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# Rainbow trout (*Oncorhynchus Mykiss*) from aquaculture – meat quality and importance in the diet*

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*A b s t r a c t: Rainbow trout (Onchorhynchys mykiss) is one of the most popular fish species in nature, but in many countries it is also recognized and accepted as cultivated/farmed fish species, due to its fast growth and excellent nutritional quality. In the farming technology for rainbow trout, the following elementary conditions must be fulfilled: clear water with sufficient oxygen content (10 mg/l), adequate temperature (8–12 ºC) and flow of water, systematic nutrition using different types of industrial or natural food, etc. In Serbia, most of the produced marketable size rainbow trout is marketed as fresh, cooled (90%), and, in less extent, as scaled and gutted and packaged.*

*Of all fresh water salmonid species, rainbow trout is mainly farmed for consumption. In addition to the fact that the farming of this fish species is very attractive for a large number of producers, considering the potential for high yields per unit of water volume, it is also characterized by high tolerance to temperature fluctuations and aggravation of the water quality, as well as fast growth rate.*

*The nutritive value of fish meat is determined by the amount of protein, fat, minerals and vitamins contained and it depends on the fish species and age, farming method, composition of food and season of the year. Rainbow trout farmed in our country contains approx. 18% proteins, 3.3% of fat, 76.3% of water, 1.3% of ash and 48.5 mg/100g of cholesterol. Its energy value is approx. 440 kJ/100g.*

*The amounts of n–3 and n–6 fatty acids in lipids of marketable size rainbow trout from aquaculture in Serbia give a very favourable n-3/n-6 ratio of approx. 1.60. P/S index for studied fish species is 1.54, and ratio between unsaturated (UFA) and saturated fatty acids (SFA) is 3.51.*

***Key words**: Rainbow trout, proximate chemical composition, cholesterol, fatty acid composition.*

## Introduction

Fishing is an ancient art. Fishing, for people was easy and simple way to get food, because hunting of other animal species, mammals, required more skill, experience, agility and guile, and also it was considerably more dangerous. Consequently, fish meat, through history of mankind, has represented significant source of food, important for the survival as well as for human development. Fish as the source of food has always been particularly appreciated in countries that had access to the sea. The real economic development of fishing started from the second half of the 19th century, and it peaked in the 20th century. Main cause is in the fact that it was then that method for artificial spawning of fish was invented. Artificial spawning of fish was discovered in the early 18th century by the scientist *Jacobi*, but this discovery was forgotten, before it was introduced into practice 100 years later by two Frenchmen, *Remy* and *Gehin*, who successfully spawned trout *(Drecun et al., 1984).*

Rainbow trout was imported to Europe around 1882, for the purpose of farming for human consumption. The fish was named "Californian trout" based on its origin, it comes from tributaries of the great Sacramento river, California, USA. Rainbow trout was imported for the first time to fish hatchery Studenac, near Maribor, in 1890, and in 1894 one of the biggest fish hatcheries at the source of the river Bosnia near Sarajevo was constructed. First facilities

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for farming of salmonid species on the territory of Serbia and Montenegro were erected after the Second World War. In Serbia, 16 trout farms were built with total area of 10,38 ha and annual production of 2,333 t. In the mean time, this production dropped to 1.145,33 t per year (*Plavša, 1998*).

Our country has high potentials for development and improvement of trout production, primarily because of very rich natural springs in mountain areas, where trout farming facilities of different purposes and capacities can be erected. Despite a relatively short period of existence, fish farms today have excellent results in fertilization of fish eggs, production of rainbow trout used in human consumption, production of fish spawn for stocking of open waters. However, in Serbia, the most popular fresh water fish from aquaculture is carp species (carp, grass carp, bighead carp), (*Baltić et al.,* 2009). Production of trout makes only 15% of total fish production and it takes place in fish farming facilities with cold water, in hilly-mountainous regions of the country.

Rainbow trout (*Onchorhynchys mykiss*), as one of the most popular fish species in nature, in many countries is also recognized and accepted as farmed fish species, because of its fast growth and exceptional nutritive quality (*Tikeiogly*, 2000). This kind of fish is farmed intensively for consumption, as species exceptionally tolerant to environmental conditions *(Simonović, 2001)*. In the farming technology the following elementary conditions must be fulfilled: clear water with sufficient oxygen content (10 mg/l), adequate temperature (8-12 ºC) and flow of water, systematic nutrition using different types of industrial or natural food, etc. *(Soldatović and Zimonjić, 1988)***.** Fresh fish is, due to its chemical composition, susceptible to spoilage which obligate producers to develop new technologies for its processing and conservation (*Babić et al., 2009*).

In our country, most of produced marketable size rainbow trout is marketed as fresh, cooled fish (90%), and less as scaled and gutted, frozen and packaged into dishes in portions of 4 to 5 pieces, than as smoked and fillets. Chosen technology for processing of fish, as well as complying with necessary technical and technological as well as hygienic conditions and requirements in trout fish farms enables expanding of the range of fish products and improvement of its quality. The rainbow trout product range on the market of Western countries is significantly more diverse and adjusted to the standard, way of living and nutrition of their consumers. Live fish is offered on the market, also cooled, cleaned, frozen, smoked, dried, deboned and breaded.

Considering its nutritional value, fish has always been very important part of the eating habits of our population. Although, today, considerable part of this food originates, either from warm water fish farms situated on flat areas, or cold water, trout fish farms, fishing of trout in their natural habitats in Serbia still represents significant source of fish intended to market *(Simonović, 2001).* Fish in Serbia is mainly consumed during religious holidays and in the days of fasting. In urban environments consumption of fish has less pronounced osciallations than in rural areas where it is mainly associated with religious holidays. However, in the period from 2001 to 2007, consumption of fish increased from approx. 3 kg to approx. 7kg per capita (*Marković et al., 2009*). It is considered that non-agricultural households consume 4.1 kg of fish, mixed households 3 kg, and agricultureal households 2.9 kg of fish per year *(Milanović, 2000).* Despite of moderate increase of domestic production, lately, the import of fish and fish products showed drastic increase (*Marković et al., 2009*).

Reasons for such low consumption of fish meat is lack of habit of consuming fish, high price, undeveloped trade network, lack of continuous supply to the market, insufficient supply of different fish species and fish products prepared ready for consumption or quick cooking, according to needs of modern consumers today.

Of all fresh water salmonid species in Serbia, rainbow trout is mainly farmed for consumption. In addition to the fact that the farming of this fish species is very attractive for large number of producers, considering the potential for high yields per unit of water volume, it is also characterized by high tolerance to temperature fluctuations and aggravation of the water quality, as well as fast growth rate (*Marković and Poleksić*, *2008)*. It feeds the fauna from the river bottom, flying insects and other smaller fish, bit it adopts and adjust very easily to additional food (fresh or concentrated) used on fish farms. Because of the quality of meat and poor bone development, they are considered as the most valuable fish species. Farming of fresh water trout species can be divided into two directions: farming of "wild" fish species for the purpose of stocking of open cold waters, flowing and standing, and farming of fish for human consumption.

## Proximate composition and cholesterol content

Nutritional and health benefits achieved by consumption of fish is one of the reason of increased demand for these products on the market *(Burger* *and Gochfeld, 2009).* Fish represents necessary supplement in total animal protein balance, considering that in regard to its biological value do not differed from proteins of other meat types. Fish meat is important and, in many countries, dominant protein source. It is estimated that close to 15% of demand for animal proteins in the world is covered by the consumption of fish *(Anon, 1999).* Protein content in fish ranges from 12 to 24%, or in average around 18% *(Cvrtila and Kozačinski, 2006)* and it is very similar to protein content of meat from mammals. Daily needs in proteins for humans can be met by 400 g of fish meat. Fish muscles contain less connective tissue compared to farm animals (less collagen and insignificant amounts of elastin), and, therefore, fish meat is digested faster and easier. Resorption availability of fish proteins and fats is 95% and 91%, respectively *(Baltić and Teodorović, 1997; Baltić and Tadić, 2001).* Fish meat contains higher quantities of minerals, particularly calcium, phosphorus, magnesium and potassium. In fish fats, vitamins A and E are dissolved (especially in trout) as well as considerable quantities of vitamin D (*Ćirković et al., 2002; Anon, 2003*). Fish meat has high water content (60 to 80%) and negligible content of carbohydrates in form of glycogen (*Šoša, 1989; Ćirković et al., 2002*). However, due to high water content, this type of meat is more susceptible to spoilage compared to meat from warm blooded animals.

Low fat content and relatively low cholesterol content, as well as significant content of minerals, vitamins and essential fatty acids, make fish one of the nutritionally most valuable food stuffs in human nutrition (*Conor*, 2000; *Sidhu*, 2003). Energy value of fish meat is directly dependant on the content of fat, and depending on the type of fish it ranges from 400 kJ/ 100g (trout, codfish) to approx. 900 kJ/ 100g (mackerel, catfish). Fatty fish (mackerel, catfish), in regard to the energy value, can be compared with pork, contrary to lean fish (codfish, trout) which can be compared to chicken meat.

Chemical composition of fish meat, in addition to the genetic factors, is also influenced by quality of water, its pH and temperature, feeding, type of food used, i.e. season of the year, oxygen content, motor activity, age and size of the fish (*Fauconneau et al.,* 1995; *Buchtova et al.,* 2007; *Menoyo et al.,* 2007).

Content of fat increases with the increase of fish size, as well as growth rate and is largely affected by nutrition, and inversely associated with water content (*Kaushik*, 1995; *Vranić et al., 2010*). Protein content is stable during growth period (*Shimeno et al.,* 1990), except in case of insufficient and unbalanced food (*Zeitler et al.,* 1984). It was found that protein content increases if the growth is stimulated by using steroids (*Lone and Matty,* 1984; *Basavaraja et al.,* 1989). Other factors (temperature, mobility, adding of steroids) indirectly stimulate nutrition and also increase the fat content (*Lone and Matty,* 1984; *Viola et al.,* 1992).

Chemical composition and energy value of carp, trout, mackerel, catfish and codfish meat and meat from other types of slaughter animals is presented in *Table 1.*

**Table 1.** Content of nutrients and energy value of some fish species and certain meat categories (**Bogut et al.*, 1996; ***Ćirković et al.*, 2002; ****Cvrtila and Kozačinski*, 2006)
**Tabela 1**. Sadržaj hranljivih materija i energetska vrednost u nekim vrstama riba i pojedinim kategorijama mesa (**Bogut i dr.,* 1996; ***Ćirković i dr.*, 2002; ****Cvrtila i Kozačinski,* 2006)

| Type of meat/ Vrsta mesa | Water/Voda (%) | Proteins/Proteini (%) | Fats/Masti (%) | Ash/Pepeo* (%) | Energy value/ Energetska vrednost (kJ/ 100g) |
|---|---|---|---|---|---|
| Mackerel/Skuša* | 61.4 | 22.5 | 14.5 | 1.6 | 920 |
| Catfish/Som* | 71.1 | 16.5 | 11.3 | 1.0 | 729 |
| Codfish/Bakalar * | 81.3 | 17.0 | 0.7 | 1.0 | 317 |
| Trout/Pastrmka** | 76.3 | 19-20 | 0.8 | 1.2 | 351 |
| Pork/Svinjsko meso** | 56.8 | 17-19 | 25.3 | 0.8 | 1238 |
| Beef/Goveđe meso** | 74.3 | 20 | 3.5 | | 485 |
| Poultry/Piletina** | 74.6 | 21.5 | 2.5 | 1.2 | 460 |
| Mutton/Jagnjetina** | 66.4 | 19.7 | 12.7 | | 812 |
| Carp/Šaran *** | 75.8 | 18.0 | 4.8 | 1.17 | 522 |

It is known that increased intake of fish meat is very important for human health because it enables normal development and functioning of the organism and reduces cardiovascular diseases (*Kris-Etherton et al.,* 2002). In addition to being easy digestible, it is important to mention that fish meat is less burdened by different additives used in modern production during technological procedure of processing of meat from livestock and poultry (*Ćirković et al., 2002)***.**

In case of rainbow trout, average protein content is 20%, content of fat 3% and content of mineral substances 1.2 %, which makes it lean fish meat, recommended as ideal food for children, old and sick persons. Also, trout meat is particularly appreciated because of its softness, juiciness and taste (*Ćirković et al.,* 2002.).

Phillips and Brockwey, 1956, established certain differences in chemical composition of fillets from wild (stream) trout and trout farmed in fish pond. Content of proteins and minerals was lower, and content of fat in meat from farmed trout was higher compared to meat from the wild creek trout. Different literature data (Table 2) show that protein content in marketable size trout fillets ranges from 17.13 to approx. 21%, and of fat from 2.7 to approx. 9%. Content of ash was in the range from 1 to 2%. It is noticeable that contents of main nutrients (proteins, fat and water) range in wide limits, depending on the age, physiological condition (spawning), time of catching and individual differences (*Brkić, 1966*). As a consequence of differences in the content of fat (from 2,7 % to 9 %), the energy value of studied rainbow trout fillets in the mentioned studies varied from 102 to 151 kJ/100g and from 424 to 635 kJ/100g, respectively.

ditions, size of the fish and genetic potential affect the composition and quality of farmed fish. The greatest influence considered is composition of food. Most of fish species will use proteins from the food as source of energy rather than lipids. When the content of lipids in food exceeds the maximum that fish can metabolize, fat will be stored in muscle tissue. The higher content of fat will influence the overall quality of fish meat, and, since the excess fat is stored in the belly region which is thrown away in the process of filleting, the utilization of fish is reduced. In controlled farming conditions, with uniform quality of food, it is possible to produce fish of constant quality, without variations in content of proteins, water, fat and ash.

In Table 3, own research results of the chemical composition of most often consumed fish species in Serbia are presented.

The highest content of proteins (18.09%) was determined in rainbow trout fillets, and the lowest in pangasius fillets (11.67%). In addition to the highest water content (85.78%), pangasius also showed the lowest content of fat (0.94%). The highest content of fat and the highest energy value were determined in grass carp (11.59% and 168.75 kcal/100g, respectively). The lowest energy value, beside pangasius (56.14 kcal/ 100g) was established in rainbow trout (105.76 kcal/ 100 g, 3.24% of fat).

Fish fats, very rich in polyunsaturated fatty acids, also contain cholesterol. Previous researches showed that most of the studied fish had similar cholesterol content (49- 92 mg/ 100g), as pork or

**Table 2.** Average chemical composition of rainbow trout fillet – literature data (g/100g)
**Tabela 2.** Prosečan hemijski sastav fileta konzumne pastrmke – literaturni podaci (g/100g)

| Nutrients/Hranjive materije | Phillips and *Brockwey,* 1956 | | *Bud et al.*, 2008 | *Celik et al.,* 2008 | *Grujić*, 2000 | *Plavša et al.,* 2000 | *Savić et al.,* 2004 | *Ćirković et al.,* 2002 |
|---|---|---|---|---|---|---|---|---|
| | Rainbow t. kalifor. | Stream t. potočna. | | | | | | |
| Proteins/Proteini **(%)** | 13.70 | 21.20 | 18.88 | 19.60 | 20.00 | 18.33 | 17.13 | 19-20 |
| Fat/Mast **(%)** | 5.50 | 3.40 | 2.94 | 4.43 | 3.80 | 7.64 | 9.07 | 2.70 |
| Water/Voda **(%)** | 77.20 | 71.50 | 77.03 | 71.65 | 75.00 | 73.52 | 71.95 | 76.30 |
| Ash/Pepeo **(%)** | 2.00 | 3.30 | 1.15 | 1.36 | 1.20 | 1.28 | 1.45 | 1.50 |
| Energy value/Energetska vrednost (kcal/100g) | 110.70 | 117.80 | 102.00 | 130.10 | 105.20 | 142.10 | 151.80 | 102.30 |
| Energy value/Energetska vrednost (kJ /100g) | 452.00 | 488.34 | 422.96 | 540.34 | 435.70 | 593.60 | 635.12 | 423.80 |

Fish reared in aquaculture can show certain variations in chemical composition, but these changes are more constant and can be predicted. Controlled farming conditions, composition of food, content of proteins and fat in the food, environmental con-

beef (45- 84 mg/ 100g), (*Piironen et al.,* 2002). In the mentioned study, it is stated that cholesterol content is not in correlation with fat content, and that, same as in case of meat from livestock, consuming of fish with reduced fat content doesn't imply that

**Table 3.** Average chemical composition of fillet of marketable size trout, carp, bighead carp, grass carp and farmed Vietnamese catfish (g/100g)- own data (*Vranić et a*l., 2010, *Đinović et al.,* 2011)
**Tabela 3.** Prosečan hemijski sastav fileta konzumne pastrmke, konzumnog šarana, tolstobika, amura i gajenog vijetnamskog soma (g/100g)-vlastiti podaci (*Vranić i dr.*, 2010, *Đinović i dr.*, 2011)

| Nutrients/Hranjive materije (%) | Rainbow trout/ Kalifornijska pastrmka (*Oncorhynchus mykiss)* | Carp/Šaran (Cyprinus carpio) | Bighead carp/ Tolstobik (Hypophthalmichtys molitrix) | Grass carp/Amur (Ctenopharyngodon idella) | *Vietnamese catfish* /Pangasijus (Pangasius hypophthalmus) |
|---|---|---|---|---|---|
| Proteins/Proteini | 18.09 | 15.92 | 18.69 | 16.41 | 11.67 |
| Fat/Mast | 3.24 | 6.99 | 4.39 | 11.59 | 0.94 |
| Water/Voda | 76.30 | 75.59 | 75.04 | 71.22 | 85.78 |
| Ash/Pepeo | 1.31 | 0.96 | 1.16 | 0.95 | 1.36 |
| Energy value/ Energetska vrednost (kcal/100g) | 105.76 | 127.07 | 117.40 | 168.75 | 56.14 |
| Energy value/ Energetska vrednost (kJ /100g) | 438.74 | 531.53 | 493.33 | 702.78 | 237.50 |

the intake of cholesterol is also reduced. Results obtained by *Cahu et al.,* (2004) indicate that fish from aquaculture, although with higher content of fat, have the same cholesterol content (expressed as g/ 100g of sample) as the same fish species caught in free-catch. However, *Moreira et al., 2001*, indicate that cholesterol content in fresh water fish that had been caught and from aquaculture differs and that it depends on the type of fish. In some fish species there are no significant differences, but in others cholesterol content differs even by 10 mg/ 100g. *Mathew et al.* (1999) and *Luzia et al.* (2003) concluded that, for human health, nutrition which included fresh water fish is more adequate, compared to sea fish, and that cholesterol content in river fish is lower compared to sea fish. Considering clinical and epidemiological studies which point out to the connection between cholesterol introduced by food, cholesterol in blood plasma and atherosclerosis (*Orban et al.,* 2006) relatively low cholesterol content, in addition to composition of PUFA, make the trout very suitable type of fish for human nutrition. However, it is important that the level of cholesterol in blood, in addition to increased alimentary intake of cholesterol and excessive energy intake, is also under influence of increased intake of certain long chain saturated fatty acids (SFA) and increased intake of trans-isomers of unsaturated fatty acids (*Hornstra,* 1999; *Lepšanović,* 200*3*; *Kris-Etherton et al.,* 2001).

Table 4 shows cholesterol content of meat from different slaughter animals ranging from 44 to 85 mg/ 100g, and in different fish species ranging from 41 to 50 mg/ 100g. Different literature data show considerable variability in the same fish species, which is a consequence primarily of different approaches in sample selection and implementation of different analytical methods (*Žlender and Gašperlin, 2005).*

## Fatty acid profile

Quality of fish meat, in addition to other factors, is valued according to the fatty acid profile. There is growing number of literature studies carried out in order to investigate fatty acid profile of fish from aquaculture which indicate its nutritional significance, compared to same fish species caught in the nature (*Weaver et al.,* 2008). It was concluded that of 30 fish species from aquaculture and free-catching, the highest amounts of n-3 PUFA were determined in farmed salmon and farmed trout (above 4g/100g). The highest variations in content of n-3 fatty acids were established in trout, as a consequence of different rearing methods and feeding systems, in different aquaculture conditions.

It was established that fish fats contain 17-21% of saturated and 79-83% of unsaturated fatty acids (*Bogut et al., 1996*). Of total saturated fatty acids, palmitic (C16:0), stearic (C18:0), myristic (C14:0) and, only in some fish species and in low concentration, also lauric (C12:0) acids were at the most present. Most present monounsaturated fatty acids were oleic (C18:1, n9) and palmitoleic (C16:1n7) acids (Table 5). In addition to mentioned acids, of monounsaturated fatty acids C14:1, C20:1 and C22:1 were present, too. Most of unsaturated fatty acids can be synthesized in the organism during the process of elongation and desaturation of fatty acids, but few of fatty acids are considered essential because they can not be synthesized in the organism. There are two essential fatty acids, *cis n-6*

**Table 4.** Cholesterol content (mg/ 100g) in different meat types and fish meat
**Tablela 4.** Sadržaj holesterola (mg/ 100g)u različitim vrstama mesa i mesu ribe

| Meat type/Vrsta mesa | Piironen et al., 2002 | Emadfa et al., 2001 | Kopicova and Vavreinova, 2007 | Žlender and Geršperlin, 2005 2000-2004 | Celik et al., 2008 | Vranić et al., 2010 | Đinović et al., 2011 |
|---|---|---|---|---|---|---|---|
| Beef shoulder/ goveđa plećka | 55 | | | 80 | | | |
| Back/ leđa | | 44 | | 64 | | | |
| Leg/but | 52 | | | 68 | | | |
| Pork loin/svinjski kare (lean meat/krto meso) | 45 | 60 | | | | | |
| Pork leg/svinjski but (lean meat/krto meso) | 47 | 70 | | | | | |
| Poultry breast, no skin/ pileće grudi bez kože | 56 | | | | | | |
| Poultry thigh with skin/ pileći batak sa kožom | 84 | 85 | | | | | |
| Farmed table trout/ pastrmka-gajena, konzum | 60 | 55 | 41 | | 35.04 | 48.55 | |
| Tuna, can/tuna-konzerva | 49 | | | | | | |
| Shrimp/škampi | 142 | 100 | | | | | |
| Table carp/šaran, konzum | | | 49.50 | | | 50.86 | 50.55 |
| Bighead carp/tolstolobik | | | | | | | 42.27 |
| Grass carp/amur | | | | | | | 40.12 |
| Pangasius/pangasijus | | | | | | | 47.14 |

**Table 5.** Fatty acid content (% of total fats in certain food stuffs), (*Kulier,* 1990; *Vacha and Tvrzička,* 1994; *Valfre et al.*, 2003)
**Tabela 5.** Sadržaj masnih kiselina (% od ukupnih masti u pojedinim životnim namirnicama) (*Kulier,* 1990; *Vacha i Tvrzička,* 1994; *Valfre i dr.*, 2003)

| Fatty acid/ Masna kiselina | Poultry meat with skin/Pileće meso sa kožom | Pork steak/ Svinjski biftek | Eggs/ Jaja | Carp/ Šaran | Catfish/ Som | **Rainbow trout/ Kalifornijska pastrmka** | Mackerel/ Skuša | Salmon/ Losos | Anchovy/ Sardela |
|---|---|---|---|---|---|---|---|---|---|
| 14:0 | 1.1 | 1.5 | 0.03 | 0.97 | 3.39 | 3.57 | 7.2 | 3.6 | 5.5 |
| 16:0 | 25.2 | 25.1 | 2.10 | 20.01 | 19.97 | 23.67 | 13.4 | 17.0 | 39.0 |
| 16:1 | 8.0 | 3.6 | 0.37 | 8.33 | 8.47 | 7.72 | 4.8 | 9.6 | 4.0 |
| 18:0 | 7.0 | 12.1 | 0.36 | 5.97 | 5.17 | 6.61 | 2.2 | 3.5 | 5.1 |
| 18:1 n9 | 41.4 | 44.0 | 4.08 | 48.29 | 19.04 | 34.79 | 11.9 | 21.2 | 6.7 |
| 18:2 n6 | 12.2 | 8.1 | 0.78 | 9.68 | 6.51 | 7.30 | 2.1 | 3.7 | 2.8 |
| 18:3 n3 | 0.90 | 0.5 | 0.05 | 0.73 | 2.97 | 0.89 | 2.0 | 2.5 | 0.4 |
| 20:1 | 0.80 | 1.2 | 0.02 | 1.53 | 4.73 | 2.20 | 11.4 | 1.6 | 0.4 |
| 20:4 n3 | 0.50 | 0.50 | 0.12 | 0.02 | 1.01 | 0.25 | 0.5 | 2.9 | |
| **20:5 n3** | **0.30** | / | / | **0.38** | **3.24** | **1.17** | **6.2** | **7.5** | **10.7** |
| 22:5 n3 | 0.30 | 0.30 | 0.01 | 0.12 | 1.78 | 0.58 | 0.9 | 2.5 | |
| **22:6 n3** | **0.60** | **0.40** | **0.12** | **0.48** | **9.24** | **3.86** | **10.8** | **13.1** | **20.6** |

polyunsaturated fatty acid ( linoleic acid, 18:2*n-6*) and *cis n-3* polyunsaturated fatty acid (α-linolenic acid, 18:3*n-3*). From these two types of "parent" essential fatty acids, *n-3 (*the most important are EPA, eicosapentaenoic, C20:5 and DHA, docosahexaenoic fatty acid, C22:6) and *n-6* „families" (the most important is arachidonic acid, C20:4) are created, through series of enzyme -catalyzed reactions of desaturation and elongation *(Hunter and Roberts, 2000;. Lunn and Theobald, 2006).*

Favourable influence of n-3 PUFA from fish meat on human health has been proven in numerous studies (*Mozafarian et al., 2004; Sahena et al., 2009; Barcelo-Coblijn and Murphy, 2009)*, confirming the link between the consumption of fish and prevention of coronary disease, especially myocardial infarction, artherosclerosis, hypertension and other cardio-vascular diseases (*Kris-Etherton et al., 2002; Mayneris-Perxachs et al., 2010)*. Mechanism responsible for favourable effect of n-3 PUFA on human organism is multiple and its perception exceeds the framework of this study. In addition to prevention of coronary diseases (*Mozafarian et al.,* 2005) and reduction of incidence of hypertension (*Calder*, 2001), favourable influence of n-3 PUFA reflects also in prevention of inflammatory (*Moreno and Mitjavila*, 2003), autoimmune (*Zamaria*, 2004) and malignant diseases (*Terry et al.*, 2004), diabetes (*Nettleton and Katz,* 2005) and other diseases. It was established that lack of polyunsaturated fatty acids plays important role in the ethiology of depression, dyslexia, schizophrenia and Alzheimer's disease *(Lunn and Theobald, 2006)***.** Studies carried out by *Schiepers* et al. *(2010***)** indicate the positive effect of fish consumption on quality of life, in sense of improvement of general physical condition, but with less significant impact on improvement of mental health.

of n-3 PUFA, too, due to the fact that this type of fish has better ability of fatty acid desaturation and their transformation in long-chain PUFA (EPA and DHA) compared to sea fish. Table 6. presents data on the content of polyunsaturated fatty acids (n-3; EPA and DHA) in most often consumed fresh water and sea fish (g/ kg*)*. It is known fact that fresh water fish, caught in the nature, contains less fat and higher amounts of EPA and DHA, compared to farmed fish of same species, when these values are expressed as percentage of total fatty acids. However, it should be considered that fish from aquaculture contains higher percentage of total fat and, when values for PUFA are expressed per 100g of fish, intake of EPA and DHA into human organism is higher when farmed fish is consumed, compared to same fish species caught in the nature.

Fatty acid profile in fish varies within and between species (*Haliloglu and Aras,* 2002; *Celik and Ali Gocke,* 2003), and numerous factors, such as temperature, water quality, type and availability of food, season, age, genus, reproduction status, geographical location and individual differences are considered as significant factors which additionally contribute to these variations *(Skalli et al.,* 2006*; Valente et al.,* 2007*; Rubin and Skalli,* 2007*)*. Fatty acid profile of fish feed has significant impact on fatty acid composition of fish meat *(Steffens and Wirth,* 2007*; Valente et al.,* 2007*)*. Food rich in n-3 fatty acids, in same rearing conditions, significantly influences the increase of n-3/ n-6 PUFA ratio in fish tissues (*Bell et al.,* 2001*; Grisdale-Helland et al.,* 2002*; Skalli et al.,* 2006*)*.

**Table 6.** Content of polyunsaturated fatty acids (n-3; EPA and DHA) in most often consumed fresh water and sea fish (g/kg)- comparison of literature data with own studies (*Farkas and Csengeri,* 1990; **Luzia et al.*, 2003; ***Vranić et al.,* 2010; ****Trbović et al.,* 2011)

**Tabela 6.** Sadržaj polinezasićenih masnih kiselina (n-3; EPK i DHK) u najčešće konzumiranim slatkovodnim i morskim ribama (g/kg)-poređenje literaturnih sa vlastitim podacima (*Farkas i Csengeri,* 1990; **Luzia i dr*., 2003; ***Vranić i dr.,* 2010; ****Trbović i dr.*, 2011)

| Fresh water fish/ Slatkovodana riba | 20:5 EPA | 22:6 DHA | Sea fish/Morska riba | 20:5 EPA | 22:6 DHA |
|---|---|---|---|---|---|
| Sterlet/Kečiga | 13.0 | 9,1 | Meckerel/Skuša | 14.5 | 24.6 |
| Grey carp/Sivi glavaš | 8.9 | 6,5 | Herring/Haringa | 10.5 | 12.9 |
| White carp/Beli glavaš | 8.5 | 4,5 | Flat fish/List | 3.4 | 2.8 |
| Eel/Jegulja | 2.5 | 5,8 | Eel/Jegulja | 3.0 | 6.6 |
| Tench/Linjak | 1.7 | 0,7 | Salmon/A.losos | 2.5 | 7.3 |
| Carps/Šarani | 0.7 | 0,7 | Halibut/A.iverak | 1.6 | 2.2 |
| Pike/Štuka | 0.5 | 1,7 | Codfish/Bakalar | 1.2 | 1.9 |
| Grass carp/Amur | 0.4 | 0,5 | Grouper/Škarpina | 1.4 | 0.7 |
| Perch/Smuđ | 0.4 | 0,9 | Hake/Oslić | 0.8 | 2.3 |
| Trout/Pastrmka** | 1.2 | 3,4 | Anchovy/Sardina* | 3.0 | 10.1 |
| Carp/Šaran*** | 0.01 | 0,1 | Croaker* | 6.7 | 5.9 |
| Pangasius/Pangasijus*** | 0.001 | 0,04 | Shrimp* | 4.2 | 8.2 |

Since n-3 fatty acids are necessary for development of central nervous system, brain, growth and development, forming of blood vessels of the foetus, it is necessary to provide them in sufficient amounts during pregnancy *(Innis, 2007; Sidhu, 2003)*. Also, studies have shown that *n-3* fatty acids are essential for growth and development of children.

Study by *Cahu et al.*, 2004 and *Lichtenstein et al., 2006* indicates that fresh water fish can be source

Nutrition with balanced n-3/ n-6 ratio is important for farming of healthy fish and for production of high quality food for human nutrition (*Steffens,* 1997).

Quality of fish lipids is determined by PUFA/ SFA and n-3/ n-6 ratios (*Ahlgren et al.,* 1996). Beside optimal quantities of essential fatty acids, the intake ratio is important, too. According to *Baltić et al., 2003* the optimal n-3/ n-6 FA ratio is from 1:4 to 1:5. *Henderson and Tocher* (1987) reported n-3/ n-6 value of 0.5-3.8 for freshwater and 4.7-14.4 for marine fish. Higher amounts of n-3 in marketable size trout fillets and lower amounts of n-6 PUFA give very favourable n-3/ n-6 ratio (1.60) compared to, for instance, carp, where this ratio is less favourable (0.08), due to higher amount of n-6 and lower content of n-3 fatty acids.

In regard to nutritional value, ratio between polyunsaturated and saturated fatty acids is very important, as well as P/S index, which should be above 0,5 (*Žlender and Geršperlin,* 2005). P/S index below 0.45 is considered inadequate (*Santos-Silva et al.,* 2002) because it can lead to hypercholesterolemia. Based on our studies, the obtained P/S value in marketable size rainbow trout was 1.55. Ratio between unsaturated (UFA) and saturated fatty acids (SFA) in fish fat is very important and preferably it should be above 3 (*AFSSA,* 2003). The highest values were determined in rainbow trout (3.51, 2.12, 2.54) and carp (2.68 and 2.68), (Table 7).

\Trout reared in extensive conditions had higher content of PUFA and n-3 fatty acids, as well as n-3 / n-6 ratio, whereas the content of SFA showed no differences in regard to the value registered in conditions of intensive farming, which is probably associated with very strict role of SFA in fish physiology, also confirmed by numerous studies where fish was fed diets of different composition (*Turchini et al.,* 2003a, 2003b). Such fatty acid profile is a consequence, primarily of nutrition of studied fish, but also of of the species, size, age, water quality, region, season, etc.

**Table 7.** Contents of SFA, MUFA, PUFA (% of total fatty acids), n–3, n–6, n–3/ n–6, P/S , UFA/ SFA ratios in fillets from various fish species, literature and own research data

**Tabela 7.** Sadržaj *ZMK, MNMK, PNMK* (% od ukupnih masnih kiselina ), n–3, n–6, n–3/ n–6, P/S, UFA/ SFA odnosi u filetima različitih vrsta riba, literaturni i vlastiti podaci

| Nutrients/Hranjive materije | SFA/ ZMK | MUFA/ MNMK | PUFA/ PNMK | n–3 | n–6 | n–3/n–6 | P/S | UFA/ SFA |
|---|---|---|---|---|---|---|---|---|
| Sea bob shrimp[2] | | | | 12.50 | 2.35 | 5.32 | | |
| Croaker[2] | | | | 12.60 | 8.52 | 1.47 | | |
| Mackerel/Sardina[1] | 39.4 | 18.0 | 42.6 | 37.8 | 4.8 | 7.88 | 7.57 | |
| Mackerel/Sardina[2] | | | | 13.40 | 2.59 | 5.17 | | |
| Marketable size carp feed peletted food//Konzumni šaran,hranjen peletiranom hranom[3] | 27.21 | 50.40 | 21.67 | 1.43 | 20.12 | 0.07 | 0.80 | 2.65 |
| Marketable size carp Carp feed food based on cereals/ Konzumni šaran, hranjen hranom na bazi žitarica[3] | 27.02 | 63.50 | 8.91 | 0.63 | 8.28 | 0.08 | 0.33 | 2.68 |
| Bighead carp/Tolstolobik[3] | 29.40 | 54.87 | 16.52 | 1.14 | 15.39 | 0.07 | 0.56 | 2.43 |
| Grass carp/Amur[3] | 34.48 | 54.90 | 9.83 | 6.70 | 3.12 | 2.15 | 0.28 | 1.88 |
| Pangasius (farmed Vietnamese catfish)/ Pangasius (gajeni vijetnamski som)[3] | 41.36 | 42.36 | 15.77 | 1.31 | 14.46 | 0.09 | 0.38 | 1.40 |
| Marketable rainbow trout, int. production/ konzum. kalifornijska pastr., int. proizvodnja[4] | 22.17 | 43.50 | 34.33 | 21.12 | 13.21 | 1.60 | 1.54 | 3.51 |
| Lake trout/Pastrmka, jezerska[5] | 27.65 | 35.56 | 23.09 | 15.64 | 7.45 | 2.10 | 0.83 | 2.12 |
| Marketable rainbow trout,/Pastrmka, kalifornijska, konzum[6] | 31.92 | 30.81 | 36.88 | 22.41 | 14.47 | 1.58 | 1.55 | 2.12 |
| Table carp/Šaran, konzum[7] | 26.41 | 59.50 | 12.07 | | | 0.74 | 0.46 | 2.70 |
| Trout, extensive production/Pastrmka, ekstenzivna proizvodnja[8] | 28.00 | 17.17 | 54.20 | 46.70 | 7.50 | 6.6 | 1.93 | 2.54 |

[1]Marin, 2005
[2] Luzia et al., 2003
[3]Trbović et al., 2011
[4]Vranić et al., 2010
[5]Celik et al., 2008
[6]Haliloglu and Aras, 2002
[7]Bieniarz et al., 2001
[8]Turchini et al., 2004

## Recommendations

*American Heart Association* recommends consumption of fish at least twice per week. For persons with cardio vascular problems, daily consumption of 1g EPA + DHA is recommended, but for patients with elevated content of triglycerides in blood 2–4 g EPA + DHA is recommended *(Domingo,* 2007*; Zatsick and Mayket,* 2007*)*.

Our research showed that the content of EPA+DHA in total fatty acids in rainbow trout was 14.12% (*Vranić et al.,* 2010), in carp 0.22% and in pangasius 0.50% (*Trbović et al.,* 2011). When obtained values are calculated per portion, by consumption 200g of fish, intake of desirable fatty acids for trout is 0.91g, for carp 0.03 g, and for pangasius only 0.01 g.

Recommendations for daily intake of fats and essential fatty acids are given in Table 8 (*Lunn and Theobald,* 2006*)*.

and trout, and farming of other fresh water fish species is in very low extent. Our country has the necessary infrastructure and human resources for improvement of production in the sector of fishery, as well as experienced personnel for realization of all activities aimed at harmonization of national regulations relevant to the fishery sector with EU legislation.

Future research in aquaculture should be directed to the study of required amount of energy components, as well as fatty acids in fish food, which will contribute to reaching of optimal production performances, as well as the amount of n-3 fatty acids in fish meat which are essential for preservation of the health of consumers.

Bearing in mind considerable nutritional value of trout (high protein content, relatively low cholesterol content and significant content of n-3 fatty acids) and insufficient presence of fish in the diet of dome stic population, one of the ways to increase its market value in total supply of farmed fish is the improved supply of trout and trout products adapted to needs of modern consumer. In addition to enriching the product assortment, it is necessary to promote the benefits of fish in the diet, in order to increase its consumption and use in human nutrition.

**Table 8.** Recommendations for daily intake of fat (% of energy) *Lunn and Theobald* (2006)
**Tabela 8.** Preporuke o dnevnom unosu masti (% od energije) *Lunn i Theobald* (2006)

| | USA and Canada/ SAD i Kanada | Europe/Evropa (EURODIET project) | FAO/WHO | UK |
|---|---|---|---|---|
| Fats/masti | 20–35 | < 0 | 35 | < 35 |
| *n–3* | 0.6–1.2 | 200 mg DHK/EPK; 2 g | LK:ALK = 5:1–10:1 | > 0.2 (450 mg DHK/EPK) |
| *n–6* | 5–10 | 4–8 | 4–10 | > 1 |

## General conclusions

Serbia disposes with considerable surface of fish ponds, which, mainly, have small extensive or semi-intensive production. Main production activities in aquaculture in Serbia are farming of carp

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# Kalifornijska pastrmka (*Oncorhynchus Mykiss*) iz akvakulture – kvalitet mesa i značaj u ishrani

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*R e z i m e: Kalifornijska pastrmka (Onchorhynchys mukiss) je jedna od od najpoznatijih vrsta ribe u prirodi, ali je, u mnogim zemljama, poznata i prihvaćena kao uzgajana vrsta, zbog brzog rasta i odličnog nutritivnog kvaliteta. U tehnologiji gajenja kalifornijske pastrmke neophodno je da se obezbede elementarni uslovi: čista voda sa ispunjenim zahtevima za sadržaj kiseonika (10 mg/ l), odgovarajuća temperatura (8–12 ℃) i protok vode, sistematska ishrana različitim vrstama industrijske i prirodne hrane, i dr. U Srbiji, najveći deo kalifornijske pastrmke proizvedene za konzum plasira se na tržište kao sveža, ohlađena riba (90%), a u manjoj meri kao očišćena, zamrznuta i upakovana.*

*Od slatkovodnih salmonida, za konzum se u Srbiji najviše gaji kalifornijska pastrmka.Osim što je gajenje ove vrste ribe privlačno za veliki broj proizvođača, s obzirom na mogućnost postizanja visokih prinosa po jedinici zapremine vode, nju odlikuje i visoka tolerantnost na temperaturna kolebanja i pogoršanje kvaliteta vode, kao i brz rast.*

*Hranljiva vrednost mesa riba uslovljena je količinom proteina, masti, minerala i vitamina u njemu i zavisi od vrste i starosti ribe, načina uzgoja, sastava hrane i godišnjeg doba Kalifornijska pastrmka gajena na našem području sadrži oko 18% proteina, 3,3% masti, 76,3% vode, 1,3% pepela i 48.5 mg/ 100g holesterola. Njena energetska vrednost iznosi oko oko 440 kJ/ 100g.*

*Količine n–3 i n–6 masnih kiselina u lipidima konzumne kalifornijske pastrmke iz akvakulture Srbije daju veoma povoljan n-3/ n-6 odnos, koji iznosi oko 1,60. P/S indeks, za ispitanu vrstu ribe je 1,54, a odnos nezasićenih (NMK) prema zasićenim masnim (ZMK) kiselinama iznosi 3,51.*

***Ključne reči***:*Kalifornijska pastrmka, hemijski sastav, holesterol, masnokiselinski sastav.*

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