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Vectors of Scientific and Research Work of Modern Ukrainian Aquaculture with an Emphasis on the Multitrophic Model

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Abstract

The main results of the comprehensive research work with the vector of optimization of technological solutions in aquaculture of Ukraine are presented. The best indicators are achieved when optimizing feeding conditions with natural components in the diet. Under technological conditions of using recirculation systems with an additional element - solar mini-panel and aquaponics. The data of research work reflect the positive results of optimizing the cultivation of aquaculture objects: carp in polyculture (*Cyprinus carpio, Hypophthalmichthys hybrid*), tilapia (*Florida red*) and rainbow trout (*Oncorhynchus mykiss*). The use of spirulina, black soldier, Artemia nauplii in the diet of young fish feeding in combination with alternative energy sources contribute to obtaining the status of environmentally safe aquaculture products. The model of multitrophic aquaculture demonstrates high parameters of the qualitative and quantitative nature of the cultivation of hydrobionts. The possibility of combining extensive and intensive technology provides an increase in the growth rate of aquatic organisms and rational use of resources. Also, using the example of young carp in polyculture, an improvement in their growth rate, fattening coefficient, survival, histological indicators, and blood was established. The results of the analysis of the influence of the feeding factor on the development in the ontogenesis of carp in polyculture conditions, its condition before and after wintering are presented. The cultivation model demonstrates additional cultivation in a recirculation system of young fish. The results of the cultivation of tilapia and rainbow trout in a recirculation system under the influence of natural feeding factors, the use of aquaponics and alternative energy sources are also separately presented.

Keywords: Optimization; Ukrainian Aquaculture; Development Vectors; Technologies; Hydrobionts; Multitrophic Model; Physiological And Biochemical Processes; Ontogenesis; Natural Components

Introduction

Ukrainian aquaculture is experiencing stages of industry restart in each production sector. Modern transformation is taking place against the background of the influence of abiotic and biotic factors [1,2]. In particular, these are European strategies for the development of aquaculture, environmental protection and rational use of the resource potential of water resources.

By directing all potential to the qualitative and quantitative parameters of the industry, optimization of technologies is relevant. The issue of increasing the level of «environmental friendliness» of aquaculture products has high practical value [3]. Modern Ukrainian aquaculture involves the use of closed water supply systems (RAS). Systems can be combined in a complex with other forms of the industry (for example, pond farming). Also, there are enterprises using RAS as a monotechnology. Against this background, the introduction of natural components into the fish diet as additional nutrition is of both scientific and practical interest. [4-7]. The qualitative characteristics of feed are correlated with the qualitative composition of fillets or other muscle tissue of fish (finished biological products). When searching for the optimization of aquaculture technology, the authors draw attention to the physiological indicators, ecological and biological features of hydrobionts and the specifics of metabolism in their organism [8-11]. Classical forms of industry management, for example, the use of ponds, for successful development require a good, enriched fodder base, which also depends on fish productivity, mass accumulation coefficient, feed conversion, etc. If the fish is grown in the RAS, then there are restrictions in the diet of only those components that are fed to the fish. Therefore, the issue of additional feeding with high-protein components, the use of «green» technologies (solar panel) is gaining relevance. In addition, if the goal is to stock water areas with resistant juveniles, then the method of additional growth of juvenile fish and its feeding with biologically active natural components is also valuable and relevant.

Materials and Methods

Scientific and experimental work is carried out by the Kherson State Agrarian and Economic University together with representatives of the production sector. With the introduction of technological developments in production and experiments in the conditions of the university's research laboratories. They studied the modular system and its effectiveness when using microalgae, zooplankton, obtaining alternative sources of protein in aquaculture. Practical modular parts of the research work were carried out on the basis of the "Kherson Production and Experimental Plant for Breeding of the Ordinary Fish" (Ukraine); "Production-experimental Dnipro Sturgeon Fish Breeding Plant named Acad. S.T. Artyushchyka" (Ukraine) and on the basis of the Scientific Research Laboratory "Aquaculture Perspectives". Research Laboratory of Physiological and Biochemical Research named of S. Pentelyuk", Scientific Research Laboratory on ecological and chemical analysis and water monitoring" (Kherson State Agrarian and Economic University (KSAEU, south of Ukraine). The entire experimental part was organized and implemented in strict accordance with aquaculture standards [12,13].

The principles of bioethics were entirely in research. The experiments presented in this work were approved by the Academic Council of the Kherson State Agrarian and Economic University in accordance with the section of the Recommendations of the Council of the European Union (2010/63/EU) on the use of experimental animals and the principles of the Animal Research: Reporting of In Vivo Experiments (ARRIVE).

Object of research, growing conditions

The scientific and experimental studies were conducted using carp in polyculture *Cyprinus Carpio Linnaeus, 1758*, *Hypophthalmichthys hybrid,* tilapia *Florida red* and rainbow trout *Oncorhynchus mykiss, Walbaum, 1792*. The feed components, the qualitative and quantitative indicators of which were studied: *spirulina*, vermiculture, H*ermetia illucens*, *Artemia nauplii*. All components are studied in the form of various diets, the percentage ratio of which takes into account the nutritional characteristics each fish separately, to which additives are added to the diet.

Rainbow trout in the control group were fed a general diet without additives. All ingredients in the diet were balanced in terms of nutrients and energy. In the experimental group, the fish received the main diet and additional feed: Spirulina (25%) + Vermiculture (50%) + Hermetia illucens (25%). Rainbow trout were fed in a recirculating fish culture system for intensive multi-species culture with an average dissolved oxygen level of 9.45-10.3 mg/L and an average water temperature of 13.1 ± 0.2°C (according to technological recommendations for RAS). The initial weight of rainbow trout was 1.46 ± 0.16 g. Were grown in recirculating fish tanks as the fish developed, the volume of the pools was increased. Rainbow trout were placed in two pools of a recirculating system. The planting density was based on the generally accepted recommendations for trout rearing, consideirng body weight, 20 kg/m^3<5 g, 25 g/m^3– 5-15 g, 30 kg/m^3 – 15-30 g; for organic cultivation – up to 35 kg/m^3. Each of them corresponded to the Control (n=250) and Experimental groups (n=250). Mini solar panel was used as additional energy.

Cyprinus carpio in polyculture *Hypophthalmichthys hybrid* the fish were divided into Control (n=260) and Experimental groups (n=260) for growing in RAS until reaching a weight of at least 24 grams. First body weight was 1.5–1.6 mg. In the experimental group, the fish received the main diet and additional feed: Spirulina (35%) + Hermetia illucens (65%). In the RAS pools, the temperature was on average 22.1 to 24.2°C, the oxygen content was 5.8-6.4 mg/l. For larvae and early juvenile cyprinids during their growth before landing in the RAS, the temperature was on average 24-26°C, the oxygen content was 6.3-7.6 mg/l. The planting density for RAS took into account the recommendations of 200-400 larvae per m^3. At the beginning of the first stage of development, carp fish were being fed with finely dispersed flour (0.1-0.2 mm) at the ratio 1:1 according to the requirements of standard ration in fish breeding. Cages were placed in the pond for wintering of fish. In order to individually study the state of wintering and the influence of natural components on the organism of fish. Each cage with a volume of 1000 dm^3 contained 18 specimens.

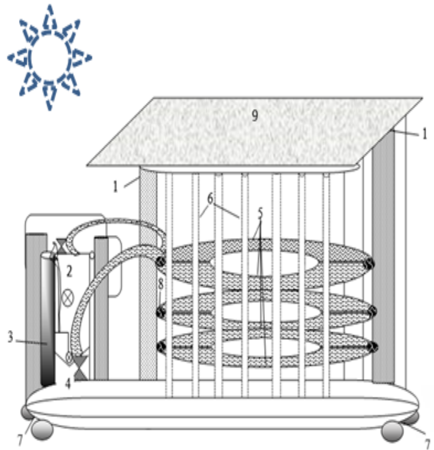


Figure 1: Device for cultivation of microalgae by using energy-saving technologies: mobile platform (1); bioreactor (2); carbon dioxide cylinder (3); recirculation pump (4); glass tubes for recirculation of microalgae culture (5); fluorescent lamps (6); wheels (7); pipe retainer (8); monocrystalline solar panels (9) (received a declaratory patent in co-authorship with O.V. Honcharova, P.S. Kutishchev).

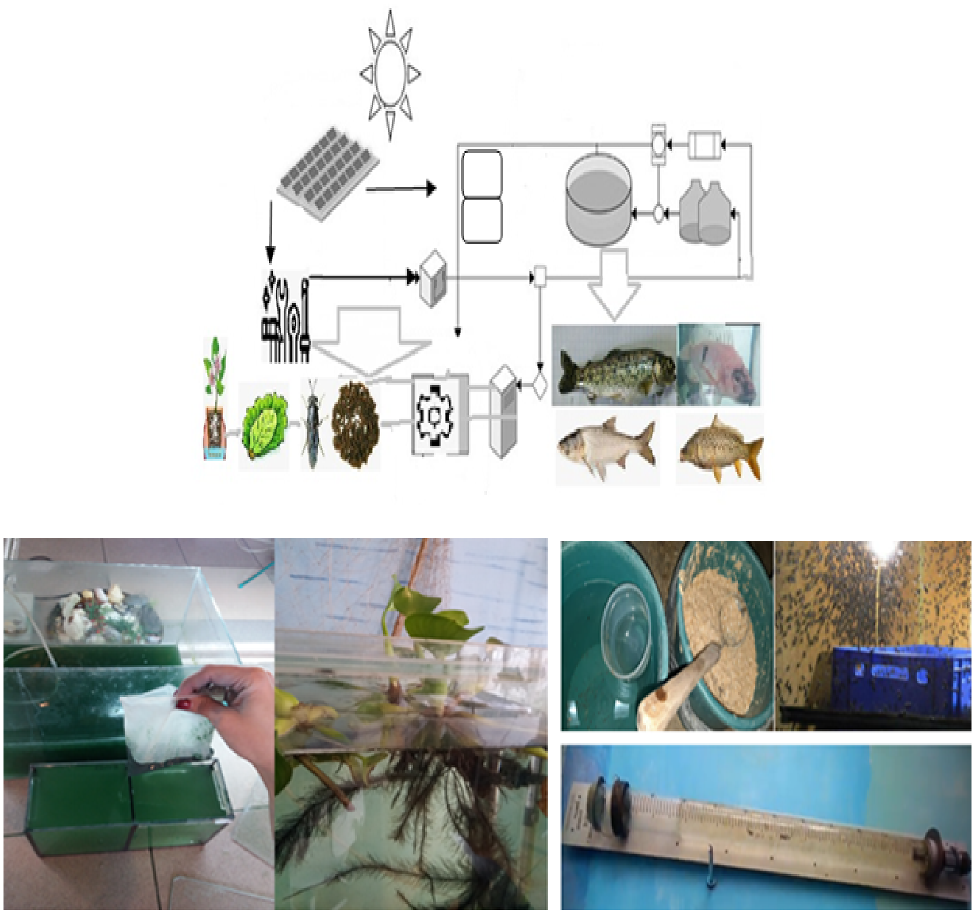


Figure 2: Technological fragments of a modular system for multitrophic aquaculture.

Tilapia *Florida red* was additionally fed the following components: Spirulina (75%) + Hermetia illucens (25%). After feeding the tilapia with natural food, the water is slightly cloudy (the first 10-15 minutes lasted). the fish were divided into Control (n=250) and Experimental groups (n=250). At the beginning, the average body weight was 2.5-2.8g. The stocking density of tilapia at the beginning of the experiment in the RAS was calculated at 15-25 specimens/м^3. Dietary standards corresponded to the basic recommendations for tilapia grown in RAS. The average temperature in the pools was 26.9-28.1; pH 7.4-7.6; oxygen content not less than 3.5 mg/l.

The main technological scheme, according to the principle of multitrophic aquaculture, is presented in the following Figures 1 & 2. In accordance with the technology, all components that were added to the diet were obtained in laboratory and production conditions.

Morphological and biochemical studies

To study blood composition, blood samples from fish were obtained from the tail vein. For this purpose, a puncture and a medical syringe were used. We studied the hematological profile of the blood of fish (total number of red blood cells (RBC), hemoglobin content (HGB), hematocrit concentration (Ht). The corpuscular indices of trout erythrocytes were also studied: mean red cell volume (MCV), mean red cell hemoglobin (MCH), mean red blood cell hemoglobin content (MCHC)). The hematological profiles of fish blood by hemoglobin was determined cyanmethemoglobin method. The biochemical profile of fish was determined on Humalyzer 3000 (Germany, 2010) biochemical analyzer (in combination with using standard unified kits by Human GmbH (Germany). Also used quantitatively analysis using a spectrophotometer (with wavelength 530 nm), UNICO 1201 (United States of America (USA), 2010).

Studies of the hydrochemical regime of basins

Studies of the hydrochemical regime in the pools where all types of fish were grown were carried out systematically. The conformity of biological, physiological, and ecological characteristics of each fish (rainbow trout, tilapia, carp in polyculture) was taken into account. An express method was used, and studies were also carried out in laboratory conditions in accordance with generally accepted recommendations in fish farming (Alekin, 1970). Hydrochemical analysis was carried out using a Palintest 7500 photometer (United Kingdom (UK), 2018), using the appropriate Palintest reagents (United Kingdom, 2018). When collecting water samples from the pools, the following parameters were determined in each test tube: dissolved oxygen content, pH, hardness, oxidizability, nitrate and nitrite concentrations. Water temperature was measured before the start of the experiment three times a day. After that, the concentration of dissolved oxygen and water temperature were studied twice a day.

Each fish species for the experiment and control was selected using the analog group method. Initially, they were grown in RAS tanks with natural component feeding and using a modular aquaponics system and a solar panel. After that, the carp in polyculture was transplanted into the pond (Control, Experiment). The condition was monitored before and after wintering. Rainbow trout was divided into experimental and control groups. Grown in RAS. Tilapia was also divided into control and experimental groups. They continued to grow in RAS tanks until reaching marketable weight. The studied values were expressed as the mean value (x) ± standard deviation (SD) using one-way analysis of variance (ANOVA), taking into account that P < 0.05 is statistically significant.

Results and Discussion

The results of the research allowed us to analyze the efficiency of the multitrophic aquaculture model. The study of the growth rate of juvenile fish is presented in Figure 2.

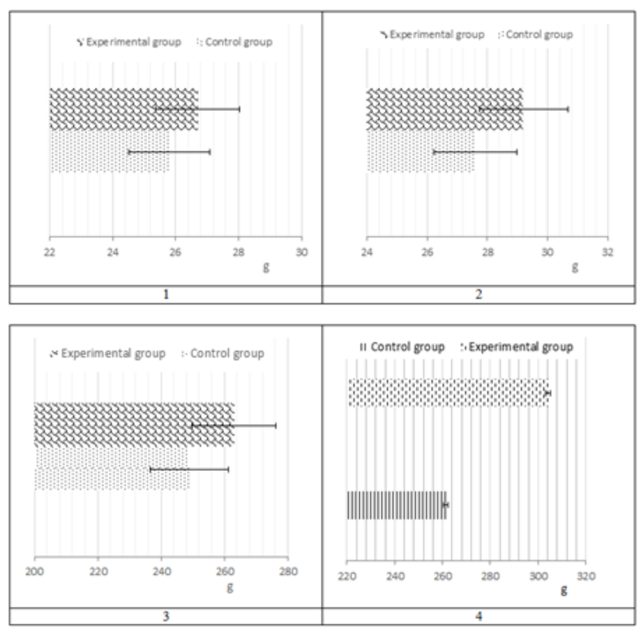


Figure 2: Analysis of the factor of additional growth *Cyprinus carpio* (1) in polyculture with silver carp *Hypophthalmichthys hybrid* (2) rainbow trout *Oncorhynchus mykiss* (3), tilapia *Florida red* (4) under the conditions of RAS and feeding with natural components.

The body weight of *Cyprinus carpio* in the experimental group was higher by 3.5 % of the parameter of fish in the control group. The body weight of *Hypophthalmichthys hybrid* in the experimental group was higher by 5.8 % of the parameter of fish in the control group. In the RAS, where juvenile rainbow trout *Oncorhynchus mykiss* were additionally grown using the multitrophic aquaculture system, the body weight of the experimental fish was higher by 5.7 % of the parameter in the control group. The same was true for tilapia *Florida red* where the weight of fish in the experimental group was higher by 16.4 % of the value in the control group. The fatness coefficient and the percentage of survival of juveniles in all fish in the experiment were better than in the control group (Figures 2 & 3).

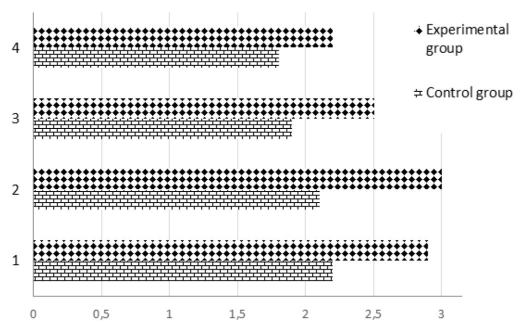


Figure 3: Analysis of the Fatness coefficient *Cyprinus carpio* (1) in polyculture with *Hypophthalmichthys hybrid* (2) rainbow trout *Oncorhynchus mykiss* (3), tilapia *Florida red* (4) under the conditions of RAS and feeding with natural components.

The use of natural components affected the main indicators of blood composition in the body of all fish in the experiment. In the Experimental groups, all fish had higher and better characteristics of ontogenesis, physiological and biochemical status of the organism than in the Control group. We believe that the natural components entered the body of the experimental fish through the neuro-humoral pathway and contributed to the activation of the metabolism, assimilation of nutrients. Considering that the blood is a labile system that reflects the reactive functional picture of all the processes that occur in the living organism, we analyzed the leading parameters (Figures 4-7).

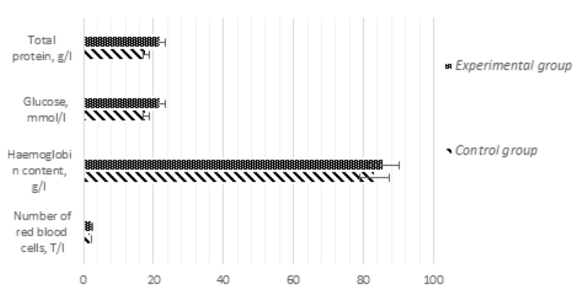


Figure 4: Analysis of morpho-functional blood parameters *Cyprinus carpio* under conditions of cultivation in RAS.

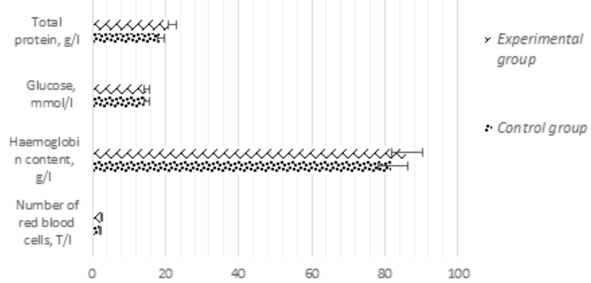


Figure 5: Analysis of morpho-functional blood parameters *Hypophthalmichthys hybrid* under conditions of cultivation in RAS.

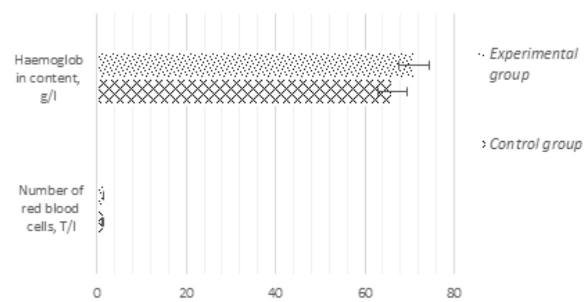


Figure 6: Analysis of morpho-functional blood parameters tilapia *Florida red* under conditions of cultivation in RAS

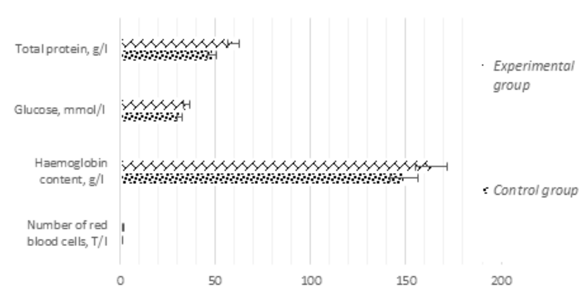


Figure 7: Analysis of morpho-functional blood parameters rainbow trout *Oncorhynchus mykiss* under conditions of cultivation in RAS.

In fish from each experimental group, the level of assimilation of feed was better in comparison with the fish of the control group. It can be concluded that the natural components were a catalyst for physiological, biochemical and metabolic processes. The use of the aquaponics model made it possible to reduce the environmental load, as well as to obtain additional plant products for use as fertilizer and compost in vermiculture. When growing in entomology (for the black soldier), a feeding base was used. In addition, a bioreactor for growing microalgae, which was used in the technological scheme of fish farming, made it possible to obtain our own microalgae (spirulina) and Artemia nauplii, which increased economic efficiency.

The growth rate analysis showed that the fish in the experimental groups grew better than in the control group. The body weight of juvenile carp after feeding with natural components and using alternative energy sources and aquaponics was 26.7 g before wintering and 24.8 g after. The body weight of carp in the control group was 25.8 g before wintering and 23.4 g after. In the experimental group, carp were placed in a cage for wintering.

Parameters	Period	**Control group**	**Experimental group**
Average body weight, g	before	25.78±1.492	27.58±1.329
	after wintering	23.38±1.125	24.80±1.243
Fatness coefficient (according to Fultan)	before	2.23±0.244	2.84±0.299**
	after wintering	1.94±0.245	2.43±0.327*
Survival, %	after wintering	72,2	88,9

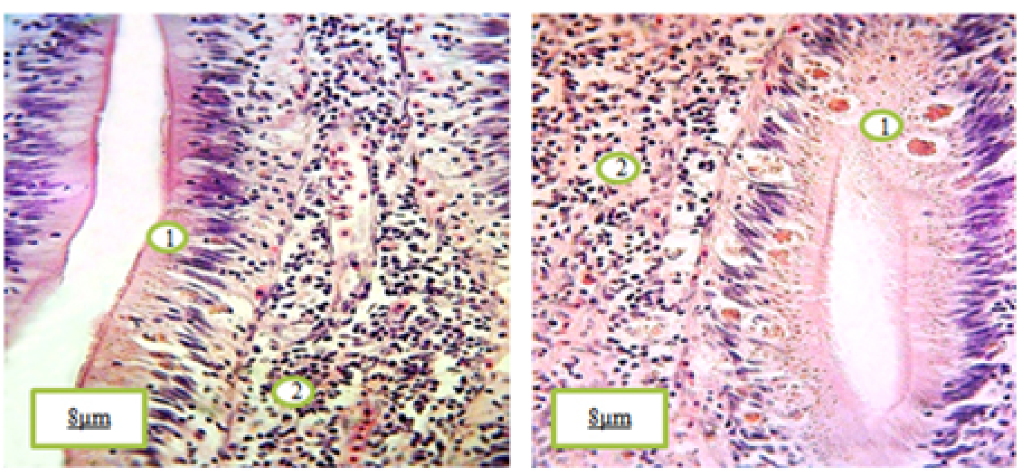
[*]Note: [*]– $P<0.05$; [**]– $P<0.01$ between the control and expermental groups

Table 1: Analysis of the impact of the multitrophic aquaculture model on the morphometric parameters of carp before and after wintering, $x \pm SD$, $n= 18$.

The results demonstrate the positive influence of the feeding factor on the general functional status of the fish organism. Growth indicators in the Experimental group were higher than in the Control group. The parameters were also confirmed by better blood composition, metabolic activation, and hematopoietic function. As a result, the young fish were more resistant to potentially negative influences. This is clearly seen in the example of carp, which after being grown in the RAS was planted in a pond for wintering.

Silver carp belong to stomachless fish, and therefore, for the convenience of histological analysis, sections of the middle intestine were subjected to analysis. In a comparative aspect, their micropattern is the most demonstrative (Figure 8).

Optimization of feeding conditions ensured an improvement in the absorption process of chyme components. Optimization of feeding conditions ensured an improvement in the absorption of chyme components. The digestive activity of the intestinal folds also increased. There is an activation of lymph and hemodynamics in the mucosal lamina propria. All this is confirmed by the presence of a large number of formed elements, and also indicates an improvement in the assimilation of feed components.



A B

Figure 8: The level of secretory activity of the intestinal folds of silver carp depending on the influence of the technological factor: A – 1 Control group; B - 2 Experimental group: 1 – mucous membrane; 2 – the proper plate of the mucous membrane. Böhmer's hematoxylin, Hart's fuxelin (in modification). X320.

The multitrophic aquaculture model makes it possible to increase the rationality of using available resources in aquaculture. Technological aspects make it possible to combine two forms of aquaculture (intensive and extensive). This is growing young fish in RAS pools and in ponds. Also, the use of natural components for feeding and alternative energy sources. By activating protein, lipid and carbohydrate metabolism, it is possible to improve the quality of fish growth. Replacing with high-protein components makes it possible to reduce the load on the ecosystem.

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