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Fish aquaculture

EFFECTS OF DIFFERENT DIETARY LIPID LEVELS IN EXTRUDED FOOD ON THE GROWTH OF 1+-OLD CARP (*CYPRINUS CARPIO*) CULTURED IN COOLING WATER

WPŁYW RÓŻNEJ ZAWARTOŚCI LIPIDÓW W PASZACH EKSTRUDOWANYCH NA WZROST JEDNOROCZNYCH KARPI (*CYPRINUS CARPIO* L.) W WODZIE POCHŁODNICZEJ

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Carp of the initial individual weight of 1020 g (+55 g) were fed in cages with four kinds of extruded, isoprotein feeds differing in the lipid content (7.5% in feed A, 11.6% in feed B, 15.3 % in feed C, and 19.5% in feed D). The main source of lipids was a poultry fat. After the completion of the 52-day-long experiment the following values of the SGR and FCR indices were achieved (respectively): A—1.59 and 1.58, B—1.47 and 1.42, C—1.59 and 1.30, and D—1.59 and 1.29. The stage results, calculated every 7 days, as well as, the above-mentioned final values f FCR and SGR indicated, that throughout the entire period of study, the most favourable results of rearing were achieved while feeding the carp with the feed containing 15.3% of lipids, regardless of the water temperature, which ranged from 22.0–30.0°C at the time of the experiment.

INTRODUCTION

In the intensive culture of carp and other fishes an important role of one of the growth stimulators is played by the lipids present in the diet. Like in the case of the proteins, the

level of this stimulation depends among other factors, on the amount and origin of the lipids. The above factors are important, because of the exogenous fatty acids present in the lipids and the generally understood "quality" of fats used for manufacturing individual feeds (Viola et al. 1981; Kaushik 1995). At the same time, the lipids present in the carp feed compared with proteins and carbohydrates, constitute respectively 1.9 and 2.4 times more effective source of metabolic energy (Smith 1971; Chiou and Ogino 1975; Austreng 1978). The studies conducted on the carp fry demonstrated, that in the cooling water temperature within 25–30°C the highest body-weight increment was achieved with the feed containing 15% of fat in the pellet feed (Filipiak 1995). The lack, in the accessible literature, of the data pertaining to the effects of different lipid content in the extruded feeds on the growth and other parameters of cooling water culture of one-year-old carp was a reason for conducting the present experiment.

MATERIAL AND METHODS

The feeding study was conducted from 22 July to 12 September 1996 in the Fisheries Experimental Station (FES). The station, located near the "Dolna Odra" power plant at Nowe Czarnowo, is owned by the Department of Aquaculture, Agricultural University of Szczecin. The experimental material consisted of 360 carp of the initial average body weight of 1020 g (± 55 g) which at the time of the experiment were kept in 12 cages (0.75 × 2.0 × 0.8 m). Each cage had the usable volume of 1 m^3, hosting 30 fish. On the very first day after arriving from a private fish-farmer from Gryfino, the individual weight of the fish was 5.0 g (± 1.0 g).

During the experiment the carp were fed daily with four feeds differing in the lipid content. The feeds were identified by the symbols A, B, C, and D. Each of the feeds was tested in three repetitions (Tab. 1). The feeds were manufactured using an extrusion method at the Experimental Facility of the Division of Food Technology and Aquaculture of the University of Agriculture at Poznań. The diameter of the pellets was 8 mm. All fish were fed with identical rations of each feed, which were calculated in relation to the metabolic weight of the fish (Filipiak et al. 1995a). The daily rations were 3.0% within 22 July and 15 August, 2.5% within 16 and 21 August, and 2.0% $W^{0.8}$—from 22 September to the end of the experiment.

On the beginning and at the end of each experiment, a total of 4 fish was sampled from each variant. They were subjected to complete homogenisation and examined for the content of: dry mass (drying for 12 hours at 105°C), crude protein (Kjeltec 1026), lipids (Soxhlet method; 12 hours of extraction with ethyl ether), ash (combustion at 550°C for 12 hours). Chemical analyses of the feeds were conducted using the same methods, however the content of N-free extract was determined from the difference between the dry mass and

the sum of the remaining components, including the fiber. The content of the latter component was determined using a standard of acid and base hydrolysis. The level of the gross energy in the feeds was determined from the individual components using the following conversion coefficients: 39.53 kJ/g (lipids), 23.63 kJ/g (crude protein), and 17.15 kJ/g (carbohydrates) (Jobling 1994). The metabolic energy was calculated adopting the method of Jauncey (1981), who in turn followed Smith (1971) assuming the value of 4.5 for protein, 8.51 for fat (after Austreng 1978) and 3.49 kcal/g for N-free extract (after Chiou and Ogino 1975).

To asses the dynamics of the changes in the basic rearing parameters and to adjust the amounts of the administered feed to the current needs, the fish were weighed in each cage every 7 days. The results of the control weighing the stage values of the following coefficients were determined: FCR (Food Conversion Ratio), SGR (Specific Growth Rate), aNPU (apparent Net Protein Utilisation), ER (Energy Retained), and aLR (apparent Lipids Retained). To determine the significance of the differences between the variants all values of the above-mentioned rearing coefficients were subjected to statistical analysis (LSD test, $P = 0.05$).

The temperature, oxygen content, and pH of the cooling water were constantly monitored (every 60 minutes) using an automated recorder. The mean diel values and the ranges of changes of the analysed physical-chemical parameters were shown on Fig. 1.

RESULTS AND DISCUSSION

Description of the experimental feeds

Specifically designed formula of the feeds tested, guarantied almost equal content of crude protein which exceeded slightly (about 3–4%) the level of the protein demand recommended by Filipiak (1995) in the rearing process of two-year-old carp in cooling water. The feeds differed in the lipid content. The alternative A contained 5.5%, B—11.6%, C—15.3%, and D—19.5% of this component (Tab. 1). The variable lipid content was achieved through spraying the pellets with variable amount of semi-liquid poultry fat (4.0% in B, 8% in C, and 12% in D). The structural lipid content amounting to 7.4% was a result of the fat present in the respective components: fishmeal (9.9%), poultry slaughter by-product meal (15.6%), lupine (4.2%), and rapeseed lecithin. The latter component responsible, among other things, for enhancing emulsification and nutritive absorption of the lipid fraction, was added to each feed in the amounts optimal for carp cultured in cooling water in summer season (Sadowski et al. 1997).

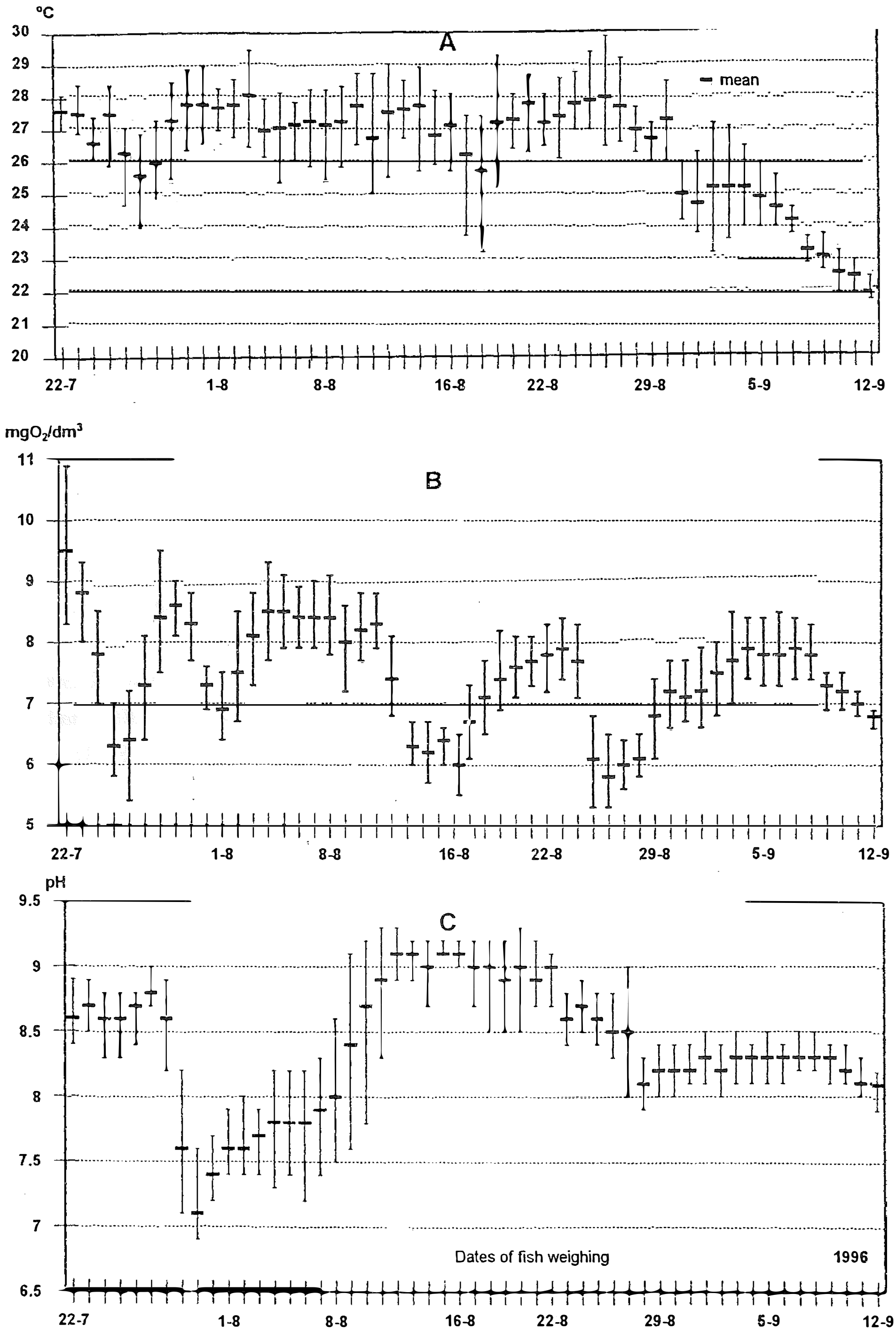

Fig. 1. Diel changes of temperature (A), oxygen contents (B) and pH (C) in cooling water during the experiment

Table 1

Components and chemical composition (%) of diets used for feeding carp

Components	Feed variants			
	A	B	C	D
Fish meal	33.0	33.0	33.0	33.0
Poultry by product meal	21.0	21.0	21.0	21.0
Lupine crude	11.0	11.0	11.0	11.0
Wheat meal	22.7	18.7	14.7	10.7
Wheat bran	10.0	10.0	10.0	10.0
Polfamix W* (commercial vitamin mixture)	1.5	1.5	1.5	1.5
Witasol AD_3E	0.1	0.1	0.1	0.1
Rapeseed lecithine	0.5	0.5	0.5	0.5
Choline chloride	0.2	0.2	0.2	0.2
Poultry fat	—	4.0	8.0	12.0
Chemical composition				
Dry matter	91.8	91.9	92.0	92.1
Crude protein (P)	41.8	41.4	40.9	40.5
Lipids	7.5	11.6	15.3	19.5
Ash	9.9	9.9	9.8	9.8
Fiber	4.3	4.3	4.2	4.1
N-free extract	28.3	24.7	21.8	18.2
Gross energy (E) (KJ/g)	18.4	19.3	20.2	21.1
Metabolic Energy (KJ/g)	14.7	15.5	16.3	17.2
P/E (mg/KJ)	22.7	21.4	20.3	19.2

* In 1 kg—Vitamin: A – 10000 IU, D_3 – 2000 IU, E – 1.5 g, K – 0.2 g, B_1 – 0.05 g, B_2 – 0.4 g, B_{12} – 0.001 g, nicotinic acid – 2,5 g, pantothenian Ca – 1.0 g, choline chloride – 7.5 g, folic acid – 0.1 g, methionine – 150 g, lysine – 150 g, Fe – 2.5 g, Mn – 6.5 g, Cu – 0.8 g, Co – 0.04 g, Zn – 4.0 g, J – 0.08 g.

Environmental conditions

Throughout the entire experiment the values of the studied physical-chemical parameters of the cooling water were typical for the summer season and they did not differ from those recorded in earlier years (Filipiak et al. 1995b). The average diel water temperature was within 22.0–28.1°C. The oxygen content changed within 6.0 to 9.5 mg/dm^3 and pH was from 7.1 to 9.2. (Fig. 1).

Rearing results

Based on the weakly weighing the experiment was divided into 7 stages. For each stage and for each variant the rearing coefficients were calculated and they were presented in Tab 2. In the first three weeks the daily ration of the feeds calculated in relation to the metabolic weight of the fish was 3% $W^{0.8}$, while in the last three weeks—2% $W^{0.8}$. The prevailing temperature of the cooling water oscillated around 26–28°C, whereas in the last two weeks it declined from 25 to 22°C. Despite the differences in the amount of the feed ad-

ministered and the changes in the temperature of the water—the most favourable values of the FCR and SGR coefficients in all stages of the study, were achieved in the alternatives C and D. The tested feeds in the latter alternatives contained 15.3% and 19.5% of lipids respectively. Usage of lower fat-content feeds (11.6%—A and 7.5%—B) led, in all stages of the experiment not only to unfavourable high consumption of feed related to a unit of fish weight increment, but it also had an effect on a distinct, statistically significant, limitation of the growth rate of carp, described by the SGR coefficient. It must be emphasised that at each stage of the study no statistically significant differences were observed between the SGR values for C and D alternatives. In the final result of the 52-day-long feeding experiment the increment of the mean individual weight of the carp was identical for the two mentioned above alternatives and it amounted to 128.8% (for comparison, it reached 101.4% in alternative A and 115.1% in alternative B). Alternatives C and D also yielded the highest and similar values of the SGR coefficient (Tab. 3). It means that for maximising the growth rate of carp within 1000–2300 g it was sufficient to use a feed containing 15.3% of lipids, which was similar as the value recommended by Watanabe et al. (1987) and Filipiak (1995) in feeding fry and 2-year-old carp.

Table 2

Mean individual weight of carp, Specific Growth Rate (SGR) and Food Conversion Ratio (FCR) in each part of experiment

Variants (% lipids in food)	Dates of fish weighings							
	22 Jul.	1 Aug.	8 Aug.	16 Aug.	22 Aug.	29 Aug.	5 Sept	12 Sept.
	mean individual weight (g)							
A (7.5)	1027	1219	1377	1532	1633	1763	1907	2069
B (11.6)	1018	1214	1386	1564	1681	1832	2002	2190
C (15.3)	1017	1229	1413	1611	1748	1919	2113	2327
D (19.5)	1029	1242	1428	1629	1769	1942	2139	2354
SGR (%/day)								
A	—	1.72[c]	1.73[c]	1.33[c]	1.07[c]	1.09[c]	1.12[c]	1.16[c]
B	—	1.77[b]	1.89[b]	1.52[b]	1.19[b]	1.23[b]	1.26[b]	1.28[b]
C	—	1.89[a]	2.00[a]	1.64[a]	1.36[a]	1.33[a]	1.38[a]	1.37[a]
D	—	1.88[a]	2.00[a]	1.64[a]	1.37[a]	1.34[a]	1.38[a]	1.37[a]
		SE	0.04	0.03	0.02	0.02	0.01	0.02
FCR								
A	—	1.59[c]	1.57[c]	1.67[c]	1.66[c]	1.60[c]	1.54[c]	1.45[c]
B	—	1.55[b]	1.43[b]	1.48[b]	1.47[b]	1.40[b]	1.34[b]	1.30[b]
C	—	1.43[a]	1.34[a]	1.33[a]	1.28[a]	1.28[a]	1.21[a]	1.19[a]
D	—	1.44[a]	1.34[a]	1.33[a]	1.27[a]	1.28[a]	1.21[a]	1.20[a]
		SE	0.02	0.01	0.02	0.01	0.01	0.02
Daily food ration (%$W^{0.8}$)	—	3.0	3.0	3.0	2.5	2.0	2.0	2.0

Table 3

Specific Growth Rate (SGR), Food Conversion Ratio (FCR), apparent Net Protein Utilization (aNPU), apparent Lipid Retained (LR) and Energy Retained (ER) of carp fed different level lipids in food after 52 days of experiment

Variants (% lipids in food)	SGR[1] (%/day)	FCR[2]	aNPU[3] (%)	aLR[4] (%)	ER[5] (%)
A (7.5)	1.35^{c}	1.58^{c}	24.5^{c}	99.7^{a}	29.2^{d}
B (11.6)	1.47^{b}	1.42^{b}	29.2^{b}	71.6^{b}	38.4^{c}
C (15.3)	1.59^{a}	1.30^{a}	32.0^{a}	59.7^{c}	46.7^{b}
D (19.5)	1.59^{a}	1.30^{a}	32.3^{a}	46.8^{d}	53.1^{a}
SE	0.02	0.01	0.19	0.03	0.19

[1] – defined as a different between ln of final and initial individual weight of fish divided by time × 100,
[2] – total food ration per unit of fish weight gain,
[3] – amount of crude protein retained per unit of crude protein intake × 100,
[4] – amount of lipids retained per unit of lipids intake × 100,
[5] – amount of gross energy retained per unit of gross energy intake × 100

In the general perception, effective usage of individual nutritive components of feed mixtures for fish are dependent on properly balanced energy and the energetic homeostasis of an organism is in large extent dependent on lipid transformation (Przybył 1996). It is evident from the literature data summarised by Jobling (1994) and Kaushik (1995) that the optimal level of energetic demand of carp increases, among other factors, along with the increase of their unit weight and the water temperature. Taking into account the high temperatures of the cooling water discharged from the "Dolna Odra" power plant, the growth maximising of those fish was possible only through usage of feed characterised by a sufficiently high energy level. Therefore the feed used in alternative C was considered the most advantageous among the all feeds tested. It should be emphasised that the metabolic energy content in the feed C was only by 0.33 kJ/g higher than the amount recommended by Jauncey (1981) for feeding carp fry cultured in water of the temperature 28°C. The reason for less favourable results of rearing in alternatives A and B were probably not only insufficient amount of metabolic energy used in those feeds but also too high, as for the needs of carp, protein-energy factor (P/E). According to Watanabe et al. (1987) and Takeuchi et al. (1989) the above-mentioned parameter should not exceed the range of 18–20 mg/kJ.

The other factor, which might have influenced the "superiority" of the feed used in alternative C was the fact that the 12% addition of the poultry fat, most probably, in the respect of its quantity, was an appropriate source of—important for the carp growth—certain exogenous fatty acids (EFA). The results of Scott et al. (1978) and Viola and Amidan (1978) indicate that poultry fat constitutes a substantially higher (16–23 times) source of

linolic acid (18:2 n-6) than for instance—fish oil. It was one of the reasons why this component was added to the feeds in the studies conducted by Viola and Amidan (1980) on a tilapia hybrid (*Sarotherodon aureus* × *S. niloticus*), eel (*Anguilla anguilla*) (Degani 1986; Gallager and Degani 1989),and also on the fry and two-year-old carp (Viola et al. 1981, 1982; Filipiak 1989, 1995; Filipiak and Trzebiatowski 1992). Relatively low content of poultry fat in the feeds of alternatives A and B was a factor influencing unfavourably low level of metabolic energy. On the other hand it can be concluded, that in a limited degree it fulfils the demand of carp for EFA. As a result alternatives A and B were characterised by relatively high values of FCR coefficient, slower fish growth, and in the consequence also by low coefficients of protein retention (aNPU) and energy retention (ER). The limited values of those latter parameters were substantially influenced by distinctly lower value of the crude protein and also fat in the bodies of carp of the alternatives A and B compared to alternatives C and D (Tab. 4). It is worth to mention, that along with the growth of the amount of lipids in the feeds tested, the levels of fat in the fish body increased, which means that the level of the processes of re-synthesis and accumulation of fat by carp in a significant way was dependent upon the amounts of those components provided in the diet. A similar relationship was recorded also in the fry of carp fed with feeds of variable content of fish oil (Schwarz et al. 1983; Zeitler et al. 1983; Murai et al. 1985) and poultry fat (Filipiak 1995).

Table 4

Chemical body composition (%)* of carp at the start and the end of experiment

Variants (% lipids in food)	Dry matter	Crude protein	Lipids	Ash
Start of experiment				
	31.0	16.5	12.2	2.2
After 52 days of experiment				
A (7.5)	30.1[d]	16.1[b]	12.0[d]	2.1[a]
B (11.6)	32.3[c]	16.7[a]	14.4[c]	2.2[a]
C (15.3)	35.8[b]	16.6[a]	17.0[b]	2.1[a]
D (19.5)	39.0[a]	16.6[a]	20.3[a]	2.1[a]
SE	0.09	0.09	0.16	0.05

* in wet weight

High level of lipids, reaching 20.3%, observed in alternative D indicates a great potential of those fish to deposit unused metabolic energy of the feed in a form of reserve fat. Complete lack of disease symptoms in the fish of this alternative (they were not present in the remaining alternatives either) proves a substantial physiological plasticity of carp, enable in relatively high water temperature utilise high-fat feeds in a degree not-threatening their health. This regularity is confirmed also by the results of the recent study of Filipiak et al.

(1998) indicating substantial suitability of the high-energy, extruded trout feeds in the intensive market-size carp culture in cooling waters. Those feeds ensure 100-% survival and very low feed rates (1.1–1.3) and substantial weight increments of the fish reaching 1.5–2% daily.

The experiment described above indirectly confirms the existence in several-month-old market carp—ill known adaptive physiological processes enabling utilisation in intensive growth of those fish—high-energy extruded feeds of a substantial 15–20% content of lipids, originating from poultry fat.

CONCLUSIONS

1. The most favourable SGR and FCR indices in the rearing process of one-year-old market carp in the water of the temperature of 22–30°C can be achieved using an extruded high-protein feed containing ca. 15% of lipids provided chiefly by poultry fat.
2. Increase from 7.5 to 19.5% of the lipid content in high-protein extruded carp feeds had a significant effect on the increase of energy retention coefficient (RE) and the level of fat in their body, whereas in a lower degree it had effect on protein retention factor (aNPU).

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WPŁYW RÓŻNEJ ZAWARTOŚCI LIPIDÓW W PASZACH EKSTRUDOWANYCH NA WZROST JEDNOROCZNYCH KARPI (*CYPRINUS CARPIO* L.) W WODZIE POCHŁODNICZEJ

STRESZCZENIE

Karpie o masie 1020 g/szt. (±55 g), obsadzone po 30 sztuk do 12 sadzów, przez 52 dni żywiono czterema ekstrudowanymi paszami różniącymi się zawartością lipidów (wariant A – 7,5; B – 11,6; C – 15,3 i D – 19,5%) przy zbliżonym poziomie białka ogólnego (od 41,8% w wariancie A do 40,5% w wariancie D). Główne źródło lipidów w paszach stanowił tłuszcz drobiowy. Po zakończeniu badań uzyskano następujące wartości wskaźników SGR oraz FCR, odpowiednio: wariant A – 1,35 i 1,58; B – 1,47 i 1,42; C – 1,59 i 1,30 oraz D – 1,59 i 1,29. Etapowe (obliczane co 7 dni) jak i ww. końcowe wartości FCR i SGR wskazują, że przez cały okres badań najkorzystniejsze rezultaty chowu uzyskano żywiąc karpie paszą zawierająca 15,3% lipidów, bez względu na temperaturę wody pochłodniczej, która w czasie doświadczenia zmieniała się w zakresie 22,0–30,0°C. Wzrastający poziom lipidów w paszach spowodował wzrost wskaźników retencji białka – aNPU (od 24,5% w wariancie A do 32,3% w D) i retencji energii – ER (od 29,2% w A do 53,1% w D), przy jednoczesnym spadku retencji tłuszczu – aLR (od 99,7% w wariancie A do 46,8% w D).

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