AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 15, No 1, pp 32-41, 2023
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2023.01.004

Nutrition and Physiology

Effects of replacement of fishmeal with other alternative protein sources in the feed on hydrochemical parameters and flesh quality of rainbow trout *(Oncorhynchus mykiss)*

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(Manuscript received 13 May 2022; accepted for publication 8 March 2023)

Abstract. *The rainbow trout is preferred for cultivation in Bulgaria due to the high rate of growth and its meat quality. The aim of this study was to track the substitution of fishmeal and fish oil with alternative sources of protein and lipids. The results obtained after substitution with such protein sources – soya worm flour, oil seeds – were controversial. The aim of the experiment was to replace fishmeal and fish oil with an alternative - Ω-3 – FORPLUS algea (Alltech Neogreen®). The hydrochemical and growth parameters were examined, along with the chemical composition of meat during the cultivation of rainbow trout in a recirculating system. Each tested fodder was cultivated in four tanks. The experiment continued for 60 days. The substitution of fishmeal and oil did not influence the hydrochemical parameters. The replacement with - Ω-3 – FORPLUS algea did not lower the growth indicators of the rainbow trout. Fishmeal and fish oil replacement did not exert a negative effect on the chemical composition of the meat.*

Keywords: rainbow trout, alternative protein sources, hydrochemical parameters, growth parameters, flesh quality

Introduction

Rainbow trout (*Oncorhynchus mykiss*) is one of the main cultivated species of great importance to world aquaculture. According to data provided by the Executive Agency of Fisheries and Aquaculture, in 2017 the production of fish and other aquatic organisms raised for consumption increased by 8.8% on an annual basis, reaching 13 468.8 tonnes. Traditionally, the largest production of fish for consumption belongs to the species rainbow trout, carp and bighead carp. (agroplovdiv.bg)

As the main species in Bulgarian freshwater aquaculture, rainbow trout is sensitive to the quality of water and food, which together with its susceptibility to different diseases require strict discipline in respect of compliance with the technological parameters in growing the species (Zaykov and Staykov, 2013).

Rainbow trout is a predatory species and its cultivation requires protein of animal origin from 35% to 45% (NRC, 2011). Fish meal is a major raw material in the compilation of wholesome rations for predatory fish due to its high protein content. Also, fish meal is a source of minerals, vitamins, and essential fatty acids for the trout species of fish.

According to Tacon (1993) fishmeal is the most expensive raw material when compiling recipes for feeding fish. Reducing dependence on fishmeal is of paramount importance for sustainable and environmentally friendly water production, especially in predatory fish species that need more protein. Feed used in the aquaculture sector accounts for over 80% of the world's fishmeal yield, which is a result of the global hydrobionts fishing (FAO, 2012). Some authors, such as Drew et al. (2007) and Gaitlin et al. (2007), believe that fishmeal is a major source of protein

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with economic importance in the compilation of dietary rations for aquatic organisms. For the future development of aquaculture, the ideal source to be used as a substitute for fishmeal should be of high nutritional value, easily accessible and inexpensive for the development of sustainable aquaculture (Jobling, 2016). According to (Ghosh, et al., 2019) algae are an alternative protein source of fishmeal. Araújo et al. (2016) used algae flour in the feeding of rainbow trout (*Oncorhynchus mykiss*) as a source of protein in a ratio of 5% and 10% to the total composition of the feed for rainbow trout. The authors conclude that up to 5% of fishmeal can be replaced with algae flour without harming the growth indicators of this hydrobiont. According to Sirakov et al. (2012), spirulina algae flour can be used for up to 10% of the total feed ration of the rainbow trout, without reducing the growth indicators of this species. The authors think that the addition of algae spirulina does not affect hydrochemical indicators. An experiment performed by Yildirim et al. (2009) on the use of algae *Ulva lactuca, Enteromorpha linza* as a source of protein in the feeding of the rainbow trout *(Oncorhynchus mykiss*) involving 10% of both species of algae showed higher levels of crude protein, ash, lipids in fish meat compared to the control group given standard feed without algae.

The addition of 5% of the algae *Sargassum polycystum* to the barramundi (*Lates calcarifer*) feed increases the ash content in the meat of this species compared to other experimental groups of algae feed *Kappaphycus alvarezii, Eucheuma denticulatum*. However, in the control variant without algae - the standard barramundi feed, the meat of the aquatic organism has a higher content of lipids and protein, compared to the groups fed with the addition of seaweed (Shapawi and Zamry, 2016).

When feeding Nile tilapia (*Oreochromis niloticus*) with red algae *Gracilaria arcuate* with 20%, 40%, 60% of the daily ration, the increase of the share of algae used *Gracilaria arcuate* led to a rise in the ash levels, and crude protein in the body of experimental fish (Younis et al., 2018).

The use of the algae *Ulva intestinalis* in the diet of tropical fish affects the dissolved oxygen and pH of water (Siddik et al., 2015).The addition of macroalgae has a positive effect on water quality when used in the diet of hydrobionts, according to Valente et al. (2006), Ergün et al. (2009), Siddik et al. (2015).

The addition of algae *Ulva rigida* as a source of protein at a ratio of 0.5%, 2.5%, 5% to the feed of Nile tilapia (*Oreochromis niloticus)* does not affect the level of ash, crude protein and dry matter in fish meat (Khalafalla and El-Hais, 2015). The addition of brown algae flour *Laminaria* spp., kelp to the feeding of Atlantic salmon (*Salmo salar*) at the amount of 3%, 6.10%, leads to an increase in feed consumption at the highest percentage tested, which can consequently improve growth indicators. Brown algae lead to a decrease in stress factors, such as a sharp rise in temperature (Kamunde et al., 2019).

Fish oil is an excellent source of lipids, n-3 unsaturated fatty acids (Rice, 2009). It is also a source of eicosapentaenoic, docosapentaenoic, docosahexaenoic acid which are essential for bone fish (NRC, 1993). Fish oil provides lipids in various feeds for hydrobionts (NRC, 2011). The limited supply and increased demand of aquaculture for fish oil needed for the production of hydrobionts, and the necessity for environmentally sustainable aquaculture are reasons to look for alternatives to replace fish oil in their diet (Domingo et al., 2007). Unlike other plant sources of lipids, algae have higher levels of essential polyunsaturated fatty acids (Brasky et al. 2011). According to Menoyo et al. (2004), the replacement of fish oil with flaxseed oil, and soybean oil in the diet of sea bream (*Sparus aurata*), leads to a deterioration in fatty acid levels. The replacement of fish oil with algae (*Schizochytrium spp)* in the diet of Nile tilapia (*Oreochromis niloticus*) shows satisfactory results for the deposition of fatty acids in the meat of the experimental species (Sarker et al. 2016).

The brown algae *Durvillaea antarctica* can be used as a substitute for fish oil with up to 6% in the diet of rainbow trout which improves the taste of this species of fish (Quiñones et al., 2021).

The combined use of the algae *Schizochytrium limacinum,* and *Nannochloropsis oceanica* in the feeding of rainbow trout shows that at high levels of substitution of fish oil with meal from both of these species, a deterioration of the growth factors and compromised feed conversion ratio (FCR) can be observed. The authors believe that up to 90 g of meal can be added to 1 kg of feed given to the rainbow trout (*Oncorhynchus mykiss*) to replace fish oil (Serrano et al., 2021).

According to Bélanger et al. (2021), the macroalgae (*Schizochytrium spp*) can potentially be used in the feeding of rainbow trout when replacing fish oil.

Prebiotics such as mannan oligosaccharides offer an alternative to improve intestinal digestion of hydrobionts, their growth, and health status (Staykov et al., 2007; Torrecillas et al., 2007; Burr et al., 2008). Mannan oligosaccharides or MOS are complex carbohydrates derived from yeast cell walls (Salze et al., 2010). The benefits of mannan oligosaccharides have been reported by Ali et al. (2017) who added 1% of the prebiotic to the total ration of barramundi fish (*Lates calcarifer).* Prebiotics improve the growth indicators of the fish species. Grisdale-Helland et al. (2008) think that the addition of 10 g of mannan oligosaccharides to 1 kg of feed to the ratio of the Atlantic salmon (*Salmo salar*) improves the production of the aquatic organism. The effectiveness of adding mannan oligosaccharides to carp feeding has also been reported (Momeni-Moghaddam et al., 2015). According to them, the addition of 0.20% to the diet of carp *(Cyprinus Carpio*) improves the feed conversion ratio (FCR) and intestinal digestion. The use of mannan oligosaccharides in the diet of cod (*Huso huso)* does not have a positive effect on growth and meat quality (Mansour et al., 2011).

Research on the implementation of algae as a protein source of food for aquaculture is still scarce. Much more research is needed to establish the benefits of using algae as a protein source (Makkar et al., 2016).

Research on the alternative sources of fishmeal, oil and the use of mannan oligosaccharides is still rare in aquaculture, and comparisons between the effects of using such feed on hydrochemistry, growth and meat quality in rainbow trout have not been thoroughly studied. This problem is of practical interest because this type of feed allows the set-up of sustainable aquaculture, envisioned in the development of this sector in the EU for the next programming period 2021-2027.

The aim of the present study is to determine the effect of providing rainbow trout with three types of feed. Neogreen (N) fishmeal and Supreme (S) oil were replaced with algae during the feeding of the rainbow trout, while for the third feed type we added mannan oligosaccharide to compile the feed mixture (U). Our aim was to determine the effect of feed on the production indicators of the rainbow trout (*Oncorhynchus mykiss*) and meat quality during cultivation in recirculation systems.

Material and methods

The experiment with rainbow trout was conducted at the Training and Experimental Aquaculture Base of the Department of Biology and Aquaculture, Faculty of Agriculture, Trakia University-Stara Zagora. Recirculation system (Figure 1) consisting of cement baths was used for the experiment, each with a total volume of 1 m^3 and an effective volume of 0.8 m^3. The flow rate of the recirculation system was 25 L min^{-1}. The water purification was performed by means of a mechanical filter (precipitator) and a biofilter. To reduce the amount of nitrates and to compensate for the loss of water from the baths, a quantity of fresh water was added daily to 10 - 15% of the total volume of the recirculation system.

Tank 8	**Tank 7**	**Tank 6**	**Tank 5**	**Tank 4**	**Tank 3**	**Tank 2**	**Tank 1**
Tank 9	**Tank 10**	**Tank 11**	**Tank 12**	**Precipitator**	**Biofilter**	**Mechanical filter**	**Pump**

Figure 1. Recirculation aquaculture system used in the current trial

A total of 480 small rainbow trout fish were transported from the farm in the town of Tvarditsa and distributed in 12 baths with 40 fish each. The experiment started following a 7-day adaptation period, which lasted 60 days, after which each fish was weighed individually.

Feeding the experimental fish

The feeding of the experimental fish was carried out manually, the amount of the daily ration in all experimental variants was 2% of the live weight of the experimental fish. The determined daily rations were divided into five equal portions, given at regular intervals at 09.00, 11.00, 13.00, 15.00 and 17.00. In the first experimental variant (Ultra) (Table 1) the fish were fed with the addition of mannan oligosaccharides. In the second experimental variant, the fish were fed with feed (Neogreen) (Table 2), in which the fish meal was replaced with an alternative source of protein - microalgae. In the third experimental variant, the fish were fed with feed (Supreme) (Table 3) in which fish oil was replaced by seaweed.

The average initial weight in the different experimental variants was as follows:

- Average initial weight of the Ultra group - 7.60 ± 0.01 g (U)
- Mean initial weight of the Neogreen group - 7.60 ± 0.08 (N)
- Average initial weight of the Supreme group - 7.55 ± 0.08 (S)

Table 1. Nutritional content of the control feed was a source of fish meal protein provided by the company Ultra Alltech®

Parameters	Quantity
Protein	44%
Fat	25%
Crude fiber	1.5%
Ash	5.2
Total P	0.84%
Vitamins added	
Vitamin A (IE kg^{-1})	10.000
Vitamin A (IE kg^{-1})	1.240
Vitamin A (IE kg^{-1})	200
Vitamin C (stable) (mg kg^{-1})	250
Energy	
Gross (MJ / kg)	23.4
Digestible (MJ \ kg)	21.3

Table 2. Nutritional content of the experimental feed was a source of algae protein provided by the company Neogreen Alltech®.

Parameters	Quantity
Protein	43%
Fat	28%
Crude fiber	1.7%
Ash	7.4%
Total P	0.84%
Vitamins added	
Vitamin A (IE kg^{-1})	10.000
Vitamin A (IE kg^{-1})	2.40
Vitamin A (IE kg^{-1})	200
Vitamin C (stable) (mg kg^{-1})	250
Energy	
Gross (MJ / kg)	23.3
Digestible (MJ \ kg)	21.3

Table 3. Nutritional content of the experimental feed Supreme substitute for fish oil with algae provided by the company Alltech®.

Parameters	Quantity
Protein	41%
Fat	22%
Crude fiber	2.00%
Ash	8.00%
Total P	0.87%
Vitamins added	
Vitamin A (IE kg^{-1})	8936
Energy	
Gross (MJ / kg)	23.2
Digestible (MJ \ kg)	19.2

The following hydrochemical parameters were monitored every week during the experiment:

- Water temperature, ^{o}C;
- Quantity of dissolved oxygen, $mg.L^{-1}$;
- Active reaction, pH;
- Electrical conductivity, $\mu S.cm^{-1}$

They were tracked using a portable multimeter "HQ30D", (Hach Lange) (Germany)

The following chemical parameters were monitored during the experiment and samples were taken once a week:

- Ammonium ions – mg. L^{-1} (BDS-ISO 3587);
- Nitrites – mg. L^{-1} (BDS-ISO 3762)
- Nitrates – mg. L^{-1} (BDS-ISO 3762)
- Orthophosphates – mg. L^{-1} (BDS-ISO 687)

At the beginning of the experiment, all fish were weighed individually on a scale (Elicom S300PM) with a precision of 0,1 g. The growth indicators of the species were monitored. At the beginning and at the end of the experiment the fish were weighed individually, and the mortality of the fish at the end of the experiment was monitored. A protocol of fish mortality was kept daily. At the end of the experiment, four fish were randomly taken from each bath. After being caught and stunned, the fish were transported in a cooler bag to the Central Research Laboratory at Trakia University-Stara Zagora, where samples were taken from the back muscles of the fish to determine the chemical composition of meat - moisture, protein, lipids, dry matter, ash content (%). Meat samples for the relevant analyses were prepared according to the AOAC (2006, method 983,18) to determine the following parameters: moisture content (%) (AOAC, 1997, method 950,46 and BDS 11374 - 86), protein (%) (BDS- ENISO 5983, Kjeldahl method, using Keltec 8400 apparatus, FOS, Sweden), lipid content (%) (BDS-ISO 6492, Soxlet method using automatic system Soxlet 2050, FOS, Sweden), dry matter content (%) (BDS 11374-86), crude ash content (%) (BDS - ISO 5984) by burning in a muffle furnace (MLW, Germany) 550°C for 8 hours.

Determination of the rainbow trout growth indicators:

Average individual weight gain (g) = Average final body weight in fish (g) - Average initial body weight

Determination of survival

Survival (%) = (final number of fish / initial number of fish) x100

Statistical analyses

All data were statistically analyzed by Anova single factor (Microsoft office, 2010). All differences between replicate groups were considered significant at $p < 0.05$.

Results and discussion

Oxygen is one of the most important indicators for the cultivation of the rainbow trout. During the experiment we conducted at our base, the oxygen value ranged between 6 $mg.L^{-1}$ and 8 $mg.L^{-1}$ (Figure 2). Most aquatic organisms need 5 to 8 ppm of oxygen (Staykov, 2001). Sirakov et al. (2012) do not report a statistically significant difference (p>0.05) in the addition of spirulina in the diet of the rainbow trout. When replacing fishmeal with *Spirulina platensis* during feeding with *Litopenaeus vannamei,* Macias-Sancho et al. (2014) also do not report a statistically significant difference (p>0.05) in the control and experimental group. In the group of fish given S feed, the oxygen level had the highest average value of 7.02 ± 0.01. The difference from U feed-fed fish is 0.01% in favor of S feed-fed fish. The difference between the mean values of S and N was 0.03% in favor of S, and there were no statistically significant differences (p>0.05).

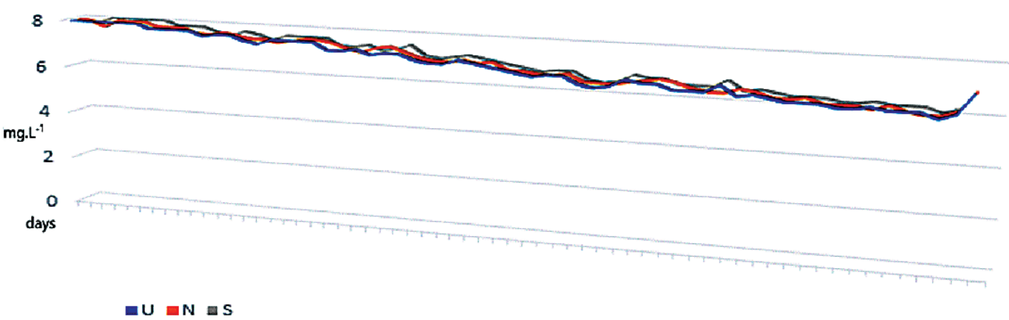

Figure 2. Oxygen content during the experiment

Temperature is a limiting factor in the cultivation of the rainbow trout. During the experiment the temperature varied from 14 -17°C (Figure 3). According to Zaykov and Staykov (2013) the rainbow trout, being a cold-water species, thrives at a temperature of 14-18°C. It can briefly withstand 26-30°C. Below 5°C and above 20°C its growth is greatly reduced. The highest average temperature is for S-fed fish and it is 15.35°C. The average value of the temperature indicator between N and S groups was 0.02% in favor of S-fed fish with no statistically significant differences (p> 0.05.) The average value of the fish from groups N and U was 0.01% higher than the average value of the temperature indicator in group S, but there were no statistically significant differences (p> 0.05).

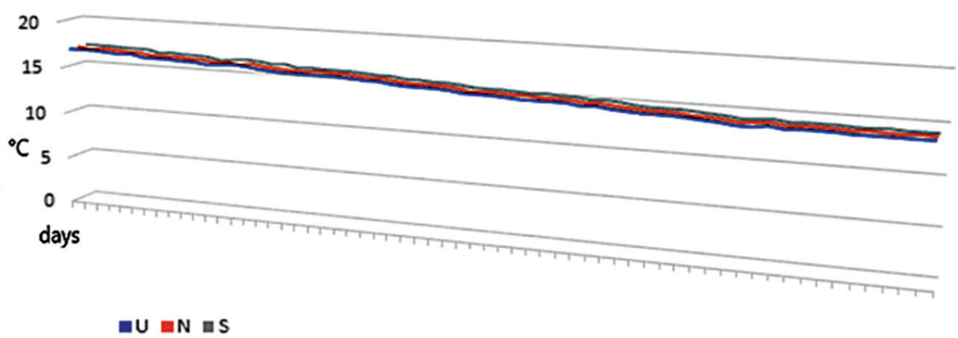

Figure 3. Temperature during the experiment

During the experiment, the pH values ranged from 6.8 to 7.4 (Figure 4). The data obtained correspond to the norms of Kozlov et al. (1998) who claims that pH values from 6.5 to 8.5 are normal for the cultivation of the rainbow trout. According to Sang et al. (2010), the addition of mannan oligosaccharides to the feed of *Panulirus ornatus* does not affect the pH indicator, when compared to the control group which does not contain the food additive. The highest average pH value 7.06 ± 0.01 was registered in U-feed fed fish. The difference with the N group was 0.01% higher than the average pH value in U-fed fish, as there were no statistically significant differences (p>0.05). The difference between U and S groups is 0.02% in favor of U-fed fish, with no statistically significant differences (p>0.05).

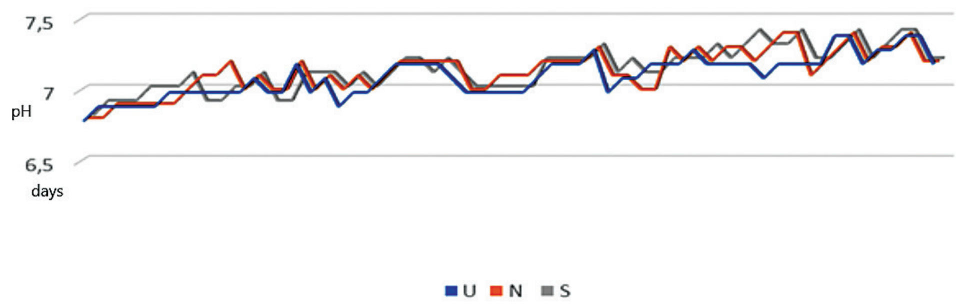

Figure 4. The values of pH during the experiment

U-fed fish showed the highest average value of 274.39± 1.21 µS.cm^{-1} for electric conductivity (Figure 5). Hydrobionts of group U had a 1.05% higher value of electrical conductivity compared to tanks containing N-fed hydrobionts without any statistically significant differences (p>0.05). The difference between the mean value between U and S groups was 1.21% in favor of U-fed fish with no statistically significant differences (p>0.05).

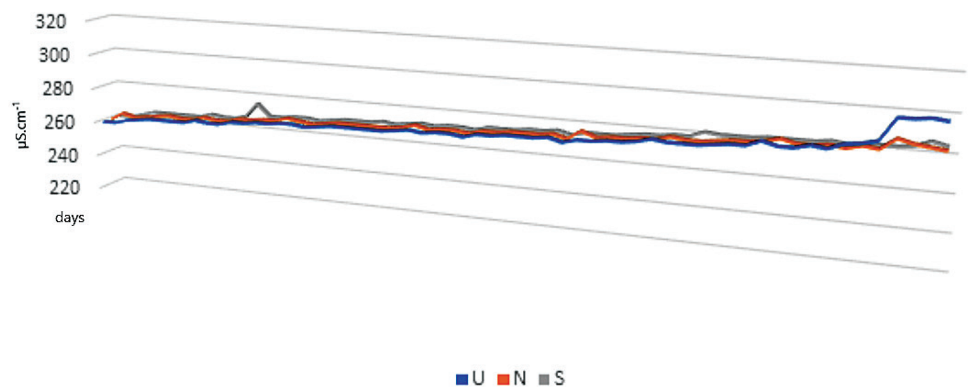

Figure 5. Electric conductivity during the experiment, µS.cm^{-1}

Table 4. Nitrogen and phosphorus parameters measured in the recirculation system during the experiment

Experimental variant	Ammonium ion mg. L-^{1}	Nitrate mg.L-^{1}	Nitrite mg.L-^{1}	Phosphate mg.L-^{1}
Ultra	0.32± 0.02	0.50±0.04	0.034±0.05	0.983±0.16
Neogreen	0.34± 0.02	0.48±0.08	0.030±0.06	0.973±0.12
Supreme	0.28±0.05	0.44±0.12	0.039±0.04	0.864±0.04

The results obtained for the nitrogen and phosphorus parameters of the recirculation system are presented in Table 4. The concentration of ammonium ions was the highest in N-fed fish: 0.34 ± 0.02 mg.L^{-1}. The concentration of this indicator was 6% higher in group N, compared to the U-fed group, whereas there were no statistically significant differences (p>0.05). The difference between the values of N and S groups was 18% higher in N-fed fish, however, there were no statistically significant differences (p>0.05). A biofilter was used in the recirculation system to maintain the concentration of ammonium ions. According to Wicaksana et al. (2015), the use of a biofilter helps to keep ammonium ions within acceptable limits. The content of nitrates was the highest in U-fed fish: 0.76 ± 0.04 mg. L^{-1}. The difference between variants U and S was with 12% higher content of the nitrate indicator in N group fish, without statistically significant differences (p>0.05). The content of the nitrate indicator between variant U and N was 2% in favor of U-fed fish, without any statistically significant differences (p>0.05). Nitrate concentrations above 500 mg.L^{-1} may affect the growth parameters of hydrobionts (Monses et al., 2017). The difference between the content of nitrite in variants (S) and (U) 14% was the highest in variant S, but there were no statistically significant differences (p>0.05). The difference between the content of nitrite in variants (S) and (N) was the highest with 17% in variant S, but there were no statistically significant differences (p>0.05).

The content of orthophosphates was the highest in variant U: 0.983 ± 0.16 mg.L^{-1}. The difference between the content of orthophosphates in variants U and N was 2.7% in favor of the group fed with the addition of mannan oligosaccharides, but there were no statistically significant differences (p>0.05). The difference between U and S groups was 0.02% in favor of U-fed fish, with no statistically significant differences (p>0.05). According to Strauch et al. 2019, the orthophosphates values of up to 80 mg.L^{-1} are permissible for cultivation of hydrobionts.

Table 5. Growth performance of rainbow trout

Experimental Variant	Initial body weight, g	Final body weight ,g	Survival rate %
Ultra	7.6±1.2	61.5±2.09	62.5±0.89
Neogreen	7.55±1.24	71.75±3.9	62±0.74
Supreme	7.65±1.45	61.75±2.05	60±0.81

The N-fed group had the final body weight of 71.75 ± 3.9 g which was 14% higher compared to the group fed with the addition of mannan oligosaccharides (U) and statistically significant differences were found (p<0.05). Our findings have been confirmed by El-Tawil (2010), who reports the positive effect of algae on the growth parameters of red tilapia (*Oreochromis spp.)* with the addition of 15% algae *Ulva spp.* to the regular food. Khalafalla and El-Hais (2015) also confirm the positive effect of algae nutrition on growth indicators with the addition of 5% *Ulva rigida* to the total diet of Nile tilapia. Wassef et al. (2005) stated that the alga *Pterocladia capillacea* can have a positive effect on the growth indicators of *Sparus aurata*, as the added alga can comprise up to 10% of the total diet of aquatic organisms.

The difference in growth rates between N and S-groups was 14% in favor of feed in which the fishmeal was replaced (Table 5). Fish fed with feed U had the highest survival rate of 62.5± 6.99. Compared to the N-fed group, it reached 0.8% in favor of U-fed fish, but no statistically significant differences were found (p>0.05). The difference between the survival rate in U and S-groups was 4% in favor of U-feed, while no statistically significant differences were found (p>0.05). Our data correspond to the results of other authors who have worked in this field (Ye et al., 2011; Salem et al., 2016; Forsatkar et al., 2017). They also report higher survival rate with the addition of mannan oligosaccharides to the diet of sea bass (*Dicentrarchus labrax*), Japanese flounder (*Paralichthys olivaceus)* and *Danio rerio.*

Table 6. Chemical composition of the fillet of rainbow trout *(Oncorhynchus mykiss*) cultivated in a recirculation system

Used feed	Number of meat samples taken	Moisture %	Dry matter %	Crude protein %	Ash %	Crude fat %
Ultra	12	72.06±0.12	27.94±0.12	20.61±0.07	1.59±0.01*	5.18±0.09
Neogreen	12	72.46±0.13	27.54±0.13	20.63±0.11	1.69±0.02	5.10±0.07
Supreme	12	72.43±0.07	27.57±0.07	21.15±0.05	1.78±0.02*	5.15±0.05

The chemical composition of *O. mykiss* meat is presented in Table 6. Regarding the percentile moisture content in the meat, the group of fish fed with feed containing seaweed flour (N), has the highest value of the studied indicator 72.46%±0.13. This is 0.43% higher moisture content than S-fed fish, and respectively, a 0.51% higher content in the meat of U-fed fish, with no statistically significant differences (p> 0.05). Our findings correspond to the results of Younis et al. (2018), who discovered that the addition of algae helps to increase moisture in the meat of Nile tilapia (*Oreochromis niloticus*). Azaza et al. (2008) also report higher moisture levels when algae (*Ulva rigida*) were added to the tilapia diet.

The highest value of dry matter was reported in the meat of fish fed with standard feed + addition of mannan oligosaccharides (U) 27.94 ± 0.12. We noted an increase of 1.43% in the reported indicator in N-fed fish, and 1.36% of the obtained result in the muscles of S-fed fish, without statistically significant differences (p> 0.05). The results obtained for the content of crude protein in the group fed with the substitute for fish oil with seaweed (S) were 21.15 ± 0.05, which is 2.93% higher than the content of crude protein in N-fed fish, without statistically significant differences (p>0.05). The difference between S and U was 2.55 % in favor of fish fed with feed S, with no statistically significant differences (p>0.05). Some authors, such as Soler-Vila et al. (2009) and Davies et al. (1997) have concluded that the addition of algae *Porphyra purpurea*to as 10% of the total diet of rainbow trout (*Oncorhynchus mykiss*) and the addition to the feed of *Chelon labrosus* increases protein levels in the muscles of fish meat. According to Torrecillas et al. (2007), the addition of the dietary supplement of mannan oligosaccharides at a ratio of 2.4 g to 1 kg of feed does not affect the content of crude protein in the meat of *Dicentrarchus labrax.*

The obtained results for the percentage of ash content in the meat of the studied fish indicate that it is the highest in S-fed fish 1.78 ± 0.02, which is 10.68% higher than

U-fed fish, and 5.05% higher than the group N fish. There were no statistically significant differences between the individual groups (p>0.05). Our results have also been supported in the studies of other authors (Pereira et al., 2012) in their experiments with Nile tiliapia. According to Wassef et al. (2005), the addition of *Pterocladia capillacea* up to 10% of the total food of sea bream increases the value of ash in the meat of the aquatic organism. Whereas, Akter et al. (2021) report an increase in the ash content of the meat of *Clarias batrachus* with an addition of 0.6% of mannan oligosaccharides to the diet of Asian catfish.

The highest value of lipids was reported in U-fed fish: 5.18 ± 0.09, which is 1.54% higher than in N-fed fish, and shows a 0.58% higher content of the studied indicator in the meat of fish from the S-fed group. No statistically significant differences were found (p>0.05). The results from our study are similar to those of Al-Asgah et al. (2016), who also report that the lipids in the body of the African catfish (*Clarias gariepinus)* decrease when algae are added to the diet of this aquatic organism. Younis et al. (2018) also note a reduction in lipids in the meat *of Oreochromis niloticus* with the addition of algae flour *Gracilaria arcuata.* The addition of mannan oligosaccharides to the diet of sea bass (*Dicentrarchus labrax)* leads to an increase in lipids in the meat of hydrobionts when comparing control feed without food additives (Salem et al., 2016).

Conclusion

From the obtained results we found that the concentration of ammonium ions was the lowest in the S-fed fish, whereas the N-fed group had the highest content of this compound. The value of nitrates was the highest in U-fed hydrobionts, and the lowest in the S group of fish. The reported nitrite indicator had the highest value in S-fed fish and the lowest in N-fed fish. The value of orthophosphates was the highest in group U and the lowest in group S. The results show that S feed has the best hydrochemical parameters for rainbow trout cultivation. Growth rates were the highest in N-fed fish and survival rate was the highest in group U.

The results obtained from the chemical composition of the meat reported the highest moisture content in fish of group N, and the lowest in group U. The dry matter index was the highest in fish in group U and the lowest in group N. The value of crude protein in fish meat was the highest in fish of group S, while N-fed fish had the lowest value of crude fat. Fish of group S showed the highest value of the ash indicator in meat, and group N - the lowest. Crude fats in fish meat had the highest value in U-fed fish, and the lowest in N-fed fish.

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