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PRODUCTIVITY OF RAINBOW TROUT DEPENDING ON PROTEIN LEVELS IN PRODUCTIVE FEED

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Abstract. *The article considers the efficiency of using complete feeds with different levels of protein in rearing commercial rainbow trout. The purpose of the experiment was to establish the effect of different protein levels in nutrition of two-year old trout on its productivity. For this purpose, five experimental groups were formed by the method of analogues. During the equalizing period, the experimental fish consumed feed of the control group. In the main period, the protein level in trout feed ranged from 44 to 52 % per 1 kg. As a result of the studies it was established that the increase of protein content in compound feed from 48 to 52 % leads to an increase in the weight of commercial fish by 13.0 % ($p < 0.001$), an increase in its growth intensity – by 7.4-16.7 %, while the reduction of protein in feed to 44 % leads to a reliable ($p < 0.05$) reduction in trout weight by 9.4 %, and a decrease in its growth intensity – by 6.5-12.1 %. It is proved that different levels of experimental trout's protein nutrition have a highly reliable ($p < 0.001$) effect on the growth of marketable fish - the share of this factor's influence is 89.8 %. Analysis of the feed costs, proves that using combined feed with 52 % protein for feeding two-year old trout, leads to a decrease in feed costs per 1 kg of weight gain by 5.1 %, whereas reducing this index to 44% causes increase of feed costs by 6.4 % per a unit of product, compared to feeding fish with production feed having the protein content of 48 %. At this, the preservation of experimental fish was high enough and made 94.3 to 96.2 %. In rearing trouts according to the criteria of maximum productivity, it is recommended to feed commercial trout with production combined feeds with the protein level of 52 %, whereas, in production according to the economic optimization criteria, this index should make 48 %.*

Keywords: *commercial rainbow trout, fish feeding, combined feed, protein, economic efficiency.*

Rationale and background.

It is known that the feeding factor plays a key role in industrial trout farming (Cowey, 1992; FAO, 2016). Along with this, the completeness of protein nutrition is one of the main factors determining the efficiency of feed nutrients, fish growth intensity and economic performance of the industry (Yehorov, Fihurska, 2011; Shcherbyna, Hamyhyn, 2006). Research by scientists in the field

of fish nutrition shows that a deficiency of protein in the diet can provoke a slowdown in trout growth and increase feed consumption per unit of growth, and its excess - leads to the release of more nitrogen and pollution – the environment (Sherman et al., 2002; Jobling, 2016).

Some scientists believe that productivity of trout and the quality of its products are most influenced by the ratio of energy, protein and amino acids and their content in the diet (Karabulut et al., 2010; Kim, Kaushik, 1992; Mahmud, 1996). Other researchers claim that the growth and development of rainbow trout are most influenced by the level of protein in the feed (Khan et al., 2019; Takeuchi et al., 1978).

Thus, the study of the impact of different protein nutrition of commercial rainbow trout in modern industrial conditions of cold-water fish farms of Ukraine is important, necessary and relevant.

The purpose of the scientific and economic experiment was to establish the effect of different protein levels in nutrition of commercial rainbow trout on its productivity.

Materials and methods.

Experimental studies on two-year-old rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) were carried out at the "Shipot" farm in Perechyn district of Transcarpathian region.

The five experimental groups formed by the method of analogues (table 1). During the equalizing period of the experiment, which lasted 10 days, the experimental fish consumed the compound feed of the control group. In the main period of the experiment (200 days) the level of protein in the trout's feed of the experimental groups was regulated by changing individual components of the feed (using combined mathematical methods to optimize the calculation using the program AgroSoft WinOpti).

Feeding of rainbow trout during the study period was performed 4-6 times a day, during the day time at regular intervals. The required amount of feed was calculated according to the indices of individual fish weight and ambient temperature at the time of feeding.

Weighing of experimental trout was performed once every 10 days using electronic balance in a tared container with water, with accuracy up to 0.1 g. Rearing commercial two-year trout was carried out in aquaculture ponds with fish-holding density of 50 specimens/m^2 and the water level of 1 m. The total amount of trout specimens in the experimental studies was 25 thousand specimens. Conditions for keeping ex-

1. Scheme of scientific and economic experiment

Group of fish	fish-holding density at the beginning of experiment, specimens./m^2	Mean weight at the beginning of experiment, g	Experimental period	
			equalizing (10 days)	main (200 days)
			crude protein content per 1 kg of feed stuff, %	
1- control	50	55.3 ± 2.48	48	48
2- experimental	50	56.1 ± 2.13		44
3- experimental	50	54.8 ± 2.37		46
4- experimental	50	55.1 ± 3.13		50
5- experimental	50	54.5 ± 2.99		52

perimental fish met the regulatory requirements in salmon farming (Instructions for breeding rainbow trout, 1985; SOU 05.01.37-385:2006).

Studies of the rainbow trout growth rate were carried out based on the results of test fishing. No less than 100 specimens from each group was weighed with electronic balance. The study results were processed by the method of variation statistics (Plokhynskyi, 1969) using MS Excel and STATISTICA 7.0 software by means of built-in statistical functions.

Results of the study and their discussion.

The presented data indicate that commercial trout, which were fed production feeds with different protein nutrition levels, had different weights at all times during the main period of the experiment (table 2).

At the end of the experiment, the highest weight was reached by commercial two-year trouts, which were fed compound feed with a protein content of

2. Dynamics of weight gain in experimental trout at different protein nutrition, g

Day of experiment	Group of fish				
	1	2	3	4	5
1	55.3 ± 2.48	56.1±2.13	54.8±2.37	55.1±3.13	54.5±2.99
10	61.6±2.73	62.3±2.46	61.2±2.52	61.4±3.52	60.7±3.20
20	69.0±2.99	69.6±2.87	68.6±3.13	68.9±3.96	68.1±3.45
30	76.4±3.24	76.0±3.10	75.6±2.88	76.5±3.52	75.8±3.77
40	83.4±3.98	81.9±3.56	82.1±3.87	84.4±4.33	84.1±4.01
50	90.7±4.30	87.5±4.20	88.6±4.49	92.3±4.27	92.5±4.18
60	98.2±4.78	94.1±4.92	95.7±4.68	101.2±4.62	101.7±5.22
70	106.9±5.16	101.8±4.76	103.9±4.89	111.8±4.83	113.4±5.03
80	116.3±5.89	110.4±5.36	113.0±4.89	124.3±5.56	127.8±5.46
90	128.5±5.24	121.1±4.78	124.5±5.46	137.4±5.08	142.7±5.62
100	140.9±5.96	131.4±5.11	135.8±5.70	151.9±5.74	158.4±6.03*
110	155.3±5.58	143.7±4.99	148.9±5.02	166.9±6.17	174.4±6.32*
120	170.1±6.05	155.9±5.32	162.3±5.47	182.6±6.38	191.5±7.22*
130	186.4±6.37	170.6±5.79	177.6±5.86	200.1±5.99	210.9±6.87**
140	203.5±5.74	186.4±6.26*	194.1±6.22	218.7±6.28	231.1±6.08***
150	221.8±6.02	203.0±5.94*	211.2±7.01	238.4±6.17	251.6±6.29***
160	238.0±6.15	218.1±6.78*	226.7±6.56	255.8±5.86*	270.0±7.84***
170	253.4±6.92	232.3±6.38*	241.4±7.14	271.5±6.11*	286.5±7.11***
180	268.1±7.45	244.6±6.65*	255.0±6.82	286.9±6.68	302.7±7.23***
190	279.9±7.24	254.7±6.84*	266.2±7.08	299.2±7.08	315.8±7.56***
200	288.6±8.01	262.0±7.14*	274.3±7.35	308.4±7.25	325.7±7.91***
210	296.4±8.25	268.6±7.43*	281.5±8.23	316.9±7.89	334.8±8.07***

* $p < 0.05$; ** $p < 0.01$; *** < 0 .001 compared to group 1

50 (group 4) and 52% (group 5), which outperformed analogues consuming feed with a protein level of 48% (group 1), respectively, 20.5 and 38.4 g ($p < 0.001$), or by 6.9 and 13.0 %. At the same time, trouts, which consumed productive feed with a protein content of 44 (group 2) and 46 % (group 3), were inferior in the above indices compared to their peers who consumed food with a protein level of 48 % (group 1), respectively, by 27.8 ($p < 0.05$) and 14.9 g, or by 9.4 and 5.0 %. The difference between the weight of two-year-olds of groups 2 and 5 who consumed feed with a metabolic energy content of 44 and 52 %, respectively, at the end of the experiment was highly reliable ($p < 0.001$) and was 24.6 % in favor of the latter.

The description of the commercial trout's growth using mathematical methods confirmed the ascending shape of the growth curve (fig.).

Trout growth is further described by a mathematical model with a nonlinear characteristic. In a certain period of commercial fish growth (x), depending on the level of protein in the production feed, its weight (y) can be predicted:

Group 1 (48 % crude protein – *CP*):
$y = 0.0027x^2 + 0.6797x + 51.569$
$(R^2 = 0.9942)$;
Group 2 (44 % *CP*):
$y = 0.0024x^2 + 0.5811x + 53.851$
$(R^2 = 0.9936)$;
Group 3 (46 % *CP*):
$y = 0.0025x^2 + 0.635x + 52.009$
$(R^2 = 0.9943)$;
Group 4 (50 % *CP*):
$y = 0.0026x^2 + 0.8156x + 48.768$
$(R^2 = 0.9942)$;
Group 5 (52 % *CP*):
$y = 0.0027x^2 + 0.8905x + 46.174$
$(R^2 = 0.9936)$.

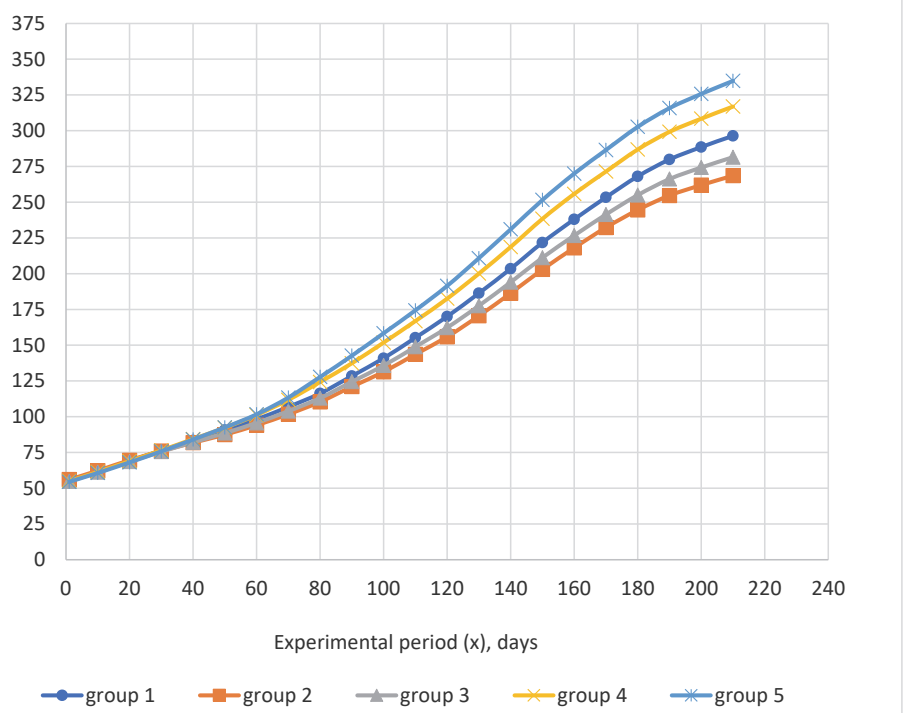

Fig. Graphic model of commercial trout growth with different protein nutrition

According to the variance analysis of the obtained data, different levels of protein nutrition of experimental trout highly significantly ($p < 0.001$) effected the increase in the commercial fish weight. The share of this factor's effect is 89.8 %, which is by 8.8 times more than the influence of other paratypic and genotypic factors.

Different levels of protein in the feed consumed by trout, having considerably effected its weight, significantly affected the mean daily weight gain (table 3).

In general, during the main period of the experiment, the highest mean daily weight gain was observed in commercial trout, which consumed feed with the protein content of 50 (group 4) and 52 % (group 5), it, on average, outperformed the analogues which consumed feed with the content of protein 48 % (group 1), 110 and 200 mg, respectively. At the same time, the experimental fish consuming food with the protein content of 44 (group 2) and 46 % (group 3) were inferior in the mentioned index to their control peers by 140 and 70 mg, respectively. The difference between the mean daily weight gain in trout of groups 2 and 5 for the main period of the experiment was 340 mg in favor of the latter.

3. Average daily gain of two-year trout, g

Experimental periods, days	Group of fish				
	1	2	3	4	5
1-10	0.63	0.62	0.64	0.63	0.62
11-20	0.74	0.73	0.74	0.75	0.74
21-30	0.74	0.64	0.70	0.76	0.77
31-40	0.70	0.59	0.65	0.79	0.83
41-50	0.73	0.56	0.65	0.79	0.84
51-60	0.75	0.66	0.71	0.89	0.92
61-70	0.87	0.77	0.82	1.06	1.17
71-80	0.94	0.86	0.91	1.25	1.44
81-90	1.22	1.07	1.15	1.31	1.49
91-100	1.24	1.03	1.13	1.45	1.57
101-110	1.44	1.23	1.31	1.50	1.60
111-120	1.48	1.22	1.34	1.57	1.71
121-130	1.63	1.47	1.53	1.75	1.94
131-140	1.71	1.58	1.65	1.86	2.02
141-150	1.83	1.66	1.71	1.97	2.05
151-160	1.62	1.51	1.55	1.74	1.84
161-170	1.54	1.42	1.47	1.57	1.65
171-180	1.47	1.23	1.36	1.54	1.62
181-190	1.18	1.01	1.12	1.23	1.31
191-200	0.87	0.73	0.81	0.92	0.99
201-210	0.78	0.66	0.72	0.85	0.91
Average for the main experimental period (11-210 days)	1.17	1.03	1.10	1.28	1.37

Analyzing the changes in fish weight depending on the quality of its feed at different stages of the experiment, it was found that feed costs per unit weight gain were significantly lower in trout, which consumed feed with a higher content of digestible protein. In particular, individuals of the 5th group, who consumed food with a protein level of 52 % had the mentioned indicator for the main period of the experiment at the level of 1,152 kg, and outperformed the analogues of the 1st, 2nd, 3rd and 4th groups by 5.1; 10.9; 7.5 and 2.8 %.

It should be noted that the survival rate of the experimental fish during the entire experimental period was high enough, met the existing standards and ranged from 94.3 to 96.2 %.

Analyzing the efficiency indices of commercial trout cultivation, it can be stated that with different protein nutrition, they differed from each other (table 4). The highest ichtyomass gain was found in two-year-old trout of the 5th group, who consumed compound feed with the protein content of 52 %. They outperformed the analogues of other experimental groups, respectively (according to the scheme of the experiment) by 13.1; 24.3; 17.7 and 6.7 %. The lowest cost of weight gain was found in fish of

4. Economic efficiency of commercial trout rearing with different protein nutrition

Index	Group of fish				
	1	2	3	4	5
Ichtyomass at the beginning of the main experimental period, kg	307.38	310.57	305.08	306.39	302.89
Survival rate, %	95.1	95.4	96.2	94.3	95.2
Ichtyomass at the end of experiment, kg	1409.38	1281.22	1354.02	1494.18	1593.65
Ichtyomass gain for the main experimental period, kg	1102	970.65	1048.94	1187.79	1290.76
Feed costs per 1 kg of ichtyomass gain, kg	1.211	1.278	1.238	1.184	1.152
Feed costs for the total ichtyomass gain, kg	1334.52	1240.49	1298.59	1406.34	1486.96
Production cost per 1 kg of compound feed, UAH	63.24	68.1	64.03	71.8	70.85
Cost of feed fed for the total ichtyomass gain, UAH	69690.48	66101.27	67163.63	85283.32	91450.35
Cost of feed consumed per 1 kg of ichtyomass gain, UAH	76.58	87.03	79.27	85.01	81.62
Net cost per1 kg of ichtyomass gain, UAH	109.41	124.33	113.24	121.44	116.60
Selling price per 1 kg of fish, UAH	140.0	140.0	140.0	140.0	140.0
Total cost of trout rearing, UAH	154193.5	159295.6	153331.4	181460.1	185817.8
Total revenue from the sale of fish, UAH	197313.2	179370.8	189562.8	209185.2	223111.0
Profit, UAH	43119.7	20075.2	36231.4	27725.1	37293.2
Level of production profitability, %	27.96	12.60	23.63	15.28	20.07

Note: in prices of 2017

group 1, which was fed food with the nutritional value of 48 % protein. They were superior in this respect to their peers of groups 2, 3, 4 and 5 by 13.6; 3.5; 11.0 and 6.6 % respectively. Given the sale of fish in all groups at the same price – 140 UAH / kg, the highest level of production profitability was set for commercial trout consuming productive feed with the protein level of 48 % (group 1) – 28.0 %, and the lowest was that with the protein level 44 % (group 2) – 12.6 %.

Thus, from an economic point of view, for rearing of commercial rainbow trout, it is most appropriate to feed it with productive feed having the protein level of 48 %.

Conclusions

1. It is established that different protein level in feeds of rainbow trout before reaching the market weight significantly affects its productivity. In particular, an increase in this index in feed from 48 to 52 % leads to an increase in the weight of commercial fish by 13.0 % ($p < 0.001$), an increase in its growth rate - by 7.4-16.7 %, while protein reduction in compound feed up to 44 % leads to a significant ($p < 0.05$) decrease in trout weight by 9.4 %, and a decrease in the intensity of its growth - by 6.5-12.1 %.
2. Different levels of experimental trout's protein nutrition have a highly reliable ($p < 0.001$) effect on the increase in the weight of commercial fish. The share of this factor's influence is 89.8 %, which is by 8.8 times more than the influence of other paratypic and genotypic factors.
3. Analysis of feed costs shows that the use of feed with the protein content of 52 % in feeding two-year-old trout reduces feed costs per 1 kg of weight gain by 5.1 %, while reducing this figure to 44 % increases feed costs per a unit of production by 6.4 %, compared to feeding fish productive feed with the protein content of 48 %. Survival of the experimental fish was high enough and ranged from 94.3 to 96.2 %.
4. Analysis of biological and economic indices of commercial trout rearing shows that in the production of trout products according to the criteria of maximum productivity it is recommended to use commercial feed with the protein level of 52 % for feeding trout, and in the production of fish according to economic optimization criteria, this figure should be 48 %.
5. Prospects for further research are related to the study of different rainbow trout's amino acid nutrition influence on the indices of its productivity at all stages of its rearing.

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Анотація. *У статті розглянуто питання ефективності використання повнораціонних комбікормів з різним рівнем протеїну за вирощування товарної райдужної форелі. Метою досліду передбачалося встановити вплив різних рівнів протеїнового живлення дволітків форелі на показники її продуктивності. Для цього за методом аналогів було сформовано п'ять піддослідних груп. У зрівняльний період піддослідна риба споживала комбікорм контрольної групи. В основний період рівень протеїну в комбікормах форелі коливався від 44 до 52 % у 1 кг. У результаті проведених досліджень встановлено, що збільшення вмісту протеїну у комбікормі з 48 до 52 % призводить до збільшення маси товарної риби на 13,0 % ($p < 0,001$), підвищення її інтенсивності росту – на 7,4-16,7 %, в той час як зниження протеїну у комбікормі до 44 % призводить до достовірного ($p < 0,05$) зменшення маси форелі на 9,4 %, та зниження інтенсивності її росту – на 6,5-12,1 %. Доведено, що різний рівень протеїнового живлення піддослідної форелі високодостовірно ($p < 0,001$) впливає на наростання маси товарної риби – частка впливу даного фактору становить 89,8 %. Аналіз витрат кормів, засвідчує про те, що використання у годівлі дволітків форелі комбікорму з вмістом протеїну 52 % сприяє зниженню витрат корму на 1 кг приросту маси на 5,1 %, тоді як зменшення цього показника до 44 % підвищує витрати корму на одиницю продукції на 6,4 % у порівнянні з годівлею риб продукційним кормом із вмістом протеїну на рівні 48 %. Збереженість піддослідних риб водночас була достатньо високою і становила від 94,3 до 96,2 %. За виробництва продукції форелівництва за критеріями максимальної продуктивності рекомендується для годівлі товарної форелі використовувати продукційні комбікорми з рівнем протеїну 52 %, в той час як за виробництва продукції за економічними критеріями оптимізації цей показник має становити 48 %.*

Ключові слова: *товарна райдужна форель, годівля риб, комбікорми, протеїн, економічна ефективність.*