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Analysis of Nutritional Components in Muscle of Different Strains of Rainbow Trout

[1,2]Xue Shu-Qun, [1]Sun Zhong-Wu and [2]Yin Hong-Bin
[1]College of Life Sciences, Northeast Forestry University, 150040 Harbin, China
[2]Heilongjiang River Fisheries Research Institute, CAFS, 150070 Harbin, China

Abstract: To analyze the nutritional components in muscle of five varieties of *Oncorhynchus mykiss*. Conventional and biochemical analytical methods were used. The content of crude protein, lipid, ash was 16.08-20.98, 2.06-3.96 and 1.42-1.62%, respectively. The total content of amino acids was 63.29-71.03%, eight essential amino acids 26.27-29.76%, four delicious amino acids 23.72-26.31%. There were 21 classes (29 kinds) of fatty acids. The content (of total fatty acid) of unsaturated fatty acids was 76.86-81.18% in which the content of EPA+DHA was 4.58-13.19%. The five varieties of *Oncorhynchus mykiss* belong to super cultured ones involved in high nutritional and economic value and worth to explore for food.

Key words: *Oncorhynchus mykiss*, muscle, nutritional components, food analysis, lipid, amino acids

INTRODUCTION

The rainbow trout (*Oncorhynchus mykiss*), belonging to *Oncorhynchus* genus, Salmoninae Subfamily, Salmonidae Family, Salmoniformes Order, native to rivers of the mountains in North America is one of the fishes that are commonly cultured. Rainbow trout is a kind of cold-water carnivorous fish whose meat has delicate and fleshy texture, fresh and tender flavor and few fish bones. Rainbow trout has high economic value and broad market prospects. Since, it was introduced in 1959, rainbow trout has been domesticated and cultured for dozens of years, now it has became one of the main cultured freshwater fish species in China (Jue-Min, 1995).

Currently, studies on rainbow trout are mainly focused on artificial breeding and farming, physiological and pathological, reproductive biology, population genetics or single nutrient composition and etc. (Faruk, 2002; Gavriilidou *et al*., 2003; Cakmak and Girgin, 2003; Guner *et al*., 2005, 2006a, b; Allameh *et al*., 2007; Tanrikul, 2007; Asl *et al*., 2007, 2008; Mahjoor and Loh, 2008; Roozbahanim *et al*., 2009; Sattari *et al*., 2009). The general evaluation of nutrients in muscle among different strains of rainbow trout has not yet been reported. In this study, the regular nutrient content, amino acid and fatty acid content in muscle of five different strains of rainbow trout including Denmark rainbow trout, Donaldson rainbow trout, Norway rainbow trout, Finland rainbow trout, America rainbow trout were analyzed. These data will provide basic information and scientific basis for the reasonable exploitation and utilization of rainbow trout resources.

MATERIALS AND METHODS

Sample collection and preparation: On May, 2010, five different strains of rainbow trout (rainbow trout of Denmark DM, Donaldson rainbow Trout DT, rainbow trout of Norway NW, rainbow trout of Finland FL, rainbow trout of America AM) were collected at the Coldwater Fish Experiment Station of Heilongjiang River Fishery Research Institute of Chinese Academy of Fishery Sciences. The 15 fishes out of each strain were sampled their dorsal muscles were cut from the rest of the body and shredded with skin peeled off.

Detection method: According to GB 5009.3-1985, moisture content was assayed by oven-drying at atmospheric pressure at 105°C. According to GB 5009.4-1985, crude ash content was assayed by High Temperature Incineration Method. According to GB 5009.5-1985, crude protein content was determined using the Micro-Kjeldahl Method according to GB 5009.6-1985, crude fat content was determined by Soxhlet Extraction Method. According to GB/T 14965 in 1994, amino acids were analyzed by Hitachi Model 835-50 automatic amino acid analyzer, via tryptophan by alkaline hydrolysis and other amino acid by acid hydrolysis. Fatty acid was determined using Agilent Model 6890-5973N gas Chromatography-Mass Spectrometry System (AOAC, 2000; SAS, 1985; Williams, 1984; GB 5009, 1985).

Evaluation method: According to the FAO/WHO recommendation in 1973, the nutritional value was

Corresponding Author: Sun Zhong-Wu, College of Life Sciences, Northeast Forestry University, 150040 Harbin, China

evaluated by the amino acid scoring pattern (per gram of nitrogen) and egg protein pattern. The Amino Acid Score (ASS), Chemical Score (CS) and Essential Amino Acid Index (EAAI) was calculated for each amino acid using the following equation (Pellett and Yong, 1980; Gehrke, 1985; Hong-Bin *et al*., 2006):

- ASS is content of an amino acid in the investigated protein (mg/g N)/content of the same amino acid in the FAO scoring pattern (mg/g N)
- CS is content of an amino acid in the investigated protein (mg/g N)/content of the same amino acid in egg protein (mg g^{-1} N)

$$EAAI=\sqrt[n]{\frac{Lysine^{t}}{Lysine^{S}}\times 100\times\frac{Leucine^{t}}{Leucine^{S}}\times 100\times\ldots\times\frac{Valine^{t}}{Valine^{S}}\times 100}$$

Where:
n = The number of amino acids compared
t = The investigated protein
S = Egg protein

RESULTS

General nutritional contents: In muscle of the 5 strains of rainbow trout, moisture and ash content was basically the same; crude protein content had slight differences ranging from 16.08-20.98%; crude fat content ranging from 2.06-3.96% was close to the data of wild Atlantic salmon (2.1~3.3%) (Zhong-Wu and Hong-Bin, 2004) and brown trout (2.3~4.5%) (Kaushik *et al*., 2006). It was reported that muscle fat content must reach 3.5~4.5% of fresh tissue to have good palatability, the flavor of meat changes constantly with the increase of muscle fat content within a certain range (Shi-Lu *et al*., 2002). While the crude fat content of the investigated five strains of rainbow trout were close to this level, the taste of them was delicate and fresh (Table 1).

Amino acid composition and content: Muscle protein of the five strains of rainbow trout had full range of amino acid, the total content of amino acids were close to each other, ranging from 63.27-71.03%. Among all the amino acids, glutamic acid content was the highest and cystine content was the lowest.

Table 1: Nutrient content in muscle of five varieties of *Oncorhynchus mykiss* (g/100 g fresh)

Varieties	Water	Protein	Fat	Ash
DM	78.52±0.44	16.08±0.83	2.82±0.10	1.42±0.14
DT	77.41±0.57	20.98±1.23	2.06±0.06	1.62±0.02
NW	76.20±0.68	20.81±0.14	3.96±0.14	1.54±0.06
FL	76.48±1.78	20.35±0.61	3.55±0.05	1.62±0.02
AM	74.39±1.64	19.48±1.27	3.12±0.10	1.59±0.15

The content of Essential Amino Acids (EAA) ranged from 26.27-29.45%, the ratio of Essential amino acids to Total amino acids (E/T) ranged from 40.72-42.00%, the ratio of essential amino acids to non-essential amino acid (E/N) ranges from 68.68-72.42%, these data were close to *Salvelinus leucomaenis* and several other kinds of salmonid fish, respectively (Zhong-Wu and Hong-Bin 2004). According to the ideal FAO/ WHO Model, the E/T ratio and E/N ratio of high-quality protein should be around 40 and >60%, respectively the muscle amino acid composition of the 5 strains of rainbow trout were all higher than the FAO/WHO evaluation standard so, this protein was a kind of high-quality protein source (Table 2).

Fatty acid composition and content: Muscle of the five strains of rainbow trout had abundant varieties of fatty acid about 21 kinds 29 types. The most abundant fatty acid was linoleic acid (C18: 2) ranging from 29.06-34.44%. The proportion of unsaturated fatty acids in the total fatty acid content ranging from 76.86-81.18% was much higher than the *oncorhynchusmasou* (57.37~63.45%) Hong-Bin *et al*. (2004). n-6 and n-3 series polyunsaturated fatty acids content was relatively high, ranging 31.02~36.27% and 6.99~5.09%, respectively. The ratio of n-6 to n-3 (2.1~4.7:1) was corresponded to the domestic recommendations (n-6: n-3 is 4~6:1) basically (Yuan-Ming, 2006). The sum content of EPA (C20: 5) and DHA (C20: 6)

Table 2: Composition and contents of amino acids in muscle of five varieties of *Oncorhynchus mykiss* (g/100 g dry)

Composition	DM	DT	NW	FL	AM
Ile	3.25	3.31	3.04	3.47	3.41
Leu	5.72	5.88	5.31	6.04	5.80
Lys	6.43	6.51	5.32	6.46	5.79
Met	2.29	2.35	2.07	2.38	2.19
Cys	0.65	0.67	0.60	0.63	0.64
Phe	3.73	3.69	3.44	2.70	3.70
Tyr	2.63	2.62	2.41	2.67	2.63
Thr	3.24	3.32	3.03	3.40	3.28
Trp	0.75	0.74	0.66	0.69	0.75
Val	3.58	3.65	3.40	3.78	3.74
Ala	4.18	4.26	3.84	4.42	4.12
Asp	7.00	7.16	6.61	7.39	7.31
Glu	10.97	11.31	10.10	11.57	11.03
Gly	3.36	3.58	3.17	3.71	3.21
Arg	4.18	4.26	3.80	4.36	4.06
His	1.66	1.66	1.46	1.69	1.70
Pro	2.65	2.68	2.49	2.79	2.66
Ser	2.75	2.84	2.54	2.88	2.70
TAA	69.02	70.47	63.29	71.03	68.72
EAA	28.99	29.45	26.27	28.92	28.66
E/T (%)	42.00	41.79	41.51	40.72	41.71
E/N (%)	72.42	71.79	70.96	68.68	71.54
DAA	25.51	26.31	23.72	27.09	25.67
D/T (%)	36.96	37.34	37.48	38.14	37.35

EAA: Essential Amino Acids; DAA: Delicious Amino Acids; TAA: Total Amino Acids; E/N: Essential amino acids/Nonessential amino acids; E/T: Essential amino acids/Total amino acids; D/T: Delicious amino acids/Total amino acids

of trout ranging from 4.58-13.19% was higher than the data of grass carp, *Schizothorax davidi* and *Nile perch*. (Xing-Hua *et al*., 2006; Jia *et al*., 2007) EPA, DHA and other polyunsaturated fatty acids had a motive function to reduce blood fat, lower blood viscosity, prevent arteriosclerosis, support brain development and etc., these fatty acids can significantly reduce the incidence of cardiovascular diseases, indicating that the consumption of rainbow trout is beneficial for the patients with cardiovascular and cerebrovascular diseases (Table 3).

Table 3: Composition and contents of fatty acids in muscle of five varieties of *Oncorhynchus mykiss* (g/100 g fat)

Composition	DM	DT	NW	FL	AM
C12:0	0.02	0.02	0.02	0.02	0.04
C14:0	1.18	1.52	1.14	1.36	1.39
C15:0	0.17	0.22	0.17	0.23	0.21
C16:0	10.35	10.78	9.88	12.44	13.11
C16:1 n-7	2.55	3.35	2.80	2.21	2.32
C16:1 n-9	0.40	0.42	0.38	0.39	0.51
C16:2 n-8	0.07	0.18	0.08	0.13	0.06
C17:0	0.19	0.23	0.20	0.23	0.26
C18:0	3.73	3.93	3.55	3.76	4.79
C18:1 n-7	2.11	2.22	1.97	1.99	2.07
C18:1 n-8	0.20	0.33	0.31	0.26	0.10
C18:1 n-9	25.93	21.76	26.54	24.29	26.10
C18:2 n-6	33.47	29.06	33.06	34.44	30.20
C18:3 n-3	2.59	2.93	2.33	2.45	2.27
C18:3 n-3t	0.37	0.89	0.45	0.47	0.49
C18:3 n-6	0.69	0.92	0.92	0.79	1.10
C20:0	0.22	0.19	0.26	0.23	0.25
C20:1 n-9	1.79	1.24	1.67	1.28	1.50
C20:2 n-5	1.84	0.89	1.66	2.07	1.90
C20:2 n-9	0.25	0.25	0.24	0.25	0.21
C20:3 n-3	0.12	0.09	0.10	0.14	0.14
C20:3 n-7	1.61	0.99	1.55	1.20	1.31
C20:4 n-6t	0.92	1.04	1.09	1.04	1.27
C20:5 n-3	0.56	2.01	0.56	0.81	0.30
C20:5 n-5	0.50	2.01	0.56	0.30	0.50
C21:0	0.05	0.10	0.07	0.07	0.08
C22:0	0.10	0.03	0.13	0.12	0.14
C22:1 n-9t	0.97	0.55	0.86	0.58	0.72
C22:6 n-3	3.78	9.17	4.05	4.44	3.78
SFA	16.01	17.02	15.42	18.46	20.27
MUFA	33.96	29.87	34.53	31.00	33.32
PUFA	46.77	50.43	46.65	48.53	43.54
UFA	80.73	80.30	81.18	79.53	76.86
EPA+DHA	4.84	13.19	5.17	5.56	4.58

SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; UFA: Unsaturated Fatty Acids; EPA: C20:5; DHA: C22:6; t: trans

Nutrition evaluation: The content (mg/g N) of essential amino acids in muscle of the 5 strains of rainbow trout ranging from 2059-2747 is <3,096 of the standard egg protein except for the rainbow trout of Norway (2059 mg g N^{-1} which is a little low), the other 4 strains of rainbow trout contained higher concentration of essential amino acids than the FAO/WHO standard (2200 mg g N^{-1}) when using ASS as the criteria, the first and second limiting amino acid of four strains of rainbow trout were valine and tryptophan, respectively except for the rainbow trout of Finland whose first and second limiting amino acid were tryptophan and valine, respectively while using CS as the criteria, the results showed slight differences, the first and second limiting amino acid of five strains of rainbow trout were tryptophan and methionine + cystine, respectively which met the data of *Salvelinus leucomaenis* and several other kinds of salmonids (Table 4 and 5).

In addition, using ASS and CS as the criteria, the limiting amino acids of four strains of Siluriformes, nile perch and *Brevifilis brevifilis* (Ying-Gui *et al*., 2006) were also tryptophan, valine, methionine + cystine. This showed tryptophan, valine, methionine + cystine were common limiting amino acids in salmonoid and freshwater fishes. Muscle of the five strains of rainbow trout had the highest level in ASS and CS of lysine, suggesting that eating rainbow trout can make up for the lack of lysine and improve the body's utilization of protein for those dieters mainly having foods of cereal. Essential Amino Acid Index (EAAI) is one of the commonly-used indexes to evaluate the nutritive quality of protein, using essential amino acid of egg protein as the criteria standard, EAAI

Table 4: The comparison of essential amino acids content in muscle of five varieties of *Oncorhynchus mykiss* with egg protein and FAO/WHO standard (mg/g N)

Varieties	Ile	Leu	Lys	Met+ Cys	Phe+ Tyr	Thr	Trp	Val	Sum
DM	277	487	547	250	541	276	64	305	2747
DT	232	412	456	212	442	233	52	256	2294
NW	214	373	374	188	411	213	46	239	2059
FL	251	437	467	218	389	246	50	274	2332
AM	286	486	485	237	530	275	63	313	2675
FAO/WHO	250	440	340	220	330	250	60	310	2200
Egg protein	331	534	441	386	565	292	106	441	3096

Table 5: The comparison of AAS, CS and EAAI of five varieties of *Oncorhynchus mykiss*

Varieties	Score	Ile	Leu	Lys	Met + Cys	Phe + Tyr	Thr	Trp	Val	Sum	EAAI
DM	ASS	1.11	1.11	1.61	1.14	1.64	1.10	1.060	0.980	9.75	83.25
	CS	0.84	0.91	1.24	0.65	0.96	0.94	0.600	0.690	6.83	
DT	ASS	0.93	0.94	1.34	0.96	1.34	0.93	0.860	0.830	8.12	69.47
	CS	0.70	0.77	1.03	0.55	0.78	0.80	0.490	0.580	5.70	
NW	ASS	0.86	0.85	1.10	0.85	1.25	0.85	0.773	0.771	7.30	62.57
	CS	0.65	0.70	0.85	0.49	0.73	0.73	0.440	0.540	5.12	
FL	ASS	1.00	0.99	1.37	0.99	1.18	0.98	0.830	0.880	8.24	70.76
	CS	0.76	0.82	1.06	0.56	0.69	0.84	0.470	0.620	5.82	
AM	ASS	1.14	1.10	1.43	1.08	1.61	1.10	1.050	1.010	9.52	81.66
	CS	0.86	0.91	1.10	0.61	0.94	0.94	0.590	0.710	6.67	

of 5 strains rainbow trout was 62.75~83.25. Nutritional value of rainbow trout of America and rainbow trout of Denmark were slightly better than the other three strains of rainbow trout, similar with several other salmonids (Atlantic salmon 80.12, *Oncorhynchus masou* 81.46, *Salvelinus leucomaenis* 81.51, *Hucho taimen* 82.89) and higher than general freshwater fish (silver carp 60.73, grass carp 62.71, carp 65.92, catfish 68.08, crucian 68.96 and Nile perch 73.16).

DISCUSSION

Compare the analyzing results of muscle nutrient composition of the five strains of rainbow trout with the data showed in China food composition table 2002 (Yue-Xin *et al*., 2002), the content of protein and fat differed a lot, the content of moisture and ash were basically the same. This differences came from different sampling parts, dorsal muscle were sampled in this study while the edible part of fish including the abdominal muscle and internal organs were sampled in the later data. In addition, the nutrient composition of fish was closely related to diets, sampling season and living environments. These factors would affect the nutrient composition of individual fishes directly. The main nutrition part of fishes is muscle; content and composition of protein, fat, amino acid and fatty acid are the main nutrient in muscle presents the nutritional value of fishes. The muscle crude protein content in muscle of the five strains of rainbow trout ranging from 16.08-20.98% was higher than 4 kinds of catfish (14.03~15.87%) and some common commercial fishes (bighead carp 15.30%, grass carp 16.60%, carp 17.60% and silver carp 17.80%) (Yue-Xin *et al*., 2002).

In dietary amino acids, essential amino acids were mostly concerned by the general public, especially lysine and sulfur amino acids. The content of lysine and total sulfur amino acids (methionine, cystine) in muscle of five strains of rainbow trout ranging from 5.32-6.51% and from 2.67-3.02%, respectively were close to 4 kinds of catfish, *Salvelinus leucomaenis* and several other kinds of salmonids and 6 kinds of cultured sturgeons. The content of lysine and sulfur-containing amino acids in muscle suggested that the 5 strains of rainbow trout had a variety of essential amino acids and thus had higher nutritional value. Among amino acids in muscle of the five strains of rainbow trout, the content of glutamic acid was the highest (10.10~11.57%), the ratio of delicious amino acid to total amino acid (D/T) ranging from 36.96-38.14% was slightly lower than yellow catfish (40.32%), close to the data of *Folifer brevifilis* (36.96%), grass carp (37.10%) and *Schizothorax davidi* (38.25%) and higher than the Ussuri catfish (25.42%), catfish (31.70%) and *Silurus glanis* Linnaeus (34.18%), indicating data of muscle of rainbow trout had abundant content of delicious amino acid and tasted delicious. The nutritional value of fish fat was related with the variety, content and composition of fatty acids. For the general public, the desirable dietary fat had the composition as follows: ratio of Saturated, Polyunsaturated and Monounsaturated fatty acids (S:M:P) being 1:1:1 and ratio of (n-6)/(n-3) serious polyunsaturated fatty acids being (4-6):1. According to the results of this experiment in muscle of five strains of rainbow trout had average ratio of S:M:P 1:1.8:2.6 and ratio of n-6/n-3 ranging from 2.1-4.7 which basically met the demand of fatty acids in human body. Additionally, the content of linoleic acid (C18:2), one of the essential fatty acids, ranging from 29.06-34.44% was much higher than that of grass carp, *Schizothorax davidi*, black carp, silver carp, bighead carp and other common commercial fishes.

Amino acids and fatty acids played a special role in many metabolic processes in the human body, especially unsaturated fatty acids whose function in nutrition and health maintenances had been increasingly concerned, amino acids and fatty acids could be considered as the nutritional indicators to evaluate the nutritional value of fishes and therefore, to guide the breeding of fish scientifically, it was very important for the establishment of fish germplasm standards. On the aspect of same nutritional indicators, five strains of rainbow trout had their own characteristics comparing with each other of which muscle in rainbow trout of Denmark had the highest level of EAAI, suggesting that its protein had the best nutritional value; muscle in Donaldson trout has an obvious feature of high-protein low-fat which met the nutrition needs of modern people; muscle in rainbow trout of Norway had the highest content of unsaturated fatty acids due to the effect of unsaturated fatty acids in decreasing blood pressure and antitumor, rainbow trout of Norway had high health maintenance value; muscle in rainbow trout of Finland had the highest content of delicious amino acids and had extremely delicious flavor; muscle in rainbow trout of America had the best composition of n-6 and n-3 series polyunsaturated fatty acids (4.7:1) could mostly improve cardiovascular health.

CONCLUSION

The results of this study showed that muscle in five strains of rainbow trout had high content of protein, rich varieties of essential amino acids and unsaturated fatty acids, delicious flavor, abundant nutrients and unique characters so, they were ideal sources of nutrients for human were fishes who had high nutritional value and high economic values should be promoted and utilized as a project that has broad culturing prospect.

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