Growth performance of juvenile pikeperch, *Sander lucioperca* (L.) fed graded levels of dietary lipids

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ABSTRACT: The aim of the experiment was to determine the effect of graded lipid content in experimental isoprotein feed (6, 10, 14% lipids and 45% protein) on the growth performance of juvenile pikeperch (initial body weight ≈ 210 g) in a recirculation system. No significant effect of the applied feed on the final average body weight was observed. However, average daily weight gain (g/d), SGR index (%/d) and condition coefficient of the fish receiving 10% lipid feed were significantly higher than the corresponding values in the other two groups (6 and 14% lipid, $P < 0.05$). Feed conversion ratio (FCR) and protein efficiency ratio (PER) attained the most advantageous values in this group of fish. The application of the experimental feed had a significant effect on the lipid values in fish bodies and viscera ($P < 0.05$) although no relationship was detected between the lipid content of the feed and that of the fish muscles. The lipid content was approximately 7.7% in all the experimental groups and the differences between the groups were statistically insignificant ($P > 0.05$).

Keywords: *Sander lucioperca* (L.); dietary fat levels; growth; body composition

Percid fish species are highly appreciated by consumers due to the high organoleptic and dietary qualities of their flesh (Kołakowska *et al*., 2000; Jankowska *et al*., 2003). A small percentage of these fish in catches made in natural waters prompted various research teams to devise methods for the controlled rearing of these species, including yellow perch, *Perca flavescens*, Eurasian perch, *Perca fluviatilis*, walleye, *Sander vitreum* and pikeperch, *Sander lucioperca* (Brown *et al*., 1996; Mélard *et al*., 1996; Kestemont and Mélard, 2000; Zakęś *et al*., 2000). Methods were developed for rearing in recirculation systems and ponds using artificial feed. The percid fish species were nourished with widely available commercial feeds which are formulated for the dietary requirements of salmonid fishes (Brown *et al*., 1996; Fontaine *et al*., 1996; Zakęś *et al*., 2001). These feeds have a high energy concentration and high lipid content (often from 20 to 30%; Alsted *et al*., 1995). The application of feeds with such high lipid contents may have a negative effect on the growth of percid fishes, as well as cause liver dysfunction and provoke pathology in the histological picture of the liver (Kestemont *et al*., 2001). In extreme cases, the hepatic cells can decompose leading to the organ becoming fibrous (Zakęś *et al*., 2002).

The study by Brown *et al*. (1996) indicated that the feed applied in the culture of yellow perch should have a high protein content and lower concentration of lipids. Similar conclusions can be drawn from the study of dietary needs of Eurasian perch (Xu *et al*., 2001). The feed utilized in studies of pikeperch contained from 14 to 30% lipids (Zakęś *et al*., 2001; Zakęś, unpublished data). There are no commercial feeds available on the European market with low lipid content that satisfy the dietary requirements of predatory fish. This is primarily a matter of economics – lipids are a far cheaper source of energy than protein.

The aim of this experiment was to determine the effect of lipids in experimental feed (in the 6–14% range) on the growth and chemical composition of juvenile pikeperch reared in recirculation systems.

MATERIAL AND METHODS

Technical aspects of the experiment

The experiment was conducted at the Dgał Experimental Hatchery of the Inland Fisheries Institute in Olsztyn in north-eastern Poland. The experimental material, juvenile pikeperch, was obtained by intensive rearing on artificial feed in recirculation systems. The fish chosen for the experiment weighed from 150 to 260 g (average body weight approximately 210 g, body length Lc approximately 25.5 cm). The fish were stocked into six 1.2 ×1.2 × 0.6 m tanks in a recirculation system. Thirty fish were placed in each tank and the stock biomass ranged from 7.27–7.43 kg/m^3. Water temperature was maintained at 20.0 ± 0.3°C. The water flow rate in the initial phase was 15 l/min (1.0 exchange/h); after four days of rearing it was increased to 25 l/min (2.2 exchanges/h). The oxygen concentration at the tank outflow did not fall below 6.0 mg/l (65% saturation). The total ammonia nitrogen concentration (TAN = NH_4^+-N + NH_3-N) did not exceed 0.35 mg TAN/l, and the water pH was maintained at a level of 7.9–8.1. The experiment lasted seventy days.

Measurements of body weight (BW ± 0.1 g) and body length (Lc ± 0.1 cm) of individual fish were taken every two weeks. During the measurements the fish were anaesthetised with a PROPISCIN (IFI Olsztyn, Poland) solution of 1.0–1.5 ml/l (Kazuń and Siwicki, 2001). Six specimens were chosen from each rearing tank on the final day of the experiment and were used to determine the chemical composition of the body. The fish were anaesthetised with a PROPISCIN solution (4 ml/l) and then decapitated.

Feed and feeding

The fish were fed three experimental isoprotein (45% protein) feeds with graded lipid levels (6, 10 and 14% of dry weight, groups L6, L10 and L14, respectively), with an energy value ranging from 18.5 to 20.4 MJ/kg of gross energy (pellet size 3 mm) (Table 1). Each feeding variant was replicated twice. The fish were fed continuously 24 h per day with an automatic belt feeder. The daily feed ration was maintained at 1% of the stock biomass.

The experimental feed was manufactured at a Feed Laboratory of the Experimental Plant of Feed Production Technology and Aquaculture, Agricultural University in Poznań, Poland. The formula was developed using a computer program that was written in the line code by Simplex method in Turbo Pascal 5.0. The feed mixtures were made using the barothermal method in an endogenous single-start worm extruder (N-60 model, Metalchem, Gliwice, Poland). The feed ingredients were fish meal with blood, sodium caseinate, soybean meal, wheat flour, husked oats, rapeseed oil with low erucic acid content and cod-liver oil (Table 1). The extrusion method was used to make the feed mixes. The dried granulate was coated with rapeseed oil heated to a temperature of 70°C at quantities of 2.0% of the dry feed weight for the mix containing 6.0% lipids and 4.0% for the other two feeds.

Chemical analysis of feed and fish

The chemical composition of the experimental diets and whole fish was analysed according to the procedures in Skulmowski (1974). The fish (six specimens from each tank) were pooled prior to analysis (two samples per treatment), then they were minced, homogenised, and lyophilised. Dry matter was determined (drying at 105°C for 15 h); crude protein (N × 6.25) by the Kjeldahl method after acid digestion (Kjel-Foss, Automatic 16210); crude lipids (Soxhlet method). The ash content of the whole fish bodies (decrepitated at a temperature of 600°C for 20 h) and crude fibre in the feed (Tecator Fibertec, System M1020, Hot Extractor) were both determined. The crude lipid contents of the muscles and viscera of the fish were also determined.

The mineral (phosphorus and calcium) content of the feed was determined with atomic absorption spectrophotometer (ASS3, Carl Zeiss Jena, Germany) according to the methods in Gawęcki (1988). The amino acids were separated after hydrolysing the samples in 6n HCl at a temperature of 106°C over a 24-hour period in an AAA T339 analyser (Microtechnic). The sulphuric amino acids methionine and cysteine were determined after they were oxidised and fixed in formic acid. Tryptophan was determined by the colorimetric method (Votisky and Gunkel, 1989). Based on the results of the protein amino acids, the chemical values of the experimental diet were determined by calculating Chemical Score (CS) and Essential Amino-Acid Index (EAAI) (Steffens, 1985). The gross energy of the feed and fish bodies was calculated based on the

Table 1. Composition and proximate analysis of experimental diets (% dry weight) and the amino acid content (g/100 g protein)

	Diets		
	L6	L10	L14
Ingredients			
Blood meal	16.0	16.0	16.5
Fish meal	5.5	5.5	5.5
Sodium caseinate	19.4	19.9	20.0
Soybean meal	14.0	14.0	14.0
Husked oats	8.0	8.0	8.0
Wheat flour	26.9	22.2	17.4
Rapeseed oil	1.5	5.7	9.9
Cod-liver oil[1]	1.0	1.0	1.0
Soybean lecithin	0.5	0.5	0.5
Polfamix W[2]	1.9	1.9	1.9
Fodder chalk	2.0	2.0	2.0
Phosphate1-Ca	1.0	1.0	1.0
Vitazol AD_3EC[3]	0.1	0.1	0.1
Choline chloride	0.2	0.2	0.2
DAKA binder[4]	2.0	2.0	2.0
Chemical composition			
Total protein	45.01	45.02	44.98
Exogenous amino acids:			
Arginine	4.65	4.64	4.65
Histidine	3.24	3.25	3.26
Lysine	7.23	7.27	7.33
Tryptophan	2.27	2.26	2.30
Phenylalanine + tyrosine	7.77	7.79	7.79
Methionine + cysteine	2.67	2.65	2.64
Threonine	3.77	3.78	3.79
Leucine	8.41	8.43	8.44
Isoleucine	4.29	4.30	4.31
Valine	5.64	5.66	5.66
EAAI[5]	78.50	78.53	78.57
Crude lipids	6.05	10.02	14.02
Nitrogen-free extract (NFE)	29.86	26.44	22.94
Crude fibre	1.17	1.15	1.13
Ash	6.58	6.57	6.59
Phosphorus	0.89	0.89	0.90
Calcium	1.86	1.86	1.88
Gross energy (MJ/kg) (E)[6]	18.5	19.4	20.4
Digestible energy (MJ/kg)[7]	15.1	16.1	17.2
Gross E/Protein E (kJ/g protein)	41.1	43.1	45,4

[1]Jecoris Aselli LYSI HF, Iceland – 1 000 ml contains: vitamin A – 920 000 IU, vitamin D_3 – 92 000 IU, vitamin E – 276 IU

[2]BASF S.A., Kutno, Poland – 1 kg contains: vitamin A – 1 000 000 IU, vitamin D_3 – 200 000 IU, vitamin E – 1.5 g, vitamin K – 0.2 g, vitamin B_1 – 0.05 g, vitamin B_2 – 0.4 g, vitamin B_{12} – 0.001 g, nicotinic acid – 2.5 g, D-calcium pantothenate – 1.0 g, choline chloride – 7.5 g, folic acid – 0.1 g, methionine – 150.0 g, lysine – 150.0 g, Fe – 2.5 g, Mn – 6.5 g, Cu – 0.8 g, Co – 0.04 g, Zn – 4.0 g, J – 0.008 g, carrier > 1 000.0 g

[3]BIOWET Drwalew, Poland – 1 kg contains: vitamin A – 50 000 IU, vitamin D_3 – 5 000 IU, vitamin E – 30.0 mg, vitamin C – 100.0 mg

[4]High Protein Binder, DAKA a.m.b.a. Losning, Denmark

[5]Essential Amino Acid Index

[6]gross energy calculated from the chemical composition using the following energy conversion factors: 39 kJ/g lipids, 24 kJ/g protein and 17 kJ/g carbohydrates (Jobling, 1994)

[7]the digestible energy of feed was calculated based on data from Halver (1988)

Table 2. Growth, condition and size variation and the efficiency of feed utilisation by juvenile pikeperch receiving feeds with graded lipid levels of 6, 10, 14% (L6, L10, L14 groups; average values ± SD, *n* = 2). Data in one row that have the same letter index do not differ statistically significantly ($P > 0.05$)

Specification	Experimental groups		
	L6	L10	L14
Initial body weight (g)	210.1^{a} (± 16.83)	212.7^{a} (± 12.30)	208.4^{a} (± 2.76)
Final body weight (g)	251.6^{a} (± 20.65)	269.3^{a} (± 5.87)	240.6^{a} (± 0.42)
Body weight gain (g/d)	0.59^{a} (± 0.05)	0.81^{b} (± 0.15)	0.46^{a} (± 0.05)
Specific growth rate – SGR (%/d)[1]	0.26^{a} (± 0.00)	0.34^{b} (± 0.07)	0.21^{a} (± 0.02)
Initial condition factor – K[2]	1.25^{a} (± 0.03)	1.26^{a} (± 0.01)	1.24^{a} (± 0.01)
Final condition factor – K[2]	1.11^{a} (± 0.01)	1.16^{b} (± 0.01)	1.08^{a} (± 0.02)
Initial body weight coefficient of variation– CV_{BWi} (%)[3]	14.3^{a} (± 0.92)	15.0^{a} (± 4.17)	15.6^{a} (± 0.57)
Final body weight coefficient of variation – CV_{BWf} (%)[3]	34.0^{a} (± 1.83)	38.6^{a} (± 1.41)	42.4^{a} (± 7.50)
Feed conversion ratio – FCR[4]	3.76^{ab} (± 0.07)	2.93^{a} (± 0.23)	4.65^{b} (± 0.53)
Protein efficiency ratio – PER[5]	0.59^{a} (± 0.01)	0.80^{b} (± 0.12)	0.48^{a} (± 0.05)

[1]SGR = 100 × (ln final mean body weight (g) – ln initial mean body weight (g))/time of rearing (days)
[2]K = (body weight (g) × 100)/body length Lc^3 (cm)
[3]CV_{BW} = (SD/mean body weight) × 100
[4]FCR = total feed supply (dry weight, kg)/fish biomass increment (wet weight, kg)
[5]PER = fish biomass increment (kg)/food protein consumption (kg)

chemical composition using the following energy conversion factors: 39 kJ/g lipids, 24 kJ/g protein and 17 kJ/g carbohydrates (Jobling, 1994). The level of carbohydrates was calculated based on the difference [100 – (water + lipids + protein + ash)] (Shearer, 1994). The digestible energy of the feed was calculated using data from Halver (1988).

Statistical analysis

One-way analysis of variance (ANOVA) was applied to determine the significance of differences ($P \leq 0.05$) in growth rate, condition factor, variability of body weight (CV_{BW}) between the groups (Table 2) and in the chemical composition of bodies of fish receiving feeds with different lipid contents. If statistically significant differences were detected, the Duncan's test was applied (STATISTICA PL software). Prior to statistical analysis, the percentage data was transformed using the *arcsin* function (SGR, CV_{BW} and levels of protein, lipids, ash and dry matter).

RESULTS

The application of feeds with 6, 10 and 14% lipids did not have a significant effect on the values of the average final fish body weight. A statistically significant difference was detected, however, between the average daily growth rate of body weight (g/d), the SGR index (%/d) and the fish condition factor. The highest values were found for the group receiving feed that had a 10% lipid addition (Table 2). The coefficients of variation of body weight CV_{BW} between the groups increased more than twice during the 70-day rearing. However, differences between the groups were not confirmed statistically ($P > 0.05$; Table 2). The application of feed with different lipid levels was reflected in the conversion indicators of the nutritional ingredients of the studied feeds. The group of fish that received the feed with 10% lipid content had a significantly lower, and the most advantageous feed conversion ratio (FCR). The protein efficiency ratio (PER) in this group was also more advantageous than in the groups on diets with 6 and 14% lipids (Table 2).

Table 3. Chemical composition of the bodies of juvenile pikeperch (% wet weight; average values ± SD; *n* = 2) after 70 days of rearing in a recirculation system and receiving feeds with three lipid levels – 6, 10 and 14% (groups L6, L10, L14). The data in one row that have the same letter index do not differ statistically significantly ($P > 0.05$)

Specification	Experimental groups		
	L6	L10	L14
Whole fish			
Dry matter	33.5^{a} (0.24)	33.6^{a} (0.32)	33.4^{a} (0.17)
Protein	20.4^{a} (0.37)	19.1^{b} (0.09)	18.7^{b} (0.58)
Lipids	8.9^{a} (0.20)	10.7^{b} (0.25)	10.3^{b} (0.45)
Ash	3.8^{a} (0.07)	3.5^{a} (0.13)	3.7^{a} (0.13)
Energy (kJ/g)[1]	8.4^{a} (0.15)	8.8^{b} (0.18)	8.6^{ab} (0.23)
Muscle			
Lipids	7.7^{a} (0.22)	7.6^{a} (0.11)	7.7^{a} (0.13)
Viscera			
Lipids	39.9^{a} (0.72)	44.6^{b} (1.18)	50.5^{c} (0.68)

[1]calculated from the chemical composition of the body using the following energy conversion factors: 39 kJ/g lipids, 24 kJ/g protein and 17 kJ/g carbohydrates (Jobling, 1994)

The chemical composition of whole pikeperch bodies from each group in the final phase of the experiment indicated that the highest protein levels were attained by the group of fish receiving the leanest diet (L6). Additionally, the lipid levels in this group were significantly lower than in the remaining two groups (L10, L14; $P < 0.05$). The bodies of the fish from group L10 had the highest energy values (Table 3). No correlations between the lipid levels in feed and fish muscle were detected. The lipid level was approximately 7.7% in each experimental group, and the differences between the groups were not statistically significant ($P > 0.05$). The largest differences between the groups were noted in lipid levels in the viscera. Their increases corresponded to an increase in this nutrient in the feed (Table 3).

DISCUSSION

The application of experimental feed (isoprotein – 45% protein) containing 6, 10 and 14% lipids to pikeperch had a significant effect on the values of the following zootechnical indices: daily weight increase, relative specific growth rate (SGR) and fish condition. The highest values of these indices were noted in the fish group that received feed with 10% lipids (protein/lipids – 45/10). Yellow perch, with an initial body weight of 51 g, achieved the fastest growth rates when they received commercial trout feed containing a similar amount of protein (40%) and 10% lipids (40/10). The growth rates of fish that received commercial trout feed with protein to lipid percentages of 33/8, 38/12 and 50/17.5 or commercial feed for channel catfish *Ictalurus punctatus* (35/4, 32/3.5) were significantly lower (Brown *et al*., 1996). The effect of lipid levels on zootechnical indices is, however, species specific. The growth of juvenile Eurasian perch (BW ≈ 35 g) on a diet containing 19.3% lipids was higher than that of those administered the feed containing 11.7 or 15.0% lipids (Xu *et al*., 2001). In the case of sea bass, *Dicentarchus labrax*, a faster growth rate was also noted in fish that received a diet richer in lipids (19% versus 15 or 11%) (Lanari *et al*., 1999). Jobling *et al*. (1998) did not observe that the dietary lipid levels had a significant effect on the amount of consumed feed or on the weight gains of juvenile rainbow trout, *Oncorhynchus mykiss* (BW ≈ 90 g), which received feed with either high or low lipid contents (27.5 versus 12.6%). Likewise, Koskela *et al*. (1998) did not find that the dietary lipid content had an effect on the whitefish *Coregonus lavaretus*

(BW ≈ 260 g). The authors of these two experiments both believe that the feeding schedule – the fish were fed for four hours per day – could influence the obtained results. Time limitations of access to feed with low lipid content could have an effect on the amount of consumed feed, efficiency of its utilisation and growth rates of fish. If the feeding frequency were increased, perhaps the amount of consumed low-lipid feed would increase. It is known that the frequency of feeding can influence fish growth as well as the efficiency of feed utilisation (Jarboe and Grant, 1997; Lee *et al*., 2000). The reaction of a given species to various lipid levels can also depend on developmental stage. Lipid levels ranging from 12 to 20% were not seen to have an effect on the growth rates of larval gilthead sea bream *Sparus aurata* (Salhi *et al*., 1994), but increasing lipid levels from 9 to 15% significantly improved the growth rate of juvenile stages of this species (Vergara, 1996).

Percid fishes are particularly sensitive to oxidised lipids in feed. They lead to lowered growth rates and feed consumption and result in other physical dysfunctions in yellow perch (Cartwright *et al*., 1998, cited in Kestemont *et al*., 2001) and other fish species (Sargent *et al*., 2002). Kestemont *et al*. (2001) reported that the use of stabilised lipids (ethoxyquin added as an antioxidant, 500 mg/kg lipid) could significantly improve the majority of zootechnical indices in the culture of juvenile Eurasian perch (BW ≈ 23 g). The growth of fish receiving isoprotein feed (40% protein) containing 12 and 18% stabilised lipids was significantly higher than in the group on a diet with 6% lipids. For the purpose of comparison, the growth rate of fish which received feed containing the same amount of lipids that were not stabilised was inversely proportional to the amount of this nutrient in the feed and the poorest growth was exhibited by fish which received the feed containing 18% lipids. The experimental feeds used in this study contained stabilised lipids, mainly vitamin E. This should prevent auto-oxidation which would influence the quality of the feed and the efficiency of its utilization (Table 1).

The lipid content in feed is generally correlated with the increase of this nutrient in fish bodies (Shearer, 1994; Jobling *et al*., 1998; Koskela *et al*., 1998; Jobling, 2001; Sargent *et al*., 2002). In the present study the chemical composition of pikeperch bodies was also significantly influenced by the dietary lipid content. The level of lipids in the bodies of fish from group L10 was significantly higher than in group L6. However, a further increase in lipids (group L14) did not result in increased levels of this nutrient in the fish bodies. A similar phenomenon was noted in sea bass. Increasing levels of lipids were noted in the bodies of fish receiving feeds containing from 12 to 24% lipids, but further increases in the dietary lipid content to 30% did not result in the increase in this nutrient in the fish bodies (Peres and Oliva-Teles, 1999).

Storage energy reserves in fish mainly in the form of lipids in the muscles, viscera, skin, liver, gonads, head or skeleton depend on the species (see the review in Jobling, 2001). The feed used in our experiment had a significant effect on the level of lipids in the viscera, which ranged from 39.9% (group L6) to 50.5% (group L14). No differences in the amount of lipids in the muscles (7.6–7.7%) were detected between the groups. This indicates that pikeperch, like other percid species, accumulate (deposit) energy surpluses mainly in the viscera and that the increase in the dietary lipid level does not significantly affect its content in the muscles of this species (McClelland *et al*., 1995; Peres and Oliva-Teles, 1999; Xu *et al*., 2001). It cannot be concluded, however, that the experimental feed did not have any effect on the increase of lipid levels in the muscles of pikeperch. According to human nutrition classifications for lipid content in muscles, fish are divided into four groups (Macrae *et al*., 1993). The level of lipids in the muscles of wild pikeperch (from natural conditions) does not exceed 2% of the wet weight, thus this meat is categorised as lean (lipid levels < 2%) (Kołakowska *et al*., 2000). Comparisons of the lipid content in the muscles of reared pikeperch (fed commercial trout granulate) and wild pikeperch from a lake (BW in both groups ≈ 1 kg) indicated that there were significant differences between groups (2.9 versus 1.0%; Jankowska *et al*., 2003). What is striking is that the lipid level in the muscles of pikeperch from the present study is significantly higher in comparison with that cited above (7.7 versus 2.9%). This might be explained by the factors such as different fish sizes, feeding level, feed ration and feed composition, all of which are fundamental parameters that influence the metabolism of lipids in fish (Jobling, 2001; Sargent *et al*., 2002).

Increased energy in feed improves the protein utilisation efficiency in many fish species. Lipids are primarily used by fish to meet energy requirements, which means that protein can be more effectively utilised as a building material (protein-sparing effect; Cho and Kaushik, 1990). This was partially confirmed by the present study. Only the increase of lipids (energy) from 6 to 10% resulted in an increased level of protein in the bodies of fish (Tables 1 and 3), as well as in an increase of the protein efficiency ratio (PER) and lowered feed conversion ratio (FCR). It should be stressed that the FCR of experimental feeds used in the present experiment (2.93–4.65) differed significantly from that of commercial trout granulates used in the culture (0.8–2.0; Zakęś *et al*., 2000, 2001; Zakęś, 2003). The reason for this might have been that the experimental feeds had quite high levels of carbohydrates (Table 1), which are known to be rather ineffectively metabolised by predatory fish (Sargent *et al*., 2002).

The present study indicates that juvenile pikeperch should receive the feed that has a lower lipid level than that applied in commercial salmon or trout feeds. The optimum lipid level in feed is 10% as it guarantees the fastest weight gain and the most effective feed utilisation (FCR and PER indices). The application of higher levels did not improve the values of the basic production parameters.

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ABSTRAKT

Růst juvenilního candáta obecného *Sander lucioperca* (L.) odchovaného krmivem se stupňovanými hladinami lipidů

Cílem pokusu bylo stanovení vlivu stupňovaného obsahu lipidů v pokusném izoproteinovém krmivu (6, 10, 14 % lipidů a 45 % bílkovin) na růst juvenilního candáta obecného (o počáteční tělesné hmotnosti ≈ 210 g) v recirkulačním chovném systému. Použité krmivo nemělo významný vliv na konečnou průměrnou tělesnou hmotnost. Avšak průměrný denní přírůstek hmotnosti (g/d), index specifické rychlosti růstu (%/d) a koeficient vyživenosti u ryb, které dostávaly krmivo s 10 % lipidů, byly významně vyšší než odpovídající hodnoty ve dvou zbývajících skupinách (se 6 a 14 % lipidů, $P < 0,05$). V této skupině ryb byly i nejpříznivější hodnoty krmného koeficientu (FCR) a indexu účinnosti bílkovin (PER). Použití pokusného krmiva významným způsobem ovlivnilo hodnoty lipidů v těle a ve vnitřnostech ryb ($P < 0,05$), ačkoliv jsme nezaznamenali žádný vztah mezi obsahem lipidů v krmivu a obsahem lipidů ve svalovině ryb. Ve všech pokusných skupinách dosahoval obsah lipidů přibližně 7,7 % a rozdíly mezi skupinami byly statisticky nevýznamné ($P > 0,05$).

Klíčová slova: *Sander lucioperca* (L.); hladiny tuku v krmivu; růst; složení těla

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