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EFFECT OF FEEDING CARP WITH FAT-SUPPLEMENTED PELLETED DIETS ON CHEMICAL COMPOSITION OF MEAT

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Abstract

The quality and quantity of fatty acids was studied in the meat of carp fed Aller Classic pellets (control group I) and Aller diet with the following fat supplements: sunflower oil and rapeseed oil (50%:50%) in group II; sunflower oil and linseed oil (80%:20%) in group III; fish oil (100%) in group IV; and pellets with pork scratchings in group V. Each group contained 12 fish. Carp were fed *ad libitum* for 5 months in basins with a closed water circulation system. At the end of feeding, fish were slaughtered and muscle samples were collected and analysed in accordance with AOAC procedures. Total cholesterol content of the muscles was determined colourimetrically. The mean weight of carp was the highest in group III and the lowest in group V. The addition of oils to carp diets resulted in the highest EUFA levels in fish from groups III and II.

Key words: carp, fat-supplemented diet, fatty acids

Today's consumers are showing increasing interest in the quality of foods consumed, in particular the dietetic and health effects they have on the body. Some products may have health-promoting or health-damaging effects depending on certain components or active substances they contain (Ziemlański, 1992; Bartnikowska and Kulasek, 1994; Ackman, 1996). One of the food components dangerous to the body are fats, especially those high in saturated fatty acids (SFA) and cholesterol (Connor et al., 1992; Bartnikowska and Kulasek, 1994). It is therefore recommended that foods rich in essential unsaturated fatty acids (EUFA) should be consumed (How, 1995; Leaf, 1998).

However, a large part of the human diet consists of animal products (meat, eggs, milk and milk products) that contain low levels of EUFA in fat. Studies are therefore underway to increase the concentration of unsaturated fatty acids (UFA) using vegetable or fish oil supplements in feeds and to reduce the level of cholesterol in animal products through appropriate nutrition. Positive results in this respect were obtained for milk (Micek et al., 2004), eggs (Sosin et al., 2006) and meat (Borowiec et al., 2004; Szewczyk et al., 2006).

The meat of fish (in particular marine fish) and fish products, which form only a small part of the human diet, are high in health-promoting polyunsaturated fatty acids (PUFA) (Sargent, 1997). Recent research has focused on the quality and quantity of fatty acids in the meat of freshwater fish (Bieniarz and Kołdras, 2000; Bieniarz et al., 2001a, 2001b; Ostaszewska and Sawosz, 2004), and on increasing the level of EUFA in the meat of farmed freshwater fish. It was shown that the muscles of predatory fish have a higher percentage of PUFA and a lower percentage of monounsaturated fatty acids (MUFA) and cholesterol compared to farmed non-predatory fish fed wheat. The muscles of cereal-fed pond carp are markedly higher in SFA than PUFA. Fish receiving feeds with increased levels of fat show disturbed homeostasis and lipid metabolism, and inhibited growth (Ostaszewska and Boruta, 2006; Ostaszewska and Sysa, 2004). On the other hand, some EUFA are necessary for normal gonadal development as they take part in steroidogenesis (Wade et al., 1994). According to Kołoczek (2003), the addition of oil industry waste to cereal feeds increased the body weight gain of carp.

Relevant experiments under pond rearing conditions should be preceded by laboratory tests to determine the best supplements for use in pelleted feeds. Therefore, in the present study (carried out as part of the research project no. 311 2454 33) we reared two-year-old carp under controlled conditions using pelleted feed containing vegetable oils, fish oil and pork scratchings to determine the possibility of increasing the level of EUFA and reducing the level of cholesterol in the meat of carp. Carp with this fatty acid profile would qualify as health food and would be new to the market.

Material and methods

Two-year-old carp, *Cyprinus carpio* L. (age 2+) of equal weight (160 g) were raised at the Experimental Fish Farm of the University of Agriculture in Krakow. The fish were stocked in 800 l basins with controlled water temperature (23–25°C) and oxygen concentration of 5–6 mg O_2/l. A closed water circulation system with biofilters was used. Carp were assigned to 5 experimental groups with 12 fish per group and fed *ad libitum* on Aller Classic pelleted feed for carp. The control group (I_K) received standard pellets, and the other groups were fed standard pelleted mixture supplemented with 6% oils: group II_{S+Rz} – sunflower oil + rapeseed oil (50%:50%); group III_{S+L} – sunflower oil + linseed oil (80%:20%); group IV_R – fish oil; and group V_{SK} – pork scratchings at a rate of 6%. The study was carried out for 5 months, after which 10 carp were randomly selected from each group, slaughtered and measured for body length (with an accuracy of 1 mm) and for body weight (with an accuracy of 1 g) to determine overall body weight and to calculate mean body weight gains and mean individual gains. Increases in the body weight of particular groups were analysed statistically using one-way analysis of variance (ANOVA) and Tukey's test.

Samples of meat from the left side of the carcass were taken for analysis. Muscle samples and feed samples were analysed for basic nutrients according to the AOAC procedure (1995). The total cholesterol content of muscles was determined colourimetrically (Korzeniowski et al., 1992). The fatty acid profile (% of total acids) in carp muscle fat and in experimental diets was determined using a Varian 3400 CX gas chromatograph with an FID detector (argon as a carrier gas, column CP WAX 58, 50 m in length × 0.53 mm in diameter, programmed column temperature 60°C–220°C, sample injector temperature 200°C, detector temperature 240°C). The results from this part of the experiment were analysed statistically using one-way analysis of variance and Scheffe's test (SAS 1995).

Results

In accordance with the methodology, vegetable oils (rapeseed, sunflower and linseed oils) and fish oil were used to supplement the standard mixture. The linseed oil used during the experiment was of commercial quality and was characterized by a lower level of linoleic acid (about 4.5% of total acids). This oil is obtained from a mixture of various linseeds which have high and low levels of linoleic acid.

Table 1. Chemical composition of carp feeds

Components	Carp diets				
	I_K	II_{S+Rz}	III_{S+L}	IV_R	V_{SK}
Dry matter (%)	89.08	90.72	91.43	90.60	91.50
Ash (%)	8.49	6.44	6.50	6.33	6.06
Crude protein (Nx6.25) (%)	36.31	28.94	28.56	28.25	29.56
Crude fibre (%)	5.80	4.43	4.44	4.71	5.00
Crude fat (%)	8.27	14.01	13.84	14.08	18.53
N-free extractives (%)	30.21	36.90	38.09	37.23	32.35
Calorific value (kcal/kg)	4665	4836	4835	4835	5117

The supplementation of oils to the experimental mixtures had a considerable effect on their chemical composition and fatty acid profile. Table 1 shows the content of chemical components in the pelleted mixtures used in carp nutrition. A supplement of 6% oils and pork scratchings increased the amount of fat in the mixtures while increasing their energy value. This supplement was responsible for a certain reduction in the content of crude protein, ash and crude fibre. The content of the other components in the mixtures remained unchanged. Analysis of the fatty acid profile in the fat of experimental mixtures (Table 2) showed that this profile was altered by the oil or pork scratchings supplement. The vegetable oil supplement increased the levels of linoleic acid C18:2 (*n-6*) and oleic acid C18:1 (*n-9*), while the pork-scratching supplement increased the level of C18:2 (*n-6*). When sunflower and rapeseed oils were added to the mixture, the level of C18:3 (*n-3*) increased markedly. The supplement of fish oil to the mixtures did not change the level of the acids discussed. Fish oil, however, was found to increase the level of C22:1 (*n-9*), C14:0 and C16:0.

Table 2. Fatty acid profile of carp feeds

Components	Carp diets				
	I_K	II_{S+Rz}	III_{S+L}	IV_R	V_{SK}
C12	0.02	0.02	0.04	0.06	0.04
C14	3.30	1.86	1.94	3.36	3.12
C14:1 *(n-5)*	0.11	0.07	0.05	0.10	0.11
C15	0.26	0.15	0.14	0.19	0.20
C16	13.59	8.59	15.75	16.68	10.79
C16:1 *(n-7)*	2.77	1.48	2.08	3.76	3.26
C18	3.94	2.70	8.05	7.30	3.46
C18:1 *(n-9)*	33.95	44.72	36.87	32.02	28.74
C18:2 *(n-6)*	15.47	21.41	21.58	10.73	23.18
C18:3 *(n-3)*	3.45	5.05	2.25	1.95	2.44
C20	0.38	0.54	0.36	0.27	0.26
C20:1 *(n-9)*	5.78	3.75	2.98	7.13	7.26
C20:2 *(n-6)*	0.21	0.13	0.22	0.29	0.17
C20:3 *(n-6)*	0.08	0.05	0.05	0.04	0.03
C20:3 *(n-3)*	0.14	0.10	0.07	0.05	0.03
C20:4 *(n-6)*	0.26	0.18	0.17	0.20	0.20
C20:5 *(n-3)*	3.28	2.00	1.53	2.14	2.58
C22:1 *(n-9)*	6.14	4.34	3.40	9.06	9.59
C22:5 *(n-6)*	0.06	0.08	0.12	0.20	0.19
C22:6 *(n-3)*	3.53	1.80	1.48	1.90	2.16
Unidentified acids	3.28	0.98	0.87	2.57	2.19
Total SFA	48.75	54.36	45.38	52.07	48.96
Total UFA	26.48	30.80	27.47	17.50	30.98
Total MUFA	21.49	13.86	26.28	27.86	17.87
Total PUFA	75.23	85.16	72.85	69.57	79.94
SFA:UFA ratio	1:3.5	1:6.14	1:2.77	1:2.5	1:4.47
n-6:n-3 ratio	1.55:1	2.42:1	4.15:1	1.90:1	3.30:1

Mixtures supplemented with vegetable oils and pork scratchings contained greater amounts of PUFA and lower amounts of SFA. This increased the UFA to SFA ratio. Except fish oil, all the dietary supplements improved the *n-3* to *n-6* acid ratio compared to the control mixture. This ratio approached 1:4.

Table 3. Body weight and weight gains of carp in different groups with an initial individual weight of 160 g

Group	Initial stock (head)	Final stock (head)	Initial weight of stock (g)	Final weight of stock (g)	Mean individual weight (g)	Mean individual weight gain (g)	Survival (%)
I_K	12	8	1920	3120	390	230 a	66.6
II_{S+Rz}	12	10	1920	4400	440	280 b	83.3
III_{S+L}	12	10	1920	4680	468	308 cd	83.3
IV_R	12	10	1920	4690	469	309 d	83.3
V_{SK}	12	8	1920	2760	345	185 e	66.6

Values with different letters are significantly different: a, b, c, d – (P<0.05).

Table 4. Chemical composition of carp meat

Components	Carp group				
	I_K	II_{S+Rz}	III_{S+L}	IV_R	V_{SK}
Dry matter (%)	21.42	22.87	23.22	22.17	21.23
Ash (%)	1.12	1.20	1.78	1.24	1.15
Crude protein (Nx6.25) (%)	19.40	19.52	19.33	19.08	18.53
Crude fat (%)	1.07b	0.88 ab	0.90 ab	0.55 a	0.95 ab
Cholesterol (mg/dl)	114.68 Aa	86.87 aB	103.95 Ab	101.16 ABb	88.42 aB

Values with different letters are significantly different: a, b – (P<0.05); A, B – (P<0.01).

The initial weight of fish from each group was 1920 g (with individual weight of 160 g) (Table 3). Survival ranged from 66.6% (groups I_K and V_{SK}) to 83.3% (groups II_{S+Rz}, III_{S+L} and IV_R). The mean individual body weight of fish ranged from 345 (group V_{SK}) to 469 g (group IV_R). The mean individual body weight gains of carp were significantly (P<0.05) higher in all the groups in comparison to group V_{SK}.

The chemical composition of carp meat is given in Table 4. The fat supplements added to pelleted mixtures for carp had no effect on dry matter, ash and crude protein. There was a decrease in fat content in the carp from the groups supplemented with fat. A significant decrease in fat (P<0.05) was found when a mixture with sunflower and rapeseed oil (50%:50%) and fish oil was fed. The sunflower and linseed oil supplement (80%:20%) did not reduce meat fat content to such a significant degree. The fat supplements used significantly reduced the level of cholesterol in the fat of carp meat. However, the greatest (P<0.01) reduction was obtained when feeding sunflower and rapeseed oil and pork scratchings.

The present study showed a significant effect of dietary oil supplements on reducing the proportion of SFA and increasing the proportion of UFA in carp fat (Table 5). C14:0 and C16:0 decreased in the group of saturated acids, while in the group of unsaturated acids, some acids increased significantly (P<0.05) according to the fat supplement used. The use of a sunflower oil and rapeseed oil mixture significantly increased linoleic acid (C18:2) *n-6* and DHA (C22:6) *n-3*, a sunflower oil and linseed oil mixture increased C20:1 *n-9*, C20:5 *n-6*, C22:1 *n-9*, C22:5 *n-6* and C22:6

n-3, whereas a fish oil supplement increased the level of C18:2 *n-6* and C18:3 *n-3* in carp meat.

Table 5. Fatty acid profile of carp fat

Acids	Carp group				
	I_K	II_{S+Rz}	III_{S+L}	IV_R	V_{SK}
C14	1.53 b	1.16 a	1.08 a	1.16 a	1.20 a
C14:1 *(n-5)*	0.08 AaBb	0.12 Bb	0.09 AaBb	0.06 Aab	0.05 Aa
C15	0.25 Ab	0.20 AaBb	0.25 Ab	0.16 ab	0.17 Aab
C16	21.02 d	17.76 ab	18.98 bc	16.92 a	20.73 cd
C16:1 *(n-7)*	4.66 a	3.38 a	5.75 b	3.13 a	3.93 a
C18	7.03	7.53	6.02	6.18	8.18
C18:1 *(n-9)*	38.65 Aa	38.61 Aa	32.46 Bb	35.63 AaBb	37.87 AaB
C18:2 *(n-6)*	10.37 Aab	14.14 Bc	10.91 Aab	21.22 Cd	11.63 ABb
C18:3 *(n-3)*	2.88 ab	2.88 ab	2.80 ab	3.71 b	1.83 a
C20	0.06 Aa	0.10A aB	0.10 AaB	0.17 Bb	0.09 AaB
C20:1 *(n-9)*	3.22 A	3.37 A	6.58 B	3.08 A	3.57 A
C20:2 *(n-6)*	0.20 Aa	0.50 BbC	0.36 AaBC	0.55 Cb	0.32 AaB
C20:3 *(n-6)*	0.15	0.40	0.35	0.51	0.72
C20:4 *(n-6)*	1.59 Aab	1.70 AaBb	1.55 AaB	1.23 Aa	2.23 Bb
C20:5 *(n-3)*	2.37 AaBb	2.01 AaBc	2.98 Bb	1.37 Aa	2.23 AaBb
C22:1 *(n-9)*	1.14 A	0.72 A	3.33 B	0.98 A	0.91 A
C22:5 *(n-6)*	0.31 a	0.33 a	0.74 b	0.27 a	0.46 ab
C22:6 *(n-3)*	2.76 a	4.24 b	4.40 b	2.74 a	3.70 ab
Unidentified acids	1.73	0.85	2.27	0.93	0.18
Total SFA	29.89	26.75	26.43	24.59	30.37
Total UFA	68.38	72.40	72.30	74.48	69.45
Total MUFA	47.75	46.20	48.21	42.88	46.33
Total PUFA	20.63	26.20	24.09	31.60	23.12
SFA:UFA ratio	1:2.29	1:2.71	1:2.74	1:3.03	1:2.29
n-6:n-3 ratio	1.57:1	1.87:1	1.37:1	3.04:1	2.46:1

Values with different letters are significantly different: a, b, c, d – (P<0.05); A, B – (P<0.01).

Changes in the fatty acid content of carp meat fat increased the UFA to SFA ratio, which from the physiological point of view is beneficial for animals and for consumers of this meat or other products. In the present study, the *n-6* to *n-3* ratio was lower than optimal.

Discussion

Feeding is a very important environmental factor that affects animal productivity and product quality (Bieniarz et al., 2001 b; Micek et al., 2004; Sosin et al., 2006; Szewczyk et al., 2006). These are considerably influenced by feeding and the nutritional value of feeds used in the nutrition of animals, including fish. The dietary oils used caused changes in the basal composition of the mixture, increased fat content and thus the energy value of the feed. Particular changes emerged in the fatty acid profile of dietary fat. A direct relationship was found between the amount of a fatty acid in oil and in feed. This reduced the level of SFA and increased the level of UFA, which is considered favourable (Ziemlański, 1992; Sosin et al., 2006). Because of the physiological impact of EUFA on animal bodies, not only the absolute amount of these acids in the feed but also their proportions are important. The normal *n-6:n-3* ratio should be 4–10:1 (Bartnikowska and Kulasek, 1994). In the experimental feeds studied, after using oil supplements, this ratio was 1.9–4.15:1, a value close to the recommended value.

The results of the present study, concerning body weight gains of carp indicate that oils supplemented to the pelleted mixtures are highly efficient additives, which increase body weight gains of fish. The best results were obtained for a mixture of sunflower and linseed oils and for fish oil, which corresponds with the results reported by Kołoczko (2003), who showed a favourable effect of fat supplement used in carp diets.

The supplementation of pork scratchings to the carp diets significantly decreased body weight of fish. This fact indicates that pork scratchings should not be used in carp feeding.

The nutritive and dietetic value of fish meat depends on the content of nutrients (especially fat) in meat, as well as on the content of acids and cholesterol (Bell et al., 1986; Bieniarz et al., 2001a). The oil-supplemented diets fed had no effect on the dry matter, ash and protein content of carp meat, although fat and cholesterol levels were found to decrease. The carp meat obtained can therefore be classified as lean (Bieniarz et al., 2001 a). It is worth noting that the best results concerning fat and cholesterol content were obtained when feeding a mixture of sunflower and rapeseed oils, as well as pork scratchings. The total cholesterol content of carp meat, obtained in the present study for all the groups, was comparable with the values reported by Bieniarz and Kołdras (2000). Based on our study, it is therefore concluded that the cholesterol content of carp meat fat can be reduced by adding oil, which enhances the health-promoting value of this food.

From the consumer and nutritional point of view, not only the amount of fat in a product consumed but also the composition of fat in terms of SFA (in particular UFA) content are important. The increase in fatty acids (especially PUFA) and the decrease in SFA obtained when dietary oils were fed are considered very positive modifications of carp meat fat in terms of health-promoting value (Bieniarz et al., 2001 b). This is also consistent with the findings for other species of animals reported by other authors (Borowiec et al., 2004 b; Sosin et al., 2006), who found that the addition of fats containing UFA to the diets increased the level of UFA in animal products (eggs, milk, meat). This hypothesis has been confirmed for fish (Bell et al., 1986; Bieniarz et al., 2001 a). Special mention should be made of the fact that feeding diets supplemented with a mixture of sunflower and rapeseed or linseed oils increased the content of docosahexaenoic acid (DHA), and in the latter case it also increased the content of eicosapentaenoic acid (EPA). It is therefore assumed that the carp's body, with a sufficient supply of linoleic acid (C18:2 *n-6* and C18:3 *n-3*), can synthesize the necessary EPA and DHA acids through chain desaturation and elongation (Kulasek and Bartnikowska, 1994).

Changes in the fatty acid content of carp meat fat increased the UFA to SFA ratio, which from the physiological point of view is favourable for animals and for consumers of this meat or other products (How, 1995; Christiensen, 1998).

The amount of EUFA consumed in feed is as important as the proportions between *n-6* and *n-3* acids. An increase in this proportion may induce *n-3* EUFA shortages reflected by visual disorders and abnormal electroretinogram (Connor et al., 1992; Drevon, 1992).

In summary, it is concluded that the addition of oils to carp diets results in leaner meat with a higher content of EUFA in fat and lower cholesterol content. Thanks to the use of this feeding, the meat of carp is characterized by a high nutritive value and has health-promoting properties.

The highest mean individual body weight gains were obtained for the group receiving sunflower oil with linseed oil, while the lowest mean individual body gains were for the group fed pork scratchings.

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PIOTR EPLER, FRANCISZEK BOROWIEC, MIROSŁAWA SOKOŁOWSKA-MIKOŁAJCZYK

Wpływ żywienia karpia granulatami z dodatkiem olejów na skład chemiczny mięsa

STRESZCZENIE

Badano jakość i ilość kwasów tłuszczowych w mięsie karpi żywionych paszą granulowaną firmy Aller Classic (grupa I kontrolna) oraz paszą Allera, w której jako tłuszcz wprowadzono mieszaninę olejów: słonecznikowego i rzepakowego (50%:50%) (grupa II), słonecznikowego i lnianego (80%:20%) (grupa III), rybi (100%) (grupa IV) oraz granulat ze skwarkami wieprzowymi (grupa V). Każda z grup liczyła 12 szt. karpia kroczka. Ryby żywiono *ad libitum* przez okres 5 miesięcy w basenach z zamkniętym obiegiem wody. Po zakończeniu żywienia ryby poddano ubojowi, pobrano próbki mięśni i poddano analizie zgodnie z procedurą AOAC. Określono także całkowity cholesterol w mięśniach metodą kolorymetryczną. Średnia masa ryb była najwyższa w grupie III, a najmniejsza w grupie V. Dodanie olejów do granulatów karpiowych skutkowało najwyższym poziomem EUFA u ryb z grupy III oraz II.