the degradation of fatty acids. The enzymes that regulate these paths revealed variable affinity to

different fatty acids available in the liver (Kiessling and Kiessling 1993, Henderson 1996). The lack of equilibrium in dietary fatty acids may, therefore, modify the functioning and morphology of the liver. This organ is the main energy reservoir, where energy is often stored in the form of a fat fraction such as triacylglycerols (TGs) (Kaushik 1997). With a high content of lipids in the diet or the deposition of energetic surplus in the liver in the form of fat, morphological changes and the accumulation of vacuole TGs in the cytoplasm of hepatocytes may occur. The increased volume of hepatocytes and the higher relative volume of lipids in the livers of the pikeperch fed the AN diet resulted from higher lipid levels in the feed. This has also been suggested by other authors (Caballero et al. 1999). In spite of the similar content of C 18:2 n-6 in both commercial feeds, the higher content of it in the larvae fed the AN diet could cause greater fatness of the liver. This probably resulted from the lipogenic effect of linoleic acid C 18:2 n-6, which is similar to what was described in mammals, namely, that diets rich in this acid increase the synthesis of FA and the activity of dehydrogenase glucose-6-phosphate (Ide 2000). On the other hand, the higher content of lipids in the cytoplasm of hepatocytes in the pikeperch fed Artemia nauplii probably stemmed from the difference in the FA profile of the freshwater invertebrates which constitute the natural feed of larval and juvenile pikeperch and Artemia nauplii. The main PUFA of freshwater invertebrates are C 18:3 n-3, C 18:2 n-6, and C 20:5 n-3 (Bell et al. 1994). The artificial feeds had a higher content of C 18:2 n-6 but that of C 18:3 n-3 was two-fold lower than in Artemia nauplii. The considerable reduction of PUFA in the pikeperch fed Artemia nauplii was either evidence of the inappropriate metabolism of fatty acids or the lack of nutritional equilibrium (Tacon 1996). PUFA, and especially C 20:5 n-3, are components of the cellular membranes of such organs as the liver, the swim bladder, or the pyloric caeca during larval stages (Awaïss et al. 1996). The ratio n-3/n-6 was higher in the larvae than in the diets. It is possible that pikeperch synthesize PUFA and are able to ensure a physiologically necessary level of fatty acids (Guillou et al. 1995, Bell et al. 1997).

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STRESZCZENIE

WPŁYW ŻYWIENIA NA PROFILE KWASÓW TŁUSZCZOWYCH I HISTOLOGIĘ WĄTROBY LARW SANDACZA (*SANDER LUCIOPERCA* (L.))

Celem badań było określenie wpływu żywienia (dwie komercyjne pasze sztuczne i pokarm naturalny (Artemia i zooplankton) na wzrost, przeżywalność, profile kwasów tłuszczowych i histologię wątroby sandacza, *Sander lucioperca* (L.). Larwy (początkowa masa ciała 5,0 ± 0,3 mg) podchowywano w laboratoryjnych obiegach recyrkulacyjnych, w szklanych akwariach o objętości 20 dm^3 (temperatura wody 19 ± 0,12°C).

Na podstawie uzyskanych wyników można przypuszczać, że skład kwasów tłuszczowych w obu paszach komercyjnych (Bio Kyowa i Aglo Norse) i naupliusach Artemia zaspokajał zapotrzebowanie larw sandaczy podczas rozwoju. Wskazywała na to wysoka przeżywalność i zadowalające tempo wzrostu (przeżywalność 50,8-54,4%, masa ciała 0,481-0,575 g, długość całkowita 37,85-48,31 mm). Analiza składu kwasów tłuszczowych w ciele larw wykazała, że zastosowane w żywieniu pasze komercyjne wpłynęły podobnie na zawartość poszczególnych kwasów tłuszczowych jak pokarm naturalny sandaczy odchowywanych w stawie (tab. 1, 2 i 3). Żywienie sandaczy naupliusami Artemia spowodowało redukcję wielonienasyconych kwasów tłuszczowych w ciele larw oraz wzrost jednonienasyconych kwasów tłuszczowych w porównaniu z żywieniem paszami komercyjnymi (tab. 4). Na podstawie obserwacji histologicznych stwierdzono, że larwy żywione dietą Aglo Norse miały największą objętość hepatocytów oraz największą względną objętość cytoplazmy zajmowanej przez lipidy (rys. 1 i 2).