Nutritive value of cereals in feeds for common carp (*Cyprinus carpio* L.)

A. Przybył, J. Mazurkiewicz

Department of Inland Fisheries and Aquaculture, August Cieszkowski Agricultural University of Poznań, Poland

ABSTRACT: Four isonitrogenous (gross protein content 32%) and isoenergetic (gross energy content 4 080 kcal/kg) diets were prepared by extrusion to investigate the effects of different cereal grains (barley – diet A, wheat – diet B, triticale – diet C, rye – diet D) as carbohydrate compounds of extruded feeds for carp. The physical and chemical properties of the feeds were established. A 60-day growth test was performed in experimental ponds of $40m^2$ area. Each diet was fed to three groups of fish (initial average weight 200 ± 10 g). The following rearing effectiveness indices were used in the final evaluation of the growth test: weight gain (WG, %), specific growth rate (SGR, %/d), food conversion ratio (FCR), protein efficiency ratio (PER) and protein retention (PR, %). Conclusions were based on statistical analysis using the Statistica 5.0 package. The results obtained in the growth test did not show any differences in the evaluated feeds regarding their usefulness in the nutrition of carp (there were no statistically significant differences in the values of fish rearing parameters, $P \leq 0.05$). The recorded growth parameters of carp were as follows: WG: 308.48–324.0%; SGR: 2.81–2.92%/d; the feed conversion coefficients were: FCR: 1.43–1.50; PER: 1.75–1.83; PR: 29.54–31.72%.

Keywords: common carp; feeding; feeds; extrusion; carbohydrate components

The effects of four experimental diets manufactured in Feed Laboratory of Experimental Plant of Feed Production Technology and Aquaculture in Muchocin were compared as exerted on the production performance of common carp. In the feeds used in the nutrition of carp, the main carbohydrate component consisted of cereal grains (their proportions in the diets amounted on average to 35–45%). Their basic component consisted of starch (60–70%) whose digestibility in the raw state in the carp is about 70%. When the grain is subjected to thermal treatment (roasting, cooking, expanding), starch becomes gelatinous, its digestibility reaches 90%. Such high digestibility of carbohydrates makes them the basic source of energy in the diet and this in turn allows better utilisation of dietary protein for fish weight gains (Sadowski and Trzebiatowski, 1995).

Total protein content in the grains of cereals is diversified depending on the species and it ranges between 7 and 15%. This protein is poor in essential amino acids for fish, on average it contains only 0.35% of methionine with cystine, 0.3% lysine, 0.1% tryptophan and is of poor biological value. Other characteristics decreasing the nutritive value of cereals in animal nutrition including fish are the antinutritional agents – chemical compounds naturally occurring in grains which can disturb the regular course of metabolic transformations in the organism. Inhibitors of proteolytic and amylolytic enzymes, phytates, betaglucans and pentosans were reported in cereals in amounts dangerous for the fish organism (Przybył, 1999).

The value of cereals in animal nutrition is commonly accepted in the order: wheat-triticale-maize-barley-rye. It results mainly from the nutritive value of protein of these cereals (content and quantitative ratios of amino acids) and the level of antiquality compounds (Scholtyssek *et al.*, 1986).

The present study aims to compare the nutritive values of four cereal species (wheat, barley, triticale and rye) as the main carbohydrate component of extruded feeds for carp.

MATERIAL AND METHODS

Formulations of experimental diets were calculated using a computer program written by the linear Simplex Method in Turbo Pascal 5.0. Different kinds of cereal grains as main carbohydrate components were used in the feeds: in feed A – barley, in feed B – wheat, in feed C – triticale and in feed D – rye (Table 1).

Feeds were produced by the barothermal method in a single-start worm extruder, type N-60, manufactured by Metalchem Gliwice, Poland. Feeds were conditioned by adding hot water and steam to the mixer to reach 65–70°C and 9–11% moisture level and then they were extruded under the following technological parameters:

- moisture of feed 10%
- cylinder temperature in the zone of increasing pressure 81°C
- cylinder temperature in the zone of high pressure 93°C
- head temperature 105°C
- worm revolutions 63 rev/min
- time of passage through the extruder 78 s
- nozzle diameter 6.0 mm

The extrudate leaving the extruder was cut with rotary knife into 8 mm pellets, they were spread on sieves, let cool down and then dried in a stream of heated air. After drying, the diameter of pellets was 6.6–6.9 mm. The granules were covered with rapeseed oil (2.0% of the granule weight) heated to 70°C by spraying in a pelletising drum.

Water stability of experimental feeds was determined by Hastings-Hepher method (Hepher, 1968) modified by Szumiec and Stanny (1975). It was done in a water bath, on the basis of feed weight loss after the bath treatment and subsequent drying to a constant temperature 105°C. Another criterion of water

Table 1. Composition (%) of tested feeds

Component	Feed			
	A	B	C	D
Fish meal	14.5	14.0	14.5	17.0
Blood meal	8.0	8.0	8.5	8.0
Yeast	4.0	4.0	4.0	4.0
Soybean meal	13.5	13.5	13.5	13.5
Rapeseed meal	8.0	8.5	7.5	5.5
Barley cv. German	43.0	–	–	–
Wheat cv. Zyta	–	43.0	–	–
Triticale cv. Tornado	–	–	43.0	–
Rye cv. Dańkowskie Złote	–	–	–	43.0
Rapeseed oil	5.0	5.0	5.5	5.5
Soybean lecithin	0.5	0.5	0.5	0.5
Premix*	1.0	1.0	1.0	1.0
Mineral-vitamin mix**	0.1	0.1	0.1	0.1
Choline chloride	0.2	0.2	0.2	0.2
Calcium monophosphate	0.7	0.7	0.7	0.7
Chalk	1.5	1.5	1.5	1.5
Total	100.0	100.0	100.0	100.0

*Polfamix W, BASF Polska Ltd. Kutno, Poland – contains in 1 kg: vitamin A – 1 000 000 i.u., vitamin D_3 – 200 000 i.u., 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

**Vitazol AD_3EC BIOWET Drwalew, Poland – contains in 1 kg: vitamin A – 50 000 i.u., vitamin D_3 – 5 000 i.u., vitamin E – 30.0 mg, vitamin C – 100.0 mg stability assessment was the oxygen consumption (BOD) by the water used for testing in an alkaline environment described by Gomółka and Szypowski (1973).

Nutrient composition of the experimental diets (Table 2) was determined according to Skulmowski (1974). The feeds were examined for the content of: dry weight (at 105°C for 12 hours), crude protein (Kjel-Foss Automatic 16210), crude fat (Soxhlet method; drying at 60°C, 12 hours of extraction with paraffin ether), crude fibre (Tecator Fibertec System M 1020 Hot Extractor) and ash (combustion at 550°C for 12 hours, Linn Electro-Therm). The content of N-free extract was estimated as the difference between dry weight and the sum of the remaining components. Total calcium in the feed was determined in an atomic absorption spectrophotometer, model ASS3 (Carl Zeiss, Jena) according to the method described by Gawęcki (1988). Total phosphorus was determined by the flame ionisation technique. Amino acids of the feed protein were assayed in a Microtechna AAT 339 analyser after hydrolysis of a sample (0.1 ml) in 6n HCl at 106°C for 24 hours. Methionine and cystine were determined after previous oxidation in formic acid. Tryptophan was determined by the colorimetric method (Votisky and Gunkel, 1989). On the basis of the results of amino acid analyses of protein, the chemical value of experimental diets was defined by calculating the chemical score (CS) and the indispensable amino acid index (IAAI) (Hardy and Barrows, 2002).

Gross energy of the model diets was calculated from the chemical composition using the conversion factors of gross energy for fish: carbohydrates – 4.1; protein – 5.6 and fat – 9.4 kcal/g (Bureau *et al.*, 2002).

A 60-day experiment was carried out in twelve concrete ponds (each of 40m^2 area and 1.2m depth, with the bottom and sides lined with 10cm layer of gravel) in triplicates. The 12 experimental groups comprised 12 individuals in each group; initial average weight was 200.33 ± 10.5 g (mean ± SD). During the experiment (every day at 8.00 a.m.) temperature (°C) and dissolved oxygen (mg O_2/dm^3) were controlled using an electronic oxymeter Elmetron CO-315.

The daily feed rations were calculated according to the feeding curves given by Schreckenbach *et al.* (1987) with the consideration of the actual water temperature and fish biomass. Feeding was done by hand at 2-h intervals, 5 times per day and with equally divided portions. Samples of three fishes per treatment at the start and at the end of the experiment were analysed for dry weight, total protein, crude fat and crude ash. Fish weights were taken at the beginning and at the end of the experiment.

From the data, the following parameters were calculated: specific growth rate (SGR, %/d), protein retention (PR, %), food conversion ratio (FCR), protein efficiency ratio (PER), survival rate (SR, %). In order to find statistically significant differences between the treatments, data were analysed using the Statistica 5 PL Program. Significance between the means of treatments at the 0.05 level was determined by Duncan's multiple range test.

RESULTS

Characteristics of the feeds

Water stability of the experimental feeds was expressed as the percentage of weight loss and the oxidability index (Table 2). Weight losses ranged from 23.0 (feed D) to 29.1% (feed B). According to this criterion all feeds were characterized by their good water stability. As regards the oxidability, feeds A and B proved to be good and feeds C and D proved to be very good; the value of this index ranged from 38.4 to 43.4 mg O_2/dm^3.

Total protein level in the diets ranged from 31.93 to 32.03%, and the level of crude fat from 7.08 to 7.21%. The highest levels of crude fibre (3.49%) and crude

Table 2. Water stability of tested feeds

Parameter	Feed			
	A	B	C	D
Weight loss (after 40 min) (%)	27.3	29.1	25.3	23.0
Score	good	good	good	good
Oxygen demand mg O_2/dm^3	40.1	43.4	38.4	39.8
Score	good	good	very good	very good

Table 3. Chemical composition (%), gross energy (GE) level (kcal/kg) and energy/protein (E/P) ratio (kcal/g protein) of the experimental feeds

Component	Feed			
	A	B	C	D
Crude protein	31.93	32.03	31.96	32.01
Crude fat	7.08	7.11	7.17	7.21
Nitrogen-free extractable compounds	38.69	39.52	39.73	39.33
Crude fibre	3.49	2.83	2.72	2.89
Ash	6.37	6.19	6.15	6.24
Phosphorus	0.75	0.73	0.74	0.76
Calcium	1.55	1.51	1.52	1.62
GE	4 039.9	4 082.3	4 092.7	4 082.8
E/P	12.65	12.74	12.8	12.75

ash (6.37%) were found in feed A. The level of gross energy was similar for all feeds, from 4 039.9 (feed A) to 4 092.7 kcal/kg (feed C), at a constant energy/protein relationship from 12.65 to 12.8 kcal/g protein (Table 3). The essential amino acid composition of the feeds was similar in all cases. Methionine with cystine was the first limiting amino acid in all feeds, from 45.86 to 49.85%, followed by isoleucine and tyrosine. The biological value of protein (IAAI) ranged from 76.78 (feed C) to 77.94 (feed A) – Table 4.

Environmental conditions during the growth test

Average daily water temperature ranged from 17.5 to 24.2°C during the experiment. The content of dissolved oxygen was very variable: from 2.30 to 7.10 mg O_2/dm^3 (Figure 1).

Weight gains and feed utilisation

After 60 days of experiment, no statistically significant differences were found ($P \leq 0.05$) in fish weight growth (WG) and in growth rate (SGR), whereby the highest values of both these indices were obtained in feed with wheat portion. The food conversion ratio (FCR) in all experimental groups had a value close to 1.45, however, the differences between groups were not statistically significant. The protein efficiency ratio (PER) and protein retention (PR) were also very similar and did not differ significantly between the particular variants (Table 5).

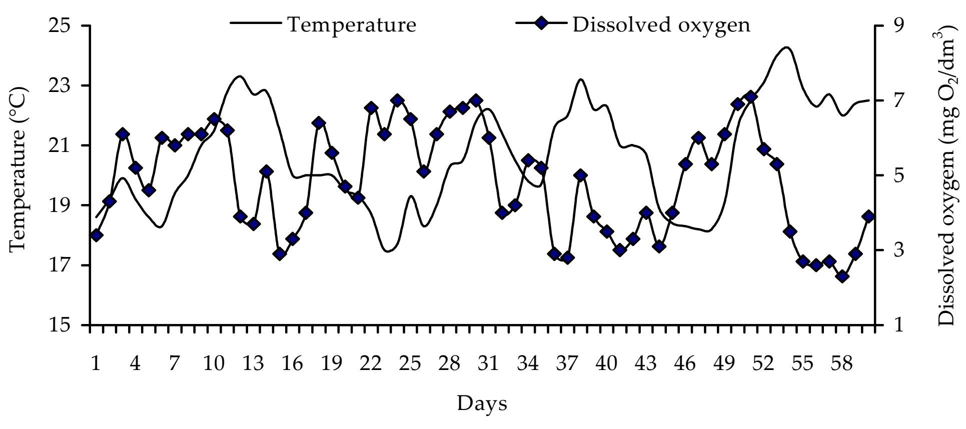

Figure 1. Daily changes in water temperature and dissolved oxygen during the growth test

Table 4. Essential amino acid composition (g/100 g protein), Chemical Score (CS) and Indispensable Amino Acid Index (IAAI) in tested feeds

Amino acid	Feed			
	A	B	C	D
Arg	5.40	5.33	5.31	5.39
His	3.86	3.85	4.01	3.97
Lys	7.43	7.29	7.51	7.71
Tryp	2.97	2.89	2.93	3.20
Phen + Tyr	7.14	7.09	6.85	6.93
Met + Cys	2.79	2.87	2.78	2.66
Treo	3.99	3.92	3.90	3.97
Leu	8.60	8.59	8.62	8.56
Isoleu	3.66	3.66	3.52	3.67
Val	5.60	5.58	5.59	5.60
CS	I. Met + Cys 48.10	I. Met + Cys 49.85	I. Met + Cys 47.93	I. Met + Cys 45.86
	II. Isoleu 53.04	II. Isoleu 53.04	II. Isoleu 51.01	II. Isoleu II. 53.19
	III. Tyr 70.18	III. Tyr 70.20	III. Tyr 67.54	III. Tyr 68.95
IAAI	77.94	77.78	76.78	77.10

Table 5. Percent weight gains (WG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), protein retention (PR) and survival rate (SR) in common carp fry fed the experimental diets*

Parameter	Variants			
	A	B	C	D
WG (%)	308.48 ± 5.54	324.00 ± 26.72	313.43 ± 18.07	319.42 ± 13.16
SGR (%)	2.81 ± 0.03	2.89 ± 0.13	2.90 ± 0.01	2.92 ± 0.04
FCR	1.50 ± 0.02	1.44 ± 0.12	1.46 ± 0.01	1.43 ± 0.03
PER	1.75 ± 0.03	1.83 ± 0.15	1.78 ± 0.10	1.81 ± 0.07
PR (%)	30.38 ± 2.03	31.10 ± 1.95	29.54 ± 2.31	31.72 ± 1.25
SR (%)	100.0 ± 0	100.0 ± 0	97.0 ± 4.81	97.0 ± 4.81

*values are means ± SD from triplicates
WG = (final wt. – initial wt.) × 100/initial wt.; SGR = [ln (final wt.) – ln (initial wt.)]/days; FCR = dry feed intake (g)/wet weight gain (g); PER = wet weight gain/protein intake; PR = [protein content of fish (g) at the end of the experiment – protein content of fish (g) at start of the experiment] × 100/dry protein fed (g)

The survival rate (SR) of fish in all experimental variants during the experiment was between 97 to 100% without significant differences.

Fish body composition

In all experimental variants the final dry weight, crude protein, crude fat and ash content of the body did not differ significantly. In comparison with initial values, only the dry weight and crude protein content increased significantly from 24.16 to more than 28% and from 10.69 to more than 14%, respectively (Table 6).

DISCUSSION

In conditions of pond rearing, water temperature and oxygen content in water are abiotic elements that

Table 6. Chemical composition of fish body before and after the experiment (%)*

		Dry weight	Ash	Crude protein	Crude fat
Before the experiment		24.16[a] ± 0.61	3.08 ± 0.08	10.69[a] ± 0.21	2.93 ± 0.85
After the experiment	A	28.22[b] ± 2.46	1.91 ± 0.20	14.60[b] ± 0.12	3.35 ± 0.30
	B	28.35[b] ± 1.97	2.26 ± 0.23	14.37[b] ± 0.27	3.36 ± 0.19
	C	29.03[b] ± 0.77	2.11 ± 0.27	14.14[b] ± 0.30	3.51 ± 0.12
	D	28.22[b] ± 2.17	2.09 ± 0.41	14.74[b] ± 0.24	3.43 ± 0.30

*values are means ± SD from triplicate sample of fish and means in each column denoted by the same letters are not significantly different ($P \leq 0.05$)

have a significant impact on fish growth (Steffens, 1986). Mean water temperature during the growth test was 20.66°C (min 17.5°C, max 24.2°C) and it was insignificantly lower than the values required to insure the optimal growth of carp. In turn, the amount of oxygen dissolved in water oscillated between 2.30 and 7.10 mg/dm^3, which should be regarded as the values having no negative effect on carp growth.

The use of experimental feeds enabled to achieve high weight gains of fish in a short time and good utilisation of the nutritive components of feeds. It resulted from an optimal balancing of the diets regarding the content of total protein and fat (Ogino, 1980a; Jauncey, 1982; Watanabe, 1982, 1988), mineral components (Satoh, 1991; NRC, 1993; Kim *et al.*, 1998), essential amino acids (Nose, 1979; Ogino, 1980b) as well as the energy level in the diet and its relation to the protein amount (Ohta and Watanabe, 1996).

The tested feeds were isonitrogenous and isocaloric on the basis of the grain of barley, wheat, triticale and rye. The absence of any significant differences between the particular variants indicates that all cereals represent equally valuable components of carp feeds. The value of the cereal species in the nutrition of carp juveniles (fry) was also found in an earlier study (Mazurkiewicz and Przybył, 2003). In the case of younger fish being potentially more susceptible to the composition and quality of feed, the absence of any significant intergroup differences indicates that the applied cereal species are valuable nutritional components.

Triticale is a very valuable carbohydrate component of extruded feeds for carp (Przybył *et al.*, 1994). In the nutritional experiment, feeds containing alternatively triticale or wheat were applied at levels: 0, 15, 23, 34, 45 and 57%; no significant differences were found between the values of the basic parameters in the rearing of 2 years old carp (SGR: 2.24–2.39%/d; FCR: 1.43–1.72 and PER: 1.91–2.24). It confirms possible substitution of the grain of triticale for wheat in carp feeds, which will bring a decrease in the feed cost.

An evaluation of cereals as the main components of full-value feeds in the intensive rearing of carp and tilapia was carried out by Viola and Arieli (1983). The best production results were obtained in the carp receiving a feed with wheat component, but this was the most expensive. Lower values of indices in carp rearing were obtained using maize; it increases the fat content in fish bodies to 15% at the same time. The application of barley decreased the growth rate of fish indicating that the grain of this cereal has a lower usability in carp nutrition. The present data suggest that these differences may be overcome by the expansion of feeds in some cases.

CONCLUSIONS

The results of the presented studies confirmed a high effectiveness of feeds containing expanded grain of wheat, barley, triticale or rye in the intensive production of carps in ponds.

The absence of significant differences between the experimental variants with expanded grains indicates that the tested cereals used in feeds have an equal usefulness for carp.

In the case of application of nutritionally balanced feeds in carp rearing, the type of used cereal may have no essential effect on the obtained production results because the deficiency of nutritive substances in one component is supplemented by their higher amount in others.

REFERENCES

Bureau D.P., Kaushik S.J., Young Cho C. (2002): Bioenergetics. In: Halver J.E., Hardy R.W. (eds.): Fish Nutrition. 3rd ed., Academic Press, San Diego. 2–60.

Gawęcki K. (1988): Practicals in animal feeding and feedstuff science (in Polish). Wyd. AR Poznań.

Gomółka E., Szypowski W. (1973): Laboratorial and mathematical practicals in water chemistry (in Polish). Wyd. Politech. Wroc.

Halver E.J. (1988): Fish Nutrition. Academic Press, San Diego.

Hardy R.W., Barrows F.T. (2002): Diet formulation and manufacture. In: Halver J.E., Hardy R.W. (eds.): Fish Nutrition. 3rd ed. Academic Press, San Diego. 506–601.

Hepher A. (1968): A modification of Hastings method for the determination of water stability of fish feed pellets. In: Symposium "New Developments in Carp Nutrition". Fifth Session European Inland Fisheries Advisory Commission, Rome, 49–54.

Jauncey K. (1982): Carp (*Cyprinus carpio* L.) nutrition – a review. In: Muir J.F., Roberts R.J. (eds.): Recent advances in Aquaculture. Croom Helm, London. 216–263.

Kim J.D., Breque J., Kaushik S.J. (1998): Apparent digestibilities of feed components from fish meal or plant protein based diets in common carp as affected by water temperature. Aquat. Liv. Res., *11*, 269–272.

Mazurkiewicz J., Przybył A. (2003): Comparison of nutritional usability of cereals as carbohydrate components of extruded feeds for common carp (*Cyprinus carpio* L.) fry. Acta Sci. Pol., Piscaria, *2*, 195–206.

Nose T. (1979): Summary report on the requirements of essential amino acids for carp. In: Tiews K., Halver J.E. (eds.): Finfish Nutrition and Fishfeed Technology. Heenemann, Berlin. 145–156.

NRC (1993): Nutrient Requirements of Fish. National Academy Press, Washington, DC. 114.

Ogino C. (1980a): Protein requirements of carp and rainbow trout. Nippon Suisan Gakkaishi, *46*, 385–388.

Ogino C. (1980b): Requirements of carp and rainbow trout for essential amino acids. Nippon Suisan Gakkaishi, *46*, 171–175.

Ohta M., Watanabe T. (1996): Dietary energy budgets in carp. Fish Sci., *62*, 745–753.

Przybył A. (1999): Technological processes of fish feeds production (in Polish). Zakład Upowszechniania Postępu IRŚ Olsztyn.

Przybył A., Madziar M., Tarłowski I. (1994): Assesment of the suitability of triticale in the extruded feed for table carp. Arch. Ryb. Pol., *2*, 103–112.

Sadowski J., Trzebiatowski R. (1995): Fish feeds (in Polish). Pasze Polskie, *1/2*, 110–118.

Satoh S., Viyakarn V., Yamazaki Y., Takeuchi T., Watanabe T. (1991): A simple method for determination of available phosphorus content in fish diet. Nippon Suisan Gakkaishi, *58*, 2095–2100.

Scholtyssek S., Landfried K.E., Świerczewska E. (1986): Improvement of broiler rations with domestic Polish feed components. Second report: The feeding value of triticale for broilers. Arch. Geflugkel., *50*, 20–25.

Schreckenbach R., Steffens W., Zobel H. (1987): Technologien, Normen und Richtwerte zur Fishproduktion. Berlin.

Skulmowski J. (1974): Methods for feed composition and quality determination (in Polish). PWRiL, Warszawa.

Steffens W. (ed.) (1986): Intensive fish production (in Polish). PWRiL, Warszwa.

Szumiec J., Stanny L. (1975): Water stability evaluation of granulated feeds used in carp nutrition (in Polish). Gosp. Ryb., *12*, 3–5.

Viola S., Arieli Y. (1983): Evaluation of different grains as basic ingredients in complete feeds for carp and tilapia in intensive culture. Bamidgeh, *35*, 38–42.

Votisky E., Gunkel J. (1989): Colorimetric determination of tryptophan in feeds. In: II. International Symposium on Amino Acids, 7–10 May 1989, Brno. 113–119.

Watanabe T. (1982): Lipid nutrition in fish. Comp. Bioch. Physiol., *73 A*, 3–15.

Watanabe T. (1988): Nutrition and growth. In: Shepherd C.J., Bromage N.R. (eds.): Intensive Fish Farming. BSP Professional Books, London. 154–197.

Received: 03–10–09
Accepted after corrections. 04–05–12

ABSTRAKT

Nutriční hodnota obilnin v krmivu pro kapry (*Cyprinus carpio* L.)

Ke sledování vlivu různých druhů obilnin (ječmene – směs A, pšenice – směs B, triticale – směs C, žita – směs D) jako uhlohydrátových sloučenin v extrudovaných krmivech pro kapry byly připraveny čtyři krmné směsi se shodným obsahem dusíku (32 % bílkovin) a energie (4 080 kcal/kg) a stanoveny fyzikální a chemické vlastnosti těchto krmiv. Růstový test trvající 60 dní se uskutečnil v pokusných rybnících o velikosti 40 m^2. Každá krmná směs byla podávana třem skupinám kaprů (počáteční průměrná hmotnost ryb činila 200 ± 10 g). Pro závěrečné hodnocení růstového testu jsme použili tyto ukazatele efektivnosti odchovu: hmotnostní přírůstek (WG v %), specifickou rychlost růstu (SGR v %), koeficient konverze krmiva (FCR), bílkovinný produkční index (PER) a retenci bílkovin (PR v %). Závěry vycházejí se statistické analýzy pomocí programů Statistica 5.0. Výsledky růstového testu nenaznačily žádné rozdíly mezi hodnocenými krmivy. Pokud se jedná o jejich prospěšnost ve výživě kaprů (mezi hodnotami ukazatelů odchovu kaprů nebyly shledány statisticky významné rozdíly, $P \le 0{,}05$), byly zjištěny tyto ukazatele růstu kaprů: WG: 308,48–324,0 %; SGR: 2,81–2,92 %/d a koeficientů konverze krmiva: FCR: 1,43–1,50; PER: 1,75–1,83; PR: 29,54–31,72 %.

Klíčová slova: kapr; výživa; krmiva; extruze; uhlohydrátové složky

Corresponding Author

Prof. dr hab. Antoni Przybył, Department of Inland Fisheries and Aquaculture, August Cieszkowski Agricultural University of Poznań, Wojska Polskiego 71c, 60-625 Poznań, Poland
Tel./fax +48 061 848 77 06, e-mail: karp@owl.au.poznan.pl