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Research article

EFFECTS OF VARIOUS MEAL COMPOSITIONS ON PRODUCTION RESULTS, ECONOMIC PERFORMANCE AND FISH MEAT QUALITY

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The purpose of this study was to assess the effects of various dietary meal compositions on production, economic performance and meat quality of the rainbow trout (*Oncorhynchus mykiss*). Experimental group (0-I) was fed with a mixture containing 30% fish meal, 35% soybean meal, 30% sardines and 5% fish oil. Experimental group 0-II was fed with a combined meal consisting of 75% of fish food pellets and 25% of sardines. The control group (C) was fed with a standard complete pelleted feed. The best result was obtained in group 0-II, while group C achieved results common for local food quality and farming conditions in Serbia. Group 0-I had less productive results compared to group C and group 0-II. Feed used in group 0-II has its own nutritional, biological and economic justification.

Use of different fish meals had no significant influence on trout meat chemical composition, except the fat content which was significantly higher in group 0-II. Considering current market prices of fish feed and fish as a final product, the best economic results were achieved by using the combined feed in group 0-II.

Key words: rainbow trout, feed, meat quality, cost-effectiveness

INTRODUCTION

Progressive growth rate of the world population imposes an increasing need for food of animal origin, where the development of intensive aquaculture has a great opportunity to provide an additional amount of cheap and high quality food for human consumption [1-3]. In the second part of the last century, great attention was paid to the development of aquaculture. Experts have realized that sea and fresh waters are a rich source of healthy food for people [4]. The majority of rivers in Serbia are inhabited by warm water species like carp, catfish, asp, chub, pike and various species

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of smaller cyprinids. Brown trout is the dominant Salmonid species, while rainbow trout and grayling live in some rivers only, as well as huchen, the most endangered of the Salmonide family [5]. Although the current situation of aquaculture in Serbia is not favorable at the moment, our country has a great potential for improvement and development of trout production thanks to the terrain morphology and numerous mountain rivers and springs. In the last decades, cage systems for trout production located in high-altitude reservoirs are used [6]. Rainbow trout (*Oncorhynchus mykiss*) is the dominant type of trout fish in commercial farming in the Balkans. However, although fish meat is a high quality food, our country is ranked at the bottom of the list of fish meat consumption in Europe [7].

Composition and quantity of feed have an important influence on production results and meat quality in trout cage farming [8]. For appropriate growth and development of trout a high level of quality proteins in the pelleted feed is required, which considerably increases the feed price. Therefore, the cost of feed is highly related to the product (fish) value.

In order to minimize production expenses in the cage farming system and satisfy the trout's biological and nutritional needs as well, it is necessary to provide the most cost-effective feed. In order for cost-effectiveness to be achieved, raw material prices used in fish farming need to be taken into account. Substituting the more expensive ingredients with a cheaper option makes the fish feed cost-effective [9-11]. Due to the importance of increasing production in the trout cage farming system, in this study we compared production results, cost-effectiveness and quality of meat in groups of trout fed with different fish feed.

MATERIALS AND METHODS

Evaluation of the effects of different fish diets on performance, efficiency and meat quality of the rainbow trout, was carried out on a pond with all conditions needed for intensive fish production. The pond was located at an altitude of 225 m, with quality river water. The rainbow trouts (*Oncorhynchus mykiss-Walbaum*) used in the study were of homogeneous size with an average initial weight of 88-90 g and a length of 190-210 mm. The fish were divided into three groups, two were experimental (0-I and 0-II), and one was the control group (C) with 1320 fish in each group. The study lasted for 90 days, and each group was placed in a separate pool.

The groups were fed with three different formulated feeds. The control (C) group feed was a pelleted formulation providing all the essential nutrients recommended for this trout category [18], with an ingredient composition of 45% fish meal, 30% wheat gluten meal, 6% corn gluten meal, 2% corn, 2% powder milk, 2% fish oil, 12% soybean meal and 1% vitamin and mineral premix and a chemical composition of: protein 41.49%, water 10.16%, fat 9.27%, ash 8.08%, cellulose 1.09%, and NFE 29.91%.

The experimental group 0 - I was fed a mixture of 30% fish meal, 35% soybean meal, 30% sardines and 5% fish oil; with a chemical composition of: protein 41.34%, water 25.73%, fat 10.45%, ash 7.92%, cellulose 2.55%, and NFE 12.01%. The experimental group 0-II was fed a fishmeal consisting of 75% of pellets and 25% sardines.

At the beginning of the study, the fish average length and weight was measured, and the fish weight gain and quantity of feed used was measured at the end. In order to determine the meat quality parameters, chemical composition and fish meat quality were examined. For meat quality determination the Rang test was used [28].

Fish meal for group 0-I was an iso-protein, with almost the same concentration of animal and plant origin proteins; the energy content was higher compared to the feed of group C. The fish meal for group 0-II had a wider ratio of animal and plant proteins and lower energy content.

Taking into account the fish meal ingredients, the price of feed per kilo for each group was calculated. Economical parameters (cost-efficiency, the actual cost and financial result) are calculated at the end of the study, using revenues and production costs. January 2013 fishmeal ingredients prices, as well as fresh fish retail prices were used for the study. The calculation of the trout production cost has been done according to the actual cost, so that the amortization costs, the cost of labor, indirect costs, raw material costs, and other material costs were fixed for all groups. Thus, only fish meal costs were variable.

The results obtained in the study were analyzed using descriptive statistical methods and variance analysis (ANOVA). Statistical analysis was conducted in GraphPad Prism statistical package 5.

RESULTS

The increase in the trout's weight rate during the study is shown in Figure 1. Weight gain differed between groups, as well as within the groups during the controlled periods. The best average trout weight during the controlled periods was in group 0-II, and the worst average trout weight was in group 0-I. At the beginning of the experiment, the average weight of the trout in all groups was uniform, and there was no significant difference ($p > 0.05$) between them. The difference in trout weight arose as the study progressed, and by the end of the experiment the biggest weight gain was in group 0-II ($\bar{x} = 156.78 \pm 23.31$).

The trout weight gained in group 0 - II was by 16.41% higher than in group C, and by 17.51% higher than in group 0 - I. The difference between the trout average weight in group 0-II and the trout average weight in groups 0-I and C was statistically highly significant ($p<0.01$). The difference between the final trout weight in group 0-I and group C was not statistically significant ($p>0.05$).

Overall growth, daily growth and feed consumption per group at the end of the experiment are shown in Table 1. The table shows that the best growth rate was achieved in group 0-II, with a total weight gain of 67.800 g (0.753 g /per day), which is by 47.94% higher than the growth attained in the control group, and by 51.81% greater than in group 0-I ($p < 0.05$). The overall growth rate in group 0-I was 44.660g (0.496 g/day), which is by 2.55% lower than the growth rate of trout in group C which showed an overall growth of 45.810 g (0.509 g/day).

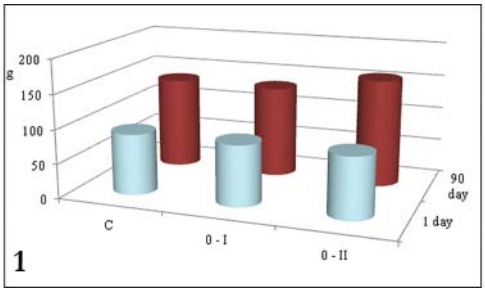

Figure 1. Measures of the variation of the average trout weight (in grams)

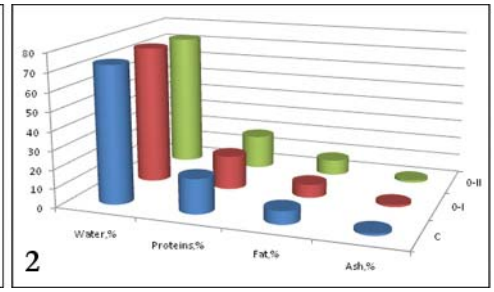

Figure 2. Chemical composition of trout meat

By analyzing the total and daily feed intake expressed as dry matter, it is evident that the trout in both experimental groups (0-I and 0-II) had a lower total and daily feed intake in the control periods compared to the fish in group C. At the end of the experiment, the total and daily feed intake of trout in group 0-II was 78.38 g and 0.86 g respectively. Results obtained in group 0-I were lower by 6.52% overall and by 7.53% per day compared to group 0-II and by 10.83% overall and 12.25% lower compared to group C. The feed utilization efficiency varied significantly between the groups. The best ratio was achieved in the 0-II group (1.16), which was by 39.58% more favorable than for group C, or by 47.93% compared to group 0-I.

Table 1. Change in weight gain and feed intake

Mark	Group		
	C	**0-I**	**0-II**
Growth from 0-90-th day. grams			
- total	45.810[b]	44.660[a]	67.800[ab]
- daily	0.509	0.496	0.753
Feed intake from 0-90-th day. grams			
- total	87.89	83.85	78.38
- daily	0.98	0.93	0.86
The feeding coefficient			
- total	1.92	1.87	1.16

The variability in water content, protein, fat and ash (Figure 2) was determined by analyzing the chemical composition of fish meat by groups. However, in spite of the existence of a numerical difference between the groups, the obtained differences are not statistically significant ($p>0.05$) considering the content of water, protein and ash. The fat content ranged from 7.025% in group C to 8.27% in group 0-II. However, the differences established by the percentage of fat content of trout in group 0-II were statistically highly significant ($p<0.01$) compared to groups 0-I and C. The differences between groups 0-I and C were not significant ($p>0.05$).

According to nutrients content the price of feed per kilogram for each group was calculated. The valid, accurate market prices of feed components were taken into account (Table 2). The price of one kg of the feed mixture used for trout feeding in group 0-I was higher by 47.00% compared to group C, and by 50.42% compared to feed price for group 0-II. The feed price for group 0-II was lower by 2.28% compared to group C.

Table 2. The structure of the cost price per kg of food by groups

Type of feed	Price of feed (RSD/kg)	Group					
		C		0-I		0-II	
		%	RSD.	%	RSD.	%	RSD.
Fish meal	130.00	–	–	30.00	39.00	–	–
Soybean meal	60.00	–	–	35.00	21.00	–	–
Sardines	50.00	–	–	30.00	15.00	25.00	12.50
Fish oil	117.00	–	–	5.00	5.85	–	–
Pelleted feed	55.00	100.00	55.00	–	–	75.00	41.25
Price of kg of food	–	100.00	55.00	100.00	80.85	100.00	53.75
The cost of food (RSD)	–	–	11,771	–	17,123	–	10,794

The cost of feed was calculated as the result of multiplication of feed price per kilo and used quantity of feed (C group -214.02; 0-I group -211.79; 0-II group -200.81). Production value was calculated as the result of the obtained fish weight (C group -356.11; 0-I group -339.02, 0-II group -418.22 g) and market price (600.00 RSD/kg). The financial result is the difference between value and production costs, and cost-effectiveness is a ratio between the value and cost.

Total production cost was the highest in group 0-I (by 45% higher than the cost for group C and by 59% for group 0-II) (Table 3). However, the highest production result was obtained by group 0-II: 17% higher than the C group and by 23% higher than group 0-I. The financial performance of all three groups was positive. The price per kg of live weight was the best in group 0-II (250.58 RSD). Cost-efficiency as a synthetic indicator of business activity was best in group 0-II (2.39) comparing to group C (1.86) and group 0-I (1.22).

Table 3. Financial data generated by groups

Result	Group					
	C		0-I		0-II	
	RSD	ind.	RSD	ind.	RSD	ind.
Total costs	114,605.65	100	166,242.72	145	104,796.12	159
The value of production	213,666.00	100	203,412.00	95	250,932.00	117
Financial results	+99,060.35	100	+37,169.28	38	+146,135.88	148
Cost price / kg	321.83	100	490.66	152	250.58	78
Cost-effectiveness, coeff.	1.86	100	1.22	66	2.39	129

DISCUSSION

Fish feeding is one of the most important factors in intensive fish farming. The most important issues in the trout diet are feed ingredients prices and their nutritional value. The trout's biological needs in proteins, carbohydrates, fats, vitamins and minerals, as well as their content in the diet were examined in numerous studies [9,12,13]. Although biological needs of fish in protein, energy, vitamin and mineral content are clearly defined, many studies are based on the evaluation of the effect of different meal composition on fish growth, using different ratio of nutrients, different pellets, and various production methods [14-17].

The aim of the study was to assess the results obtained by using different fish meals in the rainbow trout (*Oncorhynchus mykiss*) diet. The cost of production and meat quality in every group was evaluated. The feed for the control group (C) consisted of a pellet mixture of standard composition including all important nutrients as recommended for certain trout categories [18].

Feed for group 0-I was an iso-protein meal, with almost the same ratio of animal and vegetable proteins and higher energy content compared to the feed for group C. The feed for group 0-II with a wider ratio of proteins had less protein content and lower energy compared to the feed for group C.

Also, many authors emphasize the different chemical composition of the meals considering the content and correlation of certain amino acids, vitamins and minerals [19-21], as well as the content of fishmeal, which varies from 37-65% in the starter to 20-50% in the grower feed [22]. The influence of different fish diets and feed quality were evaluated according to the trout weight gain during the trial period. Based on the trout weight at the beginning and at the end of the experiment, the total and daily weight gain of the observed groups was calculated. The results show significant differences between group 0-II and the other two groups ($p < 0.05$).

However, the difference in the total and daily gain achieved by group 0-I (44.66 and 0.496 g) and group C (45.81 and 0.509 g) was not significant at the end of the experimental period ($p > 0.05$).

Authors reported trout average daily weight gain to be from 0.7 to 1.2 g [23-26]. However, daily weight gain in our experiment with the combined meal was 0.753 g. According to Kulišić et al. [27] daily weight gain was 0.660 g. Mijailović et al. [24] by using a combined meal (pellet + fish guts) achieved a higher daily weight gain (2.14 g) compared to our results.

Trout in group C consumed 1.92 kg, while the trout in group 0-I and 0-II consumed 1.87 and 1.16 kg, respectively. Feed conversion ratio (FCR), i.e. the relation between feed consumed and weight gain is one of the best indicators of the feed quality impact on growth and production efficiency. FCR in group C was higher by 39.58% and in group 0-I by 83.62% compared to group 0-II fed with a combined feed (pellet + sardines).

According to the results of Kulišić et al. [27] who examined the effect of a combined meal (pellet + worms), a FCR of 1.31 was achieved, which is slightly lower than the result obtained in our experiment where a meal of pellets and sardines (1.16 kg) was used. According to the results obtained one can conclude that trout diet with a combined meal (pellet + sardines) has a nutritional and biological justification.

The FCR in the C group of trout fed with a standard pelleted feed is close to the results obtained by Apostolski et al. [25] of 1.88 to 2.03 kg, while Mijailović et al. [24] reported a FCR of 2.21 kg, and Dalbelo [26] of 2.10 to 2.24 kg. Comparing the results obtained from group C with previously published results, we concluded that the trout in group C have reached the FCR characteristic for farming conditions and feed quality in Serbia.

Chemical composition is an important parameter in the fish meat quality assessment. The content of the basic chemical substances ranges within very wide limits, depending on fish species, category, time of catch, gender and individual differences [1,28,29].

The fish meat nutritional value is estimated according to its chemical composition, energy value, essential fatty and amino acids content, vitamins and minerals content and digestibility [30,31].

The water content in the trout meat was consistent. In group 0-II the average water content was 72.45%, in group 0-I it was 74.20%, and in group C it was 73.05%. There was no significant difference among the groups in the water content, and the obtained results correspond to the results reported by other authors [25,32,33], while the results of Francetić showed a significantly lower water content [34].

The ash content in trout meat was consistent: 1.24% in group 0-I, 1.28% in group 0-II, and in group C ash content was 1.26%. Similar results were reported by a number of authors [25,33,34]. The percentage of protein in trout meat was relatively constant, ranging from 18.16% in group 0-II to 18.51% in group C, and the average value in group 0-I was 18.17%. Brkić stated that fish meat contains 16-22% of proteins, and Francetić reported a value up to 21.1%, similar to the results obtained by Apostoliski et al. [25,33,34].

In spite of different literature data, the results obtained in our experiment confirmed the fact that fish meat protein content is relatively constant. Fat content in trout meat varied, and unlike other nutrients, showed the greatest variations among the groups. The obtained results are not surprising, considering literature data relative to the fat content in fish meat.

Brkić [33] reported that fish meat contains up to 20% of fat, Francetić [34] lists a content of about 13.5% of fat, and according to the findings of Apostolski et al. [25] rainbow trout flesh contains from 2.62% to 3.70% of fat. However, Lovell [35] in his research concluded that the content of fat, protein and essential amino acids is significantly higher in fish from aquaculture.

Analysis of the chemical composition of trout meat in our experiment showed that fish diet had no influence on water, ash and protein content in trout meat. Since fat content is an important parameter of meat quality, the increase of its content should not be assessed as a negative result of the used dietary treatments.

Critically speaking, the fat content did not vary significantly, but the differences between the groups suggest that feed composition influenced fat content in fish meat.

The protein content, especially the ratio of animal and vegetable proteins in the 0-II group of trout fed a combined feed (sardines + pellet) was significantly higher than the protein content in the feed of group 0-I. As a result the weight increase of the trout was followed by the appropriate growth in length and deposition of proteins and minerals, as well as buildup of fat in the meat.

During the evaluation of trout production results and meat quality, the achieved economic effect in a particular production system was very important. The results showed that the partial use of fresh animal feed (0-II group) decreased feed cost compared to the pellet feed diet (C group), and significantly reduces cost compared to a combined meal (0-I group).

The price of feed components used in the experiment, as well as the achieved weight gain and the cost of feed per kilogram of weight gain is important for the economic analysis of the production. Comparing the financial parameters (financial results and cost-effectiveness ratio), one can conclude that the best results were obtained in the 0-II group of trout fed a combined feed (sardines + pellets). The worst results were obtained in the 0-I group of trout fed a combined meal.

These results showed that the use of feedstuff of fresh animal origin, especially in combination with dry pelleted feed, has its biological, nutritional and economic justification.

Appropriate trout growth and feed conversion, superior meat quality, financial results and the market price considered, show that feeding trout a combined meal (sardines+ pellets) gives the most favorable cost-effectiveness.

CONCLUSION

Based on the results obtained in our study, combination of sardines and pelleted feed in the trout diet has its biological, nutritional and economical justification. The highest production efficiency (2.39) and the lowest cost of live weight per kilo (250.58 RSD) were generated in group 0-II.

The chemical composition of trout meat did not differ among groups, only the fat content was significantly higher in the 0-II group fed a combined meal made of sardines and pellets. The feed used in group 0-II has its biological, nutritional and economic justification as confirmed in our results.

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UTICAJ RAZLIČITOG SASTAVA OBROKA NA PROIZVODNO-EKONOMSKE REZULTATE I KVALITET MESA RIBE

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U ovom radu je ispitivan uticaj ishrane obrokom različitog sastava na proizvodno-ekonomske rezultate i kvalitet mesa kalifornijske pastrmke (*Oncorhynchus mykiss*). Kontrolna grupa (K) hranjena je standardnom kompletnom peletiranom hranom, ogledna grupa (0-I) hranjena je kombinovanom smešom koja sadrži 30% ribljeg brašna, 35% sojine sačme, 30% sardele i 5% ribljeg ulja, a ogledna grupa 0-II hranjena je kombinovanim obrokom koji je sastavljen od 75% peletirane hrane i 25% sardela. Najbolji rezultat je ostvaren kod 0-II grupe, dok je K grupa postigla rezultate karakteristične za kvalitet domaće hrane i uslove držanja u našoj zemlji, a 0-I grupa imala je slabije proizvodne rezultate u odnosu na K i 0-II grupu. Korišćena hrana kod 0-II grupe ima svoje nutritivno, biološko i ekonomsko opravdanje. Različiti tretmani ishrane nisu bitno uticali na hemijski sastav mesa pastrmki, osim sadržaja masti koji je bio signifikantno viši kod 0-II grupe. Pri važećim tržišnim cenama hraniva i konzumne ribe kao finalnog proizvoda, najbolji ekonomski rezultati postignuti su korišćenjem kombinovanog obroka kod 0-II grupe.