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Meat quality of fish farmed in polyculture in carp ponds in Republic of Serbia*

Ćirković Miroslav[1], Trbović Dejana[2], Ljubojević Dragana[1], Đorđević Vesna[1]

A b s t r a c t: Meat quality of one-year, two-years and three-years old carp, two year old silver carp and grass carp, and two years old catfish and zander, which were farmed in different conditions and in different feeding regimes was analyzed in this study. Twelve samples of each type and category of fish were taken from three different fish ponds in December. Chemical analysis, fatty acid and cholesterol content determinations were carried out in the Institute of Hygiene and Meat Technology, Belgrade. Statistical analysis was performed using the Statistica 10 program. The established n-3/n-6 ratios in different categories of common carp were in the range from 0.1 to 0.26. The most favourable ratio was observed in two years old carp fed pelleted food and the least favourable in three-year old carp fed corn as dominant component in food. The dependence of n-3/n-6 ratio with age and diet was established in our work, too. This ratio also widely varies between different species of fish, which is also confirmed. Nutritive value of examined freshwater fish is high since their fatty acid composition is characterized by satisfactory proportion of n-3 polyunsaturated fatty acids and by high proportion of n-6 polyunsaturated fatty acids, especially linoleic and arachidonic acids.

Key word: *fresh-water fish, polyculture, age, nutrition, fat, proteins, cholesterol, fatty acid profile*

Introduction

The high nutritional value of fish meat is reflected in favourable content of proteins, carbohydrates, minerals and vitamins (*Ćirković et al.*, 2002). It represents the most important dietary source of n-3 highly unsaturated fatty acids (HUFA), eicosapentaenoic (EPA) and docosahexaenoic acid (DHA), that have particularly important roles in human nutrition, reflecting their roles in critical physiological processes *(Calder and Grimble*, 2002; *Zhenga et al.*, 2004).

These acids (EPA and DHA) appear to play a key role in neutral development, functioning of the cardiovascular and immune systems (*Lauritzen et al.*, 2001), besides the prevention of some types of cancer, including colon, breast and prostate (*Connor,* 2000), brain aging and Alzheimer disease (*Kyle,* 1999). It is necessary to take into account the nutritional quality of meat because fish is also one of the best sources of animal protein (*Ozogul et al.*, 2006). Composition of fish proteins is better than the composition of proteins of other animals, which is mainly due to more favorable amino acid composition and lots of free amino acids (*Tope et al.*, 2007; *Buchtová et al.,* 2010). High biological value of fish proteins results from the presence of small content of connective tissue and lack of fascia and aponeurosis. Good digestibility of fish meat comes from the content of short muscle fibers, lacks of sclerproteins, collagen and elastin (*Ćirković et al.*, 2002). Fish proteins contain all the essential amino-

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[1]University of Novi Sad, Faculty of agriculture, Department of veterinary medicine,, Trg Dositeja Obradovića 8, 21000 Novi Sad, Republic of Serbia;
[2]Institute of meat hygiene and technology, Kaćanskog 13, 11 000 Belgrade, Republic of Serbia.

Corresponding author: miroslavcirkovic@yahoo.com

acids for the human organism and they can be used as the sole source of protein in the diet (*Vladau et al.,* 2009). Mammals and fish have a similar percentage of proteins, which in fish is usually in the range of 14-20% (*Spirić et al.,* 2009; *Trbović et al.,* 2009; *Ćirković et al.,* 2010), although some authors state that this range is slightly higher and amounts from 13 to 25% (*Vladau et al.*, 2008), which accounts for 80 to 90% of the energy content of the fish. In terms of fat, the meat of mammals contains much higher percentage of fat (*Saičić et al.*, 2010). The lipid content of fish varies depending on the type of fish, the time of year and what the fish feeds on (*Guler et al.*, 2008; *Ćirković et al.*, 2011). Meat of fish contains insignificant amounts of carbohydrates in the form of glycogen and high percentage of water (60–86%) (*Ćirković et al.*, 2002). The content of vitamins and minerals in meat of freshwater fish is very favourable (*Özurt et al.*, 2009). The energy value of fish meat is directly proportional to fat content. It was found that fish fats vary greatly in regard to the percentage of saturated and unsaturated fatty acids and usually contain 15–36% saturated fatty acids (*Ackman,* 2000; *Buchtova et al.,* 2007; *Zakes et al.*, 2010) and 58–85% unsaturated fatty acids (*Caballero et al.*, 2002; *Domaizon*, 2000). The most important unsaturated fatty acids are linoleic and linolenic acid, which are essential and should be ingested in the body by food. Results referring to meat quality of carp are different in communications by various authors, with differences mostly caused due to the analysis of fish of different age, breeding systems and food and because of that, there are wide ranges of fat content in carp, from 2.3 to 16.8%, while varying slightly less in case of protein and protein content in range from 14 to 18% (*Vladau et al.,* 2008; *Trbović et al.,* 2009, *Ćirković et al.*, 2010). Beside polyunsaturated fatty acids, fish fats contain cholesterol. Fish meat contains similar amount of cholesterol (49–92 mg/100 g) as pork or beef (45–84 mg/100 g) and cholesterol content is not correlated with fat content (*Piironen et al.*, 2002). Content of cholesterol in freshwater fish from a free-catch and fish from aquaculture is different and depends on the species of fish (*Moreira et al.*, 2001). The amount of cholesterol in freshwater fish is lower in comparison with sea fish *(Luzia et al.,* 2003) and, therefore, the consumption of freshwater fish is more favourable for human health.

Recent research suggests that freshwater fish are capable of producing DHA from α-Linolenic n-3 (*Buzzi et al.,* 1996; *Bell et al.,* 2001) and they express all the desaturase and elongase activities necessary for this biosynthetic pathway (*Sargent et al.*, 2002).). In contrast, sea fish are unable to produce DHA from 18:3n-3 at a physiologically significant rate (*Owen et al.,* 1975; *Sargent et al.*, 2002) due to apparent deficiencies in one or more steps in the pathway (*Ghioni et al.,* 1999; *Tocher and Ghioni,* 1999).

Meat quality of one-year, two-years and three-years old carp (*Cyprinus carpio L.*), two-years old silver carp (*Hypophthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*), and two-yearsold catfish (*Silurus glanis*) and zander (*Stizostedion lucioperca*), which were farmed in different conditions and with different feeding regimes was analyzed in this study.

Literature data

The basic reference related to fish that are farmed in polyculture in carp ponds in our country

Fish farming in our region is mostly conducted like polyculture rearing of carp with silver carp, bighead carp, grass carp, catfish and zander (*Ćirković et al.,* 2007). Common carp is the most common fish species in our country, and the cyprinid fish are the predominant fish in world aquaculture with 54% of total production (*Ćirković et al.*, 2002; *FAO,* 2006). According to many international authors (*Andrade et al.*, 1995; *Arts et al.*, 2001; *Rasoarahona et al.*, 2004), common carp is a symbol of strength, fertility and longevity. It is omnivore fish and very effectively uses food. Fertility of carp is high and it ranges up to 1 500 000 eggs per female (*Ćirković et al.*, 2002; *FAO,* 2006). Carp is tolerant to large variations of quality of ambient conditions. This species is not susceptible to disease and is tolerant to handling. Opinion on the culinary quality of carp in our country is not the same as the belief in Anglo-Saxon states, but the fact is that there is not a single fish from which a number of fish speciality can be made. According to *Steffens and Wirth* (2005) the fatty acid composition reflects, to a large extent, the diet, so the n-3/n-6 ratio ranges between 0.08 and 2.4; while in paper of *Ćirković et al.* (2010) established the ratio of these fatty acids of 0.54. A similar ratio (0.5) was found by *Fajmonova et al.* (2003). Carp fed exclusively natural food from fish-pond shows a significant level of total n-3 and n-6 fatty acids (*Ćirković et al.*, 2010). Supplementary feeding with grains leads to reduced amounts of these essential fatty acids and this is due to the lower proportion of natural food in the diet of the carp, which received additional grain.

The so-called "Chinese carps" (grass carp, silver carp, bighead carp) were introduced into the European waters (Danube Basin) in 1960s to produce their polyculture in carp fishponds and stock open waters in order to increase total ichthyoproduction at the expense of food resources available in plankton form (*Lenhardt et al.*, 2010). Silver carp, bighead carp and grass carp were introduced from the Asian continent. They use the natural feed in fish ponds very well and their percentage ranges from 20–30%, compared to carp (*Ćirković et al.*, 2002; *Ćirković et al.*, 2005). These herbivore fish exploit ecological potential of fish ponds very well and make production more economical. Chinese carps have been present in our country for about 40 years and they are well accepted on the market because of low price and good quality of meat. Culinary quality of these fish is somewhat lower than that of carp, but their biological quality is very good, what was demonstrated in our study. Catfish and zander are carnivore fishes, whose participation in polyculture has a task to significantly reduce the number of less valuable fish, as well as to select fish of poor growth and adverse health conditions. Catfish is reared successfully and effective artificial reproduction have already been developed, including out-of-season spawning (*Brzuska,* 2001). Zander is a carnivorous fish; it generally feeds on other fish species rich in fatty acid (*Celik et al.*, 2005). After fertilization, perch eggs are introduced into the pond, in the form of „nests" from the open water. Perch is very sensitive to handling during introducing and harvesting, and is usually farmed as a one-year perch and rarely as two-years old fish. Production of zander and catfish is possible in monoculture, but in our conditions, due to high feed prices, high costs of balancing environmental conditions and relatively low prices of these species on the market, there is no economic justification for this type of production. In the European Union countries, these fish achieve high price, but there are significant problems in their transport as live fish. Carnivorous fish eat per kilogram of gain up to 15 kg of other fish (*Ćirković et al.*, 2002), so their production can be based on a small number of individuals that control the number of less valuable fish. Some European authors also recomanded farming the catfish species as a component in polyculture with carp, tench, and herbivorous fish (*Duda,* 1994). Growth rate and feed utilization effectiveness obtained by European catfish cultivated in polyculture were more advantageous than those in monoculture *(Ulikowski et al.*, 2003).

Material and methods

Samples of two and three years old carp, two years old silver carp, grass carp, catfish and zander were taken in the winter time from a pond, where the production is organized in the semi-intensive system with the addition of corn (80%) and wheat (20%). The three-year old carp was sampled from two ponds. In one case, feeding was performed using the combinations of barley, maize and wheat, in proportion 40:30:30, while in the second case feeding , it was done with a full feed diet mixtures. Also, the sample of two-years old carp were taken from ponds where the feeding was done with complete feed mixture. Twelve samples of each type and category of fish were taken. Before analysis, samples were stored at the temperature of –18ºC. Before examination fish were left one hour at room temperature, in order to partially defrost and enable easy skin removal, taking the head and tail and remove the viscera. Fish fillets were blended in Braun CombiMax 600 (*Spirić et al.*, 2009; *Trbović et al.*, 2009). For purposes of the examination of fatty acide profiles and cholesterol content, samples were stored in dark plastic bags at temperature of –18ºC, until examination. Meat from dorsal muscles was used for chemical analysis.

Chemical analysis

Chemical composition of fish muscle tissue was determined by standard SRPS ISO methods. Protein content was determined by Kjeldahl (N x 6.25), (Kjeltec Auto 1030 Analyzer, Tecator, Sweden). Water content was determined by drying at 103 ± 2ºC to constant weight (SRPS ISO methods). For determination of total fat, sample was hydrolyzed with 4M hydrochloric acid and extracted with petroleum ether by Soxhlet apparatus. Ash was determined by combustion at 550 ± 25º C. (*Spirić et al.*, 2009; *Trbović et al.*, 2009).

Extraction of lipids by ASE

Total lipids for fatty acids determination were extracted from fish muscle tissues by accelerated solvent extraction (ASE 200, Dionex, Sunnyvale, CA). Homogenate of sample mixed with diatomaceous earth, was extracted with a mixture of n-hexane and iso-propanol (60:40 v/v) in 33 ml extraction cell at 100°C and nitrogen pressure of 10.3 MPa (*Spirić et al.*, 2009; *Trbović et al.*, 2009). The extracts were collected and the solvent was removed under stream of nitrogen in Dionex Solvent Evaporator 500, at 50°C until dryness. Fat extract was further used for fatty acids determination.

FA analysis by capillary gas chromatography (CGC)

Fatty acid methyl esters (FAMEs) were prepared by transesterification by using trimethylsulfonium hydroxide, according to SRPS EN ISO 5509:2007 procedure. The GC instrument Shimadzu 2010 (Kyoto, Japan), used for FAMEs determination, was equipped with a split/splitless injector, fused silica cianopropyl HP-88 column (length 100 m, i.d. 0.25 mm, film thickness 0.20 μm, J&W Scientific, USA) and flame ionization detector. The column temperature was programmed. Injector temperature was 250° C and detector temperature was 280° C. The carrier gas was nitrogen at a flow rate of 1.33 ml/min and injector split ratio of 1:50. Injected volume was 1 µl and total analysis time 50.5 min. Chromatographic peaks in the samples were identified by comparing relative retention times of FAMEs peaks with peaks in a Supelco 37 Component FAMEs mix standard (Supelco, Bellefonte, USA), (*Spirić et al*., 2009).

Cholesterol determination

Cholesterol determination in carp fillets (direct saponification) was performed by using HPLC/PDA system (Waters 2695 Separation module/Waters photodiode array detector, USA) on a Phenomenex Luna C18 (2) reverse/phase column, 150 mm x 3.0 mm, 5µm particle size, with C18 analytical guard column, 4.0 x 2.0 mm, according to *Maraschiello et al*. (1996). The injected volume was 10 µL. The mobile phase was isopropanol-acetonitrile (20:80, v/v) at a flow rate of 1.2 mL/min, isocraticaly. Detection was performed at 210 nm. Total analysis time lasted 10 min. Quantification of cholesterol was done by external standardization. Empower Pro software was used to control the HPLC system as well as for data acquisition and data processing, as described by *Spirić et al*., 2009. Analyses were done at the Institute of Hygiene and Meat Technology, Belgrade.

Statistical analysis

The average results are presented as means ± SD. The differences between the mean values of the studied parameters were calculated using one-way analysis of variance (ANOVA), at 0,01 significance. When significant inter-group differences were determined ($p \leq 0{,}01$) further statistical analysis was performed using Tukey HSD test. Calculations were performed by the Statistica 10 program (StatSoft Inc.).

Results and discussion

Results of chemical composition and cholesterol content in fillets of two-years old carp, silver carp, grass carp, catfish and zander, which were farmed in polyculture in semi-intensive system, where feeding was done by adding corn and wheat in ratio 80:20 are shown in Table 1. Water content was the highest in catfish (78.69 ± 0.12), followed by zander (77.58 ± 0.11), silver carp (77.00 ± 0.36), grass carp (76.22 ± 1.03), and the lowest was in common carp (75.02 ± 0.29). The amount of protein was the highest in zander fillets (19.21 ± 0.03), followed by silver carp fillets (18.02 ± 0.15), catfish (17.27 ± 0.10), carp (15.59 ± 0.21) and the lowest percentage of protein was found in grass carp fillets (14.8 ± 0.12). Percentage of fat ranged from 1.74 ± 0.10, in the muscles of zander, to 6.85 ± 0.14 in the meat of carp. Fat percentage in the fillets of catfish, carp and grass carp was 3.43 ± 0.08; 4.07 ± 0.05 and 6.39 ± 0.24, respectively. Ash content was 0.84 ± 0.03 for grass carp, 0.89 ± 0.035 for carp, 0.89 ± 0.03 for catfish, 1.04 ± 0.02 for zander and 1.18 ± 0.01 for silver carp. The total cholesterol content was the highest in silver carp fillets (65.90 ± 0.29), followed by grass carp (65.07 ± 0.13), common carp (57.8 ± 0.11), zander (42.45 ± 0. 17) and the lowest amount of cholesterol was found in catfish (33.00 ± 0.56).

The obtained fat percentage in silver carp muscle was lower compared to the results obtained by

Table 1. Chemical composition of two years old fish reared in polyculture
Tabela 1. Hemijski sastav dvogodišnje ribe gajene u polikulturi

Parameters/ Parametri	**Common carp/ Šaran *Cyprinus carpio***	**Silver carp/ beli tolstolobik *Hypophthalmichthys molitrix***	**Grass carp/ Amur *Ctenopharyngodon idella***	**Wels catfish/ Som *Silurus glanis***	**Zander/ Smuđ zander *Stizostedion lucioperca***
Moisture content/ Sadržaj vlage, %	75.02 ± 0.29a	77.00 ± 0.36b	76.22 ± 1.03c	78.69 ± 0.12d	77.58 ± 0.11b
Protein content/ Sadržaj proteina, %	15.59 ± 0.21a	18.02 ± 0.15b	14.68 ± 0.12c	17.27 ± 0.10d	19.21 ± 0.03e
Fat content/Sadržaj masti, %	6.85 ± 0.14a	4.07 ± 0.05b	6.39 ± 0.24c	3.43 ± 0.08d	1.74 ± 0.10e
Ash content/ Sadržaj pepela, %	0.89 ± 0.035a	1.18 ± 0.01b	0.84 ± 0.03c	0.89 ± 0.03a	1.04 ± 0.02d
Total cholesterol / Ukupni holesterol, mg/100g	57.8 ± 0.11a	65.90 ± 0.29b	65.07 ± 0.13c	33.00 ± 0.56d	42.45 ± 0.17e

Legend/Legenda: Values are means ± SD (n = 12); Values in the same row with different letter notation statistically significantly differ at $p < 0.01$/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12);Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou $p < 0.01$

Domaizon et al. (2000), who examined one-year and three-years old silver carp and measured the lipid content in fillets in the range of 4.51 to 6.7%. According to the obtained results, fat content in catfish was 3.43, slightly higher compared to value of 2,33 obtained by *Jankovsaka et al.* (2004) for catfish farmed in ponds with natural food. The obtained values for proteins in zander are higher compared to studies of *Celik et al.* (2005) by which the percentage of proteins was in the range of 18,1 in the cold, to 18.8 in the warm lake. Fat content in our examination was, also, higher than values obtained by the mentioned authors for zander.

Table 2 presents results of chemical analysis and total cholesterol content in one, two and three years old carp, which are sampled from the same pond, where the production took place in semi-intensive conditions with corn and wheat added into diet (80:20). The percentage of water ranged from 77.78 ± 0.07 for one-year old, 75.01 ± 0.29 for two year old to 71.04 ± 0.20 in three year old carp. Protein content was the highest in the meat of one-year old carp (16.86 ± 0.19), followed by two-years old (15.59 ± 0.21), while the lowest value was detected in meat of three-years old carp (14.44 ± 0.16). Fat percentage was the lowest value in one-year old carp (4.41 ± 0.11) and the highest in fillets of three year old carp (11.73 ± 0.11). Fat content in meat of two years old carp was 6.85 ± 0.14%. Ash content, expressed as a percentage, was 0.84 ± 0.01 in three--years old fish, 0.89 ± 0.04 in two year old and 0.94 ± 0.01 in the yearling carp. The amount of total cholesterol was the lowest in one-year carp (37.94 ± 0.02). in the fat of biannual carp it was 57.8 ± 0.11 mg/100 g, while the largest amount of cholesterol measured in the fat of three-years old carp (59.75 ± 09).

Trbović et al. (2009) determined the amount of cholesterol in lipids of one year old carp in April and it was 48.87 ± 2.18 mg/100 g and in samples that were collected in June it was 54.31±1.13 mg/100g. In our studies, the amount of total cholesterol in yearlings is lower, the sampling was done in December. And, according to results published by *Vasha and Tvrzicka* (1995), the amount of cholesterol in the meat of carp was lower during the winter months. Determined cholesterol content in lipids of carp varies considerably in the works of different authors and it is in the range of 47 to 120 mg/100 g, which is consistent with our results for amount of cholesterol in fat of two and three years old carp (*Vacha and Tvrzicka*, 1995; *Bieniarz et al.*, 2001; Kopica and Vavreinova, 2007), but it must be taken into account that tests were carried out in different seasons and at different age categories.

Chemical composition and total cholesterol content in samples of two-years old carp fillets which were sampled from the pond where the diet consisted of added pelleted complete feed in fish farmed ponds where feeding was done by addintion corn and wheat in proportion 80:20, are shown in Table 3. The amount of water, proteins and ash was higher in carp fed diet with added pelleted food. and amounted 78.36 ± 0.04, 17.17 ± 0.05 and 1.03 ± 0.01 respectively, while values of the same parameters in carp whose diet consisted of corn and wheat were 75.01 ± 0.29, 15.59 ± 0.21 and 0.89 ± 0.04 rspectively. The percentage of fat in carp from more intensive production was 3.19 ± 0.05, and for two year old fish from semi-intensive production it was 6.85 ± 0.14. Cholesterol content was higher in carp fed grain (57.8 ± 0.11), compared to carp fed pelleted food (51.31 ± 0.12).

Table 2. Chemical composition of one, two and three years of carp reared in the same conditions
Tabela 2. Hemisjki sastav jednogodišnjih, dvogodišnjih i trogodišnjih šarana gajenih u istim uslovima

Parameters/ Parametri	Carp, one year old/ Jednogodišnji šaran	Carp, two years old/ Dvogodišnji šaran	Carp, three years old/ Trogodišnji šaran
Moisture content/ Sadržaj vlage, %	77.78 ± 0.07a	75.01 ± 0.29b	71.04 ± 0.20c
Protein content/ Sadržaj proteina, %	16.86 ± 0.19a	15.59 ± 0.21b	14.44 ± 0.16c
Fat content/ Sadržaj masti, %	4.41 ± 0.11a	6.85 ± 0.14b	11.73 ± 0.11c
Ash content/ Sadržaj pepela, %	0.94 ± 0.01a	0.89 ± 0.04b	0.84 ± 0.01c
Total cholesterol / Ukupni holesterol, mg/100g	37.94 ± 0.02a	57.8 ± 0.11b	59.75 ± 09c

Legend/Legenda: Values are means ± SD (n = 12); Values in the same row with different letter notation differ significantly statistically at $p < 0.01$/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou $p < 0.01$.

Table 3. Chemical composition of two-year old carp fed with different food
Tabela 3. Hemijski sastav mesa dvogodišnjeg šarana hranjenog različitom hranom

Parameters/ Parametri	Carp, two years old. pelleted feed/ Dvogodišnji šaran, peletirna hrana	Carp, two years old, corn and wheat/ Dvogodišnji šaran, kukuruz i pšenica
Moisture content/Sadržaj vlage, %	78.36 ± 0.04a	75.01 ± 0.29b
Protein content/Sadržaj proteina %	17.17 ± 0.05a	15.59 ± 0.21b
Fat content/Sadržaj masti %	3.19 ± 0.05a	6.85 ± 0.14b
Ash content/Sadržaj pepela, %	1.03 ± 0.01a	0.89 ± 0.04b
Total cholesterol / Ukupni holesterol, mg/100g	51.31 ± 0.12a	57.8 ± 0.11b

Legend/Legenda: Values are means ± SD (n = 12); Values in the same row with different letter notation statistically significantly differ at $p < 0.01$/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou $p < 0.01$

Table 4 presents the results for chemical analysis and total cholesterol content in three-years old carps, which were grown in different ponds. Carp, which was grown in semi intensive production conditions and was fed corn and wheat. in the ratio of 80:20, had a moisture content of 71.04 ± 0.20%, protein 14.44 ± 0.16%, fat 11.73 ± 0.11%, ash 0.84 ± 0.01% and the amount of total cholesterol was 59.75 ± 0.09 mg/100g. Values in percentages of water, protein, fat and ash measured in fillets of three-year old carp, grown in semi-intensive conditions. which was fed barley. maize and wheat (40:30:30) amounted to, 70.67 ± 0.06, 15.81 ± 0.18, 11.73 ± 0.11, 0.93 ± 0.02 respectively, and the total cholesterol content was 66.07±0.04 mg/100g. Moisture content, protein, fat and ash percentage in the three-year old carp, fed complete feed mixture were 70.94 ± 0.06, 17.68 ± 0.12, 10.41 ± 0.06 and 0.94 ± 0.02, and the amount of cholesterol was 36.14 ± 0.04 mg/100g.

(SFA) was the highest in silver carp (34.05 ± 0.08) and lowest in common carp (24.23 ± 0.06). Dominant saturated fatty acids were: palmitic fatty acid (C16:0), which ranged from 17.33% in common carp to 23.04% in grass carp, stearic acid (C18:0) in the amount of 3.37% (grass carp) to 7.04% (catfish), myristic acid (C14:0) with the lowest content common carp (0.72%) and the highest in silver carp (3.82%). In low concentrations, in all species, the following acids were present: lauric (C12:0), in the amount of 0.12% in grass carp to 0.44% in silver carp; pentadecylic (C15:0), 0.01% in common carp up to 1.02% in silver carp; margaric (C17:0). whose content was also the highest in silver carp (1.37%); and arachidonic (C20:0). The most abundant monounsaturated fatty acid was oleic (C18:1. n9), in the amount of 22.56% in silver carp to 51.35% in common carp, followed by palmitooleic (C16:1. n7) and 11-eicosenic (C20:1). Silver carp contained the least amount of monounsaturated fatty acids (MUFA) (39.04%), but the largest percentage was measured in carp (64.34%). Silver carp contained the higest

Table 4. Chemical composition of three-year old carp grown in different fish ponds
Tabela 4. Hemijski sastav mesa trogodišnjeg šarana iz različitih ribnjaka

Parameters/ Parametri	Carp, three years old. corn and wheat/ Šaran trogodišnji, kukuruz i pšenica	Carp, three years old, barley wheat and corn/ Šaran trogodišnji, ječam, pšenica i kukuruz	Carp, three years old, complete feed/ Šaran trogodišnji, kompletna smeša
Moisture content/ Sadržaj vlage, %	71.04 ± 0.20a	70.67 ± 0.06b	70.94 ± 0.06a
Protein content/Sadržaj proteina, %	14.44 ± 0.16a	15.81 ± 0.18b	17.68 ± 0.12c
Fat content/Sadržaj masti, %	11.73 ± 0.11a	11.73 ± 0.11a	10.41 ± 0.06b
Ash content/Sadržaj pepela, %	0.84 ± 0.01a	0.93 ± 0.02b	0.94 ± 0.02b
Total cholesterol / Ukupni holesterol, mg/100g	59.75 ± 0.09a	66.07 ± 0.04b	36.14 ± 0.04c

Legend/Legenda: Values are means ± SD (n = 12); Values in the same row with different letter notation statistically significantly differ at $p < 0.01$/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou $p < 0.01$

Fatty acid composition of the two-years old carp, silver carp, grass carp, catfish and zander is hown in Table 5. The amount of saturated fatty acids percentage of polyunsaturated fatty acids (PUFA) 24.23%, of which 18.17% were n-3 and 6.07% n-6. The lowest percentage of PUFA was detected in common carp, which contained 10.95% and the n-3/n-6 ratio was 0.14. PUFA/SFA, which is an indicator of the quality of lipids in the examined fish was 0.45 (common carp), 0.51 (catfish), 0.53 (zander), 0.63 (grass carp) and the most favourable was in silver carp 0.71 ± 0.01. Also, significant is the ratio of unsaturated (UFA) to saturated (SFA) fatty acids in fish lipids. For studied the species ratio was the best in the fat of common carp 3.14 ± 0.01, then 2.27 in zander, 2.44 in grass carp; 2.03 in catfish and 1.94 in fat of silver carp.

Table 5. Fatty acid composition of two years old fish farmed in the same conditions
Tabela 5. Sastav masnih kiselina u mesu dvogodišnjeg šarana odgajanog u istim uslovima

Fatty acids/ Masne kiseline, %	Common carparp/ Šaran *Cyprinus carpio*	Silver carp/ Beli tolstolobik *Hypophthalmichthys molitrix*	Grass carp/ Amur *Ctenopharyngodon idella*	Wels catfish/ Som *Silurus glanis*	Zander/ Smuđ zander *Stizostedion lucioperca*
Lauric acid/ Laurinska kiselina, C12:0	0.14 ± 0.01a	0.44 ± 0.02b	0.12 ± 0.01c	0.23 ± 0.02d	0.14 ± 0.01a
Myristic acid/Miristoleinska kiselina. C14:0	0.72 ± 0.01a	3.82 ± 0.02b	1.62 ± 0.01c	2.32 ± 0.01d	0.94 ± 0.01e
Pentadecanoic acid/ Pentadekanska kiselina, C15:0	0.01 ± 0.01a	1.02 ± 0.01b	0.32 ± 0.00c	0.85 ± 0.01d	0.32 ± 0.02c
Palmitic acid/ Palmitinska kiselina, C16:0	17.33 ± 0.06a	22.12 ± 0.05b	23.04 ± 0.01c	21.04 ± 0.14d	22.07 ± 0.16b
Palmitoleic acid/ Palmitoleinska kiselina, C16:1	6.23 ± 0.01a	10.32 ± 0.02b	10.73 ± 0.01c	11.34 ± 0.05d	6.16 ± 0.03e
Margaric acid/ Margarinska kiselina, C17:0	0.12 ± 0.01a	1.37 ± 0.01b	0.41 ± 0.00c	1.26 ± 0.05d	0.45 ± 0.00e
Stearic acid/ Stearinska kiselina, C18:0	5.79 ± 0.02a	5.02 ± 0.03b	3.37 ± 0.10c	7.04 ± 0.05d	6.50 ± 0.06e
Oleic acid/ oleinska kiselina, C18:1cis-9	51.35 ± 0.04a	22.56 ± 0.01b	34.90 ± 0.06c	26.23 ± 0.10d	38.34 ± 0.12e
Vaccenic acid/ Vakcenska kiselina,C18:1cis-11	4.54 ± 0.04a	4.89 ± 0.07b	4.60 ± 0.05a	8.24 ± 0.10c	4.56 ± 0.04a
Linoleic acid/ Linolna kiselina, C18:2. ω-6	8.75 ± 0.06a	5.00 ± 0.01b	11.28 ± 0.04c	6.16 ± 0.03d	7.05 ± 0.05e
Linolenic(GLA)/ Linolenska kiselina C18:3.ω-6	0.12 ± 0.01a	0.24 ± 0.01b	0.12 ± 0.01a	0.15 ± 0.01c	0.12 ± 0.00a
α-Linolenic/ α-Linolenska kiselina, C18:3. ω-3	0.64 ± 0.00a	5.24 ± 0.01b	3.27 ± 0.01c	3.06 ± 0.04d	0.97 ± 0.02e
Arachidic acid/ Arahidska kiselina, C20:0	0.12±0.01a	0.26±0.01b	0.15±0.00c	0.22±0.00d	0.18 ± 0.01e
Eicosenoic acid/ Eikosenska kiselina, C20:1	2.22±0.01a	1.27 ± 0.01b	1.06 ± 0.01c	2.20 ± 0.06a	1.67 ± 0.01d
Behenic acid/ Behenska kiselina, C20:2	0.3 ± 0.04a	0.36 ± 0.01b	0.46 ± 0.01c	0.61 ±0 .02d	0.28 ± 0.00a
Dihomo-gamma-linolenic acid/ Di-homo-gama-linolenska kiselina, C20:3. ω-6	0.46 ± 0.02a	0.46 ± 0.01a	0.74 ± 0.01b	0.47 ± 0.02a	0.34 ± 0.02c
Eicosatrienoic acid/ Eikosatrienoična kiselina, C20:3, ω-3	0.06 ± 0.00a	0.60 ± 0.01b	0.38 ± 0.01c	0.58 ± 0.02d	0.27 ± 0.02e
Erucic acid + Arachidonic acid/ Eruična kiselina + arahidonska kiselina. C22:1+20:4	0.74 ± 0.01a	2.75 ± 0.01b	1.44 ± .01c	2.01 ± 0.05d	2.58 ± 0.08e
Eicosapentaenoic acid/ Eikosapentaenska kisleina, C20:5. ω-3	0.19 ± 0.02a	4.46 ± 0.05b	0.49 ± 0.01c	1.16 ± 0.03d	1.24 ± 0.03e
Docosapentaenoic acid/ Dokosapentaenska kiselina, C22:5. ω-3	0.18 ± 0.01a	1.14 ± 0.01b	0.50 ± 0.00c	1.47 ± 0.06d	0.68 ± 0.01e

Docosahexaenoic acid/ Dokosaheksaenska kiselina, C22:6. ω-3	0.25 ± 0.01a	6.73 ± 0.11b	1.01 ± 0.00c	3.28 ± 0.18d	5.16 ± 0.14e
SFA/ZMK	24.23 ± 0.06a	34.05 ± 0.08b	29.03 ± 0.09c	32.96 ± 0.20d	30.62 ± 0.17e
MUFA/MNMK	64.34 ± 0.06a	39.04 ± 0.08b	51.29 ± 0.08c	48.01 ± 0.17d	50.72 ± 0.13e
PUFA/PNMK	10.95 ± 0.09a	24.23 ± 0.18b	18.26 ± 0.04c	16.94 ± 0.31d	16.11 ± 0.19e
ω-6	9.63 ± 0.08a	6.07 ± 0.03b	12.61 ± 0.04c	7.39 ± 0.06d	7.78 ± 0.06e
ω-3	1.32 ± 0.02a	18.17 ± 0.17b	5.65 ± 0.02c	9.55 ± 0.26d	8.33 ± 0.16e
ω-3/ω-6	0.14 ± 0.00a	2.99 ± 0.02b	0.45 ± 0.00c	1.29 ± 0.03d	1.07 ± 0.02e
ω-6/ω-3	7.28 ± 0.08a	0.33 ± 0.00b	2.23 ± 0.01c	0.77 ± 0.02d	0.93 ± 0.02e
PUFA/SFA PNMK/ZMK	0.45 ± 0.00a	0.71 ± 0.01b	0.63 ± 0.00c	0.51 ± 0.01d	0.53 ± 0.01e
UFA/SFA NMK/ZMK	3.14 ± 0.01a	1.94 ± 0.01b	2.44 ± 0.01c	2.03 ± 0.02d	2.27 ± 0.02e

Legend/Legenda: SFA-saturated fatty acids/zasićene masne kiselina. MUFA-monounsaturated fatty acids/mono nezasićene masne kiseline/USFA unsaturated fatty acids/ nezasićene masne kiseline, PUFA-polyunsaturated fatty acids from the n-3 (n-3 PUFA) and n-6 (n-6 PUFA) families/poli nezasićene masne kiseline iz n-3 (n-3 PNMK) i n-6 (n-6 PNMK) grupa
Values are means ± SD (n = 12); Values in the same row with different letter notation statistically significantly differ at $p < 0.01$/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou $p < 0.01$.

The total value of saturated fatty acids in research of *Jankowska et al.* (2004), in catfish farmed traditionally, was 25. 41. In our experiment it was higher (32.96), probably because of the amount of the dominant palmitic acid that was 15. 89% in the research of *Jankowska et al.* (2004) and in our trial it was 21.04%. Also, we determined higher amount of C18:0, which was 7.04%, but *Jankowska et al.* (2004) detected 5.85%. The amount of C14:0 acid (mirystic), C15:0 and C20:0 was similar in both trials. The unsaturated fatty acids were the largest group 74.59% (*Jankowska et al.,* 2004) and in our trial 66.96 %. We established the amount of MUFA of 48.01%. PUFA 16.94 and n3/n6 ratio was 1.29. In research of *Jankowska et al.* (2004). these values were 39.86%, 34.73% and 2.31 respectively. According to *Bieniarz et al.* (2000), the meat of catfish cultivated in a polyculture with common carp has 21.85% PUFA, and the n-3/n-6 ratio of 2.39, but *Fullner and Wirth*. (1996) reported that value of n-3/n-6 was 1.7. The total saturated fatty acid content in lipids was in the range from 30.5 to 32.9% (*Celik et al.,* 2005) in zander caught from two lakes, which is the same value like in our experiments (30.62%). Thus, the fatty acids found in both species (about 70%) were mono and polyunsaturated fatty acids (MUFA + PUFA). The major fatty acids identified in zander were 16:0, 18:0, 18:1 n-9, 18:2 n-6, 20:5 n-3 (EPA) and 22:6 n-3 (DHA). Palmitic acid was the primary saturated fatty acid in lipids of zander. contributing approximately with 66% to the total saturated fatty acid content of the lipids. Similar results were noted for wild zander (*Jankowska et al*., 2003) and for zander caught from two lakes (*Celik et al.,* 2005). Oleic acid was identified as the primary monounsaturated fatty acid. Among the n-3 series, zander is good sources of EPA (1.24%) and DHA (5.16%).

It has been reported that the types and amounts of fatty acids in fish tissues vary with the geographic location, size, age, what the fish eat, reproductive status and seasons (*Leger et al.,* 1977; *Bandarra et al.,* 1997) silver carp and grass carp fed on phytoplankton, zooplankton, macrophytes and are rich in n-3 polyunsaturated fatty acids, especially eicosapentaenoic and docosahexaenoic acids (*Steffans and Wirth*, 2005). The proportion of total n-3 fatty acids varies between 20 and 30% and the n-3/n-6 ratio is about 2 to 3. According to our results, n3/n6 in silver carp was 2.99, which is in agreement with the results of *Steffans and Wirth* (2005), while this ratio in grass carp was lower - 0.45. This can be attributed to the changes in natural food for grass carp, in the pond the amount of macrophyte vegetation was decreased. and grass carp were predominantly fed additional nutrients. Presented by *Domaizona et al.* (2000). the n3/n6 ratio in fillets of silver carp ranged from 1.18 for one-year carp to 1.9 in three-years old carp, while it should be noted that in our study the two-years old silver carp fillets were tested. Silver carp contained significantly higher amount of docosahexaenoic acid in relation to other studied species, which is in agreement with *Domaizon et al.* (2000). He, also, found a high content of n-3 fatty acids in silver carp fillets and showed that the content of these fatty acids in silver carp increased with age of this species due to changes in diet with age. Zooplankton appears as the major contributor to the diet of the one year old silver carp (90.3% of ingested biomass), whereas three year old silver carp exhibited a more evenly balanced food spectrum between zooplankton (44.8% of ingested biomass) and phytoplankton (55.2% of ingested biomass), (*Domaizon et al.,* 2000). The amount of zooplankton in the nutrition of silver carp decreased with age, while the content of phytoplankton increased (*Shapiro*, 1985). Thus, the content of docosahexaenoic acid in their research of one-year old carp was 2.56% and 7.76% in three-years old silver carp, while in our studies, in fillets of yearlings 6.73% of this fatty acid was measured.

Table 6 shows the percentage ratio of fatty acids in common carp of different age sampled from the same pond, where the production was semi- intensive and diet was supplemented using corn and wheat, as the energy component of food, in relation 80:20. The most favourable UFA/SFA ratio was observed in three-years old carp (3.18), then in two year old 3.14 and in one-year old carps 3.12 ± 0.01. P/S ratio was 0.53 in one-year old carp, 0.45 in two years old carp and 0.42 in the three-years old carp. In all three age groups the most common were monounsaturated fatty acid (61.4% in one-year and 64. 9% in three-year old carp), followed by saturated fatty acids (SFA), (from 23.93% in three-years old to 24.98% in the lipids of yearlings). PUFA content ranged from 10.17% in fat of three-years old to 12.89% in one-year old carp. N3/n6 ratio was between 0.1 (three-years old) and 0.16 (yearling).

Table 6. fatty acid composition of one, two and three years old common carp reared in the same conditions
Tabela 6. Sastav masnih kiselina u mesu jednogodišnjih, dvogodišnjih i trogodišnjih šarana gajenih u istim uslovima

Fatty acids/ Masne kiseline, %	Carp, one years old/ Jednogodišnji šaran	Carp, two years old/ Dvogodišnji šaran	Carp, three years old/ Trogodišnji šaran
Lauric acid/ Laurinska kiselina, C12:0	0.14 ± 0.01a	0.14 ± 0.01ab	0.13 ± 0.01ac
Myristic acid/ Miristoleinska kiselina, C14:0	0.59 ± 0.02a	0.72 ± 0.01b	0.75 ± 0.01c
Pentadecanoic acid/ Pentadekanska kiselina, C15:0	0.1 ± 0.02a	0.01 ± 0.01b	0.02 ± 0.02b
Palmitic acid/ Palmitinska kiselina, C16:0	17.11 ± 0.08a	17.33 ± 0.06b	16.93 ± 0.03c
Palmitoleic acid/ Palmitoleinska kiselina, C16:1	5.78 ± 0.02a	6.23 ± 0.01b	6.01 ± 0.02c
Margaric acid/ Margarinska kiselina, C17:0	0.18 ± 0.01a	0.12 ± 0.01b	0.14 ± 0.01c
Stearic acid/Stearinska kiselina, C18:0	6.02 ± 0.01a	5.79 ± 0.02b	5.84 ± 0.01c
Oleic acid/ oleinska kiselina, C18:1cis-9	54.00 ± 0.04a	51.35 ± 0.04b	51.76 ± 0.13c
Vaccenic acid/ Vakcenska kiselina,C18:1c is-11	0 ± 0.00a	4.54 ± 0.04b	4.71 ± 0.02c
Linoleic acid/ Linolna kiselina. C18:2, ω-6	9.74 ± 0.05a	8.75 ± 0.06b	8.17 ± 0.02c
Linolenic(GLA)/ Linolenska kiselina C18:3,ω-6	0.24 ± 0.01a	0.12 ± 0.01b	0.12 ± 0.00b
α-Linolenic/ α-Linolenska kiselina, C18:3, ω-3	0.74 ± 0.01a	0.64 ± 0.00b	0.28 ± 0.01c
Arachidic acid/ Arahidska kiselina, C20:0	0.14 ± 0.01a	0.12 ± 0.01b	0.12 ± 0.01b
Eicosenoic acid/Eikosenska kiselina, C20:1	1.63 ± 0.01a	2.22 ± 0.01b	2.44 ± 0.01c
Behenic acid/Behenska kiselina, C20:2	0.34 ± 0.01a	0.3 ± 0.04b	0.28 ± 0.01b
Dihomo-gamma-linolenic acid/ Di-homo-gama-linolenska kiselina. C20:3, ω-6	0.84 ± 0.08a	0.46 ± 0.02b	0.70 ± 0.04c
Eicosatrienoic acid/ Eikosatrienoična kiselina, C20:3, ω-3	0.07 ± 0.01a	0.06 ± 0.00b	0.02 ± 0.02c
Erucic acid + Arachidonic acid/ Eruična kiselina + arahidonska kiselina, C22:1+20:4	1.46 ± 0.02a	0.74 ± 0.01b	0.99 ± 0.04c
Eicosapentaenoic acid/ Eikosapentaenska kisleina, C20:5, ω-3	0.23 ± 0.01a	0.19 ± 0.02b	0.14 ± 0.01c
Docosapentaenoic acid/ Dokosapentaenska kiselina, C22:5, ω-3	0.28 ± 0.01a	0.18 ± 0.01b	0.16 ± 0.01c

Docosahexaenoic acid/ Dokosaheksaenska kiselina. C22:6, ω-3	0.42 ± 0.02a	0.25 ± 0.01b	0.30 ± 0.02c
SFA/ZMK	24.28 ± 0.09a	24.23 ± 0.06a	23.93 ± 0.05b
MUFA/MNMK	61.41 ± 0.05a	64.34 ± 0.06b	64.92 ± 0.12c
PUFA/PNMK	12.89 ± 0.09a	10.95 ± 0.09b	10.17 ± 0.06
ω-6	11.15 ± 0.09a	9.63 ± 0.08b	9.27 ± 0.04c
ω-3	1.74 ± 0.03a	1.32 ± 0.02b	0.90 ± 0.03c
ω-3/ω-6	0.16 ± 0.00a	0.14 ± 0.00b	0.1 ± 0.00c
ω-6/ω-3	6.41 ± 0.14a	7.28 ± 0.08b	10.28 ± 0.37c
PUFA/SFA PNMK/ZMK	0.53 ± 0.00a	0.45 ± 0.00b	0.42 ± 0.00c
UFA/SFA NMK/ZMK	3.12 ± 0.01a	3.14 ± 0.01b	3.18 ± 0.01c

Legend/Legenda: SFA-saturated fatty acids/zasićene masne kiselina, MUFA monounsaturated fatty acids/mono nezasićene masne kiseline. USFA-unsaturated fatty acids/ nezasićene masne kiseline. PUFA- polyunsaturated fatty acids from the n-3 (n-3 PUFA) and n-6 (n-6 PUFA) families/poli nezasićene masne kiseline iz n-3 (n-3 PNMK) i n-6 (n-6 PNMK) grupa

Values are means ± SD (n=12); Values in the same row with different letter notation differ significantly statistically at p < 0.01/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou p < 0.01.

Fatty acid profile of two-years old carp, one of which was fed with corn and wheat (80:20) and another group was sampled from fish ponds where feeding was done by adding food pellets. is shown in Table 7. In two years old carp fed pelleted feed better ratio UFA/SFA was observed (3.46. compared with 3.14 in carp fed grain); the obtainedPUFA/SFA was 1.39 compared to 0.45, n3/n6 was 0.26 versus 0.14. Higher content of PUFA (31.04 compared with 10.95) and less SFA (22.4 versus 24.23) was obtained, too. Lipids of carp in more intensive production contained less MUFA (45.12%) compared to carp from the semi-intensive production (64.34%).

Table 7. Fatty acid composition of two-years old carp fed with different food
Tabela 7. Sastav masnih kiselina u mesu dvogodišnjih šarana hranjenih različitiom hranom

Fatty acids/ Masne kiseline, %	Carp, two years old, corn and wheat/ Dvogodišnji šaran, kukuruz i pšenica	Carp, two years old, pelleted feed/ Dvogodišnji šaran, peletirana hrana
Lauric acid/Laurinska kiselina, C12:0	0.14 ± 0.01a	0.10 ± 0.00b
Myristic acid/ Miristoleinska kiselina, C14:0	0.72 ± 0.01a	0.73 ± 0.01b
Pentadecanoic acid/ Pentadekanska kiselina, C15:0	0.01 ± 0.01a	0.23 ± 0.01b
Palmitic acid/Palmitinska kiselina, C16:0	17.33 ± 0.06a	16.89 ± 0.03b
Palmitoleic acid/ Palmitoleinska kiselina, C16:1	6.23 ± 0.01a	5.20 ± 0.04b
Margaric acid/ Margarinska kiselina, C17:0	0.12 ± 0.01a	0.18 ± 0.01b
Stearic acid/Stearinska kiselina, C18:0	5.79 ± 0.02a	4.16 ± 0.01b
Oleic acid/ oleinska kiselina, C18:1cis-9	51.35 ± 0.04a	34.45 ± 0.01b
Vaccenic acid/ Vakcenska kiselina, C18:1cis-11	4.54 ± 0.04a	2.93 ± 0.01b
Linoleic acid/ Linolna kiselina, C18:2. ω-6	8.75 ± 0.06a	22.56 ± 0.01b
Linolenic(GLA)/ Linolenska kiselina C18:3, ω-6	0.12 ± 0.01a	0.25 ± 0.01b

α-Linolenic/ α-Linolenska kiselina, C18:3, ω-3	0.64 ± 0.00a	2.12 ± 0.01b
Arachidic acid/ Arahidska kiselina, C20:0	0.12 ± 0.01a	0.10 ± 0.01b
Eicosenoic acid/ Eikosenska kiselina, C20:1	2.22 ± 0.01a	2.54 ± 0.01b
Behenic acid/Behenska kiselina, C20:2	0.3 ± 0.04a	0.73 ± 0.01b
Dihomo-gamma-linolenic acid/ Di-homo-gama-linolenska kiselina, C20:3. ω-6	0.46 ± 0.02a	1.02 ± 0.01b
Eicosatrienoic acid/ Eikosatrienoična kiselina, C20:3. ω-3	0.06 ± 0.00a	0.71 ± 0.01b
Erucic acid + Arachidonic acid/ Eruična kiselina + arahidonska kiselina, C22:1+20:4	0.74 ± 0.01a	1.43 ± 0.01b
Eicosapentaenoic acid/ Eikosapentaenska kisleina, C20:5. ω-3	0.19 ± 0.02a	0.93 ± 0.01b
Docosapentaenoic acid/ Dokosapentaenska kiselina, C22:5. ω-3	0.18 ± 0.01a	0.85 ± 0.02b
Docosahexaenoic acid/ Dokosaheksaenska kiselina, C22:6. ω-3	0.25 ± 0.01a	1.86 ± 0.04b
SFA/ZMK	24.23 ± 0.06a	22.40 ± 0.03b
MUFA/MNMK	64.34 ± 0.06a	45.12 ± 0.03b
PUFA/PNMK	10.95 ± 0.09a	31.04 ± 0.03b
ω-6	9.63 ± 0.08a	24.57 ± 0.03b
ω-3	1.32 ± 0.02a	6.48 ± 0.04b
ω-3/ω-6	0.14 ± 0.00a	0.26 ± 0.00b
ω-6/ω-3	7.28 ± 0.08a	3.79 ± 0.02b
PUFA/SFA PNMK/ZMK	0.45 ± 0.00a	1.39 ± 0.00b
UFA/SFA NMK/ZMK	3.14 ± 0.01a	3.46 ± 0.01b

Legend/Legenda: SFA saturated fatty acids/zasićene masne kiselina. MUFA monounsaturated fatty acids/mono nezasićene masne kiseline. USFA unsaturated fatty acids/ nezasićene masne kiseline. PUFA polyunsaturated fatty acids from the n-3 (n-3 PUFA) and n-6 (n-6 PUFA) families/poli nezasićene masne kiseline iz n-3 (n-3 PNMK) i n-6 (n-6 PNMK) grupa
Values are means ± SD (n = 12); Values in the same row with different letter notation statistically significantly differ at p < 0.01/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou p < 0.01

The content of n-3 in two-years old carp in this study was lower than in the two-years carp fed only natural food from the pond, which was recorded by *Ćirković et al.* (2010). The amount of n-3 in naturally fed carp was 9.85%, compared to the two year old carp fed pelleted feed (6.48%), and in relation to two years old carp in which the dominant feed was corn and the content of n-3 was 1.32%. In carp fed pelleted food a higher content of n-6 fatty acids was established. compared to the data presented by *Ćirković et al.* (2010) for carp fed only natural food (24.57% versus 17.63%), so that the total content of PUFA was higher in carp fed with pelleted food.

Percentages of fatty acids in lipids in three-year old carp sampled from three ponds with different feeding regimes are shown in Table 8. PUFA/SFA ratio was the most favourable in carp fed complete food (1.32), and less in carp fed with maize and wheat (0.42). UFA/SFA ratio was also the best in carp fed a complete feed (3.51), while in carp fed maize and wheat it was 3.18 and for three year old carp fed barley, maize and wheat the ratio was 3.00. due to high content of MUFA in lipids of carp fed corn and wheat (64.78%), which was lower in the carp fed with barley, maize and wheat (57.98%) and the lowest in common carp fed a complete food (47.98%).

Table 8. Fatty acid composition of three-year old carp grown in different conditions
Tabela 8. Sastav masnih kiselina u trogodišnjim šaranima gajenim u različitim uslovima

Fatty acids/ Masne kiseline, %	Carp, three years old, corn and wheat/ Trogodišnji šaran. kukuruz i pšenica	Carp, three years old, barley, wheat and corn/ Trogodišnji šaran, ječam, kukuruz i pšenica	Carp, three years old, complete feed/ Trogodišnji šaran, kompletna smeša
Lauric acid/Laurinska kiselina, C12:0	0.13 ± 0.01a	0.16 ± 0.02b	0.15 ± 0.02b
Myristic acid/Miristoleinska kiselina, C14:0	0.75 ± 0.01a	0.76 ± 0.01a	0.74 ± 0.01b
Pentadecanoic acid/Pentadekanska kiselina, C15:0	0.02 ± 0.02a	0.11 ± 0.00b	0.1 ± 0.00b
Palmitic acid/Palmitinska kiselina, C16:0	16.93 ± 0.03a	18.38 ± 0.15b	16.04 ± 0.05c
Palmitoleic acid/ Palmitoleinska kiselina, C16:1	6.01 ± 0.02a	7.28 ± 0.05b	4.32 ± 0.01c
Margaric acid/ Margarinska kiselina, C17:0	0.14 ± 0.01a	0.20 ± 0.01b	0.18 ± 0.00c
Stearic acid/Stearinska kiselina, C18:0	5.84±0.01a	5.21±0.05b	4.88±0.00c
Oleic acid/Oleinska kiselina, C18:1cis-9	51.76 ± 0.13a	44.63 ± 0.11b	41.96 ± 0.07c
Vaccenic acid/Vakcenska kiselina,C18:1cis-11	4.71 ± 0.02a	4.24 ± 0.08b	0 ± 0.00c
Linoleic acid/ Linolna kiselina, C18:2. ω-6	8.17 ± 0.02a	12.32 ± 0.11b	24.06 ± 0.02c
Linolenic(GLA)/Linolenska kiselina, C18:3.ω-6	0.12 ± 0.00a	0.16 ± 0.02b	0.18 ± 0.01c
α-Linolenic/α-Linolenska kiselina, C18:3. ω-3	0.28 ± 0.01a	1.54 ± 0.02b	2.25 ± 0.02c
Arachidic acid/Arahidska kiselina, C20:0	0.12 ± 0.01a	0.11 ± 0.01b	0.10 ± 0.01b
Eicosenoic acid/Eikosenska kiselina, C20:1	2.44 ± 0.01a	2.02 ± 0.01b	1.7 ± 0.00c
Behenic acid/ Behenska kiselina, C20:2	0.28 ± 0.01a	0.40 ± 0.01b	0.64 ± 0.04c
Dihomo-gamma-linolenic acid/ Di-homo-gama-linolenska kiselina, C20:3. ω-6	0.70 ± 0.04a	0.60 ± 0.01b	0.79 ± 0.08c
Eicosatrienoic acid/ Eikosatrienoična kiselina, C20:3. ω-3	0.02 ± 0.02a	0.12 ± 0.01b	0.26 ± 0.01c
Erucic acid + Arachidonic acid/ Eruična kiselina + arahidonska kiselina, C22:1+20:4	0.99 ± 0.04a	0.69 ± 0.01b	0.59 ± 0.01c
Eicosapentaenoic acid/ Eikosapentaenska kisleina, C20:5. ω-3	0.14 ± 0.01a	0.40 ± 0.01b	0.28 ± 0.00c
Docosapentaenoic acid/ Dokosapentaenska kiselina, C22:5. ω-3	0.16 ± 0.01a	0.19 ± 0.01b	0.18 ± 0.01c
Docosahexaenoic acid/ Dokosaheksaenska kiselina, C22:6. ω-3	0.30 ± 0.02a	0.33 ± 0.02b	0.66 ± 0.02c
SFA/ZMK	23.93 ± 0.05a	24.93 ± 0.15b	22.19 ± 0.05c
MUFA/MNMK	64.78 ± 0.12a	57.98 ± 0.14b	47.98 ± 0.07c

PUFA/PNMK	10.17 ± 0.06a	16.06 ± 0.11b	29.30 ± 0.11c
ω-6	9.27 ± 0.04a	13.48 ± 0.10b	25.67 ± 0.09c
ω-3	0.90 ± 0.03a	2.58 ± 0.04b	3.64 ± 0.04c
ω-3/ω-6	0.10 ± 0.00a	0.19 ± 0.00b	0.14 ± 0.00c
ω-6/ω-3	10.28 ± 0.37a	5.22 ± 0.08b	7.06 ± 0.07c
PUFA/SFA NMK/ZMK	0.42 ± 0.00a	0.64 ± 0.01b	1.32 ± 0.01c
UFA/SFA NMK/ZMK	3.18 ± 0.01a	3.00 ± 0.02b	3.51 ± 0.01c

Legend/Legenda: SFA-saturated fatty acids/zasićene masne kiselina, MUFA-monounsaturated fatty acids/mono nezasićene masne kiseline, USFA-unsaturated fatty acids/nezasićene masne kiseline, PUFA-polyunsaturated fatty acids from the n-3 (n-3 PUFA) and n-6 (n-6 PUFA) families/poli nezasićene masne kiseline iz n-3 (n-3 PNMK) i n-6 (n-6 PNMK) grupa
Values are means ± SD (n = 12); Values in the same row with different letter notation statistically significantly differ at $p < .01$/Vrednosti u tabeli su srednje vrednosti ± SD (n = 12); Vrednosti u istom redu sa različitim slovnim oznakama se razlikuju signifikantno na nivou $p < 0.01$.

According to research conduced by *Buchtová et al.* (2010) and *Ćirković et al.* (2010), carp grown on natural food had a high content of both n-6 and n-3 fatty acids. while carp fed grains, which are characterized by low levels of n-3 PUFA (*Buchtová et al.*, 2010; *Ćirković et al.*, 2011), contained lower concentrations of these fatty acids, becouse of a higher concentration of oleic acid *(Steffens et al*. 1998). The above statements are in agreement with our results, where higher content of oleic acid (51.76%) was observed in the carp fed corn, as dominant energy source. than in the carp fed with barley as dominant grain (44.63%). The lowest percentage of oleic acid has been reported in carp fed a complete mixture (41.96%). This difference is much more drastic in two-years old carp whose diet had the largest share of maize (51.35%), while the carp of the same age fed pelleted food contained 34.45% oleic acid. It is known that the application of formulated feed impact the values of many zootechnical coefficients, including, among others, the slaughter yield, proximate composition, and fatty acids profile (*Shearer*, 1994; *Jobling,* 2001).

All sampling was performed in the winter months, when the water temperature was low. *Cordier et al*. (2002) and *Tocher et al*. (2004) demonstrated the importance of temperature on fatty acid composition in lipids of fish. The most important effect of temperature is reflected in desaturation of fatty acids and their betatoxidation. so that proportion of unsaturated fatty acids decreases with the increase of temperatutre. The established n-3/n-6 ratios in different categories were in the range 0.1 to 0.26. The most favourable ratio was observed in two year old carp fed pelleted food and the least favourable in three-years old carp fed corn as dominant component in food. The obtained results are consistent with studies conducted by *Trbović et al.,* (2009) on the yearling carp, but the ratio is lower than the results obtained by *Ćirković et al*. (2010) for two years old carp fish fed with natural food. The dependence of n-3/n-6 relationship and the age and diet was established in our work. This ratio, also, varies widely between different species of fish, which is also confirmed. According to Steffans and *Wirth* (2005) the n-3/n-6 ratio in common carp varies to a large extent, between 0.08 and 2.4 and is most influenced by diet.

Freshwater fish contain high levels of n-3 polyunsaturated fatty acids, which are very important in human nutrition. Essential fatty acids affect the fluidity, flexibility, and permeability of membranes. They are precursors of the eicosanoids and are necessary for maintaining the impermeability barrier of the skin. They are also involved in cholesterol transport and metabolism *(Steffens and Wirth*, 2005). Components of fish are also important in the development and maintenance of the eyes. skin and nervous system (*Vladau et al.,* 2008). Since there are several biochemical interactions between n-6 and n-3 series, a balanced proportion of these fatty acids in the diet is important for the functioning of human and animal life.

Nutritive quality of freshwater fish is even better than quality of sea fish since fatty acid composition of freshwater fish is also characterized by high proportions of n-6 polyunsaturated fatty acids, especially linoleic and arachidonic acids. The ratio of total n-3 to n-6 fatty acids is much lower for freshwater fish than for sea fish (*Malović et al.*. 2010) and ranges from about 0.5 to 3. Unlike sea fish, freshwater fish are able to desaturate and elongate larger quantities of dietary C18 n-6 and C18 n-3 fatty acids to C20 and C22 desaturates (*Steffens and Wirth*, 2005) In addition to nutritional quality of fish from aquaculture in our country, due to the growing technologies in fish ponds, residues of antibiotic in meat of fish were not found (*Đorđević et al,* 2009).

Conclusion

Dependence of n-3/n-6 ratio with age and diet was established in our work. This ratio also varies widely between different species of fish, which is also confirmed. The class of PUFAs and HUFAs are crucial in terms of human feeding physiology. Fish provides not only n-3 fats, but the abundance of vitamins, minerals and nutrients. Fish proteins contain all essential amino-acids for the human organism, with a high biological value. Chemical composition of fish varies greatly from one species and one individual to another, depending on age, feed, environment and season. Lipid content of fish varies depending on type of fish, age, the time of the year and what the fish feeds on. Lipid content of farmed fish can vary widely depending on the feed used. Quantity of n-3 fatty acids varies largely in dependence on the fish species (herbivorous. omnivorous or carnivorous), on the age of fish and on origin of diets (natural food or cereal supplement) and its composition (rich primarily in PUFA n-3 or saccharides). Nutritive value of the examined freshwater fish is high, since their fatty acid composition is characterized by satisfactory proportion of n-3 polyunsaturated fatty acids and by high proportion of n-6 polyunsaturated fatty acids. especially linoleic and arachidonic acids.

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Kvalitet mesa riba gajenih u polikulturi u ribnjacima u Republici Srbiji

Ćirković Miroslav, Trbović Dejana, Ljubojević Dragana, Đorđević Vesna

R e z i m e: Kvalitet mesa jednogodišnjeg. dvogodišnjeg i trogodišnjeg šarana. dvogodišnjeg tolstolobika i amura, kao i dvogodišnjeg soma i smuđa, koji su gajeni u različitim sistemima proizvodnje i sa različitim načinima ishrane analiziran je u ovom radu. Po dvanaest uzoraka od svake vrste, kao i navedene starosne kategorije ribe uzeto je sa tri različita ribnjaka u decembru. Hemijske analize, određivanje sadržaja masnih kiselina i ukupnog holesterola sprovedene su u Institutu za higijenu i tehnologiju mesa, Beograd. Statističke analize su urađene u programu Statistica. Odnos n-3/n-6 masnih kiselina kod različitih kategorija šarana kretao se u opsegu od 0.1 do 0.26, pri čemu je najpovoljniji odnos ustanovljen kod dvogodišnjaka, koji su hranjeni peletiranom hranom, a najnepovoljniji kod trogodišnjaka kod kojih je kukuruz predstavljao dominantnu komponentu u ishrani. Zavisnost n-3/n-6 u odnosu na starost i način ishrane je ustanovljena u našem radu. Takođe, ovaj odnos veoma varira između različitih vrsta riba, što je takođe potvrđeno. Nutritivna vrednost ispitivanih slatkovodnih riba je visoka, pošto se njihov masnokiselinski sastav karakteriše zadovoljavajućom količinom n-3 polinezasićenih masnih kiselina, a i sa visokim sadržajem n-6 polinezasićenih masnih kiselina, od koji su posebno značajne linolna i arahidonska.

***Ključne reči:** ribe, polikultura, starost, ishrana, masti, protein, ukupni holesterol, masnokiselinski sastav.*

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