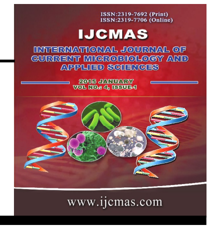

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 4 Number 1 (2015) pp. 50-57**
http://www.ijcmas.com

Original Research Article

Flesh quality in rainbow trout (*Oncorhynchus mykiss* W.) and brown trout (*Salmo trutta m. fario* L.) cultivated in recirculation aquaculture system

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A B S T R A C T

The recirculation aquaculture systems (RAS) possess a variety of advantages compared with conventional technology (raceway and net cages) which are used for rainbow and brown trout cultivation. These advantages will be obviously the reason of the increasing development of this ecologically friendly technology also in Bulgaria. But the questions connected with the quality of the raised fish still remains open. This made a study on the influence of cultivation technology on the body composition of two trout species raised in RAS both necessary and highly valuable for Bulgarian aquaculture. In current research a recirculation aquaculture system whose filter consisted from mechanical and biological compartments was used. The initial average weight of brown and rainbow trout cultivated in RAS in the conducted study was 19.56±0.08 g and 20.45±0.05 g respectively without significant differences between them. The stocking density which we used for both trout species was 57pcs.m^{-3}. For the investigation of flesh's quality 10 fishes were caught from each experimental repetition at the beginning and in the end of the trial. The flesh fillets of farmed rainbow trout and brown trout were homogenized separately to obtain a homogeneous sample. The fish homogenate was analyzed for moisture, crude protein, total fat, ash, mineral and amino acid content. The flesh samples of rainbow trout showed higher lipid (35.8% higher quantity compared with their content at the beginning of the experiment) and better essential amino acid contents (the content of total essential amino acid(TEAA)and essential amino acid/ nonessential amino acid ratios (EAA/NEAA) increased during the experiment) compared with these obtained for brown trout, but differences in the other exanimate parameters for both tested trout species were not significant which showed that both tested fish species are appropriate for the cultivation in RAS in relation to their respective fillet quality.

Keywords

Rainbow trout,
Brown trout,
Flesh quality,
RAS

Introduction

The prediction of FAO (2006) showed that an additional 40 million tons of hydrobionts will be necessary by 2030 to satisfy the nutrition need of the continuously increasing world population. Aquaculture delivers currently almost 50% of the world food fish (FAO, 2006) and emerged as one of the fastest growing production sectors.

Rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta m. fario*) are species whose cultivation has a long tradition for Bulgarian aquaculture. They are cultivated most common in concrete raceway and net cages (Staykov, 2001).

One technology which possesses a variety of advantages compared with traditional raceway cultivation and increasing its meaning for Bulgarian aquaculture in the last decade is recirculation aquaculture. The most important advantages of this production technology include: a maximization of the production, combined with the limited need of water and land as well as almost full control of environmental parameters during the cultivation of hydrobionts (Timmons and Ebeling, 2007; Martins *et al.*, 2010; Stoyanova, 2014).

Obviously fish are in contact with their water environment for their whole life. So the water quality which is connected with production technology could influence not just the growth of the raised hydrobionts, but also the quality of fish (Li *et al.*, 2000). The numerous advantages of recirculation aquaculture system (RAS) will apparently be the reason for the increased development of this ecologically friendly technology also in Bulgaria. But questions connected with the quality of the raised fish still remain open.

The aim of the current research was to studythe influence of cultivation technology on the body composition of two trout species – rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta m. fario*) – raised in recirculation aquaculture system.

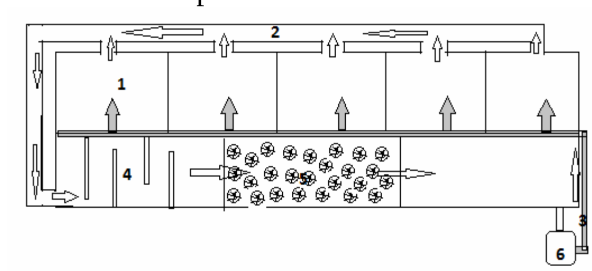
Materials and methods

The study was conducted in a recirculation aquaculture system located at the experimental aquaculture base of the Trakia Univesrity, Stara Zagora.

Recirculation aquaculture system (RAS)

The system used for the experiment consisted of a fish tank with a total volume of 1 m^{-3}anda working volume of 800 l. The out let water from the fish tanks is directed into the filtration system. The treatment of the water in the filter was assured with a mechanical filter (settling tank) and a bio filter (moving bed bio filter) (Fig. 1). The last tank in the system served as a pump tank, where cleaned water was pumped back into the fish tanks. Daily 10% of the water volume was added into the system in order to compensate for lost water from evaporation and for dilution of nitrate compounds. The RAS disposes of heaters for assuring optimal temperatures for the cultivated hydrobionts in the system. Oxygen was added continuously in the fish tank and the biological filter with an aeration system especially built for the case.

Fig.1 Recirculation aquaculture system used for the experiment



[1]Fish Tank; [2]Outlet water; [3]Inlet water; [4]Mechanical filter; [5]Biological filter (moving bed biofilter); [6]Pump

Experimental trout

Healthy rain bow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta m. fario*) without visible injuries were chosen and transported to the aquaculture base at the Agrarian faculty (Trakia Univesity), Stara Zagora. The acclimatization period lasted two weeks.

The initial average weight of brown trout was 19.56±0.08 g whereas the weight of the rainbow trout differed slightly at 20.45±0.05 g. There were no significant differences in their weight. The stocking density which we used for both trout species was 57pcs.m^{-3}. Every experimental variant was conducted in two repetitions. The fish were fed with pelleted feed with 40% crude protein three times per day.

Hydrochemical parameters

The temperature of water was measured daily with a water thermometer. The dissolved oxygen was determined by the analytical methods referring to Vinkler-Polyakov.

Flesh samples and physico – chemical analysis of meat

For the investigation of the flesh quality, we catched 10 fishes from each experimental repetition at the beginning and the end of the trial. Muscle samples were obtained as shown in Fig. 2

The flesh fillets of the farmed rainbow trout and brown trout were homogenized separately in order to obtain homogeneous samples. The fish homogenate was used for different analysis.

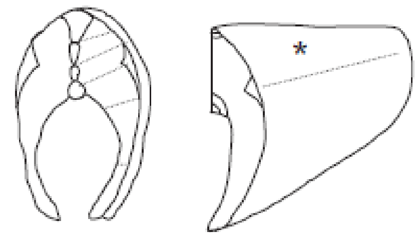


Fig.2 Muscle samples for physico – chemical analysis (by Periago *et al.*, 2005)

The fish homogenate was analyzed for moisture, crude protein, total fat, ash, mineral and amino acid content.

Moisture in fish flesh was determined by drying method in oven. The quantity of crude protein was measured by Macro – Kjeldahl Method (AOAC, 1995). Crude fat determination was made after extraction in ether by Soxhlet Method and ash content were measured after burning in muffle furnace at temperature 500°C.

For the mineral analysis, fish samples were wet digested with HNO3/HCO4. The elements Ca, Mg, Na, K, P, Fe, Zn and Cu were determinated using Perkin Elmer's atomic absorption spectrometer (BDS 11374 – 86).

The determination of amino acid content was conducted using an amino analyzer based on the principles of the cologne chromatography (method of Moore and Stein).

Result and Discussion

Hydrochemical parameters

The temperature is a very important parameter for the cultivation of rainbow and brown trout, because both species belong to the group of cold water fish species. Temperatures favorable for cultivation of those species range between 12 and 18/19 ºC (Raleigh *et al.*, 1986; Bud *et al.*, 2009). The temperature during the trial was in the range of the favorable temperature recommended for trout species. The highest measured temperature was 19.5 ºC whereas the lowest was 16 ºC. The temperature measured in the different tanks was similar and the calculated average temperature for the trial was 17.5 ºC.

The dissolved oxygen showed its highest value in April (8.5 mg l^{-1}) while the lowest oxygen concentration was measured in June (6 mg l^{-1}). The optimal content of dissolved oxygen for trout cultivation according to Kozlov (1998) should range between 9 and 11 mg l^{-1}but the permissible value for this parameter is 7 mg l^{-1}.

Chemical content of of rainbow and brown trout's flesh

The flesh moisture in both cultivated trout species was changed slightly at the end of the experiment compared with its content found out at the beginning of trial and the differences were 1.8% for the flesh of rainbow trout and 0.65% for brown trout. During the cultivation in RAS dry matter, protein, lipid and ash increased in flesh of rainbow trout respectively with 6.6%, 3.9%, 35.8% and 4.52%. At the same time the content of dry matter and protein increased in flesh of brown trout respectively with 2.28% and 6.76%, but lipid and ash decreased respectively with 3.7% and 16.1%. The analysis of differences in chemical content of flesh between the two cultivated trout species was statistically significant (P≤0.05) just for lipid content and it was in favour of rainbow trout's flesh.

The data received from us for the content of protein in the flesh of rainbow trout are in confirmation with the data received from Savić *et al.* (2004), Plavša *et al.* (2000) Bud *et al.* (2008) for rainbow trout being received from aquaculture. Some scientists found a higher level (20% and higher) of protein for trout reared in aquaculture (Phillips and Brockwey, 1956; Grujić, 2000). The lipid content found out in rainbow trout's fillet in the current research was lower compared with those received from different scientists (Grujić, 2000; Plavša *et al.*,2000; Ćirković *et al.*, 2002; Savić *et al.*, 2004; Bud *et al.*, 2008; Celik *et al.*, 2008), but the water content and ash were similar.

The content of protein in fillet of brown trout raised in RAS at Trakia University was much closer to the results received for wild brown trout (higher than 18%) than those received for cultured brown trout (17.24%) (Kaya *et al.*, 2014). The content of lipids was lower in our trial compared with those received for both wild and cultured brown trout in the experiment conducted by Kaya *et al.* (2014), but in turn the dry matter and ash were similar to those received from us.

Table.1 Chemical content of rainbow and brown trout's meatcultivated in RAS

	Start of trial	**Start of trial**	**End of trial**	**End of trial**
	Rainbow trout	Brown trout	Rainbow trout	Brown trout
Moisture	79.65±1.62	78.65±1.27	78.17±0.31	78.13±1.11
Dry matter	20.35±2.75	21.35±1.62	21.81±1.08	21.85±1.08
Protein	17.92±2.79	18.43±1.42	18.65±1.35	19.22±1.88
Lipid	1.27±0.22	1.62±0.31	1.98±0.19*	1.56±0.1
Ash	1.16±0.02	1.3±0.14	1.21±0.02	1.09±0.2

*p≤0.05

Table.2 Mineral elements in rainbow and brown trout's flesh

	Start of trial	Start of trial	End of trial	End of trial
	Rainbow trout	Brown trout	Rainbow trout	Brown trout
Ca (%)	0.016±0.001	0.014±0.0019	0.014±0.0007	0.012±0.0004
P(%)	0.195±0.02	0.197±0.02	0.271*±0.014	0.227±0.01
Na (%)	0.042±0.008	0.04±0.01	0.046±0.02	0.048±0.02
K(%)	0.398±0.04	0.39±0.05	0.297±0.01	0.289±0.001
Mg (%)	0.024±0.0009	0.028±0.001	0.016±0.001	0.017±0.0009
Fe mg/100g	0.92±0.05	1.81±0.12	0.99±0.05	1.105±0.007*
Cu mg/100g	0.15±0.02	0.096±0.002	0.199±0.0014	0.172±0.01
Zn mg/100g	0.637±0.01	0.99±0.05	1.79±0.141	2.28±0.176*

*p≤0.05

Table.3 Amino acid content in rainbow and brown trout flesh' raised in RAS /in 100 g /sample

	Rainbow trout	Brown trout	Rainbow trout	Brown trout
Asparagine	1.905±0.021	1.93±0.01	1.828±0.13	1.82±0.132
Threonine E	0.062±0.11	0.6±0.08	0.489±0.17*	0.577±0.19
Serine	0.349±0.08	0.32±0.04	0.3±0.14	0.29±0.08
Glutamic acid	3.26±0.43	3.18±0.28	3.189±0.28	3.216±0.33
Proline	0.74±0.007	0.622±0.05	0.788±0.27	0.76±0.16
Cysteine	0.189±0.04	0.09±0.0021	0.194±0.05	0.161±0.29*
Glycine	0.933±0.004	0.932±0.0014	0.813±0.29	0.872±0.154
Alanine	1.103±0.33	1.14±0.27	1.09±0.29	1.078±0.28
Valine E	1.03±0.2	1.04±0.11	1.03±0.19	1.07±0.203
Methionine E	0.384±0.002	0.456±0.03	0.374±0.06	0.385±0.04
Isoleucine E	0.892±0.32	0.917±0.27	0.866±0.34	0.885±0.33
Leucine E	1.571±0.28	1.624±0.312	1.49±0.28	1.48±0.27
Tyrosine	0.482±0.13	0.415±0.002	0.47±0.169	0.405±0.007
Phenylalanine E	0.846±0.37	0.892±0.314	0.748±0.37	0.728±0.37
Histidine	0.675±0.15	0.592±0.07	0.685±0.15	0.607±0.02
Lysine E	1.837±0.39	1.92±0.27	1.85±0.37	1.86±0.33
TAA	16.258	16.67	16.204	16.194
TEAA	6.622	7.449	6.847*	6.985
TNEAA	8.961	8.629	8.672*	8.602
TEAA/ TNEAA	0.73	0.86	0.78	0.81

*p≤0.05, E- Essential amino acid for humans, TAA - Total amino acid; TEAA - Total essential amino acid; TNEAA - Total nonessential amino acid

Mineral composition of rainbow and brown trout's flesh

The analysis of data concerning content of mineral and microelements in rainbow trout's flesh showed that phosphorus, sodium, iron, copper and zinc increased respectively with 28.04%, 9.67%, 7.07%, 24.6% and 64.4%, but calcium, potassium and magnesium decreased with 13.04%, 25.3% and 29.5% during the current experiment. The content of phosphorus, sodium, copper and zinc increased respectively with 13.21% and 17.5%, 44.18% and 56.6%, calcium, magnesium, potassium and iron decreased respectively with 15.7%, 38.9%, 25.8%, and 38.9% in the experimental brown trout's flesh. The analysis of differences in mineral and microelements content in flesh between the start and end of experiment in two cultivated trout species was statistically significant ($P \leq 0.05$) for phosphorus, iron and zinc content (Table 2).

Different studies in aquaculture are connected with mineral content in fish fillet because of two reasons: first, to satisfy the needs of the cultivated hydrobionts with essential minerals (Gonzalez *et al.*, 2006) and second, the always high interest of consumers in mineral content, because of their concern for the presence of heavy metals in aquaculture products (Haard, 1992).

The concentration of Fe, Cu, Zn in the current study were lower compared with their concentration in fillet of yellow perch cultivated in RAS (Gonzalez *et al.*, 2006).

Amino acid profiles of rainbow and brown trout's flesh

The content of three amino acids (asparagine, glutamic acid and lysine) was higher in the fillet of both tested trout species compared with the quantity of the other amino acids. The same basic amino acids content for brown trout fillet were determined by Ozyurt and Polat (2006), but Sabetian *et al.* (2012) found out that the basic amino acids in rainbow trout fillet are asparagine, glutamic acid and leucine.

The content of essential amino acid threonine increased significantly in rainbow trout at the end of the experiment (Table 3), the same tendency was determined for amino acid cysteine for brown trout.

In the present study, the total amino acids (TAA) amount was found to be lower at the end of experiment when compared with its value at the beginning of the trial for both tested trout species. TAA from the current research was similar to the value received for cultivated brown trout in the studies of Kaya *et al.* (2014). The content of EAA (valine, methionine, isoleucine, leucine, phenylalanine and histidine) increased and non-essential amino acids (NEAA) (aspartic acid, glutamic acid, alanine, glycine and proline) decreased in rainbow trout's fillet at the end of experiment. In the flesh of brown trout EAA and TNEAA decreased with time. Nevertheless in the respect of the EAA/NEAA ratio at the end of the experiment those calculated for brown trout kept higher value (0.81) than those found out for the flesh of rainbow trout (0.78).

The results obtained from this study showed that both tested trout species in RAS have a well-balanced and high-quality protein source in the respect of the EAA/NEAA ratio and the received data are in confirmation of data received for brown trout by Kaya *et al.* (2014) and for rainbow trout by Sabetian *et al.* (2012).

The ratio of E/NE was determined as 0.71 for cod (*Gadus morhua*) by Jhaveri *et al.* (1984), 0.77 for sea bream (*Pagrus major*), 0.69 for sardine (*Sardina melonosticta*), 0.74 for herring (*Clupea pallasi*) and 0.75 chum salmon (*Oncorhynchus keta*) by Iwasaki and Harada (1985).

The present study showed that the quality of fillet received from rainbow and brown trout cultivated in RAS was higher. The flesh samples of rainbow trout showed a higher lipid and better essential amino acids content in the end of the trial compared with those found out for brown trout, but differences in the other exanimate parameters for both tested trout species were not significant which showed that both tested fish species are appropriate for cultivation in RAS in relation to their fillet quality.

We can recommend recirculation aquaculture technology as appropriate for the cultivation of rainbow and brown trout in Bulgaria, because it is environmentally friendly and it allows an intensification of the process while being a source for good products for human consumption in terms of nutritional value for the population at the same time.

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