ANIMAL SCIENCE AND FOOD TECHNOLOGY

Journal homepage: https://animalscience.com.ua/en
Animal Science and Food Technology, 14(2), 28-43
Received 07.03.2023 Revised 17.03.2023 Accepted 11.04.2023

UDC 639.3.043.13:636.087.7
DOI: 10.31548/animal.2.2023.28

Physiological and biochemical aspects of the carp organism in conditions of increasing their viability when stocking water bodies

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Abstract. The relevance of the study is conditioned by the defining role of the stage of early development in the ontogenesis of young fish in the formation of their growth rate potential. The physiological and biochemical status of the body determines the adaptive capabilities of hydrobionts, so the use of biologically active substances when rearing fish was chosen as one of the vectors for improving the development parameters. The purpose of the study was to determine the effectiveness of introducing technological elements (supplementary feeding, rearing) in the early stages of the ontogenesis of young fish. The study was based on theoretical (analysis, synthesis, comparison, modelling), experimental, and laboratory methods adopted in fisheries, physicochemical studies. A clinical examination of fish, monitoring of growth rates, weight gain, survival rate, and physiological state was carried out. The results show an increase in the viability

Suggested Citation:
Honcharova, O., Bekh, V., & Glamuzina, B. (2023). Physiological and biochemical aspects of the carp organism in conditions of increasing their viability when stocking water bodies. *Animal Science and Food Technology*, 14(2), 28-43. doi: 10.31548/animal.2.2023.28.

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of young fish, activation of metabolic processes, and improvement of blood morphological and functional parameters. The average weight of fingerlings exceeded the parameters in the control group for carp by 3.5% and for silver carp by 3.8%. The total number of red blood cells in the silver carp experimental group was 7.4% higher than the control ($p < 0.05$), haemoglobin content – by 4.7%, haematocrit – 9.9%. The total number of red blood cells in the blood of carp in the experimental group was 4.9% higher, and the haemoglobin content was 3.1% higher than in the control group. In the experimental group, the total protein content exceeded the value in relation to the control group for silver carp by 15.9% ($p < 0.05$), and for carp – by 23.9% ($p < 0.01$). Enzymatic activity in the experimental group was higher compared to the control group. The proposed method of feeding helps increase the growth rate of fish. The practical value of the study is to help improve qualitative and quantitative parameters, in particular, the biochemical composition of the muscle part for carp and silver carp in samples in the experimental group in comparison with control values

Keywords: functional status; hydrobionts; technological elements; resistance; rearing

Introduction

Rational fisheries management, both the actual aquatic bioresources and the potential of fisheries enterprises, is one of the key aspects in the context of effective compensation programmes for stocking and replenishment of the ichthyofauna with resilient fish planting material. Improvement of the strategy for the development of fisheries, harmonisation of fish production in natural and artificial reservoirs with the maximum use of the potential of water resources, and consideration of physiological, ichthyological, and breeding aspects are dominant vectors in this area. Therefore, complex research on optimising technological elements and rational use of industry resources come to the fore (Buzevych, 2012; Bekh *et al*., 2014; Heina *et al*., 2015). Rearing fish planting material, increasing the level of resistance of the body of hydrobionts to the influence of various factors, and improving the development parameters of young fish are a prerequisite for the promising and sustainable development of the fisheries industry as a whole (Şen *et al*., 2017; Honcharova *et al*., 2019; Tsurkan *et al*., 2019).

In the context of modern realities, many studies focus on the need and expediency of reloading individual elements and technological systems of the fisheries industry. Moreover, it should be borne in mind that the transformation of a number of parameters of different nature: physicochemical, hydrobiological, physiological and biochemical, ecological and biological in aquatic ecosystems occurs in accordance with the adaptive capabilities of the aquatic organism (Honcharova *et al*., 2021). Aquatic ecosystems form a certain number of parameters in accordance with climatic transformations in modern conditions. At the same time, the mechanisms of neuro-humoral regulation in the body of hydrobionts are aimed at maintaining the parameters of homeostatic balance. A single functional system in the body of introduced hydrobionts or native ichthyofauna should be aimed at regulating and ensuring the constancy of vital parameters, increasing adaptive capabilities, and in some cases, the ability to globally rebuild a link of adaptive and compensatory mechanisms in order to stabilise

vital functions. Under stressful situations that may be caused by the discrepancy between neuro-humoral regulation on the influence of abiotic and biotic factors, the functional status of the fish body will have a decrease in resistance to negative effects, low development parameters, and deterioration of the reproductive ability of hydrobionts. Under such conditions, it is important to implement comprehensive system solutions with a vector of corrective and modelling effects on the fish body. In this context, the course of metabolic processes in their body forms qualitative and quantitative parameters: the rate of development in ontogenesis, survival, productivity, etc. These aspects are among the priorities in the development of strategic programmes for optimising the production of viable young fish for effective stocking of reservoirs of various shapes and purposes.

Some researchers emphasise the need for rational use of water resources, harmonisation of trophic relations, and qualitative and quantitative parameters of fish against the background of environmental conditions of a certain water area (Sherman *et al.*, 2017; Korzhov & Honcharova, 2020). Climatic transformations, technogenic load on ecosystems, rapid development of technologies and their introduction into the technological scheme often contribute to the "discrepancy" of physiological and biochemical mechanisms, and adaptive capabilities of the body of hydrobionts. As a result, there is a chain of consecutive changes: stress reactions in the body of hydrobionts, a decrease in the indicators of effective management of the industry, irrational exploitation of resources, etc.

Under these conditions, one of the solution cases is the need to reconstruct the ichthyofauna of water areas and develop certain comprehensive recommendations. In the conditions of rearing and introducing resilient fish planting material of commercial fish species, there are opportunities for successful implementation of the programme to achieve positive results and solve a considerable number of issues of fisheries activities. Researchers provide informative and objective data on a significant reduction in fish planting material for carp stocking in water areas, the need to review the main aspects of strategic programmes for the development of the fisheries industry. Given these aspects, there is an urgent need to update the ichthyofauna, thereby determining the topic and relevance of research in this line (Buzevych & Heina; 2019; Averchev *et al.*, 2019; Shcherbak *et al.*, 2020).

Summarising these aspects, it is worth noting the relevance of scientific and practical work in optimising certain elements at the stage of rearing young hydrobionts. Given that there is a rapid development of technologies, transformations in the context of abiotic and biotic factors, and the body of hydrobionts must adapt to the leading factors, studies on the possibilities of improving the adaptive capabilities of the body, activating metabolic processes, improving the speed of development of hydrobionts acquire practical and scientific value. To achieve these objectives, the aim was to study the influence of the technological factor on the main physiological and biochemical parameters in the carp organism at the rearing stage through a comprehensive study.

Literature Review

The researchers substantiate the importance of increasing the production of fish planting material in modern ecological and technological conditions for the purpose of further stocking of water areas, restoration of ichthyofauna, and rational fisheries management of reservoirs for various purposes (Shcherbak *et al.*, 2020; Regional report on the state of the environment of the Kherson region 2001–2021, n.d.). Adaptive

and compensatory mechanisms of hydrobionts are rearranged in their body depending on the abiotic and biotic factors of the environment where they are located. Introduced hydrobionts should occupy the corresponding trophic niches of the aquatic environment. Admittedly, it depends on the availability of the food resource of the aquatic ecosystem and their ecological and biological characteristics. Rational exploitation of water bodies, considering the biological needs of water bodies, will ensure efficient fishery use of water areas (Buzevych & Heina, 2019; Sherbak *et al.*, 2020).

Given the practical value of the outlined range of problems, the decisive role of optimising the technological and biological aspects of fish farming can be noted, in particular, carp in polyculture in the context of the growing cycle. The researchers focus on revising the main parameters and technological aspects in the conditions of modern climatic transformations, including fish wintering and the stages of rearing (Boychenko *et al.*, 2016; Tsurkan, 2022). There are authors who focus on the prospect of using enzymatic compounds, prebiotics, and drugs aimed at correcting the feed conversion rate and improving the overall fish-biological indicators (Hoseinifar *et al.*, 2017; Ziółkowska *et al.*, 2020). However, it is important to consider the bioavailability of each of the ingredients for the body of hydrobionts, the specificity of action and the features of physiological and biochemical processes. In this context, the issue of using "environmentally friendly" substances as part of additives or separately in aquaculture is relevant. This method brings technological aspects closer to "organic production", which in modern conditions tends to increase demand among producers of aquaculture products and consumers. It is proposed to introduce various problem-solving cases at certain stages, when the potential for the development of hydrobionts is formed. In particular, the introduction of components in the feeding of hydrobionts of active substances are of natural origin, as close as possible to environmentally friendly ones. Promising results on the introduction of biologically active, specially processed or non-traditional components of the general diet of hydrobionts in the general technological scheme are reflected by some researchers (Pivovarov *et al.*, 2017; Palamarchuk *et al.*, 2018; Pratiwy *et al.*, 2020).

The effectiveness of optimisation measures in the context of technological aspects is ensured by comprehensive in-depth studies of the environment for hydrobionts and conditions of resource feed potential (Korzhov, 2020). N.I. Kulbida (2004), O. Honcharova *et al.* (2021) focused attention on the expediency of developing strategic solutions for restarting the fisheries sector, considering the impact of climate parameter transformations both at the regional and global levels (FAO, n.d.; Intergovernmental Panel on Climate Change, n.d.).

Based on the above, there is a need to develop and implement innovative and ecological technology for the production of fish farming products and rational operation of reservoirs. Comprehensive optimisation measures of the technology of rearing fish planting material, depending on modern environmental and technological factors, will contribute to complementing the general idea and successful search for the optimal model for growing young fish. The relevance of obtaining high-quality viable fish planting material remains even in modern conditions of development of the fisheries industry.

Materials and Methods

The research is focused on the main experimental part of the component, which was performed at the premises of the Department of Water Bioresources and Aquaculture of KSAU (Ukraine), laboratories at the Faculty of

Fisheries and Nature Management of KSAU and state institution (SI) "Kherson production and experimental plant for breeding and rearing young common freshwater fish. The Department of Aquaculture of the National University of Life and Environmental Sciences of Ukraine (NUBIP) analysed and developed the feed mixture, which, after the preparatory stage, was transferred to the Department of Water Bioresources and Aquaculture of KSAU for the main part of research: feeding and rearing carp in an experimental study. Copyrights for the use of technological elements of supplementary feeding, the composition of the feed mixture, and the use of a method to increase the viability of young fish are secured by the authors of developments of the Department of Water Bioresources and Aquaculture of Kherson State Agricultural University.

The fish diet was optimised in compliance with generally accepted recommendations (Zheltov, 2003; Hrytsyniak, 2007;). For the production needs of the operation of pool systems, a solar panel was used as an additional energy source with the installation of elements for the use of additional filtration in fish pools using agricultural crops and materials capable of filtering water coming from the reservoirs of the system at a certain level. The developed scheme for rearing fish planting material of young carp *Cyprinus carpio* is proposed in polyculture with a silver carp hybrid *Hypophthalmichthys hybrid* was used in the research group. The results were compared with the control group. Technological aspects of the experimental study are as follows: a system of recirculation pools, for the experiment, 250 m^3 tanks with appropriate equipment, elements of filtration sections, a built-in autonomous section (unit) for the cultivation of microalgae with a timer for the correction of light and hydrochemical conditions. All parameters were monitored systematically and recorded in the work log. In each tank, there were *Cyprinus carpio* larvae for rearing in polyculture with *Hypophthalmichthys hybrid* with initial weight up to 400 mg (average 0.325 mg). When planting fish for rearing, samples of 260 specimens were selected into the formed groups to analyse the parameters of the physiological and biochemical state of their organism. Blood and other biological samples were taken from 50 specimens (Dehtiarov, 2001). At the end of the experimental study, the functional state of the body of carp and silver carp fingerlings was studied before and after stocking water areas.

At the beginning of the preparatory stage of experimental work, the model basin system was installed and tested in the conditions of laboratory research of KSAU and SI KPEP. Feeding at various stages of fish ontogenesis was carried out in accordance with the current standards in fish farming. At the same time, the size and dispersion of particles and granules were gradually changed to increase their bioavailability. At the time of the transition of fish larvae to mixed nutrition, these components were introduced gradually. They were cultivated in a bioreactor, followed by filtration and processing. The culture obtained from the mother liquor of its own cultivation in a medium based on water treatment was develop for introduction into the fish diet based on the calculation of 1:3 and 1:2 working solution of *S. Platensis:* humic substances of a commercial preparation of 15 mg per kg of feed, while the feed particles were evenly distributed and sprayed. The technological factor was thus a feed mixture and filtration conditions involving not only classical energy sources, but also alternative ones (solar panels).

The hydrochemical state of the tanks was monitored according to standard parameters based on the monitoring schedule. The aquatic environment is a single ecosystem for hydrobionts, which has a direct impact on

the formation of all processes and the level of functionality of their body. At this stage, monitoring studies were carried out systematically in accordance with the planned schedule, which allowed analysing the trend towards changes and fluctuations in each of them. Consequently, the temperature regime and the level of free hydrogen ions (PH) had an average value of 24.3-24.4°C (with a gradual decrease) and 7.3 units. With the development and stabilisation of the main homeostatic indicators of the body of young fish *Cyprinus carpio* and *Hypophthalmichthys hybrid*, the actual temperature value was reduced to gradually adapt to hydrochemical changes in parameters after stocking of already grown juveniles. The actual values of the hydrochemical state for the leading parameters were within the maximum permissible concentrations (MPC). At the time of the introduction of the feed mixture, the pH of the aquatic environment in the basins of the system fluctuated slightly, which is a reasonable phenomenon, the difference did not exceed 1.0 units. The oxygen regime had an average value of 3.8-4.0 mg O_2 against the background of nitrite concentration NO^-_2 0.02-0.03 and nitrates NO^-_3 0.14-0.15 mg N/dm^3. In general, the hydrochemical regime during the rearing of hydrobionts in reservoirs created an ecosystem of the aquatic environment optimal for the life of young fish in terms of basic parameters.

In addition, in parallel with laboratory studies, systematic sampling and monitoring of hydrochemical parameters of the water area where it was planned to carry out stocking of reared young fish were carried out. During the growing season, the average temperature of the aquatic environment ranged from 20.8 reaching peak maximum individual actual values of 28.2°C. The content of oxygen dissolved in water ranged from 6.8 to 7.2 mg/dm^3, at the same time, the level of hydrogen ions pH was in the range of 7.6-7.9 units, ammonium nitrogen had values at the level of 0.3 to 0.4 mg/dm^3. The content of nitrites did not exceed the maximum permissible concentration of 0.001, and nitrates – 0.4 mg N/dm^3.

The studies of the main parameters were guided by generally accepted methods (Hrytsyniak, 2001; Dehtiarov, 2001; Zheltov, 2003; Arsan *et al.*, 2006). All the necessary equipment was available in the conditions of a certified laboratory of KSAU, SI KPEP, ThermoMix was used to transport biological samples. The functional status of the fish body was assessed by the leading parameters of biological material: biochemical analysis of samples to study the level of enzymatic activity of alanine aminotransferase (ALT), aspartate aminotransferase (AST), total protein content, and glucose concentration was carried out in the laboratory of the Department of Water Bioresources and Aquaculture of KSAU on the Humalyzer 3000 analyser using Human GmbH unified kits. Catalase activity was determined by spectrophotometric method, based on the ability of hydrogen peroxide to form a stable colour with the reagent. Morphological and functional parameters of blood (total number of red blood cells, white blood cells, haemoglobin content, corpuscular parameters of blood) were analysed using standard methods using test kits and counting method. Against the background of the outlined parameters, the ethology of hydrobionts was monitored during the day. All manipulations with experimental objects corresponded to the "European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes" (1986).

Results and Discussion

The functional status of the fish body reflected the course of metabolic processes and the level of resistance to various environmental factors.

Therefore, first of all, the hydrochemical regime in the system of cultivation of research objects should be noted. The results of monitoring the rate of fish development are presented as a diagram in Figure 1. The average weight of carp and silver carp corresponded to the general recommendation parameters and was higher than in the control group.

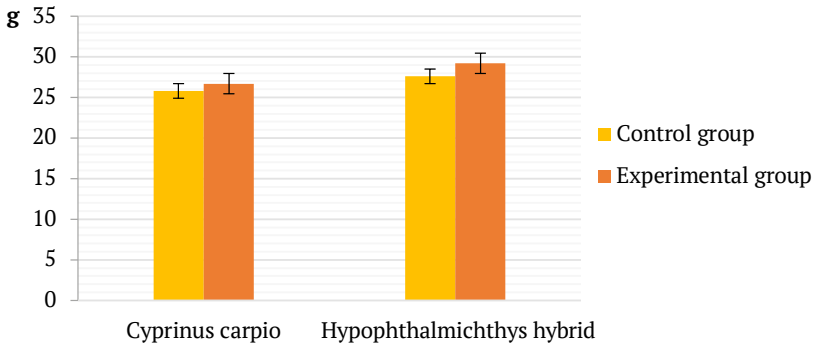

Figure 1. Comparative analysis of development parameters *Cyprinus carpio and Hypophthalmichthys hybrid* fingerlings, (M ± m, n = 260)

Source: developed by the author based on own research

In addition, against the background of higher development parameters, the survival rate of hydrobionts in the experimental group after feeding was higher than in the control group, as evidenced by higher growth rates in the group where the feed factor played the role of a stimulator of metabolic processes. Admittedly, the aquatic environment creates optimal or opposite unfavourable conditions for the viability of hydrobionts, maintaining the parameters of their homeostatic equilibrium, however, the feed factor also indirectly corrects these parameters.

Physiological and biochemical parameters of the carp body in the experimental group, where the juveniles were grown using several technological factors (improved filtration, optimisation of feeding conditions), were noted as the highest indicators in comparison with the parameters of the control group. Since the entire system functions in symbiosis, with a certain appropriate reflection on the influence of abiotic and abiotic factors, the carp blood test is an informative and important study. It informs about certain changes in neuro-humoral regulation in the body of fish, which affect the speed of development. The results of the study of the leading morphological and functional parameters of blood in fish in ontogenesis allowed identifying the adaptive capabilities of their body and assessing its functional status under the conditions of using technological factors (Table 1).

Table 1. *Functional status of the body of carp fingerlings under the influence of a technological factor a when rearing before stocking, (M ± m, n = 50)*

Parameters	Carp *Cyprinus carpio*		Silver carp *Hypophthalmichthys hybrid*	
	Control group	Experimental group	Control group	Experimental group
Number of red blood cells, T/l	2.25 ± 0.031	2.36 ± 0.092	2.29 ± 0.039*	2.46 ± 0.055

Table 1. Continued

Parameters	Carp *Cyprinus carpio*		Silver carp *Hypophthalmichthys hybrid*	
	Control group	Experimental group	Control group	Experimental group
Haemoglobin content, g/l	83.20 ± 0.512	85.81 ± 1.201	82.23 ± 1.291	86.08 ± 1.380*
MCV, mkm³	142.38 ± 2.308	161.97 ± 3.355	140.65 ± 1.953	158.50 ± 3.279***
MCH, pg	37.07 ± 0.414	36.64 ± 1.481	35.91 ± 0.675	35.15 ± 1.030
MCHC, %	24.56 ± 2.078	22.62 ± 0.119	23.39 ± 0.823	22.17 ± 0.334
Glucose, mmol/l	17.89 ± 0.625	18.10 ± 1.425	14.92 ± 1.218	15.03 ± 0.716
Total protein, g/l	17.97 ± 0.547	22.26 ± 1.016**	18.88 ± 0.704	21.88 ± 0.746*

Note: [a] – technological factor – feeding of carp with feed mixture + improved rearing conditions; *0.05 ($P < 0.05$); **0.01 ($P < 0.01$); *** 0.01 ($P < 0.001$)

Analysing the general picture of the leading parameters of homeostatic equilibrium in the fish body, there is a complete correspondence between the physiologically acceptable actual values of blood parameters that were studied for fish (Dehtiarov, 2001). However, the course of metabolic processes under the conditions of using the technological factor in the experimental group was more active in relation to the control parameters. This is actually evidenced by the higher indicators of the processes of haematopoiesis, synthesis, and accumulation of body weight in young carp and silver carp of the experimental group.

An increase in the content of red blood cells and hemoglobin in the blood of carp and silver carp confirms the activation of erythropoiesis systems in their body with an improvement in the respiratory surface of red blood cells. Each of the parameters corrects a certain functional system in the body, so the study of concentrations, analysis of the difference between experimental and control values provides an opportunity to more comprehensively consider the influence of the factors under study and evaluate their effectiveness in introducing young carp into the technological scheme of rearing.

As can be seen from the results presented in Table 1, a high level of blood oxygenation can be achieved due to a larger number of red blood cells and an increase in the content of haemoglobin in them, that is, its transport. It is important to analyse and interpret the outlined processes at the morphological level. Therefore, the analysis of microcorpular blood parameters is informative and provides an opportunity to consider the parameters of haemoglobin concentration in cells, which will be discussed later in the paper.

Based on the data in Table 1, the indicators of the morphological and biochemical composition of blood are within the limits of physiological norms. In the experimental groups, there is an increase in red blood counts. Thus, the total number of red blood cells in the fish in the experimental group on silver carp significantly ($p < 0.05$) exceeded similar data in the control group by 7.4%; the haemoglobin content – by 4.7%, respectively, the hematocrit was also higher, the difference was 9.9%.

The study of morphological and functional parameters of carp blood provided the following results: the total number of red blood cells in the blood of fish that received additional biologically active components during feeding and were reared under the conditions of additional energy-saving elements in the technological map was higher by 4.9% with a higher hae-

moglobin concentration of 3.14% than in the control group. The functionality of metabolic processes also reflects the positive dynamics of microcorpular parameters of blood: there is a certain correlation with the content of red blood cells, haematocrit, and one of the important buffer systems – haemoglobin content. The actual value exceeded the parameters in the control samples of silver carp by 12.7% ($p < 0.001$). Morphological and functional parameters according to the corpuscular index MCV in the blood of carp in the experimental group were 13.8% higher than in the control group.

The study of protein metabolism processes in the body of experimental fish complements the picture of the state of physiological and biochemical systems, in addition, it provides an opportunity to analyse the course of synthetic processes, the reserve of amino acids for protein synthesis in their body. Thus, in the experimental group, the total protein content exceeded the value in relation to the control group in the silver carp blood sample by 15.9% ($p < 0.05$). The study of this parameter in the carp group also showed higher values in the experimental group by 23.9% ($p < 0.01$) in relation to the control values. Analysis of blood glucose concentrations in experimental and control fish supplemented the study of metabolic processes under the influence of abiotic and biotic factors. Carbohydrate metabolism provides the level of energy resources in the body of hydrobionts, catabolic processes of carbohydrate metabolism. The concentration of glucose depended on the level of activity of fish against the background of the course of metabolic processes. In the experimental group, this parameter tended to have lower values relative to the control. The parameters did not exceed the maximum permissible physiological values, however, attention should be paid to the tendency to increase the concentration of glucose in the blood of fish of the control group, which can identify as one of the options, the occurrence of a stressful state.

The parameters of metabolic processes in the body of carp and silver carp fingerlings were studied using one of the leading enzymatic complexes: alanine aminotransferase (ALT) and aspartate aminotransferase (AST). Since ALT and AST provide an opportunity to analyse the level of metabolic processes, in particular, protein, carbohydrate and lipid, the functioning of organs and systems in the fish body. The results of a study of protein metabolism activity, liver function, and resistance of young fish under the influence of a technological factor demonstrated that there was no significant difference between the groups. However, the level of AST according to the measurement results in the experimental groups significantly differed from the values in the control group ($P < 0.05$). The activity of the studied enzymes is widely used in the analysis of the functional status of the body as a whole, as a physiological and biochemical indicator of resistance to stress factors of various origins, and therefore, the adaptive capabilities of the fish body. The activity of the enzyme complex according to one of the marker parameters – liver catalase in the experimental group was higher than in the control group, both when sampling *Cyprinus carpio* and *Hypophthalmichthys hybrid*.

Notably, at the end of the growing period of hydrobionts, one of the important qualitative and quantitative parameters is the chemical composition of biological products. The analysis of the muscle part of carp and silver carp from the control and experimental groups is shown in Figure 2. One of the most important links is the quality of products delivered to the average consumer. In the context of scientific research concepts, the parameters of the functional status of the fish body ensure the

development of resistance of the body to the influence of abiotic and biotic factors, the growth and development parameters in ontogenesis, weight gain, output, etc. The analysis of the biochemical composition of the muscle part of the selected carp samples showed a higher protein content of 4.5% and fat content of 6.4% in the experimental group.

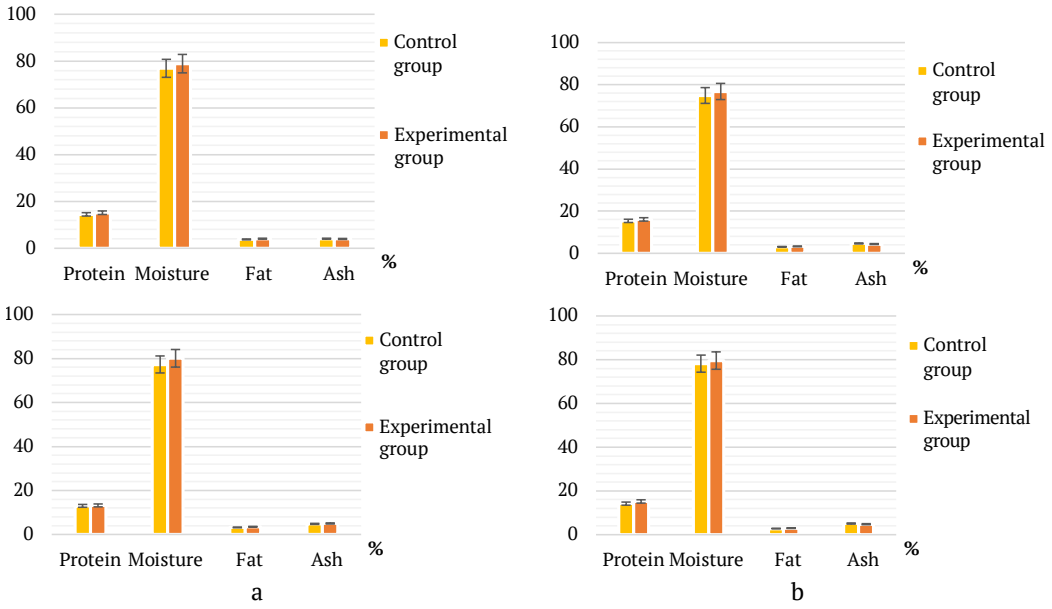

Figure 2. Analysis of the muscle part of *Cyprinus carpio* (a), *Hypophthalmichthys hybrid* (b) under the conditions of experimental research before and after stocking against the background of the introduction of the supplementary feeding of fingerlings (M ± m, n = 50)

Source: developed by the author based on own research

The selected silver carp muscle samples also had higher actual values in the experimental group than in the control group. The difference was in protein content of 4.8% and fat content of 7.8%. Comparative analysis of the biochemical composition of the muscular part of carp and silver carp before stocking and after stocking by grown young fish showed a positive effect of introducing technological elements of supplementary feeding and improving aspects of fish cultivation.

It can be noted about the stimulating effect on the processes of growth and development of hydrobionts under the conditions of supplementary feeding in the early stages of ontogenesis. Improving the parameters of the morphometric composition of blood also contributes to an increase in the growth rate of cyprinids. This stage of development is crucial for hydrobionts, since the potential for the future is being developed. In particular, the qualitative and quantitative parameters of products in aquaculture directly depend on the conditions of growing and feeding hydrobionts, and not just on their genetic potential.

Summarising the results of the experimental study, it is advisable to focus on the stimulating, corrective effect of the feed mixture when feeding young carp at the early stages of ontogenesis. The non-aggressive effect of each

of the elements contributes to the gradual restructuring of metabolic processes in the carp body, which has an important physiological and biochemical significance. Under the conditions of a mismatch of action and reaction to abiotic and biotic factors, stress reactions can occur in hydrobionts. It was the combination of all the components in the feed mixture that provided a positive effect. It is known that certain components, when ingested by aquatic organisms, also have a catalytic effect.

The available literature contains information reflecting the effectiveness of using microalgae and protein components in feeding the general diet. Such substances, when ingested, contribute to the restructuring of individual-level reactions, protein, carbohydrate, and lipid metabolism (Kovalenko & Polishchuk, 2018; Bekh *et al*., 2020; Hryhorenko *et al*., 2021). However, against the background of the use of alternative energy sources, a successful combination of all the components for feeding carp presented in this paper was investigated for the first time.

S. Nagappan *et al*. (2021), analysing the effect of microalgae on the rate of development of hydrobionts, note that a high concentration of microalgae in feed can contribute to the opposite effect – inhibition of fish growth rate. However, the researchers practised including *Arthospira* biomass in fish meal. But the method proposed by the authors of this study provides for a separate use of the manufactured feed mixture in the general economic diet. This creates the possibility of symbiosis of the proposed biologically active substances with the effect of synergy, and not vice versa. In addition, there are judgments of some researchers, supported by experimental studies, where the effect of transformation of enzymatic activity in fish was obtained under conditions of prolonged and uneven use of microalgae for feeding as an additive (Dallaire *et al*., 2007). At the same time, emphasis is placed on the method of microalgae cultivation, a certain type and ratio of the proportion of components of natural feed when feeding hydrobionts. The proposed method and ingredients of the feed mixture in this sex do not affect the leading indicators, in particular morphological and functional parameters of blood and enzymatic activity in carp, which is confirmed by the results obtained. In the context of a comprehensive study of the effectiveness of using natural feed to increase the resistance of fish organism, metabolic processes, enzymatic activity, and immunomodulatory effect, it is possible to note the positive effect of such components on metabolic processes in fish. The *Spirulina platensis* and *Isochrysis galbana* biomass function as prebiotics: when they enter the body, they contribute to the development of beneficial bacteria (Dineshbabu *et al*., 2019). In numerous studies, it is mainly represented by monocomponent mixtures. Under the conditions of the proposed method of increasing the functional activity of the fish body, several elements occur, in particular, biologically active substances of humic nature, microalgae *S. Platensis*. Thus, there is a complex effect of such composites. Accordingly, the effect has a wider range, covering neuro-humoral locus processes in the fish body.

The information presented in the reviews and research papers mentions low fermentation and assimilation of microalgae such as *Chlorella sp*., *Nannochloropsis sp*., which is explained by the presence of non-starchy substances, rather rigid cell walls (Skrede *et al*., 1998). Regarding *S. Platensis,* it can be noted that it is included in the feed mixture in combination with biologically active substances of humic nature. In turn, humic substances have a number of properties that support other components, after entering the body, individual processes are restructured, activated,

and corrected. Therefore, the additive proposed in this paper to increase the viability of young hydrobionts has a number of advantages among already known composites.

The experimental results indicate that microalgae in the composition of supplements, due to their high protein content, can be an alternative to fish meal or a supplement to adjust the nutritional qualities of ingredients in the general fish diet (Abdulrahman *et al*., 2018). There are positive results on the example of microalgae *Chlorella* regarding a significant increase in the parameters of development in carp ontogenesis. Q. Zhang *et al*. (2014) used 0.8% chlorella, which increased the fish body weight in the experimental group from 29.90 ± 0.08 to 63.75 ± 1.96 g with WG 33.85 ± 1.96 g, which was higher than in the control group ($P < 0.05$). At the same time, previous studies have shown that *Chlorella* can participate in the regulation of adaptive and innate immunity, and increase the level of immunoglobulins and enzymatic activity in the carp body (Zhang *et al*., 2014). Undoubtedly, each element of microalgae has typical characteristics, and is active and effective under certain conditions of cultivation, processing, and introduction to the general economic diet. However, the results of experimental studies present an unambiguously positive effect on the functional status of the body of hydrobionts, in particular, physiological and biochemical parameters, indicators of the rate of development, and the yield of hydrobionts.

The results of such experiments on the correction of feeding conditions are often ambiguously interpreted, since the "mixing" effect of other components and additives to the diet occurs precisely in conditions of heterogeneity of the use of similar components by other researchers. Therefore, considering this effect, it is advisable to annotate the results of the use of humic substances and spirulina with positive dynamics in the context of optimising the conditions for supplementary feeding and growth of aquaculture objects.

Conclusions

Summing up the whole complex of results obtained, it can be noted that the body of hydrobionts is a complete functional system that shows a certain reaction to each factor. The parameters of the development rate of fish are adjusted with the main physiological and biochemical processes in their body. Neurohumoral regulation of all vital functions reacts reactively to the intake of biologically active substances of various origins. The results obtained demonstrate positive indicators of improvement in fish resistance to abiotic and biotic factors. Annual stocking programmes will be effective if viable carp juveniles are used in polyculture. Based on generally accepted classical methods of growing hydrobionts, it is possible to improve individual links of the technological process. The introduction of such elements of the feed factor and the element of technological operation of basin models in the context of the filtration system and an additional element of alternative energy sources contribute to the achievement of the goals set. Young fish have a higher resistance to the negative effects of abiotic and biotic factors. In particular, the erythrocyte blood picture reflects the course of positive functional processes in the body of fish of the experimental group. As a result, the effective use of the potential capabilities of the body of experimental carp youth and the best respiratory function was noted, which positively affects the development processes, body weight accumulation, and resistance to various factors. The development potential positively corrects the physiological and biological status, growth rate, and output.

Improvement of metabolic processes and increase in the parameters of carp development occurred as a result of transformations and morpho-metric parameters of fish blood. In particular, the total number of red blood cells in the group where the technological factor under study and its direct impact on the functional status of the organism exceeded the actual values of the control parameters. In turn, this was reflected in the corpuscular parameters of the blood, the concentration of haemoglobin. Consequently, synthetic processes in the body of fish of the experimental group were more active and effective in relation to carp from the control group. Since the functional system maintains its own viability and activity due to consistent action and the influence of each of the parameters that form complex processes, it is possible to assume exactly the corrective effect of the feed mixture. By a certain activation of metabolic processes, increasing the synthesis of complex and simple compounds in the body of hydrobionts, stabilisation, increased resistance and development occurred in fish in the experimental group.

Based on the results of the positive impact of the studied factor on improving the viability of young fish, the authors note the line of future research that will provide a deeper understanding of the effectiveness. Consequently, histological studies of biological material from the control and experimental groups will complement the understanding of the mechanism of action of the feed mixture under study.

Acknowledgements

None.

Conflict of Interest

None.

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Фізіолого-біохімічні аспекти організму коропових за умов підвищення їх життєздатності при зарибленні водойм

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Анотація. Актуальність дослідження зумовлена визначальною роллю етапу раннього розвитку в онтогенезі молоді риб при формуванні потенціалу їх швидкості росту. Фізіолого-біохімічний статус організму визначає адаптаційні можливості гідробіонтів, тому одним із векторів поліпшення параметрів розвитку було обрано використання біологічно активних речовин при підрощенні. Метою дослідження було визначення ефективності впровадження технологічних елементів (підгодівлі, підрощення) на ранніх стадіях онтогенезу молоді риб. Дослідження ґрунтувалось на теоретичних (аналіз, синтез, порівняння, моделювання) експериментальних, лабораторних методах, прийнятих у рибогосподарських, фізико-хімічних дослідженнях. В ході дослідження проводився клінічний огляд риб, контроль темпів росту, масонакопичення, рівня виживання, фізіологічного стану. Результати демонструють підвищення життєздатності молоді риб, активацію метаболічних процесів, поліпшення морфо-функціональних параметрів крові. Середня маса цьоголіток перевищувала параметри в контрольній групі по коропу на 3,5 % та по товстолобику на 3,8 %. Загальна кількість еритроцитів дослідної групи по товстолобику була вище за контроль на 7,4 % ($p < 0,05$), вміст гемоглобіну – на 4,7 %, гематокрит – 9,9 %. Загальна кількість еритроцитів в крові коропа дослідної групи була вище на 4,9 %, вміст гемоглобіну – на 3,1 %, ніж в контролі. В експериментальній групі, вміст загального білку перевищував значення по відношенню до контрольної групи по товстолобику на 15,9 % ($p < 0.05$), по коропу – на 23,9 % ($p < 0.01$). Ферментативна активність в дослідній групі була вищою щодо контролю. Запропонований спосіб підгодівлі сприяє збільшенню швидкості росту риб. Практична цінність дослідження полягає у сприянні поліпшенню якісних та кількісних параметрів, зокрема, біохімічного складу м'язової частини по коропу та по товстолобику у пробах в експериментальній групі в порівнянні з контрольними значеннями

Ключові слова: функціональний статус; гідробіонти; технологічні елементи; резистентність; підрощення