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Usability of some plant protein ingredients in the diets of Siberian sturgeon *Acipenser baerii* Brandt

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Abstract. This study investigated the effect of partially replacing fish meal (FM) in diets with plant protein ingredients on the growth, feed intake, feed efficiency, and nutrient retention of Siberian sturgeon, *Acipenser baerii* Brandt, juveniles. FM was replaced with soy protein concentrate (SP) and rape meal (RM). Three experimental feeds (40% crude protein, 10% fat) were prepared by extrusion. The protein sources in diet FM were fish meal, blood meal, and fish hydrolysate. In diet SP, the fish meal and fish hydrolysate were substituted with soy protein concentrate, and in diet SP-RM, with soy protein concentrate and rape meal. Each diet was fed to triplicate groups of sturgeon with a mean initial mass of 14 ± 1.3 g. The growth test lasted for 50 days, and were carried out in flow-through tanks of 600 dm^3 capacity. The sturgeon from group FM reached an individual body weight that was about 10% higher than that of the fish from the other dietary variants; the significance of the differences was confirmed statistically ($P < 0.05$). The specific growth rates (SGR) were similar during the growth test (about 4% d^{-1}) and did not differ significantly. The feed conversion (FCR) and protein efficiency (PER) ratios were not significantly affected by the different dietary treatments, and were about 1.2 and 2.1, respectively. The proximate composition of the sturgeon bodies was similar, except with regard to lipid content. Protein retention, which ranged from 29.5 to 33.2%, was higher in groups SP and SP-RM. Lipid retention was the lowest in the SP-RM group. The results indicated that soy protein concentrate and rape meal are sufficient partial fish meal substitutes in feed for sturgeon juveniles.

Keywords: Siberian sturgeon, *Acipenser baerii*, feeding, plant protein ingredients, fish meal substitution, feedstuffs

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Introduction

Fish from the family *Acipenseridae* are of the greatest importance in Russia (Chebanov and Billard 2001), while in Europe they are cultivated in Italy, France, Germany, Austria, Bulgaria, Belgium, Estonia, Greece, and Hungary (Steffens et al. 1990, Bronzi et al. 1999, Burtzev 1999). For more than a decade, sturgeon has been bred under controlled conditions in Poland. As reported by Kolman (2005, 2006), the approach to achieving effective improvements in breeding this fish species should be comprehensive and include all of the breeding stages from artificial reproduction to larval nursing, juvenile rearing, and the creation of stationary spawner herds. An essential condition of success for the preceding plans is mastering the feeding factor, i.e., developing full-portion feeds that meet the nutritional needs of sturgeon and their specific alimentary behaviors, such as their day and night feeding activity, or the utilization of chemoreception to search for food.

For several years, one of the main directions in the study of fish nutrition has been the search for alternative components to fish meal and the implementation of them into diets. These components are most frequently plant protein ingredients available on the local (e.g., legume seeds, oil meals, oil cakes) or world (e.g., soybean and its products) markets. It is essential that the components do not have any negative effects on the nutritive value of the diets produced (Watanabe 2002).

The objective of the present work was to determine the possibility of applying selected plant protein sources in the feeding of Siberian sturgeon, *Acipenser baerii* Brandt, juveniles. The nutritive values of the experimental feeds were determined through growth tests.

Materials and Methods

The experiment was carried out at the Experimental Plant of Feed Production Technology and Aquaculture in Muchocin, Poland.

Diets

The three experimental diets were produced by extrusion in a single-start worm extruder, under the following technological parameters: moisture of feed – 10%; cylinder temperature in the zone of increasing pressure – 95°C; cylinder temperature in the zone of high pressure – 106°C; head temperature – 110°C; worm revolutions – 79 rev min^{-1}; nozzle diameter – 6.0 mm. The pellets leaving the extruder were cut into 8 mm particles with a rotary knife; these were spread onto sieves, left to cool, and then dried in a stream of heated air. After drying, the pellets were crumbled with a grinder and sieved to appropriate particle sizes for the sturgeon (Shcherbina et al. 1985); 1.6-2.0 mm for fish of an average weight of up to 30 g; 2.0-3.15 mm for fish of an average weight exceeding 30 g. The granules were sprayed in a pelletizing drum with fish oil (2.0% of the granule mass) that had been heated to 70°C.

The diets were formulated to contain 40% crude protein, 10% lipid, and from 33 to 35% carbohydrates (dry matter basis). All diets contained 8% yeast, 11% blood meal, and from 32 to 41.3% wheat. The main protein sources in diet FM were components of animal origin: fish meal, blood meal, and fish hydrolysate. In diet SP, fish meal and fish hydrolysate were substituted by soy protein concentrate, and in diet SP-RM by soy protein concentrate and rape meal (Table 1). The amino acid composition and the nutritional value of the diets are given in Table 2.

Table 1
Formulation and composition of the experimental diets

	Diet code		
	FM	SP	SP-RM
Formulation (% of wet weight)			
Blood meal	11.0	11.0	10.7
Fish meal	27.2	10.0	10.0
Fish hydrolysate[a]	5.0	-	-
Yeast (brewer's)	8.0	8.0	8.0
Soy protein concentrate[b]	-	23.6	21.0
Rape meal	-	-	7.0
Wheat meal	41.3	36.1	32.0
Fish oil	4.1	7.9	7.9
Constant ingredients[c]	3.4	3.4	3.4
Composition (% of dry mass)			
Crude protein	39.9	40.1	40.0
Lipid	9.9	9.9	10.0
N-free extract	33.4	34.7	33.4
Crude fiber	0.2	0.1	0.1
Ash	5.6	5.0	5.3
Phosphorus	0.7	0.6	0.7
Calcium	1.3	1.1	1.1

[a]C.P.S.P. Special G, Sporopeche, Boulogne-Sur-Mer, France (74% total protein)
[b]Estrilvo 70, Sporopeche, Boulogne-Sur-Mer, France (68% total protein)
[c]Constant ingredients (%): 0.5 soybean lecithin; 1.0 premix (Polfamix W, BASF Polska Ltd. Kutno, Poland); 0.1 vitamin premix (Vitazol AD_3EC Biowet Drwalew, Poland); 0.2 choline chloride (UCB Chemicals Espana S.A., Spain); 0.4 calcium monophosphate (Opolwap S.A. Tarnów Opolski, Poland); 1.2 fodder chalk (Opolwap S.A. Tarnów Opolski, Poland).

Fish, rearing conditions, and calculations

Siberian surgeon juveniles were fed the experimental diets for 50 days (07.06.-28.07.2003). Prior to the experiment, the fish were fed a commercial feed, Trouvit T (Trouw Nutrition, Denmark), which, according to manufacturer's data, contained 54% protein, 18% fat, 8% carbohydrates, and 19.5 MJ kg^{-1} gross energy. At the start of the experiment, 9 groups of sturgeon (14.0 g ± 1.3 g, 98 fish $group^{-1}$) were distributed randomly from two holding tanks into fiberglass tanks (600 dm^3

Table 2
Amino acid composition, chemical nutritive value of protein, and calorific value of the experimental diets

	Diet code		
	FM	SP	SP-RM
Essential amino acid (g 100 g^{-1} of crude protein)			
Arginine	5.66	6.10	6.11
Histidyne	3.80	3.91	3.88
Lysine	7.92	7.49	7.39
Tryptophan	2.73	2.29	2.26
Phenenyloalanine+Tyrosine	6.55	7.51	7.55
Methionine + Cystine	2.88	2.58	2.68
Treonine	3.90	3.90	3.91
Leucine	8.51	8.91	8.90
Isoleucine	3.23	3.77	3.74
Valine	5.54	5.76	5.75
Parameter*			
CS	Isoleu 47.1	Met+Cys 42.6	Met+Cys 44.5
IAAI	75.79	79.04	79.25
Gross energy (MJ kg^{-1})	19.1	19.2	19.0
Energy/protein (kJ g^{-1} crude protein)	47.5	48.0	47.5

*see Materials and Methods.

tank volume, dimension 3.0 m, water depth 40-50 cm) supplied with water from a lake. The water passed through mineral filters prior to use. During the experiment (every day at 08:00 h), temperature (°C) and dissolved oxygen (mg O_2 dm^{-3}) were monitored at the water supply using an electronic oxymeter (Elmetron CO-315, Elsent Wroclaw, Poland). During the experiment, the average daily water temperature ranged from 18.5 to 24.5°C, the content of dissolved oxygen was highly variable and ranged from 4.4 to 7.4 mg O_2 dm^{-3} (Fig. 1).

Each diet was fed to triplicate groups of fish. The fish were fed continuously (24 h d^{-1}) using automatic belt feeders for fish with clock drives. The daily feed rations were calculated according to the feeding rate in Hung and Lutes (1987) and in consideration of the actual fish body weight. The size of rations were determined every 10th day based on weight monitoring (all of the fish in each tank were weighed), which also provided the data for determining the values of rearing indices. Every day at 08:00 the tanks were cleaned with a water siphon to remove excrement and unconsumed feed.

These data were used to calculate the following parameters: specific growth rate SGR = 100 × (ln w_t – ln w_o) × t^{-1}; food conversion ratio FCR = $F \times (w_t - w_o)^{-1}$; protein efficiency ratio PER = $(W_t - W_o) \times P^{-1}$;

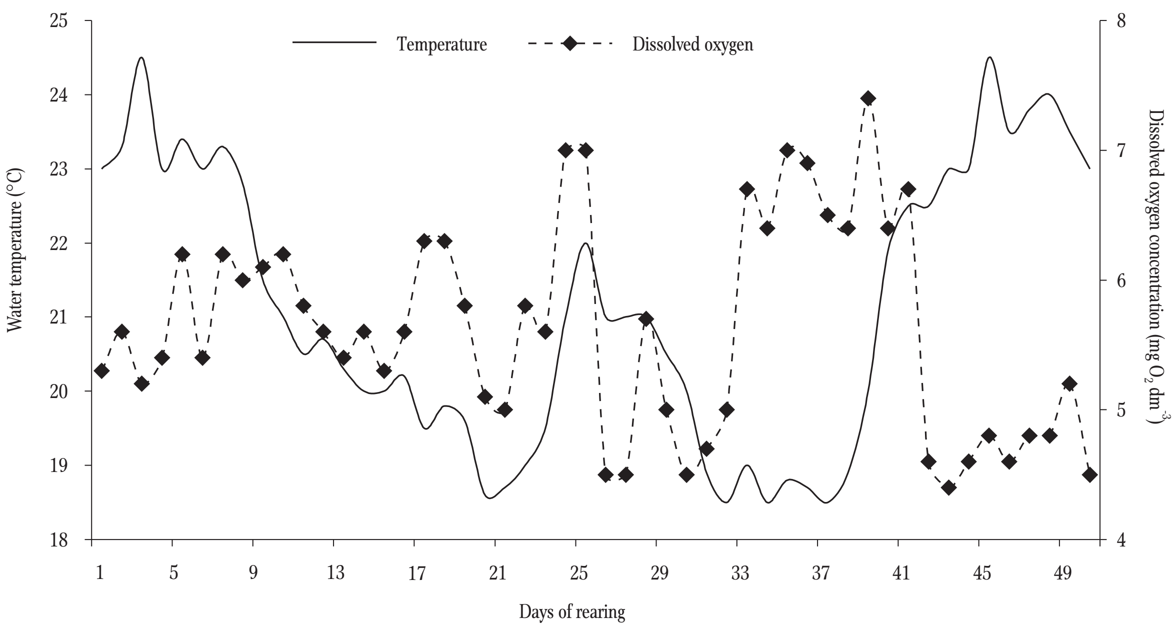

Figure 1. Diel changes of water temperature and dissolved oxygen during growth test with Siberian sturgeon.

protein retention PR = 100 × (P_t – P_o) × P^{-1}); lipid retention LR = 100 × L_t – L_o) × L^{-1}. The symbols used in the equations are as the follows: w_o and w_t – initial and final average fish weight (g); t – number of days of feeding trial; F – total amount of feed per fish consumed during the growth test (g); W_o and W_t – initial and final fish biomass (g); P – protein intake (g); P_t – final protein content in fish bodies (g); P_o – initial protein content in fish bodies (g); L_t – final lipid content in fish bodies (g); L_o – initial lipid content in fish bodies (g); L – lipid intake (g). The survival rate SR = 100 × (final number of fish × initial number of fish^{-1}).

Body composition

Before stocking the fish into the experimental tanks, nine individuals were sampled from the holding tanks. These fish were euthanized in water with the Propiscin (Siwicki 1984) anesthetic, and then decapitated. The fish bodies were ground immediately (Knifetec 1095 Sample Mill, Foss Tecator, Höganäs, Sweden), homogenized (Laboratory homogenizer H500, Polekolab, Warsaw, Poland), and frozen at -20°C as three pooled samples of three fish each. At the end of the growth trial, this procedure was repeated, sampling three fish per tank.

Chemical analyses

The diets and homogenized fish were analyzed for dry matter (in an oven at 105°C for 12 h), crude protein (Kjel-Foss Automatic 16210, AISN Foss Electric, Denmark), raw fat (Soxhlet method; drying at 60°C, 12 h of extraction with paraffin ether), crude fiber (Fibertec System M, Tecator, 1020 Hot Extraction, Flawil, Switzerland), and ash (combustion at 550°C for 12 hours, Linn High Therm GmbH, Eschenfelden, Germany). The content of N-free extract was estimated as the difference between the dry mass and the sum of the remaining components. Calcium was determined with an ASS3 type atomic absorption spectrophotometer (Carl Zeiss, Jena, Germany) and phosphorus was determined with the flame ionization technique (sample of 1 g) (AOAC 1996). Amino acids were measured after sample (0.1 ml) hydrolysis in 6n HCl at 106°C for 24 h (Microtechna AAT 339, Prague, Czech Republic). Methionine and cystine were determined after previous oxidation with performic acid. Tryptophan was determined with the colorimetric method (Votisky and Gunkel 1989). Based on the results of amino acid analyses of protein, the chemical value of the experimental diets was defined by calculating the chemical score (CS) and the indispensable amino-acids index (IAAI) (Hardy and Barrows 2002).

The gross energy of the diets was calculated from the chemical composition using the conversion factors of gross energy for fish: carbohydrates – 17.2 kJ g^{-1}; protein – 23.6 kJ g^{-1}, and fat – 39.5 kJ g^{-1} (Blaxter 1989).

Statistical analyses

The results were analyzed using the Statistica 5 PL Program (StatSoft Polska, Kraków, Poland). The mean results per tank were subjected to one-way analysis of variance (ANOVA). Homogenous groups were determined with Duncan's multiple range test. The level of significance was $P < 0.05$, and the results are presented as the mean ± standard deviation of the mean (SD).

Results

No fish died during the experiment. Until day 40 of the growth test, there were no significant statistical differences ($P < 0.05$) in the mean individual body weight of the fish (Table 3). On the final day of the experiment, the sturgeon from group FM had reached an individual weight of about 10% higher than that of the sturgeon from the remaining treatments; the significance of differences was confirmed statistically ($P < 0.05$). The values of the specific growth rate (SGR) were equal during the growth test, while the values calculated for the whole experimental period were high (about 4% d^{-1}), and did not differ significantly. In reference to the food conversion ratio (FCR) and protein efficiency ratio

(PER), no significant intergroup differences were recorded during the experiment, and their values for the whole period of the growth test was about 1.2 and 2.1, respectively (Table 3).

Additionally, the composition of the whole sturgeon bodies from the various experimental groups indicated that the dry matter, protein and ash were very similar, and differences between the groups were not statistically significant ($P < 0.05$). In turn, the fat level in the bodies of fish from the SP group was lower than those noted in the two remaining groups (FM and SP-RM), but the significance of differences was not confirmed statistically ($P < 0.05$). The level of protein retention in the bodies of sturgeons was almost equal at about 30%. Differences among the groups were noted in fat retention; in the SP-RM group, the value of this indicator was significantly statistically lower than in the other groups ($P < 0.05$, Table 4). The significant similarity of the proximate composition of the sturgeon after the termination of the growth test resulted from the balanced content of nutritive components and energy in each of the experimental diets.

Table 3
Changes of individual fish weight, specific growth rate, feed conversion ratio and protein efficiency ratio during the growth test (mean ± SD, n=3)

	Diet code		
Days	FM	SP	SP-RM
Fish body weight (g)			
10	$27.2^{a} \pm 0.09$	$24.3^{a} \pm 0.79$	$25.0^{a} \pm 1.28$
20	$46.5^{a} \pm 1.15$	$37.9^{a} \pm 1.73$	$39.6^{a} \pm 1.69$
30	$68.2^{a} \pm 0.72$	$55.4^{a} \pm 5.61$	$56.2^{a} \pm 2.57$
40	$91.2^{a} \pm 4.88$	$78.9^{a} \pm 5.85$	$80.8^{a} \pm 3.56$
50	$117.5^{b} \pm 8.86$	$99.9^{a} \pm 6.59$	$101.0^{a} \pm 8.27$
Specific growth rate SGR (% d^{-1})			
0-10	$6.35^{a} \pm 0.06$	$5.93^{a} \pm 0.17$	$5.81^{a} \pm 0.07$
11-20	$5.36^{a} \pm 0.21$	$4.46^{a} \pm 0.13$	$4.60^{a} \pm 0.09$
21-30	$3.82^{a} \pm 0.14$	$3.77^{a} \pm 0.56$	$3.49^{a} \pm 0.03$
31-40	$2.91^{a} \pm 0.43$	$3.55^{a} \pm 0.27$	$3.62^{a} \pm 0.02$
41-50	$2.53^{a} \pm 0.22$	$2.36^{a} \pm 0.08$	$2.23^{a} \pm 0.38$
0-50	$4.19^{a} \pm 0.13$	$4.01^{a} \pm 0.10$	$3.95^{a} \pm 0.08$
Food conversion ratio FCR			
0-10	$0.60^{a} \pm 0.01$	$0.65^{a} \pm 0.03$	$0.67^{a} \pm 0.01$
11-20	$0.85^{a} \pm 0.05$	$1.07^{a} \pm 0.04$	$1.02^{a} \pm 0.04$
21-30	$1.18^{a} \pm 0.05$	$1.22^{a} \pm 0.22$	$1.31^{a} \pm 0.01$
31-40	$1.35^{a} \pm 0.23$	$1.06^{a} \pm 0.10$	$1.03^{a} \pm 0.01$
41-50	$1.57^{a} \pm 0.15$	$1.69^{a} \pm 0.07$	$1.83^{a} \pm 0.35$
0-50	$1.18^{a} \pm 0.07$	$1.19^{a} \pm 0.01$	$1.22^{a} \pm 0.05$
Protein efficiency ratio PER			
0-10	$4.19^{a} \pm 0.06$	$3.82^{a} \pm 0.15$	$3.72^{a} \pm 0.06$
11-20	$2.95^{a} \pm 0.16$	$2.35^{a} \pm 0.09$	$2.46^{a} \pm 0.09$
21-30	$2.12^{a} \pm 0.09$	$2.09^{a} \pm 0.37$	$1.90^{a} \pm 0.02$
31-40	$1.88^{a} \pm 0.32$	$2.37^{a} \pm 0.22$	$2.42^{a} \pm 0.01$
41-50	$1.60^{a} \pm 0.16$	$1.48^{a} \pm 0.06$	$1.39^{a} \pm 0.26$
0-50	$2.12^{a} \pm 0.12$	$2.10^{a} \pm 0.02$	$2.06^{a} \pm 0.09$

Different superscript letters denote significant differences within each row ($P < 0.05$).

Table 4
Final proximate body composition of whole fish, protein and lipid retention in fish body during growth test (mean ± SD, n=3)

	Diet code		
Parameter	FM	SP	SP-RM
Dry matter (%)	$22.1^{a} \pm 2.09$	$21.2^{a} \pm 1.79$	$22.0^{a} \pm 3.28$
Crude protein (%)	$13.6^{a} \pm 4.25$	$13.7^{a} \pm 3.29$	$13.9^{a} \pm 4.18$
Crude fat (%)	$6.2^{a} \pm 2.22$	$5.5^{a} \pm 2.12$	$6.9^{a} \pm 1.98$
Ash (%)	$2.5^{a} \pm 1.32$	$2.4^{a} \pm 2.00$	$2.2^{a} \pm 1.80$
Protein retention PR (%)	$29.5^{a} \pm 1.82$	$33.2^{a} \pm 1.02$	$33.3^{a} \pm 1.55$
Lipid retention LR (%)	$71.8^{b} \pm 6.33$	$73.7^{b} \pm 5.15$	$59.6^{a} \pm 7.48$

Different superscript letters denote significant differences within each row ($P < 0.05$).

Discussion

The optimal water temperature during the rearing of the juvenile stages of *Acipenseridae* fish ranges from 20 to 26°C, while satisfactory body increment growth and the effective utilization of feeds are obtained in water above 18°C (Hung et al. 1993, Ronyai 1999, Mims et al. 2002). The recommended oxygen content in water during sturgeon fry rearing should be above 4 mg dm^{-3}. From a practical point of view, it is frequently reported that the water oxygen saturation should not fall below 70% (Kolman et al. 1996, Mims et al. 2002). During the growth test, the water temperature and oxygen content were maintained within optimal ranges.

When farmed on a commercial scale, sturgeon is fed commercial trout feeds with the lowest possible fat content (Medale et al. 1995). However, in recent years, several recipes for *Acipenseridae* diets have been developed, especially for Siberian sturgeon (Kaushik et al. 1989, 1991, Medale and Kaushik 1991). The results of these studies indicate that the optimal level of protein in feeds for Siberian sturgeon fry (individual weight 22 g) is 40 ± 2%; whereby the maximal incremental increase in fish weight was obtained with feed that had 49% protein. According to Hung (2000) and Hung and Deng (2002), younger stages of Siberian sturgeon (4 weeks after the onset of exogenous feeding) require diets with a higher protein level (45-50%), while the fat content should range from 12 to 20%. Diets balanced thus have proven to be significantly more effective in comparison with feeds containing 35-45% protein. The results of Russian experiments (Ponomarev et al. 1999, Sudakova and Ponomarev 1999) indicated that diets for sturgeon larvae should contain 50-55% protein and 8-12% fat, while the protein content for juveniles should be 46-50% and the fat content should remain the same as for larvae. In the current studies, the sturgeon was given balanced feeds with 40% protein and 10% fat, which satisfied the nutritive needs of the species. The proper balance of nutritive components in the diets tested was reflected in the weight increments and rearing indices obtained. The amino acids composition of the tested diets did not deviate from the values confirmed in juveniles of Siberian sturgeon (Kaushik et al. 1991), or white sturgeon, *Acipenser transmontanus* Richardson (Ng and Hung 1994). After day 50 of the growth test, the sturgeon reached a mean weight of over 100 g with individual weight increments of about 4% d^{-1}. The feed conversion ratio (FCR) was about 1.22, while the protein efficiency ratio (PER) exceeded 2.0. The recorded growth test results were similar, and there were no significant statistical differences between the fish groups.

The quality of the food ingested by fish generally influenced proximate composition. The most distinct correlation is that between the increase of fat content in the feed and increased body fat (Shearer 1994, Jobling et al. 1998, Koskela et al. 1998, Sargent et al. 2002). The experiment by Gawlicka et al. (2002) indicated that the dietary lipid level also influenced the growth rate of white sturgeon larvae. Larvae fed diet with 17% fat grew quicker in comparison to fish fed diets with 25, 33, and 42% fat. According Gawlicka et al. (2002) slowing larval growth resulted in part from the poorer uptake of high fat feeds, and, thus, decreasing consumption of other nutritive components, primarily protein. Furthermore, the study confirmed a high correlation between fat content in the diet and the retention level of this nutrient in fish. Memis et al. (2006) investigated the effect of feed composition on the growth and body components of Russian sturgeon, *Acipenser gueldenstaedtii* Brandt and Ratzenburg, in a long-term growth test (330 days). Fish fed commercial trout feed (45% protein, 12% fat) had a higher growth rate, utilized dietary components better, and had higher muscle protein content in comparison with sturgeon fed commercial carp feed (35% protein, 10% fat). The amounts of lipids in the muscles of sturgeon fed both types of diet did not differ significantly, which resulted from the similar fat contents in the tested feeds. Studies by Mohseni et al. (2007) examined the effect of formulated feeds with 40 and 45% protein and either 10, 15, 20 or 25% fat on the breeding results of Persian sturgeon, *Acipenser persicus* Borodin, juveniles. The best results were obtained with feed that was 40% protein and 25% fat. Sturgeon growth was clearly determined by the dietary fat content, which was confirmed statistically at a significance level of $P < 0.05$, by the greater body weight, and SGR values of the fish that obtained high fat feeds. The feed composition also had a distinct influence on the protein efficiency ratio (PER). On average, this index was 3.58 in the fish group fed high fat feed, while it was 2.77 for the fish fed low fat feed. In the present study the proximate composition of the sturgeon following the growth test was similar, and it is noteworthy that the high values of fat retention index confirm that dietary fats were utilized well.

Studies into the possibility of partially substituting animal protein with full-fat soybean meal in Siberian sturgeon juvenile feed were carried out by Ronyai et al. (2002). Significantly quicker fish growth and a more favorable feed conversion ratio (FCR) were recorded in fish fed diets prepared with proteinaceous components of animal origin (fish meal and meat-and-bone meal). The partial replacement of these components with extracted soybean meal resulted in a decreased fish growth rate. In turn, supplementing diets with crystalline amino acids (L-lysine and DL-methionine) improved sturgeon growth and the food conversion ratio, but the differences were not statistically significant. According to Ronyai et al. (2002), these results stemmed mainly from metabolic disorders caused by the trypsin inhibitors in soybean as well as by the less favorable amino acids composition of feeds based on plant components.

In the experiments of Ustaoglu and Rennert (2002), introducing isolated soybean protein into a diet for sterlet, *Acipenser ruthenus* L., distinctly improved protein digestibility in comparison with feeds based on fish meal. In turn, the values of fat and energy digestibility coefficients were significantly statistically higher for the feed that included fish meal. In the growth test, it was shown that higher protein digestibility in feeds with soybean concentrate did not stimulate any quicker increases in fish mass. The sterlet juveniles utilized feed with fish meal in a significantly better way.

The complementarity of feed amino acids composition can be guaranteed by introducing appropriately composed raw materials or by using several components that supplement the amino acids profile. It is also possible to supplement amino acids with their synthetic forms. This thesis appears to have been confirmed by the results of the present studies and by earlier feeding experiments carried out with sterlet juveniles (Przybył et al. 2006).

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Streszczenie

Zastosowanie wybranych komponentów białkowych pochodzenia roślinnego w paszach dla jesiotra syberyjskiego, *Acipenser baerii* Brandt

Celem badań było określenie możliwości substytucji mączki rybnej roślinnymi komponentami białkowymi w paszach dla narybku jesiotra syberyjskiego. Testowano trzy ekstrudowane izoproteinowe (40% białka ogólnego) i izokaloryczne (10% tłuszczu) pasze doświadczalne. Surowcami białkowymi w diecie FM były: mączka rybna, mączka z krwi oraz hydrolizat białka rybnego. W diecie SP mączka rybna i hydrolizat białka rybnego zostały częściowo zastąpione koncentratem białka sojowego, a w diecie SP-RM koncentratem białka sojowego oraz poekstrakcyjną śrutą rzepakową. Test wzrostowy (50 dni) wykonano w trzech wariantach, każdy w trzech powtórzeniach w przepływowych basenach o objętości 600 dm^3. Materiałem obsadowym był narybek jesiotra syberyjskiego o średniej masie 14 ± 1,3 g. Ryby z grupy FM osiągnęły masę ciała 117,5 g i była ona około 10% wyższa niż masa jesiotrów w pozostałych wariantach (istotność różnic potwierdzona statystycznie $P < 0,05$). Dobowe tempo wzrostu ryb (SGR) było wyrównane w czasie testu wzrostowego (około 4% d^{-1}), a różnice międzygrupowe nie były istotne. Wartości współczynników pokarmowych pasz (FCR) oraz wydajności wzrostowej białka (PER) osiągnęły średnie wartości, odpowiednio: 1,2 oraz 2,1 i nie różniły się istotnie. Skład chemiczny ciała jesiotrów z poszczególnych wariantów był wyrównany za wyjątkiem poziomu tłuszczu. Wskaźnik retencji białka mieścił się w przedziale od 29,5 do 33,2% i był wyższy w grupach SP i SP-RM. Uzyskane wyniki wskazują, że koncentrat białka sojowego w połączeniu z poekstrakcyjną śrutą rzepakową mogą być efektywnymi, częściowymi zamiennikami mączki rybnej w paszach dla młodocianych form jesiotrów.