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FATTY ACIDS, FAT AND CHOLESTEROL IN SOME LINES OF CARP (*CYPRINUS CARPIO* L.) IN POLAND

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ABSTRACT. Studies were conducted on the percent content of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), total cholesterol (TCh) and total fat content of muscle tissue with skin in five lines of carp cultured in the Experimental Fisheries Station in Zator during three seasons of the production cycle in grow-out ponds, storage ponds and wintering ponds. Of the five carp lines studied, the Starzawski line was characterized by the highest contents of total fat and cholesterol and the lowest percentage of PUFA in comparison to the fish of the other lines. Carp of the Hungarian line displayed a high percentage of SFA, the highest percentage of PUFA in grow-out ponds and storage ponds as well as the lowest percentage of MUFA during three seasons of the production cycle. Of the remaining lines, none were found to possess at least one trait that repeated in all three studied periods which, in turn, would allow them to be distinguished from the others. The results suggest that some individuals which display the same undesired traits (profile of fatty acids and cholesterol content) can be excluded from further breeding. In consideration of human nutrition, carp can be selected for their low cholesterol content and high percentage of polyunsaturated fatty acids.The accompanying studies of total cholesterol, high density lipoproteins (HDL), low density lipoproteins (LDL) and triglycerides (TG) in blood serum showed no correlation between these parameters and the cholesterol content of muscles.

Key words: *CYPRINUS CARPIO*, FATTY ACIDS, TOTAL FAT, CHOLESTEROL

INTRODUCTION

Polyunsaturated fatty acids (PUFA) play an important role in the biochemical processes of animals, including fish and humans. They are indispensable for the syntheses of prostaglandins, thromboxanes, prostacyclines and leukotrienes and take part in the transport and oxidation of cholesterol. In addition, they participate in cell membrane formation (Farkas 1969, Murata and Higashi 1980, Bell et al. 1986). The involvement of fatty acids (especially arachidonic acid) in gonadal steroidogenesis has been reported for male and female fish (Wade and Van Der Kraak 1991, Wade and Van Der Kraak 1993, Van Der Kraak and Chang 1990, Wade et al. 1994).

In human nutrition, the PUFA play an important role due to their hypocholesterolemic action, reducing the risk of arteriosclerosis (Ahrens et al. 1957). Marine fish

fat (Minakowski 1983) is considered to be the best source of these fatty acids for humans. Dietary fat affects blood serum cholesterol in humans and, consequently, can influence the occurrence of coronary heart disease. This important role of marine fish in human nutritional and health requirements was recently reviewed by Sargent (1997). A literature review on the topic can also be found in works by Budzyńska-Topolewska and Ziemlański (1992), Ziemlański and Budzyńska-Topolewska (1992), Gertig and Przystawski (1994).

Carp *(Cyprinus carpio* L.) is an important pond-reared fish species in many countries, including those of Central Europe and Israel. Investigations on fatty acids (FA) and total fat in pond-cultured carp were carried out in Hungary (Farkas and Csengeri 1976, Csengeri et al. 1978, Farkas et al. 1980, Farkas 1984) and in the Czech Republic (Vàcha and Tvrzickà 1995). These authors studied mainly the metabolic processes of fatty acids in carp and other fish as well as the effects of some environmental factors (temperature) and diet on the fatty acid profile (largely in the liver). Similar problems were investigated by Viola in Israel (Viola and Amidan 1980, Viola et al. 1988). Both the Hungarian and Israeli studies showed that the profile of fatty acids and their contents in carp were diet- and temperature-affected, as they are in other fish.

To our knowledge, only Vàcha and Tvrzickà (1995) have investigated cholesterol in the consumable parts of carp. The contents of fatty acids and cholesterol in the muscles of carp are still not fully defined. In this context, it seemed essential to test the contents of fatty acids, cholesterol and fat in the muscles of carp originating from five different genetic lines cultured under the same environmental conditions and fed a similar diet. The existence of carp lines with clearly higher or lower levels of PUFA and cholesterol would indicate that the profile of fatty acids and cholesterol content are genetically controlled to some extent. Such a finding may enable the selection of carp to obtain a population with a high percentage of PUFA and a low cholesterol level in the muscles.

In Poland, a country with a very long tradition of carp rearing which dates back seven hundred years, no studies have been conducted so far on the fatty acid profile or cholesterol level in the muscles of carp species.

The aim of this study was to compare the proportion of fatty acids and the contents of fat and cholesterol in muscles of five lines of carp cultured in the Experimental Fisheries Station in Zator (southern Poland). In addition, the level of total cholesterol, high density lipoproteins (HDL), low density lipoproteins (LDL) and triglycerides (TG) in carp blood serum were determined to investigate the possible relationship of these traits to the cholesterol content in muscles.

MATERIAL AND METHODS

FISH

The following five carp pure lines which have been cultured in the Experimental Fisheries Station in Zator for decades were used: the Japanese (KOI) line - **J,** the Starzawski line (scaly carp) - **St,** the Yugoslav line - **Y**, the Zatorski line - **Z** and the Hungarian line - **H**.

The orange-colored **Japanese carp** was brought to Zator in 1986. It is characterized by an elongated body and a mirror frame or an irregular type of scale cover. Scaly carp also occur in the Japanese line.

The **Starzawski carp**, reared for some decades in the fisheries farm at Starzawa (south-eastern Poland), was introduced to Zator in 1976. It is a scaly carp with an elongated body.

The **Yugoslav carp** was brought to Zator from Yugoslavia in 1973. Its characteristic features are a pronounced dorsal line, a mirror saddle scale cover and a grey--bluish color.

The **Zatorski carp**, which has been cultured in Zator for decades, is characterized by a medium-sized back, a mirror frame or saddle scale cover and an olive-blue color.

The **Hungarian carp** was imported from Szarvas, Hungary to Poland in 1973 and to Zator in 1975. It has a medium-sized back, a mirror saddle or frame scale cover, and their color is yellow-olive.

The morphologic characteristics (after Mejza 1993) of the above-mentioned carp pure lines are given in Table 1. The genetic variability of each pure line changes according to inbreeding, genetic drift and selection. Mating between related individuals depends on the genetic distance between families within each pure line. The artificial reproduction of carp allows for the mating of one pair of spawners as well as a few spawners. Seventeen lines (both pure lines and hybrids) of carp are bred in 98 experimental ponds on 40 ha, beginning from the first generation (fry) to the spawners of each cultured line. Water is supplied from the same river to each pond. The same methods of cultivation and fertilization are applied in the ponds; this means that the ponds are as similar as the conditions in general.

These studies were conducted on carp originated from one pair of spawners from each line (Mejza, unpublished data). Eggs were incubated in Weiss' glasses, and larvae were reared in water tanks in the hatchery prior to stocking the fry into ponds.

TABLE 1

Morphological characteristics of five carp lines under study (3-year-old carp), J - Japanese line, St - Starzawski line, Y - Yugoslav line, Z - Zatorski line, H - Hungarian line

Feature	J	St	Y	Z	H
Type of scale cover	irregular mirror carp or scaly carp	scaly carp	mirror saddle carp	mirror frame carp or mirror saddle carp	mirror saddle carp or mirror frame carp
Body ratio L/H (length to height)	2.9	2.5	2.0	2.3	2.3
Fulton's coefficient	3.7	3.7	4.6	4.2	3.7
Head index	26.1	26.0	28.1	29.1	28.1
Slaughtering value (percentage)	63.4	68.4	66.2	66.2	64.1

Each line of carp was reared in separate earthen ponds according to the common Dubisz system (Szczygielski 1967). Fry were stocked at a density of 100,000 fish per ha in June. The fry were caught in July and transferred to other ponds at a density of 20,000 fish per ha. One-year-old fish were stocked at a density of 5,000 fish per ha in the second year of rearing. In the third year of rearing, the carp were kept in grow-out ponds at a density of 1,000 fish per ha. The carp were caught in the fall and kept in storage ponds until the end of December. Most of the carp are sold before Christmas, but a portion is left in wintering ponds for sale in the spring.

All five lines of carp were cultured in ponds which were similar in area, soil type, water supply and fertilization with a natural productivity of about 200 kg ha^{-1}. The fish were fed identical cereal feeds (wheat, barley) at a feeding coefficient (the amount of feed converted for 1 kg of growth) of 3:1. The feed amount was adjusted according to this coefficient and preliminary growth on cereal feeds.

SAMPLING PROCEDURES

The introductory experiment was performed in the spring of 1997. The aim of this experiment was to estimate the differences among the contents of fatty acids, fat and cholesterol in four areas of each fish as follows: above the lateral line behind the head; under the dorsal fin; in front of the caudal fin; below the lateral line from the abdomen. Two 3-year-old carp weighing about 1.4 kg were sampled from each line. Two samples of muscle tissue with skin were removed from each of the above-mentioned body areas. The average values of fatty acids, fat and cholesterol in all the body areas were compared statistically for all ten fish, regardless of the lines. Since the samples collected from the various body areas did not prove to be identical with respect to the studied traits, it was decided to combine the results of samples from individual areas of each

fish in the main experiments. The studied parameters were determined in this pooled sample, and the result obtained concerned all the consumable parts of the fish jointly.

The percentage of fatty acids, fat and cholesterol contents were determined immediately after the samples were taken from each body area of every fish in the first experiment. In the second experiment, the same parameters were determined on similarly collected samples which had been kept for 60 days at - 25°C in order to verify if the storage of meat samples at low temperature can significantly affect the studied parameters.

The main experiments were done in October and December 1997 and in March 1998. Ten 3-year-old carp were sampled from each line with average body weights as follows: Japanese carp - 0.8 kg; Starzawski carp - 1.6 kg; Yugoslav carp - 1.8 kg; Zatorski carp - 1.6 kg; Hungarian carp - 1.2 kg. After slaughtering, a 25 g sample of muscle with skin was removed from each of the above-mentioned body areas. After 2 weeks of storage at - 25° C, the following parameters were determined in each sample:

- percentage of the following fatty acids: saturated (SFA) C_{14}, C_{15}, C_{16}, C_{17}, C_{18}, C_{22}; monounsaturated fatty acids (MUFA) $C_{14:1}$, $C_{16:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$; polyunsaturated fatty acids (PUFA) $C_{18:2}$, $Cg_{18:3}$, $C_{18:3}$, $C_{20:2}$, $C_{20:3}$, $C_{20:4}$, $C_{20:5}$, $C_{22:4}$, $C_{22:5}$, $C_{22:6}$;
- fat content (g 100 g^{-1} of muscle tissue with skin);
- cholesterol content (mg 100 g^{-1} of muscle tissue with skin).

In addition, cholesterol (Ch), high-density lipoprotein (HDL), low density lipoprotein (LDL) and triglyceride (TG) content were measured in the serum of carp from wintering ponds.

After isolating FA from the tissues using a modified method of Folch et al. (1957), the fatty acid profile was determined by a Varian 3400cx gas chromatograph with a FID detector. Columns DB-23, 30 m were used. Argon was used as the carrier gas. The column temperature was 100-205°C, that of sample injector 200°C and of the detector 240°C.

The content of fat was determined using the Soxhlet method, approved by the Polish Committee for Standardizing and Measures (1974) included in the Polish Norm for determining fat content PN-73/A-821 11.

The cholesterol content in muscles was determined using the method of Korzeniowski et al. (1992). The tissue fat was extracted using a mixture of chloroform and methanol at a ratio of 2:1. Next, it was saponified through heating with a metha-

nol solution of 0.5 M NaOH for 20 min. Cholesterol was extracted with hexane and was determined by the colorimetric method using acetic acid, iron (II) sulfate and sulfuric acid (VI).

Serum cholesterol and HDL levels were determined using standardized kits produced by Polskie Odczynniki Chemiczne SA Gliwice, Poland: Biochemtest Cholesterol and Biochemtest Cholesterol HDL, based on methods by Zilva and Pannali (1984).

Serum triglyceride content was determined using standardized kits from Alpha Diagnostics, Co. Ltd., Warsaw, Poland, based on methods by Faulkner and King (1976).

STATISTICAL ANALYSIS

Data expressed as percentages (referring to fatty acids) were subjected to transformation according to the Bliss table (Snedecor 1959) before testing for statistically significant differences ($P < 0.01$). Differences among body areas, carp lines and periods of sampling with respect to the parameters under study were tested using one-way analysis of variance and the Duncan's test. In addition, a possible correlation between muscular and total cholesterol, HDL, LDL and TG in the serum was evaluated.

RESULTS

Except for the percentage of the arachidonic acid ($C_{20:4}$) and cholesterol content, no significant differences were observed between individual body areas tested for fatty acid profiles, total fat and cholesterol content (Table 2). Only the middle area of the fish body (above the lateral line, under the dorsal fin) differed significantly with a higher percentage of arachidonic acid (0.4 ± 0.061%) from the abdomen muscles and a lower mean content (94.8 ± 23.2 mg 100 g^{-1}) of cholesterol.

No significant differences in the studied parameters were found between fresh and frozen samples. This allowed fish meat samples to be stored at low temperatures from the moment of sampling to the moment of performing the analyses.

SATURATED FATTY ACIDS

The following six saturated fatty acids were determined: C_{14}; C_{15}; C_{16}; C_{17}; C_{18}; C_{22}. The C_{14}, C_{15}, C_{17} and C_{22} acids occurred in small quantities, ranging from 0.1 ± 0.01% to 1.6 ± 0.08% (Table 3). The C_{18} acid accounted for 5.6 ± 0.49% to 6.5 ± 0.16%. The predominant fatty acid made up from 17.9 ± 0.23% to 21.7 ± 0.4%. The total saturated fatty

TABLE 2

Fatty acid profiles (% of total fatty acids), total fat (g 100 g^{-1}) and cholesterol (mg 100 g^{-1}) in samples of muscle tissue with skin taken from four body areas of five carp lines (SEM – standard error of the means)

Fatty acids, total fat and cholesterol		Above the lateral line behind the head	Above the lateral line under the dorsal fin	Above the lateral line in front of the caudal fin	Below the lateral line from the abdomen	Statistically significant differences between spots*
C_{14}	Mean	1.35	1.25	1.29	1.38	
	SEM	0.07	0.04	0.07	0.07	
$C_{14:1}$	Mean	0.09	0.09	0.11	0.12	
	SEM	0.02	0.01	0.01	0.02	
C_{15}	Mean	0.11	0.10	0.11	0.11	
	SEM	0.01	0.01	0.01	0.01	
C_{16}	Mean	19.33	19.28	19.37	20.04	
	SEM	0.46	0.49	0.46	0.20	
$C_{16:1}$	Mean	10.76	10.73	10.58	11.06	
	SEM	0.50	0.35	0.50	0.34	
C_{18}	Mean	4.91	4.84	4.77	4.55	
	SEM	0.31	0.26	0.17	0.18	
$C_{18:1}$	Mean	47.98	47.29	46.84	47.40	
	SEM	1.17	1.11	1.13	1.08	
$C_{18:2}$	Mean	6.97	6.99	7.18	6.88	
	SEM	0.43	0.38	0.47	0.45	
$C_{18:3}$	Mean	0.19	0.18	0.18	0.18	
	SEM	0.02	0.03	0.02	0.02	
$C_{18:3}$	Mean	1.09	1.02	1.07	1.03	
	SEM	0.09	0.08	0.09	0.09	
$C_{20:1}$	Mean	2.34	2.37	2.45	2.43	
	SEM	0.16	0.16	0.13	0.13	
$C_{20:2}$	Mean	0.33	0.31	0.34	0.33	
	SEM	0.03	0.04	0.03	0.03	
$C_{20:3}$	Mean	0.91	1.03	1.02	0.98	
	SEM	0.07	0.09	0.10	0.07	
$C_{20:4}$	Mean	0.27	0.44	0.36	0.31	2* - 4
	SEM	0.02	0.06	0.04	0.03	
$C_{20:5}$	Mean	0.96	1.27	1.19	1.00	
	SEM	0.12	0.19	0.18	0.14	
$C_{22:1}$	Mean	0.84	1.24	1.04	0.90	
	SEM	0.10	0.19	0.16	0.10	
$C_{22:4}$	Mean	0.16	0.20	0.23	0.18	
	SEM	0.02	0.02	0.05	0.03	
$C_{22:5}$	Mean	0.25	0.37	0.36	0.30	
	SEM	0.04	0.04	0.09	0.05	
$C_{22:6}$	Mean	0.64	1.00	0.92	0.77	
	SEM	0.11	0.14	0.21	0.13	
Total fat	Mean	13.62	13.29	10.83	13.10	
	SEM	1.55	1.55	1.34	1.67	
Cholesterol	Mean	137.50	94.80	162.20	211.80	2* - 4
	SEM	19.11	23.18	43.48	36.85	

acids made up from 25.8 to 29.8% of all the fatty acids.

In the grow-out ponds, the lowest percentage of total SFA was found in the muscles of the Yugoslav carp line (26.4%) and the highest percentage in those of the Japanese carp line (29.1%). These differences were statistically significant, as were those between the Yugoslav and the Hungarian lines.

In the storage ponds, the lowest amounts of total SFA occurred in the muscles of Zatorski carp (25.8%) and the highest were found in the Japanese carp line (27.3%). There was a statistically significant difference between the Zatorski line and the Hungarian line.

In the wintering ponds, the lowest percentage of total SFA was found in the Starzawski and Japanese carp lines (both 26.5%). The highest amount occurred in the muscles of the Hungarian line (29.8%), which was significantly different from all other lines (Z, Y, St, J).

MONOUNSATURATED FATTY ACIDS

The following five monounsaturated fatty acids were found: $C_{14:1}$; $C_{16:1}$; $C_{18:1}$; $C_{20:1}$; $C_{22:1}$. The lowest percentage, from 0.05 ± 0.01% to 1.5 ± 0.14%, was accounted for by acids $C_{14:1}$ and $C_{22:1}$ (Table 4). A higher percentage, from 2.0 ± 0.18% to 11.2 ± 0.6%, was accounted for by the C_{16} and $C_{20:1}$ acids. The predominant acid, which made up from 39.5 ± 0.97% to 47.4 ± 0.77%, was the $C_{18:1}$ acid. The monounsaturated fatty acids total equaled from 54.2 to 61.0% of all fatty acids.

In the grow-out ponds, the lowest percentage of total MUFA was found in the muscles of the Hungarian carp line (54.2%) and the highest in the Yugoslav carp line (59.5%). No statistically significant differences were found among the carp lines.

In the storage ponds, the lowest amount of total monounsaturated fatty acids was found in the muscles of Hungarian (55.2%) and Yugoslav carp (55.9%). The highest percentage of MUFA occurred in the Zatorski carp line (58.9%). The Yugoslav line differed significantly from both the Zatorski and the Starzawski lines.

In the wintering ponds, the total MUFA accounted for 54.4% (the Hungarian line) to 61.0% (the Starzawski line). There were statistically significant differences between the Starzawski line and all the other lines (J, Y, Z, H).

POLYUNSATURATED FATTY ACIDS

The following 10 polyunsaturated fatty acids were found: $C_{18:2}$; $C_{18:3}$; $C_{20:2}$; $C_{20:3}$; $C_{20:4}$;$C_{20:5}$; $C_{22:4}$; $C_{22:5}$; $C_{22:6}$. With the exception of the $C_{18:2}$ acid, all fatty acids made

TABLE 3

Saturated fatty acid profiles (% of total fatty acids) in the muscles of five carp lines in three periods of the production cycle; G - grow-out ponds, S - storage ponds, W - wintering ponds
(See Tables 1 and 2 for further explanations)

Saturated fatty acids			J	St	Y	Z	H	Statistically significant differences between lines*
C_{14}		Mean	1.52	1.54	1.09	1.55	1.54	Y* - J, St, Z,
	G	SEM	0.10	0.07	0.04	0.06	0.05	H
		Mean	1.29	1.12	0.99	1.06	1.14	J* - Y, Z
	S	SEM	0.10	0.06	0.07	0.05	0.04	
		Mean	1.11	1.30	1.29	1.18	1.64	H* - J, St, Y, Z
	W	SEM	0.04	0.04	0.08	0.08	0.08	J* - St, Y
C_{15}		Mean	0.20	0.19	0.17	0.23	0.25	Z* - J, St, Y
	G	SEM	0.02	0.01	0.02	0.02	0.02	H* - J, St, Y
		Mean	0.12	0.16	0.13	0.14	0.16	H* - J, Y
	S	SEM	0.01	0.01	0.01	0.01	0.01	J* - St
		Mean	0.12	0.13	0.17	0.21	0.28	H* - J, St, Y, Z
	W	SEM	0.01	0.01	0.01	0.02	0.02	Z* - J, St
								J* - Y
C_{16}		Mean	20.43	19.36	18.74	19.32	19.77	J* - Y
	G	SEM	0.27	0.31	0.50	0.33	0.39	
		Mean	19.24	18.45	18.47	17.86	19.25	Z* - J, H
	S	SEM	0.40	0.22	0.22	0.23	0.37	
		Mean	18.37	18.85	19.63	18.54	21.69	H* - J, St, Y, Z
	W	SEM	0.21	0.21	0.47	0.48	0.40	Y* - J, Z
C_{17}		Mean	0.27	0.29	0.34	0.36	0.36	-
	G	SEM	0.02	0.02	0.05	0.02	0.03	
		Mean	0.25	0.26	0.31	0.26	0.31	J* - Y, H
	S	SEM	0.03	0.01	0.02	0.01	0.01	
		Mean	0.19	0.26	0.23	0.29	0.36	H* - J, St, Y
	W	SEM	0.02	0.01	0.01	0.02	0.03	J* - St, Z
C_{18}		Mean	6.32	6.11	5.76	6.25	5.83	-
	G	SEM	0.18	0.18	0.19	0.18	0.21	
		Mean	6.27	5.77	6.16	6.41	5.98	St* - J, Z
	S	SEM	0.22	0.12	0.14	0.11	0.13	
		Mean	6.54	5.79	5.90	6.36	5.63	J* - St, Y, H
	W	SEM	0.16	0.10	0.21	0.17	0.49	
C_{22}		Mean	0.40	0.44	0.31	0.16	0.52	-
	G	SEM	0.19	0.12	0.11	0.02	0.21	
		Mean	0.16	0.28	0.18	0.12	0.23	Y* - J, St, Z, H
	S	SEM	0.04	0.04	0.05	0.01	0.03	St* - J, Z, Z* - H
		Mean	0.18	0.15	0.26	0.45	0.19	-
	W	SEM	0.06	0.03	0.08	0.21	0.02	
Total	G		29.14	27.93	26.41	27.87	28.27	Y* - J, H
saturated	S		27.33	26.04	26.24	25.85	27.07	Z* - H
fatty acids	W		26.51	26.48	27.48	27.03	29.79	H* - J, St, Y, Z

TABLE 4

Monounsaturated fatty acid profiles (% of total fatty acids) in the muscles of five carp lines in three periods of the production cycle (See Tables 1, 2 and 3 for further explanations)

Monounsatuated fatty acids			J	St	Y	Z	H	Statistically significant differences between lines*
$C_{14:1}$		Mean	0.05	0.10	0.08	0.11	0.11	J* - St, Y, Z, H
	G	SEM	0.00	0.01	0.01	0.02	0.01	Y* - H
		Mean	0.05	0.08	0.07	0.07	0.10	J* - St, Y, Z
	S	SEM	0.01	0.01	0.01	0.01	0.01	H* - J, Y, Z
		Mean	0.07	0.11	0.07	0.09	0.14	H* - J, Y, Z
	W	SEM	0.01	0.01	0.01	0.01	0.01	St* - J, Y
$C_{16:1}$		Mean	10.46	9.63	9.69	8.71	10.24	Z* - J, St, Y, H
	G	SEM	0.37	0.27	0.32	0.19	0.18	
		Mean	9.86	9.85	9.03	8.34	9.81	Z* - J, St, H
	S	SEM	0.42	0.30	0.32	0.16	0.27	
		Mean	8.47	10.42	9.48	9.54	11.17	H* - J, Y, Z
	W	SEM	0.27	0.16	0.39	0.31	0.60	J* - St
$C_{18:1}$		Mean	41.61	44.21	46.46	43.41	40.46	H* - St, Y, Z
	G	SEM	1.07	0.77	1.22	0.89	0.66	Y* - J, Z
		Mean	42.81	44.33	43.16	46.63	41.37	Z* - J, Y, H
	S	SEM	0.80	0.98	0.83	0.73	0.53	St* - H
		Mean	47.40	47.18	42.24	44.77	39.49	H* - J, St, Z
	W	SEM	0.77	0.80	1.37	1.06	0.97	Y* - J, St
$C_{20:1}$		Mean	2.32	2.41	2.47	2.59	2.22	-
	G	SEM	0.18	0.16	0.07	0.15	0.09	
		Mean	2.86	2.51	2.74	2.92	2.69	St* - J, Z
	S	SEM	0.07	0.12	0.14	0.07	0.09	
		Mean	2.81	2.43	2.52	1.99	2.10	Z* - J, St, Y
	W	SEM	0.06	0.09	0.06	0.18	0.10	H* - J, St, Y
$C_{22:1}$		Mean	1.18	1.20	0.80	1.09	1.20	Y* - J, St, Z, H
	G	SEM	0.13	0.11	0.17	0.09	0.14	
		Mean	1.07	1.22	0.93	0.95	1.19	St* - Y
	S	SEM	0.10	0.11	0.07	0.07	0.05	
		Mean	0.74	0.89	1.26	1.34	1.51	J* - Y, Z, H
	W	SEM	0.07	0.10	0.14	0.12	0.14	St* - Y, Z, H
Total	G		55.62	57.54	59.50	55.91	54.23	-
monounsat.	S		56.65	57.99	55.93	58.91	55.16	Y* - St, Z
fatty acids	W		59.49	61.03	55.57	57.73	54.41	St* - J, Y, Z, H

up from 0.06 ± 0.01% to 2. 3 ± 0.25% (Table 5). Only the $C_{18:2}$ acid (linoleic) was found in greater amounts, from 5.9 ± 0.41% to 7.9 ± 0.17%. Fatty acid $C_{20:4}$ (arachidonic) accounted for 0.2 ± 0.01% to 0.7 ± 0.04%. The $C_{20:5}$ acid (EPA) accounted for 1.0 ± 0.07% to 1.6 ± 0.16% and the $C_{22:6}$ acid (DHA) from 0.7 ± 0.07% to 1.8 ± 0.43%. The total PUFA made up from 11.5 to 15.7% of all fatty acids in the carp of the five studied lines in the three periods of the production cycle. The ratio of fatty acids of the omega

TABLE 5

Polyunsaturated fatty acid profiles (% of total fatty acids) in the muscles of five carp lines in three periods of the production cycle (See Tables 1, 2 and 3 for further explanations)

Polyunsaturated fatty acids			J	St	Y	Z	H	Statistically significant differences between lines*
$C_{18:2}$		Mean	6.60	6.14	5.87	7.48	7.84	Z* - J, St, Y
	G	SEM	0.20	0.15	0.41	0.28	0.33	H* - J, St, Y
		Mean	6.86	7.34	6.97	6.71	7.91	H* - J, Y, Z
	S	SEM	0.21	0.35	0.21	0.20	0.17	
		Mean	7.83	6.39	7.20	7.49	7.18	St* - J, Z
	W	SEM	0.53	0.20	0.38	0.32	0.18	
$C_{18:3}$		Mean	0.11	0.11	0.24	0.09	0.13	Y* - J, St, Z, H
	G	SEM	0.01	0.01	0.08	0.01	0.02	
		Mean	0.07	0.11	0.14	0.06	0.14	J* - St, Y, H
	S	SEM	0.01	0.00	0.02	0.01	0.02	Z* - St, Y, H
		Mean	0.11	0.15	0.19	0.18	0.14	-
	W	SEM	0.01	0.04	0.04	0.03	0.02	
$C_{18:3}$		Mean	1.40	1.57	1.48	1.51	1.94	J* - H
	G	SEM	0.15	0.12	0.23	0.18	0.20	
		Mean	1.87	1.91	1.74	1.60	1.74	-
	S	SEM	0.14	0.15	0.12	0.09	0.08	
		Mean	1.43	1.51	1.73	1.44	2.35	H* - J, St, Y, Z
	W	SEM	0.11	0.14	0.15	0.11	0.25	
$C_{20:2}$		Mean	0.30	0.38	0.43	0.40	0.36	J* - St, Y, Z
	G	SEM	0.03	0.01	0.02	0.03	0.02	
		Mean	0.62	0.50	0.65	0.64	0.58	St* - Y, Z
	S	SEM	0.07	0.03	0.02	0.02	0.02	
		Mean	0.40	0.42	0.38	0.35	0.31	H* - J, St, Y
	W	SEM	0.02	0.01	0.02	0.02	0.02	St* - Z
$C_{20:3}$		Mean	0.90	0.78	1.32	1.22	0.96	Y* - J, St, H
	G	SEM	0.09	0.03	0.15	0.07	0.04	Z* - J, St, H
		Mean	1.23	1.00	1.69	1.45	1.43	J* - Y
	S	SEM	0.08	0.07	0.14	0.06	0.06	St* - Y, Z, H
		Mean	0.89	0.74	1.29	0.95	0.81	Y* - J, St, Z, H
	W	SEM	0.07	0.02	0.18	0.06	0.03	
$C_{20:4}$		Mean	0.33	0.27	0.23	0.35	0.31	St* - J, Z
	G	SEM	0.01	0.01	0.01	0.02	0.02	Y* - J, Z, H
		Mean	0.71	0.53	0.58	0.61	0.72	St* - J, H
	S	SEM	0.06	0.05	0.05	0.05	0.04	
		Mean	0.39	0.25	0.30	0.33	0.26	J* - St, H
	W	SEM	0.05	0.01	0.03	0.03	0.02	
$C_{20:5}$		Mean	1.25	1.00	1.03	1.38	1.09	Z* - St, Y
	G	SEM	0.09	0.07	0.11	0.12	0.07	
		Mean	1.31	1.18	1.62	1.25	1.42	Y* - J, St, Z
	S	SEM	0.08	0.10	0.11	0.09	0.06	
		Mean	1.13	1.03	1.65	1.46	1.14	Y* - J, St, H
	W	SEM	0.12	0.07	0.16	0.13	0.09	St* - Z

Polyunsaturated fatty acids			J	St	Y	Z	H	Statistically significant differences between lines*
$C_{22:4}$		Mean	0.40	0.09	0.29	0.17	0.11	J* - St, Z, H
	G	SEM	0.19	0.02	0.10	0.03	0.01	Y* - St, H
		Mean	0.17	0.13	0.17	0.09	0.18	Z* - J, St, Y, H
	S	SEM	0.02	0.02	0.02	0.01	0.01	St* - H
		Mean	0.16	0.11	0.12	0.18	0.11	J* - St, H
	W	SEM	0.01	0.01	0.01	0.03	0.01	Z* - St, H
$C_{22:5}$		Mean	0.32	0.37	0.30	0.39	0.37	-
	G	SEM	0.04	0.03	0.04	0.06	0.02	
		Mean	0.31	0.39	0.44	0.34	0.44	J* - Y, H
	S	SEM	0.02	0.05	0.05	0.03	0.01	
		Mean	0.25	0.28	0.56	0.50	0.46	J* - Y, Z, H
	W	SEM	0.03	0.02	0.03	0.03	0.02	St* - Y, Z, H, Y* - H
$C_{22:6}$		Mean	1.82	1.11	0.88	1.14	1.12	J* - Y
	G	SEM	0.43	0.20	0.11	0.16	0.10	
		Mean	1.10	0.79	1.11	0.74	1.14	St* - J, Y, H
	S	SEM	0.11	0.10	0.11	0.06	0.06	Z* - J, Y, H
		Mean	0.74	0.67	1.40	1.14	1.27	J* - Y, Z, H
	W	SEM	0.09	0.07	0.18	0.10	0.08	St* - Y, Z, H
Total	G		13.43	11.82	12.07	14.13	14.23	-
polyunsat.	S		14.25	13.88	15.11	13.49	15.70	Z* - H
fatty acids	W		13.33	11.55	14.82	14.02	14.03	St* - Y, Z

3 family to the omega 6 family ranged from 0.4 to 1.5 (Table 6).

In grow-out ponds, the lowest content of total PUFA was found in the muscles of the Starzawski line (11.8%) and the highest in the Hungarian line (14.2%). There were no significant differences between the lines.

In storage ponds, the total values of PUFA made up from 13.5% in muscles of the Zatorski line to 15.7% in the muscles of the Hungarian line, which differed significantly from the Zatorski line.

In wintering ponds, the lowest percentage of total PUFA was found in the Starzawski line (11.5%) and the highest in the Yugoslav line (14.8%). There were significant differences between the Starzawski line and the Yugoslav line, the Starzawski line and the Zatorski line as well as between the Starzawski line versus the Hungarian line.

The most important polyunsaturated fatty acids for human nutrition, $C_{18:2}$, $C_{20:4}$, $C_{20:5}$ and $C_{22:6}$, were ranked according to the studied carp lines.

The $C_{18:2}$ fatty acid (linoleic) was the lowest (5.9 ± 0.41%) in the muscles of the Yugoslav line, and the highest mean value (7.8 ± 0.33%) was in the muscles of the Hungarian carp line in grow-out ponds. The $C_{18:2}$ fatty acid made up from 6.7 ± 0.2%

TABLE 6

Ratio of fatty acids from the omega 3 to omega 6 families; Min. – lowest value; Max. – highest value (See Tables 1, 2 and 3 for further explanations)

	J		St		Y		Z		H	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
G	0.59	1.46	0.57	1.03	0.58	0.90	0.56	1.00	0.52	0.84
S	0.62	0.84	0.54	0.81	0.65	0.99	0.59	0.76	0.57	0.71
W	0.43	0.59	0.46	0.70	0.62	1.02	0.56	0.75	0.62	1.05

in the muscles of the Zatorski line to 7.9 ± 0.17% in the Hungarian line in storage ponds. The mean value of this fatty acid in wintering ponds ranged from 6.4 ± 0.2% in the muscles of the Starzawski line to 7.8 ± 0.53% in the muscles of the Japanese line.

The lowest mean content of $C_{20:4}$ (arachidonic) was found in the Yugoslav line (0.2 ± 0.01%), while the highest was in the Zatorski line (0.3 ± 0.02%) in carp kept in grow-out ponds. The amounts of this fatty acid in the muscles of carp kept in storage ponds ranged from 0.5 ± 0.05% in the Starzawski line to 0.7 ± 0.04% in the Hungarian line. In muscles of carp kept in wintering ponds, $C_{20:4}$ accounted for 0.2 ± 0.01% in the Starzawski line to 0.4 ± 0.05% in the Japanese line.

The $C_{20:5}$ fatty acid (EPA) in the muscles of carp kept in grow-out ponds was from 1.0 ± 0.07% in the Starzawski line to 1.4 ± 0.12% in the Zatorski line. This fatty acid occurred in similar amounts in the muscles of carp kept in storage ponds and ranged from 1.2 ± 0.1% in the Starzawski line to 1.6 ± 0.11% in the Yugoslav line. In wintering ponds, the lowest mean content of $C_{20:5}$ was found in the Starzawski line (1.0 ± 0.07%) and the highest in the Yugoslav line (1.6 ± 0.16%).

The lowest mean value of $C_{22:6}$ (DHA) was 0.9 ± 0.11% in the muscles of the Yugoslav line and the highest was 1.8 ± 0.43% in the muscles of the Japanese carp kept in grow-out ponds. This fatty acid accounted for 0.7 ± 0.06% (the Zatorski line) to 1.1 ± 0.11% (the Hungarian line) in the muscles of carp kept in storage ponds. The lowest mean content of $C_{22:6}$ was found in the Starzawski line (0.7 ± 0.07%) and the highest in the Yugoslav line (1.4 ± 0.18%) in the muscles of carp kept in wintering ponds.

There were significant differences between some lines of carp (Table 5) with respect to the four main fatty acids described above.

TOTAL FAT

The mean content of muscular fat ranged from 8.0 ± 0.42 g 100 g^{-1} in the Japanese carp kept in the storage ponds to 14.8 ± 0.88 g 100 g^{-1} in the Starzawski carp kept in the wintering ponds (Table 7).

TABLE 7

Content of total fat (g 100 g^{-1} of muscle tissue) and cholesterol (mg 100 g^{-1} of muscle tissue) in the muscles of five carp lines in three periods of the production cycle (See Tables 1, 2 and 3 for further explanations)

			J	St	Y	Z	H	Statistically significant differences between carp lines*
Total fat		Mean	8.18	14.17	12.33	8.41	11.37	Z* - S, Y, H
	G	SEM	0.60	0.67	1.13	0.97	0.86	S* - J, H, J* - Y, H
		Mean	7.99	12.57	10.47	9.39	9.16	S* - J, Z, H
	S	SEM	0.42	0.53	0.42	1.12	0.93	J* - Y
		Mean	9.67	14.85	11.55	8.54	9.23	S* - J, Y, Z, H
	W	SEM	0.34	0.88	0.51	0.43	0.67	Y* - J, Z, H
Cholesterol		Mean	95.50	233.50	80.50	162.60	143.70	S* - J, Y, H
	G	SEM	3.84	40.57	5.32	37.49	13.36	Y* - Z
		Mean	130.10	220.10	118.10	180.50	118.70	S* - J, Y, H
	S	SEM	14.93	29.78	10.17	24.16	12.15	Z* - Y, H
		Mean	59.60	117.50	65.00	61.50	71.70	S* - J, Y, Z, H
	W	SEM	4.40	26.07	7.74	5.15	4.65	

The lowest mean value of total fat occurred in the Japanese line (8.2 ± 0.6 g 100 g^{-1}) in grow-out ponds, and the highest was in the Starzawski line (14.2 ± 0.67 g 100 g^{-1}). The lowest mean content of fat in the muscles of carp kept in storage ponds was found in the Japanese line (8.0 ± 0.42 g 100 g^{-1}), while the highest was in the Starzawski line (12.6 ± 0.53 g 100 g^{-1}). In wintering ponds, the mean fat content made up from 8.5 ± 0.43 g 100 g^{-1} in the muscles of the Zatorski carp line to 14.8 ± 0.88 g 100 g^{-1} in the Starzawski carp line.

There were significant differences among some lines of carp kept in grow-out ponds, storage ponds and wintering ponds (Table 7).

CHOLESTEROL IN THE MUSCLES

The mean cholesterol level was from 59.6 ± 4.4 mg 100 g^{-1} of muscle in the carp of the Japanese line kept in the wintering ponds to 233.5 ± 40.57 mg 100 g^{-1} of muscle in the carp of the Starzawski line kept in the grow-out ponds (Table 7).

In grow-out ponds, the mean cholesterol content in muscles accounted for 80.5 ± 5.32 mg 100 g^{-1} in the Yugoslav line to 233.5 ± 40.57 mg 100 g^{-1} in the Starzawski line. In storage ponds, the mean cholesterol value occurred from 118.1 ± 10.17 mg 100 g^{-1} in the Yugoslav line to 220.1 ± 29.78 mg 100 g^{-1} in the Starzawski line. In wintering ponds, the lowest mean cholesterol in muscles was found in the Japanese line (59.6 ± 4.4 mg 100 g^{-1}) and the highest in the Starzawski line (117.5 ± 26.07 mg100 g^{-1}).

There were significant differences among some lines of carp within each of the production periods (Table 7).

TOTAL CHOLESTEROL IN SERUM

The amount of serum cholesterol was much higher than muscular cholesterol (Table 7 and 8). The mean content of total serum cholesterol accounted for 161.8 ± 10.24 mg 100 dl^{-1} in the blood serum of the Hungarian carp to 238.9 ± 10.66 mg 100 dl^{-1} in that of the Yugoslav carp (significant differences). The mean value of high density lipoproteins was the lowest in the blood serum of the Hungarian line (80.6 ± 3.13 mg 100 dl^{-1}) and differed significantly from the HDL value in the blood serum of the other lines (Table 8). The highest mean value of HDL was found in the Japanese line (118.0 ± 5.28 mg 100 dl^{-1}). The values of low density lipoproteins accounted for 67.3 ± 6.46 mg 100 dl^{-1} in the Zatorski line to 107.4 ± 7.95 mg 100 dl^{-1} in the Starzawski line. There were significant differences between carp lines (Table 8). The total cholesterol in blood serum showed no correlation with cholesterol content in muscles.

TABLE 8

Level of cholesterol (mg 100 dl^{-1}) in the blood serum of carp from wintering ponds; HDL - high density lipoproteins, LDL - low density lipoproteins (See Tables 1, 2 and 3 for further explanations)

Cholesterol		J	St	Y	Z	H	Statistically significant differences between carp lines*
Total cholesterol	Mean	210.75	230.90	238.86	179.70	161.80	S* - Z, H
	SEM	11.46	10.88	10.66	12.48	10.24	Y* - Z, H, J* - H
	Mean	117.99	111.90	110.39	102.19	80.62	H* - J, S, Y, Z,
HDL	SEM	5.28	5.13	2.41	6.77	3.13	J* - Z
	Mean	78.79	107.36	105.57	67.30	74.13	S* - J, Z, H
LDL	SEM	6.73	7.95	9.06	6.46	9.84	Y* - J, Z, H
	Mean	69.89	78.21	111.45	50.88	35.20	Y* - J, Z, H
Triglycerides	SEM	24.50	6.38	13.67	6.04	4.67	S* - H

DISCUSSION

This study was the first to describe and analyze variations in fatty acid profile, fat and cholesterol levels in consumable parts of carp.

The results obtained in this work show that carp of the Japanese, Yugoslav, Zatorski and Hungarian lines differ significantly ($P < 0.01$) from each other in some of

the studied traits during periods of the production cycle. However, it is difficult to rank the lines from best to worst from the point of view of human nutritive value.

Only the Starzawski line seems to stand out among the studied lines of carp. It is characterized by:

- the highest percentage of monounsaturated fatty acids in wintering ponds;
- the lowest percentage of PUFA in grow-out ponds and wintering ponds;
- the highest content of total fat in the three periods of the production cycle;
- the highest content of muscular cholesterol in the three periods of the production cycle.

As carp of all studied lines were reared in identical ponds and fed identical feed, the differences between the Starzawski carp line and the other lines may be genetic. The Starzawski line also differs genetically in the full scale cover from the other carp lines, which have a mirror scale cover.

The quality of diet fed to carp has a significant effect on the fatty acid profile (Csengeri et al. 1978, Farkas et al. 1980, Viola et al. 1988). Thus, it can be expected that carp reared under various environmental conditions and consequently, with various feeding regimes, can differ both in the fatty acid profile as well as in fat and cholesterol contents. Such relationships have been reported for a few species, e.g. rainbow trout, *Oncorhynchus mykiss* (Walbaum) (Robinson and Mead 1973), northern pike, *Esox lucius* L., (Ince and Thorpe 1975) and coregonid species from different European lakes (Serrini et al. 1996), but not for carp.

The differences identified among the carp lines studied suggest that it may be possible to select against traits of negative values (low percentage of PUFA, high cholesterol level) or for traits of positive values (high proportion of PUFA and low cholesterol level in meat) in order to produce a nutritionally improved stock.

Studies conducted on other species of fish are indicative of the fact that various strains of the same species of fish can differ in fatty acid profile, among other factors. Hoffman and Prinsloo (1995) showed that various strains of *Clarias gariepinus* (Burchell) differ in fat content, SFA, MUFA and PUFA.

Studies conducted in Israel (Viola et al. 1988) on carp weighing initially 80 g and in Hungary (Farkas 1984) on carp weighing initially 15-25 g, demonstrated that the fat content and the fatty acid profile (in the Hungarian studies in carp liver) are subjected to a pronounced change during the colder period. Namely, the fat content and percentage of fatty acids decrease with an increase in the proportion of PUFA. These

results, however, cannot be compared with those obtained in this study since the carp investigated were several times heavier and were kept at low (7-2.5^{o}C) temperatures. Our results demonstrated no noticeable changes in fat and cholesterol contents, or in the fatty acid profile in carp weighing about 1.4 kg under climatic conditions of southern Poland during the wintering period. This indicates that these carp are well suited to wintering at low temperatures.

The only previously published data were reported by Vàscha and Tvrzickà (1995) who carried out studies on the fatty acid profile and cholesterol level in the muscles of commercial carp weighing around 1.15 kg that were caught in the fall from ponds in south Bohemia, Czech Republic. Their results were similar to our findings. The total cholesterol in the muscles of these carp amounted to 55.2 mg 100 g^{-1} and was comparable with the content of cholesterol in the muscles of carp caught from our wintering ponds - from 59.6 ± 4.4 to 117.5 ± 26.07 mg 100 g^{-1} (Table 7). Cholesterol content was much higher in the muscles of carp kept in grow-out ponds (from 80.5 ± 5.32 mg 100 g^{-1} to 233.5 ± 40.57 mg 100 g^{-1}) and storage ponds (from 118.1 ± 10.17 mg 100 g^{-1} to 220.1 ± 29.78 mg 100 g^{-1}). A more detailed comparison is not possible, as the Czech authors did not perform statistical analyses of their data and did not present the range of fluctuations between the lowest and highest values.

The ratio of omega 3 family to omega 6 family fatty acids in the studied carp was lower (0.43 to 1.46) than that considered as typical (1.3 - 1.9) of fresh-water fish. A relatively high omega 3 to omega 6 ratio was found by De Silva et al. (1977) in specimens of Australian short-fin eel *(Anguilla australis* Richardson). It was 5.3 in glass eels of this species and 2.6 in slightly older fish. It follows, that as the fish stay longer in fresh water the ratio of omega 3 to omega 6 fatty acids decreases.

The results obtained suggest that carp may be selected for improving the value of human diet, e.g. a carp popluation which has a high percentage of PUFA and a low cholesterol level in its consumable parts can be bred. It would be of great value to find an index for these traits, so that we could determine *in vivo* which fish have a low cholesterol level and/or a high proportion of PUFA. Unfortunately, the level of cholesterol in carp serum is not a useful index for cholesterol content in fish meat, because no correlation between the level of total cholesterol, HDL, LDL and TG in blood serum and the cholesterol level in consumable parts of carp was found.

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REFERENCES

Ahrens E.H., Hirsch J., Insull W. 1957 - The influence of dietary fats on serum lipid levels in man - Lancet 1: 943.

Bell M.V., Henderson R.J., Sargent J.R. 1986 - The role of polyunsaturated fatty acids in fish - Comp. Biochem. Physiol. 83 B: 711-719.

Budzyńska-Topolowska J., Ziemlański S. 1992 – Changes occurring in fats and their influence on nutritive values - Żywienie Człow. Metab. XIX (2): 114-123 (in Polish).

Csengeri I., Farkas T., Majoros F., Olah J., Szalay M. 1978 - Effect of feed on fatty acid composition of carp *(Cyprinus carpio* L.) and rainbow trout *(Salmo gairdneri)* - Lipids 10: 528-531.

De Silva S.S., Gunasekera R. M., Collins R., Ingram B.A., Austin C.M. 1977 - Changes in the fatty acid profile of the Australian shortfin eel in relation to development - J. Fish Biol. 50: 992-998.

Farkas T. 1969 - Studies on the mobilization of fats in lower vertebrates - Acta Biochem. et Biophys. Acad. Sci. Hung. 4 (3): 237-249.

Farkas T. 1984 - Adaptation of fatty acids composition to temperature - a study on carp *(Cyprinus carpio* L.) liver slices - Comp. Biochem. Physiol. 79 B: 531-535.

Farkas T., Csengeri I. 1976 - Biosynthesis of fatty acids by the carp, *Cyprinus carpio* L., in relation to environmental temperature - Lipids 11: 401-407.

Farkas T., Csengeri I., Majoros F., Olah J. 1980 - Metabolism of fatty acids in fish. Ill. Combined effect of environmental temperature and diet on formation and deposition on fatty acids in the carp, *Cyprinus carpio* Linnaeus 1758 - Aquaculture 20: 29-40.

Faulkner W R., King J W., 1976 - Fundamentals of Clinical Chemistry. Tietz, N.W. (Ed.), W B., Saunders Co., Philadelphia, Chap. 17: 993.

Folch J., Lees M., Sloane Stanley Gt.H. 1957 - A simple method for the isolation and purification of total lipids from animal tissues - J. Biol. Chem. 226: 497-509.

Gertig H., Przystawski J. 1994 – The role of fats in human nutrition - Żywienie Człow. Metab. XXl (4): 375 - 388 (in Polish).

Hoffman L.C., Prinsloo J.F. 1995 - Genetic and nutritional influence of the total lipid fatty acid profile of *Clarias gariepinus* muscle - Aquat. Living Resour. 8: 415-421.

Ince B.E., Thorpe A. 1975 - Hormonal and metabolite effects on plasma free fatty acids in the northern pike *Esox lucius* L. - Gen. Comp. Endocrinol. 27: 144-152.

Korzeniowski W., Ostoja H., Jarczyk A. 1992 - Cholesterol levels in fat and muscle tissues of purebred and hybrid pigs - Med. Wet. 48 (10): 464-465 (in Polish).

Mejza T. 1993 - Breeding studies at the Experimental Fisheries Station in Zator on new lines and hybrids of high production carp traits - Inland Fisheries Institute in Olsztyn. Department of Progress Extension. 160, 21 pp. (in Polish).

Minakowski W. 1983 - The Biochemistry of Vertebrates - PWN, Warszawa (in Polish).

Murata H., Higashi T. 1980 - Selective utilization of fatty acids as energy source in carp - Bull. Japan. Soc. Sci. Fish. 46 (11): 1333-1338.
Polish Committee for Standardizing and Measures. 1974 - Meat and meat products. Determination of fat content - Polish Norm: PN-73/A-82111.
Robinson J.S., Mead J.F. 1973 - Lipid absorption and deposition in rainbow trout *(Salmo gairdneri)* - Can. J. Biochem. 51: 1050-1058.
Sargent J.R. 1997 - Fish oils and human diet - British J. Nutr. 78, Suppl. 1: 5-13.
Serrini G., Luzzana U., Grimaldi P., Paleari M.A., Valfre F. 1996 - Fatty acid composition of some coregonid species *(Coregonus* sp.) from different European lakes - J. AppI. lchthyol. 12: 57-59.
Snedecor G.W. 1959 - Statistical methods - Iowa State College Press.
Suvorov E. 1954 - The Basis of Ichthyology - PWN, Warszawa (in Polish).
Szczygielski W. 1967 - The history of inland fisheries in Poland - PWRiL, Warszawa (in Polish).
Van Der Kraak G., Chang J.P. 1990 - Arachidonic acid stimulates steroidogenesis in goldfish preovulatory ovarian follicles - Gen. Comp. Endocrinol. 7: 221-228.
Vàcha F., Tvrzickà E. 1995 - Content of polyunsaturated fatty acids and cholesterol in muscle tissue of tench (*Tinca tinca*), common carp (*Cyprinus carpio*) and hybrid of bighead carp *(Aristichthys nobilis)* with silver carp *(Hypophthalmichthys molitrix)* - Pol. Arch. Hydrobiol. 42 (1-2): 151-157.
Viola S., Amidan G. 1980 - Observations on the accumulation of fat in carp and *Sarotherodon* (tilapia) fed oil-coated pellets - Bamidgeh 32 (2): 33-40.
Viola S., Mokady S., Behar 0., Cogan U. 1988 - Effects of polyunsaturated fatty acids in feeds of tilapia and carp. 1. Body composition and fatty acids profiles at different environmental temperatures - Aquaculture 75: 27-137.
Wade M.G., Van der Kraak G. 1991 - The control of testicular androgen production in the goldfish: effects of activators of different intracellular signaling pathways - Gen. Comp. Endocrinol. 83: 337-344.
Wade M.G., Van der Kraak G. 1993 - Arachidonic Acid and Prostaglandin E2 stimulate testosterone production by goldfish testes *in vitro* - Gen. Comp. Endocrinol. 90: 109-118.
Wade M.G., Van der Kraak G., Gerrits M.F., Ballantyne J.S. 1994 - Release and steroidogenic actions of polyunsaturated fatty acids in the goldfish testis - Biol Reprod. 51: 131-139.
Ziemlański S., Budzyńska-Topolowska J. 1992 - Current views of the physiological role of polyunsaturated fatty acids from the omega - 3 family - Żywienie Człow. Metabol. XIX (2): 100-113 (in Polish).
Zilva J.F., Pannali P.R. 1984 - Clinical Chemistry in Diagnosis and Treatment, Lloyd-Luke LTD. 232 pp.

STRESZCZENIE

KWASY TŁUSZCZOWE, TŁUSZCZ I CHOLESTEROL U KARPI (*CYPRINUS CARPIO* L.) Z KILKU LINII W POLSCE

Badano procentową zawartość nasyconych kwasów tłuszczowych (SFA), jednonienasyconych kwasów tłuszczowych (MUFA), wielonienasyconych kwasów tłuszczowych (PUFA) oraz zawartość cholesterolu (Ch) i tłuszczu ogólnego w mięśniach ze skórą u karpi z 5 linii chowanych w Rybackim Zakładzie Doświadczalnym w Zatorze, w 3 sezonach cyklu produkcyjnego: w stawach odrostowych, magazynach i zimochowach.

Z badanych linii, karpie linii starzawskiej charakteryzowały się najwyższą zawartością tłuszczu ogólnego i cholesterolu oraz najniższym procentem PUFA w porównaniu z karpiami z pozostałych linii.

Karpie linii węgierskiej charakteryzowały się najwyższym procentem PUFA w stawach odrostowych i magazynach, jak również najniższym procentem MUFA w 3 sezonach cyklu produkcyjnego.

Wśród pozostałych linii nie znaleziono takiej, która posiadałaby choć jedną cechę powtarzającą się w trzech badanych okresach, a która pozwoliłaby na jej odróżnienie od innych.

Otrzymane wyniki sugerują, że wśród populacji karpi można wykluczyć z dalszej hodowli te, które charakteryzują się niekorzystnymi cechami (profil kwasów tłuszczowych i zawartość cholesterolu) z punktu widzenia diety człowieka, oraz że można prowadzić selekcję karpia w kierunku małej zawartości cholesterolu i dużej procentowej zawartości wielonienasyconych kwasów tłuszczowych.

Wykonane przy okazji badania cholesterolu ogólnego (TCh), cholesterolu-HDL, cholesterolu-LDL i trójgliceroli w surowicy krwi wykazały brak zależności pomiędzy tymi cechami a zawartością cholesterolu w mięśniach.

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