Kafkas Univ Vet Fak Derg
19 (1): 43-49, 2013
DOI: 10.9775/kvfd.2012.7088

Journal Home-Page: http://vetdergi.kafkas.edu.tr
Online Submission: http://vetdergikafkas.org

RESEARCH ARTICLE

Productivity and Meat Nutrient in Fish: The Diet Effect

Dragana LJUBOJEVIĆ * Miroslav ĆIRKOVIĆ * Nikolina NOVAKOV *
Rade JOVANOVIĆ ** Snežana JANKOVIĆ ** Vesna ĐORĐEVIĆ ***
Zoran MAŠIĆ ****

* Department of Veterinary Medicine, Faculty of Agriculture, University of Novi Sad, 21000 Novi Sad, Republic of Serbia
** Institute for Science Application in Agriculture, 11000 Belgrade, Republic of Serbia
*** Institute of Hygiene and Meat Technology, 11000 Belgrade, Republic of Serbia
**** Scientific Veterinary Institute "Novi Sad", 21000 Novi Sad, Republic of Serbia

Makale Kodu (Article Code): KVFD-2012-7088

Summary

Meat quality of carp varies by age and rearing system as well as feed consumed. The aim of the study was to determine the impact of the diet on the survival rate, yield per unit of area, chemical composition, the amount of total cholesterol and fatty acid profile of two-year old common carp (*Cyprinus carpio* L.) reared in the basic culture systems. Fish were grown in the similar ponds and subjected to 1 of 3 feeding systems: only natural food (extensive system), supplemental grain (semi-intensive system), and extruded formula consisting of soybean, sunflower kernel, wheat flour, corn and brewery yeast (intensive system). Feeding extruded formula doubled production per hectare of pond surface area, compared with feeding supplemental grain and almost thrice compared with feeding only natural food. The n-3/n-6 ratio varied widely by the diet. Carp fed extruded formula yielded the most preferable the unsaturated fatty acid:saturated fatty acids and polyunsaturated fatty acids:saturated fatty acids ratios. In conclusion, the provision of processed plant meals can be an important protein source for common carp to improve productivity and food quality.

Keywords: *Productivity, Common carp, Meat nutrients, Nutrition, Rearing system*

Balıklarda Verimlilik ve Et Besin Bileşimi: Yemin Etkisi

Özet

Sazan balığının et kalitesi yaş ve yetiştirme sisteminin yanı sıra tüketilen yeme göre de değişir. Çalışmanın amacı; temel kültür sistemlerinde yetiştirilen iki yaşlı sazanlarda (*Cyprinus carpio* L .) farklı diyetlerle sağkalım oranı, birim yetiştirme alanından elde edilen verimlilik ve et besin bileşimi, total kolesterol ile yağ asidi profiline etkisini araştırmaktı. Aynı gölette büyütülen ba balıklarda; 1-Sadece doğal gıda (ekstansif sistem), 2- Tahıl takviyesi (yarı-entansif sistem) veya 3-Soya, ayçiçeği, buğday unu, mısır, malt içeren ekstrude karışım (entansif sistem) ile beslendi. Ekstrude karışımla besleme verimliliği hektar olarak gölet yüzeyine göre; tahıl takviyesi yapılanlara kıyasla iki, sadece doğal gıda sağlananlara göre ise üç kat artırmış oldu. Etlerdeki n-3:n-6 oranı diyete bağlı olarak varyasyon gösterdi. İnsan tüketimi için tercih edilen doymamış: doymuş yağ asidi ve çoklu doymamış: doymuş yağ asidi oranı ekstrude karışımla beslenen balıkların etinden elde edildi. Sonuç olarak, yeterli miktarda işlenmiş bitkisel küspe ve ürünlerin kullanımı sazanlar için önemli protein kaynağı olabilir ve ürünün gıda kalitesini artırabilir.

Anahtar sözcükler: *Verimlilik, Sazan, Et besin bileşimi, Besleme, Yetiştirme sistemi*

INTRODUCTION

Common carp is the most widespread fish species in Serbia. Alike other fish species, common carp cannot synthesize the essential fatty acids of the n-6 and n-3 series. Hence, these fatty acids must be provided by the feed. Their original food sources are phytoplankton and zooplankton [1] that are rich in proteins, fats, free amino acids, fatty acids, oligopeptides and vitamins. Carp farms rely on natural food during the production cycle, which is known as extensive culture system and characterized by low yield. This production system is dependent on pond fertility and economically feasible [2]. The main type of fish production in Serbia is the semi-intensive system for cyprinid production, carp being as the major

İletişim (Correspondence)
+381 64 2745389
ljubojevic.ljubojevicd.dragana@gmail.com

species. In addition to natural food, cereals are supplemented to meet protein requirement. Some fish farms increase production by introducing extruded complete feed for carp[3]. The cost of inputs per unit of fish weight is higher than in extensive and semi-intensive farming, especially because of the high cost of fish feed that contains a high level of protein with a balanced amino acid composition. High cost can be overcome by replacing animal origin feedstuffs with local available vegetable-derived protein ingredients. Many cultured warm-water fish, including carp, require no meat or fish products in their diets [4-6].

The use of plant-derived materials such as legume seeds and different types of oilseed cake contain a wide variety of antinutritional substances, including phytates, glucosinolates, saponins, tannins, lectins, oligosaccharides and non-starch polysaccharides, phytoestrogens, alkaloids, antigenic compounds, gossypols, cyanogens, mimosine, cyclopropenoid fatty acids, canavanine, antivitamins, and phorbol esters [7] that limit feed utilization. Extrusion is used to make plant protein more available to animals through denaturing termolabile antinutritional factors, resulting in improved nutrient digestibility, palatability, pellet durability, water stability, and pellet storage life [8]. Common carp meat is rich in protein and n-3 polyunsaturated fatty acids (PUFA), including eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids [9]. The typical fatty acid composition of fish species is strongly affected by the diets, sex and environmental conditions [10]. Beside PUFA, fish fats contain cholesterol. Fish meat cholesterol content (490-920 mg kg^{-1}) is similar to pork or beef (450-840 mg kg^{-1}) [11]. The aim of the study was to determine the impact of the diet on the survival rate, yield per unit of area, chemical composition, amount of total cholesterol and fatty acids profile of two-year old common carp (*Cyprinus carpio* L.) reared in the extensive, semi- intensive and intensive systems.

MATERIAL and METHODS

Pond Management and Fish Samples

The growth trial was carried out at the experimental fish farm (Mošorin, Serbia) with common carp (*Cyprinus carpio* L.) obtained from a commercial fish farm. Fish were grown in three earthen ponds each of 1 ha where were left dry and untreated during winter. The initial density of carp per hectare was equal, 2500 individuals. The average initial live weight of all fish was 250 g *(Table 3)*. The production in first pond was based on natural food consisting of benthic and planktonic organisms (extensive system). In the second pond additional feeding was done with mixture of corn (80%) and wheat (20%) (semi-intensive system). In the last pond, the common carp was supplemented with extruded formulated feed mixture (intensive system). During the experiment, the water temperature, dissolved oxygen content and pH were measured biweekly in the morning hours (around 9.00 h). The water quality parameters did not differ significantly between the ponds. The content of dissolved oxygen was highly variable, ranging from 1.4 to 14.8 (mg $O_2 l^{-1}$). The pH varied from 7.04 to 8.62, while temperature of water ranged from 15 to 28.7°C.

Soybean meal, brewery yeast, wheat flour and corn were used as ingredients for extruded formula. Ingredients were mixed and extruded using a twin screw extruder in Animal Feed Manufactory (Komponenta, Ćuprija, Republic of Serbia). Composition of formulated feed is shown in *Table 1* and fatty acid compositions of supplemental grains and extruded formula are shown in *Table 2*.

The experimental carp were measured biweekly in order to adjust the daily feed rate that was 3 % of the total fish mass. Fish were hand-fed twice daily at 8:00 and 15:00 h.

Table 1. *Composition and proximate analysis of the extruded formula diet*
Tablo 1. *Ekstrude formulanın içerik ve besin madde kompozisyonu*

Ingredients	g kg^{-1} dry diet	Chemical analysis	g kg^{-1} dry diet
Soybean meal	450	Dry matter (DM)	897.1
Sunflower kernel	150	Crude protein (CP)	280.6
Brewery yeast	50	Crude fat (CF)	63.3
Wheat flour	146	Crude ash (CA)	41.6
Corn	180	NFE[3]	61.4
Methionin	1	Gross energy (MJ·kg^{-1} DM)[4]	102.5
Lysine L	3		
Vitamin mix[1]	10		
Mineral mix[2]	10		

[1] Vitamin mix (mg/kg^{-1} of diet): vitamin B_1, 15; vitamin B_2, 10; vitamin B_6, 20; vitamin B_{12}, 0,15; vitamin K_3, 15; inositol, 250; Ca-pantothenic acid, 80; nicotinic acid, 100; folic acid, 1; vitamin H (biotin), 1; vitamin E, 140; vitamin C, 500; vitamin A, 20.000 IU; vitamin D_3, 6.000 IU; choline chloride, 1.800, and cellulose was used as a carrier, [2] Mineral mix (mg kg^{-1} of diet): Cu 20, Fe 40, Mn 30, Se 0.4, Zn 125, and cellulose was used as a carrier , [3] NFE, nitrogen-free extract, g.kg^{-1} DM = 100 - (CP + CF + CA), [4] Calculated based on the following conversion factors: CP – 24 kJ g^{-1}, CL – 39 kJ g^{-1}, NFE - 17 kJ g^{-1} [13] (Jobling 1994)

Table 2. *Fatty acid composition of the experimental diets*
Tablo 2. *Deneme diyetlerinin yağ asidi bileşimi*

Fatty Acid (% of the Total Lipid Fatty Acids)	Grain Mixture (80% Corn + 20% Wheat)	Extruded Formula
Myristic acid, $C_{14:0}$	0.40	0.47
Palmitic acid, $C_{16:0}$	10.86	10.98
Palmitoleic acid, $C_{16:1}$	0.16	0.48
Stearic acid, $C_{18:0}$	2.02	2.74
Oleic acid, $C_{18:1cis\text{-}9}$	27.62	26.32
Vaccenic acid, $C_{18:1\ cis\text{-}11}$	0.16	0.82
Linoleic acid, $C_{18:2n\text{-}6}$	56.15	54.15
αLinolenic acid, $C_{18:3n\text{-}3}$	0.98	2.23
Arachidic acid, $C_{20:0}$	0.38	0.3
Eicosenoic acid, $C_{20:1}$	0.20	0.34
Behenic acid, $C_{20:2}$	0.26	0.22
Dihomogammalinolenic acid, $C_{20:3n\text{-}6}$	0.61	0.58
Eicosatrienoic acid, $C_{20:3n\text{-}3}$	-	0.32
Arachidonic acid, $C_{20:4}$	-	0.06
Lignoceric acid, $C_{24:0}$	0.17	0.19
SFA	13.83	14.55
MUFA	28.14	27.96
PUFA	58	57.56
n-6	57.02	55.01
n-3	0.98	2.55
n-3/n-6	0.02	0.05

Measurements

The fishponds were stocked in March and harvested in October. Growth-performance indicators [body weight gain (BWG), specific growth rate (SGR), feed conversion ratio (FCR), weight gain (WG) and survival rate (SR)] were measure using following formulas:

SGR = 100 (Ln (mean final body weight)-Ln (mean initial body weight))/time (days);

FCR = dry feed intake (g)/wet weight gain (g);

SR(%) = (Final fish number/initial fish number)*100;

WG = Final body weight (g)- initial body weight(g) (g fish^{-1});

BWG(%) = 100*(mean final weight-mean initial weight)/ mean initial weight

All fish were reared under variable natural atmospheric conditions. Natural production in each pond was increased by application of agrotechnical measures such as drying of fish ponds during winter, soil treatment, fertilization and adding lime. Livestock manure (2.000 kg ha^{-1}) was applied to the bottom of each empty pond and later biweekly over the water surface (a total of 4.000 kg ha^{-1} during growing season). Agricultural limestone (250 kg ha^{-1}) was provided to increase total alkalinity and total hardness of pond water, to the bottom of each empty pond and over the water surface. The same methods of cultivation and fertilization were applied in all the ponds. The aeration of the fish ponds was continuously secured by using an aerator pre pond. The water flow was about 3.5 l s^{-1}, that provided that there were no adverse effects of carbon dioxide and ammonia on the carp.

Laboratory Analyses

Twelve samples of two years old carp were taken from each pond during the harvesting. Also, samples of supplemental grain and extruded formula were taken and stored at –18ºC until analyses. The meat from dorsal muscles without skin was used for chemical analyses. Water content of fish fillets was determined after drying the samples at 105ºC to constant weight for 24 h (SRPS ISO 1442:1997). Crude protein content was determined by Kjeldahl method (Manual book, Kjeltec Auto 1030 Analyzer, Tecator, Sweeden) and ash was determined after burning at 550±25°C (SRPS ISO 936:1998). Crude lipid in fish tissue was also analyzed using the Soxhlet System with ether as solvent (SRPS ISO 1443:1997). Fatty acids determination was performed according to Spirić et al.[12]. Cholesterol determination in carp fillets (from direct saponification) was performed by using HPLC/PDA system (Waters 2695 Separation module/Waters photodiode array detector, USA) on a Phenomenex Luna C18 reverse/phase column, according to Maraschiello et al.[13]. In quantification of cholesterol, external standardization was used, along with Empower Pro software to control the HPLC system for data acquisition and data processing as described [14].

Statistics

The group effect was determined using one-way ANOVA (Statistica 10.0, StatSoft Inc.). Inter-group differences were attained by the Tukey HSD test at P≤0.01. The results were presented as means ± SE.

RESULTS

Performance

The harvesting weight, survival rate, harvesting density, and specific growth rate were the greatest in intensive system and lowest in extensive system. At the end of the rearing period in October the average final live weight of carp in the group that had been fed on natural food was 462.58 g. Final live weight of carp in the group that had been given grains supplementary feeding was 754.08 g and in the group that had been formula feed feeding was 1188.75 g. Total harvesting density was 994.5 kg/ha in extensive, 1696.68 kg/ha in semi-intensive and 2734.12 kg/ha in intensive system *(Table 3)*. Feeding extruded formula increased production per hectare of pond surface area almost doubled compared with feeding supplemental grains and almost thrice compared with feeding only natural food.

Nutrient Composition

Carp reared in intensive system had the greatest protein and moderate lipid, ash, and cholesterol contents *(Table 4)*. Expectedly, rearing in extensive system reduced total lipid and cholesterol contents.

Fatty Acid Profile

Rearing in extensive system resulted in the greatest total SFA level in meat of carp, particularly of palmitic and stearic acids *(Table 5)*. In the semi-intensive system, MUFA was the greatest, predominantly of oleic acid. Carp that ingested

Table 3. *Growth performance of common carp reared in three different culture systems*
Tablo 3. *Üç farklı kültür sisteminde yetiştirilen sazanların büyüme performansı*

Variable	Rearing system		
	Extensive (Only Natural Food)	**Semi-intensive (Grain Mixture (80% Corn + 20% Wheat)**	**Intensive (Extruded Formula)**
Initial number of fish (ind ha^{-1})	2500	2500	2500
IBW (g)	250±16.04	250±24.92	253±15.86
FBW (g)	462.58±31.32^c	754.08±28.12^b	1188.75±49.4^a
Final number of fish (ind ha^{-1})	2150	2250	2300
Survival rate (%) SR	86	90	92
Stocking density (kg ha^{-1})	625	625	632.5
Harvesting density (kgha^{-1})	994.5	1696.68	2734.12
WG (gfish^{-1})	212.58	504.08	935.75
BWG%	85.03	201.63	369.86
SGR (%day^{-1})	0.26	0.47	0.66
FCR (g·g^{-1})		2.7	1.86

[1] *Data are means ± SE (n = 12). Values within the same row with different letter supercripts differ at P<0.01,* [2] ***IBW,*** *initial body weight;* ***FBW,*** *final body weight;* ***SR,*** *survival rate;* ***SGR,*** *specific growth rate;* ***FCR,*** *feed conversion ratio;* ***WG,*** *weight gain;* ***BWG,*** *body weight gain*

Table 4. *Proximate analysis results of common carp reared in three different culture systems*
Tablo 4. *Üç farklı kültür sisteminde yetiştirilen sazanların besin madde kompozisyonu*

Variable	Rearing system		
	Extensive (Only Natural Food)	**Semi-intensive (Grain Mixture (80% Corn + 20% Wheat)**	**Intensive (Extruded Formula)**
Moisture (g kg^{-1})	814.9±3.2^a	764±1.8^c	783.5±0.4^b
Crude protein (g kg^{-1})	154.8±2.8^b	155.9±2.1^b	171.7±0.5^a
Crude lipid (g kg^{-1})	20.7±1.1^c	68.5±1.4^a	31.9±0.5^b
Crude ash (g kg^{-1})	09.6±0.9^c	11.6±0.7^a	10.3±0.1^b
Total cholesterol (mg kg^{-1})	379.4±0.2^c	578±1.1^a	513.1±1.2^b

[1] *Data are means ± SE (n = 12). Values within the same row with different letter supercripts differ at P<0.01*

only natural food had higher n-3 fatty acids in the muscle than carp that received supplemental wheat or extruded formula *(Table 5)*. However, common carp reared in intensive culture system had higher n-6 fatty acids than carp reared other two culture systems. Thus, the total amount of PUFA was higher in muscle triacylglycerol of carp fed with extruded formulated feed compared to carp fed only on natural food. This is reflection of dietary fat being transferred to body tissues.

The n-3/n-6 ratio of the fish muscle was the highest in carp fed only on natural food, followed by carp fed extruded formula and the lowest value was observed in carp that received supplemental wheat. The highest level of n-3 fatty acids was found in the muscle of carp that received only natural food and the lowest in carp fed supplemental grains.

In two year-old carp fed extruded formula was observed the best ratio UFA/SFA, PUFA/SFA, the highest content of PUFA, the lowest content of SFA compared with other two groups. Lipids of carp in intensive production contained less MUFA (45%) than carp from the semi-intensive production (64%).

DISCUSSION

Performance

Supplementary feeding with grains leads to improved growth performance in common carp, and especially feeding with extruded formula. Survival rate in carp that ingested only natural food was lower than in carp fed grains, as well as than in carp fed formulated feed. In general, in all groups the survival rate was satisfactory and it was within the range considered normal for carp pond production in Republic of Serbia. Additional feeding with grains almost doubled average final body weight, while carp that received extruded formula showed three fold higher final body weight than carp fed only natural food and that lead to doubled harvesting density in semi-intensive system and threefold higher harvesting density in intensive system compared with extensive. Consequently, all growth parameters were the highest in intensive system and lowest in extensive system. That fact justified the use of supplemental feed in the rearing of carp and it represents a major opportunity to increase production in carp ponds. The growth parameters and total production of the carp were quite affected by that of the diets. Using adequately prepared extruded formula can further improve growth performance and yield of fish per unit of area. Administered extruded feed results in good growth and feed conversion. Higher temperature influenced the significantly higher growth rate of common carp in region of Republic of Serbia compared with Central Europe [9]. Besides the direct effect of using feed containing high protein indirect effect was achieved through nitrogen and phosphorus, which are released during digestion of formulated feed and increased development of natural food in the pond [3]. The positive effect is certainly significant in maintaining a better quality of water environment.

Nutrient Composition

In the literature, depending on age, rearing system, and food, fat content varies from 23 to 168 g kg^{-1}DM and protein content varies from 140 to 180 g kg^{-1} in carp [15-17]. In the present trial nutrient composition was highly depended on the diet. Supplementary feeding with grains leads to enlarged amounts of crude lipid in fish meat and it was doubled higher compared to supplementary feeding with extruded formula and three-fold higher compared to carp which ingested only natural food. The fillets obtained from the experimental fish were characterized by a varied content of fat and water. The same regularity was observed by Ćirković et al.[18]. The varied content of fat was compensated by the content of water, which is in agreement with the results obtained by Żmijewski et al.[19] who found a reverse correlation between the fat and water contents, which is common for many fish species. Crude protein level was the highest in the fillets of carp from intensive system, while there were no significant difference in the amount of protein in fillets of carp from extensive and semi-intensive systems. Cholesterol content in fish meat is not correlated with fat content [11]. Trbović et al.[16] reported that the amounts of total cholesterol in lipids were 490 mg kg^{-1} in one-year old carp harvested in April and 540 mg kg^{-1} in one-year old carp harvested in June. Data about influence of diet and rearing systems on cholesterol content in carp are limited. However, it is known that cholesterol content in lipids of carp varies considerably, within the range of 470-1.200 mgkg^{-1} [20,21]. Total cholesterol content in the present research was the highest in semi-intensive system and the lowest in extensive system, but in all groups was favourable and within the previously mentioned [20,21]. This great variability could be related to harvest season and age as well as rearing system.

The present results confirms that proximate composition of common carp highly depends of diet [22]. The fat content in fish meat contributes to its juiciness, tastefulness and texture, as well as organoleptic properties. Lipid content in fillets from extensive system was very low and such lean tissue is dry and perceived as thickly fibrous. On the other hand, there are certain groups of people who require meat with minimal fat and cholesterol content.

Fatty Acid Profile

The preference for a feed rich in saccharides leads to an increase in the percentage of the oleic acid in body lipids of the fish, which is produced in the organism by desaturation and elongation of SFA [23]. At the same time, proportion of PUFA n-3 decreases [23,24]. Supplementary feeding with grains leads to reduced amounts of essential fatty acids in fish meat and this is due to the lower proportion of natural food in the diet of the carp which received additional grains.

The two fatty acids 18:2n-6 and 18:3n-3 are precusors for synthesis of n-6 and n-3 PUFAs, recpectively [25]. Carp that received extruded formula showed high values of n-6 fatty

Table 5. *Fatty acid composition of common carp reared in three different culture systems*
Tablo 5. *Üç farklı kültür sisteminde yetiştirilen sazanların yağ asidi profili*

Fatty Acids (% of the Total Lipid Fatty Acids)[2]	**Rearing system**		
	Extensive (Only Natural Food)	**Semi-intensive (Grain Mixture (80% Corn + 20% Wheat)**	**Intensive (Extruded Formula)**
Lauric acid, $C_{12:0}$	0.05±0.02[c]	0.14±0.01[a]	0.10±0.01[b]
Myristic acid, $C_{14:0}$	1.14±0.07[a]	0.71±0.03[b]	0.73±0.01[b]
Pentadecylic acid, $C_{15:0}$	0.49±0.12[a]	0.01±0.01[b]	0.23±0.01[b]
Palmitic acid, $C_{16:0}$	20.99±0.28[a]	17.31±0.09[b]	16.89±0.03[b]
Margaric acid, $C_{17:0}$	0.69±0.09[a]	0.12±0.01[b]	0.18±0.005[b]
Stearic acid, $C_{18:0}$	5.26±0.2[b]	5.79±0.02[a]	4.16±0.01[c]
Arachidic acid, $C_{20:0}$	0.19±0.05[a]	0.11±0.02[b]	0.10±0.005[b]
SFA	28.82±0.36[a]	24.19±0.11[b]	22.4±0.03[c]
Palmitoleic acid, $C_{16:1}$	5.15±0.07[b]	6.23±0.01[a]	5.2±0.04[b]
Oleic acid, $C_{18:1cis\text{-}9}$	32.58±0.42[c]	51.35±0.04[a]	34.45±0.01[b]
Vaccenic acid,$C_{18:1cis\text{-}11}$	4.26±0.13[b]	4.54±0.04[a]	2.93±0.01[c]
Eicosenoic acid, $C_{20:1}$	1.51±0.18[c]	2.19±0.05[b]	2.54±0.01[a]
MUFA	43.49±0.42[c]	64.31±0.09[a]	45.12±0.03[b]
Linoleic acid, $C_{18:2,\ n\text{-}6}$	13.49±0.25[b]	8.7±0.13[c]	22.57±0.01[a]
Linolenic(GLA)$C_{18:3,\ n\text{-}6}$	0.19±0.07[b]	0.11±0.02[c]	0.25±0.01[a]
α-Linolenic, $C_{18:3,\ n\text{-}3}$	4.59±0.19[a]	0.61±0.06[c]	2.12±0.01[b]
Behenic acid, $C_{20:2}$	0.7±0.08[a]	0.27±0.05[b]	0.73±0.01[a]
Dihomo-gamma-linolenic acid, $C_{20:3,\ n\text{-}6}$	0.77±0.12[b]	0.43±0.04[c]	1.02±0.01[a]
Eicosatrienoic acid, $C_{20:3,\ n\text{-}3}$	0.86±0.1[a]	0.06±0.02[c]	0.71±0.01[b]
Arachidonic acid, $C_{20:4}$	2.79±0.21[a]	0.73±0.04[c]	1.44±0.01[b]
Eicosapentaenoic acid, $C_{20:5,\ n\text{-}3}$	1.17±0.1[a]	0.2±0.02[c]	0.93±0.01[b]
Docosapentaenoic acid, $C_{22:5,\ n\text{-}3}$	0.91±0.11[a]	0.18±0.03[b]	0.85±0.02[a]
Docosahexaenoic acid, $C_{22:6,\ n\text{-}3}$	2.22±0.3a	0.25±0.04[c]	1.86±0.04[b]
PUFA	27.69±0.39[b]	11.53±0.15[c]	32.48±0.03[a]
n-6	17.93±0.36[b]	10.24±0.13[c]	26.01±0.04[a]
n-3	9.75±0.35[a]	1.29±0.1[c]	6.48±0.04[b]
n-3/n-6	0.54±0.03[a]	0.13±0.01[c]	0.25±0.001[b]
n-6/n-3	1.84±0.09[c]	7.99±0.66[a]	4.02±0.03[b]
PUFA/SFA	0.64±0.01[b]	0.18±0.002[c]	0.72±0.001[a]
UFA/SFA	0.96±0.02[b]	0.48±0.008[c]	1.45±0.003[a]
PUFA/MUFA	2.47±0.04[c]	3.13±0.02[b]	3.46±0.01[a]

[1] Data are means ± SE (n = 12). Values within the same row with different letter supercripts differ at P<0.01, [2] ***SFA*** *= saturated fatty acids;* ***MUFA*** *= monounsaturated fatty acids;* ***USFA*** *= unsaturated fatty acids,* ***PUFA*** *= polyunsaturated fatty acids from the n3 (n3 PUFA) and n6 (n6 PUFA) families*

acids in their muscle, based on the high content of linoleic acid in the diets. However, although grain mixture contained slightly higher amount of linoleic acid than formulated feed, percentage of this fatty acid was lower than in carp fed formulated feed, as well as than in carp which ingested only natural food, but the absolute content of linoleic acid was 2-3 folds greater in muscle of carp fed grains compared with muscle of carp fed only natural food. In general, in all groups the content of the n-6 fatty acids was higher than the content of n-3 fatty acids. The fatty acid composition of the carp muscle triacylglycerols was quite affected by that of the diets. Diets containing soybean or corn were characterized by high linoleic acid content. High contents of n-6 fatty acids in the grain based and extruded formulated (soybean meal, sunflower cernel, wheat flower and corn) diet resulted in high levels of these fatty acids in the carp meat.

The fatty acid composition of common carp reflects, to a large extent, that of the diet. The n-3/n-6 ratio varies between 0.8 and 2.4 [9]. There are reports indicating this ratio is about 0.5 [17,21], even less, about 0.2 [16,26]. Ackman [27] reported EPA and DHA acid concentrations in farmed carp as low as 0.35. In the present study, feeds did not contain highly USFAs. Freshwater fish possess the bioconversion capacity to elongate and desaturate C_{18} PUFA to n-3 and n-6 fatty acids such as arachidonic acid, EPA and DHA [28].

Fish meal is expensive and mostly imported feedstuff. The use of plant-derived materials as fish feed ingredients are limited by the presence of a wide variety of antinutritional substances, so appropriate heat treatment is necessary.

In conclusion, the ratio of n-3/n-6 in common carps varied by feed and or rearing system. Using adequately processed plant meals as replacement protein sources can further improve productivity and nutritive value of carp, as reflected by n-6 polyunsaturated fatty acids, especially linoleic and arachidonic acids and favorable content of total cholesterol.

Acknowledgements

This research is a part of a project (#: 31011) of the Ministry of Science and Technological Development, Republic of Serbia, entitled "The influence of the quality of the components of food for cyprinid fish species on the quality of meat, losses and the profitability of production". We would like to thank Dr. Armağan HAYIRLI for his encouragement and assistance in the paper. For us, he had a considerable contribution.

REFERENCES

1. Adámek Z, Sukop I, Rendón PM, Kokil J: Food competition between 2+ tench: (*Tinca tinca* L.), common carp (*Cyprinus carpio* L.) and bigmouth buffalo (*Ictiobus cyprinellus* Val.) in pondpolyculture. *J Appl Ichthyol*, 19, 165-169, 2003. DOI: 10.1046/j.1439-0426.2003.00467.x

2. Milstein A: Ecological aspects of fish species interactions in polyculture ponds *Hydrobiologia*, 231 (3): 177-186, 1992. DOI: 10.1007/BF00018201

3. Marković G, Ćirković M: The possibilities for the intensification of commercial fish production in Central Serbia. *50th Jubilee Georgikon Scientific Conference, Proceedings,* p. 71, 2008.

4. Viola S, Mokady S, Rappaport U, Arieli Y: Partial and complete replacement of fishmeal by soybean meal in feeds for intensive culture of carp. *Aquaculture*, 26 (3-4): 223-236, 1982. DOI:10.1016/0044-8486(82)90158-2

5. Garg SK, Kalla A, Bhatnagar A: Evaluation of raw and hydrothermically processed leguminous seed as supplementary feed for the growth of two Indian major carp species. *Aquac Res*, 33, 151-163, 2002.

6. Khan MA, Jafri AK, Chadha NK, Usmani N: Growth and body composition of rohu *(Labeo rohita)* fed diets containing oilseed meals: partial or total replacement of fish meal with soybean meal. *Aquac Nutr*, 9, 391-396, 2003.

7. Francis G, Harinder-Makkar PS, Becker K: Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. *Aquaculture*, 199 (3-4): 197-227, 2003. DOI:10.1016/S0044-8486(01)00526-9

8. Barrows FT, Hardy RW: Feed manufacturing technology. **In,** Stickney RR (Ed): Encyclopedia of Aquaculture. pp. 354-359, John Wiley & Sons Inc, New York, 2000.

9. Steffens W, Wirth M, Füllner G: Freshwater fishan important source of n3 polyunsaturated fatty acids: A review. *Arch Pol Fish*, 13, 15-16, 2005. http://www.infish.com.pl

10. Alasalvar C, Taylor KDA, Zubcov E, Shahidi F, Alexis M: Differentiation of cultured and wild sea bass *(Dicentrarchus labrax)*: Total lipid content, fatty acid and trace mineral composition. *Food Chem*, 79, 145-150, 2002.

11. Piironen V, Toivo J, Lampi AM: New data for cholesterol contents in meat, fish, milk, eggs and their products consumed in Finland. *J Food Compos Anal*, 15, 705-713, 2002. http://dx.doi.org/10.1006/jfca.2002.1095

12. Spirić A, Trbović D, Vranić D, Đinović J, Petronijević R, Matekalo-Sverak V: Statistical evaluation of fatty acid profile and cholesterol content in fish (common carp) lipids obtained by different sample preparation procedures. *Analytica Chimica Acta*. 672 (1-2): 66-71, 2010.

13. Maraschiello C, Diaz I, Regueiro JAG: Determination of cholesterol in fat and muscle of pig by HPLC and capillary gas chomatography with solvent venting injection. *J High Resol Chromatogr*, 19, 165-168, 1996. DOI: 10.1002/jhrc.1240190309

14. Spirić A, Trbović D, Vranić D, Đinović J, Petronijević R, Milijašević M, Janković S, Radičević T: Fatty acid composition, cholesterol and total fat content in rainbow trout *(Oncorhynchus mykiss)* as influenced by fatty acids in diet. *Tehnologija mesa*, 50 (3-4): 179-188, 2009. http://www.inmesbgd.com

15. Vladau VV, Bud I, Stefan R: Nutritive value of fish meat comparative to some animals meat. *Bull UASVM Anim Sci Biotech*, 65 (1-2): 301-305, 2008.

16. Trbović D, Vranić D, Đinović J, Borović B, Spirić D, Babić J, Spirić A: Fatty acid profile and cholesterol content in muscle tissue of one year old common carp *(Cyprinus carpio)* during growth. *Tehnologija Mesa*, 50 (5-6): 276-286, 2009. http://www.inmesbgd.com/

17. Ćirković M, Trbović D, Milošević N, Đorđević V, Janković S, Ljubojević D: Meat quality of two yearsold tench and carp grown in extensive conditions. *XIV International Symposium Feed Technology, Proceedings,* pp. 400-404, 2010.

18. Ćirković M, Ljubojević D, Đorđević V, Novakov N, Petronijević R, Matekalo-Sverak V, Trbović D: The breed effect on productivity and meat nutrient compsition of fish. *Kafkas Univ Vet Fak Derg*, 18 (5): 775-780, 2012.

19. Żmijewski T, Kujawa R, Jankowska B, Kwiatkowska A, Mamcarz A: Slaughter yield, proximate and fatty acid composition and sensory properties of rapfen (*Aspius aspius* L) with tissue of bream (*Abramis brama* L) and pike (*Esox lucius* L). *J Food Compos Anal*, 19, 176-181, 2006.

20. Bieniarz K, Koldras M, Kaminski J, Mejza T: Fatty acids. fat and cholesterol in some lines of carp *(Cyprinus carpio)* in Poland. *Arch Pol Fish*, 9, 5-24, 2001. http://www.infish.com.pl

21. Kopicova Z, Vavreinova S: Occurrence of squalene and cholesterol in various species of Czech freshwater fish. *Czech J Food Sci*, 25, 195-201, 2007. http://agriculturejournals.cz/publicFiles/00312.pdf

22. Steffens W, Wirth M: Influence of nutrition on the lipid quality of pond fish: Common carp *(Cyprinus carpio)* and tench *(Tinca tinca)*. *Aquac Int*, 15, 313-319, 2007.

23. Buchtova H, Svobodova Z, Križek M, Vacha F, Kocour M, Velišek J: Fatty acid composition in intramuscular lipids of experimental scaly crossbreds in 3yearold common carp (*Cyprinus carpio* L.). *Acta Veterinaria Brno*, 76, S73-S81, 2007. doi:10.2754/avb200776S8S073

24. Fajmonova E, Zelenka J, Komprda T, Kladroba D, Sarmanova I: Effect of sex. growth intensity and heat treatment on fatty acid composition of common carp *(Cyprinus carpio)* fillets. *Czech J Anim Sci*, 48, 85-92, 2003. http://www.cazv.cz

25. Sargent JR, Tocher DR, Bell JG: The lipids. **In,** Halver J, Hardy E. (Eds): Fish Nutrition. 3rd ed., pp. 181-257, Academic, San Diego, 2002.

26. Ljubojević D, Ćirković M, Đorđević V, Trbović D, Novakov N, Vranić D, Babić J: Lipids and total cholesterol content in meat of common carp of various ages. *22nd International Symposium Food Safety Production, Proceedings,* pp. 46-49, 2011.

27. Ackman RG: Nutritional composition of fats in seafoods. *Progr Food Nutr Sci*, 13, 161-241, 2000.

28. Bell JG, Tocher DR, Farndale BM, Cox DI, McKinney RW, Sargent JR: The effect of dietary lipid on polyunsaturated fatty acid metabolism in Atlantic salmon *Salmo salar* undergoing parr-smolt transformation. *Lipids*, 32, 515-525, 1997.