KAPITEL 8 / CHAPTER 8 [10]
HIGHLIGHTS TECHNOLOGICAL ASPECTS OF RECIRCULATORY AQUACULTURE MODULAR SYSTEM (RAS) AND PHYSIOLOGICAL PARAMETERS OF HYDROBIONTS ORGANISM

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Introduction

Today, the direction of aquaculture, which can provide the population with high-quality protein, can be noted as one of the most cost-effective and promising. In the context of the development of modern technologies and high consumer demands, it is important to adapt the maximum aspects of technology and physiological characteristics of objects that are cultivated in aquaculture. The percentage of global fisheries production correlated with cultured aquaculture production exceeds capture fisheries production. Aquaculture is currently growing faster than the world's population and plays an important role in increasing food production, food security and human nutrition at the global level [1, 2].

With the development of the aquaculture industry, the disadvantages of traditional extensive aquaculture methods are being eliminated. The development of this direction acquires advantages, among which is the absence of dependence on land and natural space, leading to water pollution, outbreaks of diseases, damage to the coastal ecosystem and other uncontrollable factors that do not contribute to the sustainable development of aquaculture [3, 4, 5]. In addition, the use of RAS in aquaculture gives practitioners and producers the opportunity to not depend on seasonality. The essence of modern intensive aquaculture is the high-density aquaculture method using recycled aquaculture water, known as a recirculating aquaculture system (RAS).

Cultivation of fish and aquatic invertebrates in industrial aquaculture systems based on the recycling system is developing in our country and is quite promising, as it makes it possible to reduce the consumption of clean water to a minimum and build fish farms on small water sources. Owners of fish farms have the opportunity to switch to more water-efficient production programs that will not depend on climate change

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(which is relevant today) and on the decrease in precipitation. In this context, the sanitary and hygienic assessment of water according to organoleptic, hydrochemical, toxicological indicators in closed water supply installations throughout the year is of particular importance [6, 7].

An urgent issue is compliance with qualitative and quantitative parameters of aquaculture products. The use of natural substances in the cultivation of aquatic organisms prevails over the use of hormonal or chemical drugs and additives. Therefore, the stage of growing aquatic organisms under RAS conditions using natural components acquires practical importance in aquaculture.

8.1. Aspects of technological parameters and experience in using RAS

In aquaculture, emphasis can be placed on several aspects that ensure successful breeding and rearing of aquatic animals. Let's look at some of the leading ones in this context. For example, having made a review of the literature on this issue, it can be noted that historically, RAS was used in Japan in the 1950s due to the popularity of biological filters in carp farming for more efficient use of limited local water resources [4, 5, 8]. In the 1960s, Japanese scientists made great strides in the study of microbiology and water purification. But during this period, RAS was not used on a large scale due to the high complexity of construction and operation. As is known, these modular systems provide for several levels of water treatment and purification (UV, biological, mechanical) and corresponding water costs. RAS systems developed rapidly in Europe and North America (from the 1970 to the 1990), and were popular in Germany and the Nordic countries, as the authors’ research was presented in these years. Since then, due to the unique advantages of RAS, the technology has evolved and gained support. Today, in accordance with the results of the analysis of the authors' research, RAS systems are used for the cultivation and breeding of more than 46 species of fish, 11 species of crustaceans, 7 species of mollusks and 7 species of Echinodermata organisms [8]. North American and European countries are leading the aquaculture industry in the use of modular RAS systems. In this case, the objects that are most widespread for RAS in most cases are *Tilapia Oreochromis niloticus* and *Orechromis mossambicus*, *Florida red,* rainbow trout *Oncorhynchus mykiss*, freshwater fish, including clary catfish, *Atlantic salmon, Salmo salar*, shrimp, *Litopenaeus vannamei* and the *Pacific oyster Crassostrea gigas* and other hydrobionts [8].

So, in the technological context, RAS is a closed (recycle) water circulation system with water treatment sectors that moves in a circle. The system consists of many parts, and each sector can influence the functioning of the entire system. Technologically, the RAS system must provide for the biological characteristics of the organism of the objects of cultivation and breeding. The efficiency of physiological processes in the fish body can change by an average of 6–10% when technological parameters change. For example, a change of 1 degree in temperature can significantly alter the rate of growth and development of aquatic organisms [9]. In scientific works, the authors note that hydrochemical and feeding factors also affect the functional status of aquatic organisms, including appetite, digestive functions and feeding abilities [10, 11, 12]. As temperature changes, the fish's antioxidant and enzyme activities increase and food intake increases until the optimum growth temperature is reached. However, as the temperature rises beyond the optimal value, the activity of functional enzymes decreases and the ability to feed is inhibited, slowing growth [10, 13]. All these aspects are important to consider in aquaculture. The temperature factor can also affect the efficiency of the reproduction processes of aquatic organisms, the period of gonad maturation, reproductive function, etc. [12, 14]. For example, heat-loving female hydrobionts prefer higher water temperatures than males, therefore the influence of temperature on females is greater than on males, especially during the spawning period [9]. The RAS composition of the microbial community and the efficiency of pollutant removal (ammonia nitrogen and nitrite in the biofilter) also depend on water temperature. Typically, the biological population is large and pollutant removal efficiency is high at higher water temperatures [7, 8].

The oxygen parameter is also one of the important factors for successful RAS aquaculture, since when the oxygen content decreases, the percentage of nitrifying bacteria in the bioreactor of the RAS system significantly decreases, the growth of heterotrophic nitrifying bacteria is especially suppressed, and an increase in oxygen content (above 5 mg/l) promotes the removal of ammonia, nitrates and total nitrogen [8, 15]. Consequently, for the normal growth of most hydrobionts, it is also necessary to control the level of oxygen dissolution in the RAS [16]. The next factor to pay attention to is pH, it is an important water quality parameter in the RAS, which demonstrates the activity of hydrogen ions in the water. Recommended water values for RAS aquaculture are pH 6.0 - 9.0 units. For each country, these actual values may differ, for example, for water quality, pH for RAS aquaculture is recommended in the following range: 6.5–8.5 (for fresh water) and 7.0–8.5 units (for seawater) [8, 12]. Also, the authors recommend taking into account that the processes of biological respiration and decomposition of organic substances consume oxygen and release carbon dioxide, which leads to a decrease in pH. Acidic water causes acidosis in most fish at $pH < 5$. High partial pressure of carbon dioxide and low pH cause a decrease in the oxygen-carrying capacity of the blood. As a result, the oxygen supply to tissue cells changes and protein degeneration and weakening of tissues and organs occur. When considering biofilter nitrification in a RAS, it is important to consider that low pH levels will inhibit the growth of nitrifying bacteria, while alkaline environments with a pH of 7.0–9.0 are more suitable for the growth of nitrifying bacteria [7].

It has been established experimentally that different biological load (the basis for the reactions of nitrification and denitrification) of the RAS affects the efficiency of the functioning of the system as a whole of the RAS. Therefore, the dynamics of nitrifying processes in the bioreactor of the RAS biofilter when using different types of fillers depends on the type of filler, the quantitative content of nitrifying and denitrifying microorganisms, as well as on the density of the formed microbial biofilms on the filler. The author proved the necessity of using a method of disinfecting water in RAS with an ultraviolet bactericidal lamp, which enables safe disinfection without disturbing the microbiocenosis of the biofilter. The positive effect of the vitamin feed supplement during fish feeding due to increased immunity and increased weight gain

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was shown [7, 8].

The stocking density of cultured organisms is one of the major factors determining the productivity of an aquaculture system. Fish stocking density is necessary for the survival and growth of cultivated organisms. Stocking density can also have an adverse effect on fish muscle development, reducing the protein and crude fat content of the fish, further affecting product quality [8, 17]. In addition, high aquaculture densities will also increase the rate of oxygen consumption and ammonia excretion by fish. All these processes can contribute to oxidative processes, reducing the activity of functional enzymes, disrupting hormone levels, and negatively affecting the antioxidant system and immune system of fish [12, 13].

The next factor that affects the effectiveness of RAS is food and feeding technology. These parameters are mandatory in RAS. In aquaculture, as a rule, the cost of feeding aquatic organisms amounts to 30–70% of the total cost of aquaculture [8]. Therefore, the RAS recommends planning feeding in accordance with the nutritional characteristics of various species of aquatic organisms. Feeding is an important part of RAS, and feeding technology as a process (quantity and frequency of feeding, diet composition) are the main factors influencing the eating, growth and metabolism of aquatic organisms. An appropriate amount of carbohydrates in the feed can stimulate fish growth and improve feed processing efficiency and protein utilization efficiency. Different fish have large differences in their ability to utilize carbohydrates [8, 12, 18]. Modular RAS systems reduce the load on the biological filter and promote the denitrification process [7, 8]. At the same time, it is important to take into account that protein is an important nutrient in aquaculture feeds and a main component in the formation of various tissues and organs of fish [12]. Protein is made up of individual amino acids, of which 10 amino acids are essential but cannot be synthesized by fish, such as methionine, arginine, lysine and phenylalanine, so they must be supplied to the fish through food. Protein can not only be used for the growth and repair of tissues and organs, but is also an important component of various biologically active substances and is involved in the metabolic process and regulation of physiological functions in the body. Juvenile fish require higher levels of protein due to their high metabolic rate

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[11, 12, 14].

Thus, the feeding aspect can improve the efficiency of using RAS in aquaculture. The feed factor can regulate the osmotic balance, promote the activation of metabolism, participate in enzymatic reactions, hormonal regulation and other processes important for the life of aquatic organisms. Having examined and analyzed the leading parameters of a technological nature, let us consider the second part, which is no less important – the features of physiological processes in the body of aquatic organisms during cultivation in RAS systems.

8.2. Parameters of the physiological status of the organism of hydrobionts under the influence of growing conditions in recirculating modular RAS systems

Technological aspects are one of the determinants of the effective activity of the RAS aquaculture industry. However, taking into account the biological, physiological and biochemical features of hydrobionts is one of the important issues. Because it is necessary to adapt technological innovative and classical technologies to adaptive and compensatory processes and capabilities of the organism of hydrobionts. Only under such conditions is it possible to achieve positive results of cultivation and breeding of hydrobionts in RAS. The direction of Ukrainian aquaculture has all the resources to ensure the food security of our country [19, 20, 21]. The issue of improving technological aspects and increasing opportunities to effectively use the potential of water areas, resources of industrial aquaculture is open, constantly gaining practical and scientific value.

Taking into account the constant transformation of a considerable number of factors of various nature, it is worth emphasizing that aquaculture is a functionally active industry that involves constant contact with living organisms. Optimizing the processes of the technological map of aquaculture in the conditions of ecological transformation is aimed at taking into account the adaptive capabilities of the hydrobiont organism itself, their adaptation to new or improved technologiesIn the

Southern region of Ukraine, the climatic and geographical conditions, the number of degree days, and the number of sunny days contribute to the active implementation of elements of alternative energy conservation for use in technological maps of aquaculture. Such a vector makes it possible to achieve energy autonomy for a fishing enterprise. If we add to this the feed factor of additional feeding of young fish in RAS, then the result will be high indicators in aquaculture.

Physiological processes in the body of hydrobionts are markers that identify the general functional state. Growing up in recirculating modular systems of young fish along with additional feeding with natural components is one of the cases of increasing resistance to the influence of negative factors and accelerating metabolism in fish [22, 23, 24, 28, 29].

The recirculating modular system makes it possible to autonomously regulate the cycle and period of growing and breeding hydrobionts in aquaculture. Such a system can be both mono and multifunctional. With the use of RAS, it is possible to cultivate not only hydrobionts, but also microalgae, zooplankton for additional feeding with natural fish food. It is also possible to combine several types of hydrobionts in a single system, while adding the sector of aquaponics, biological filtration with plants, etc.

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). When cultivating young fish in modular systems of the recirculation type, several ration options were used (taking into account the biological features of the fish organism). In particular, they used: *Cyprinus carpio, Hypophthalmichthys hybrid, tilapia,* rainbow trout. In the technological aspect, we note that for all types of hydrobionts, the conditions of cultivation, breeding, hydrochemical parameters met the standards in aquaculture [25, 26, 27].

Feeding indicators also took into account the type of fish, their age group, the period of ontogenesis when forming the diet. The ration rate was calculated for the experimental groups, where fish were additionally supplemented with natural components and raised in modular RAS systems. One of the examples of such modular RAS systems with a combination of several optimized technological aspects is presented in the following Figure 1.

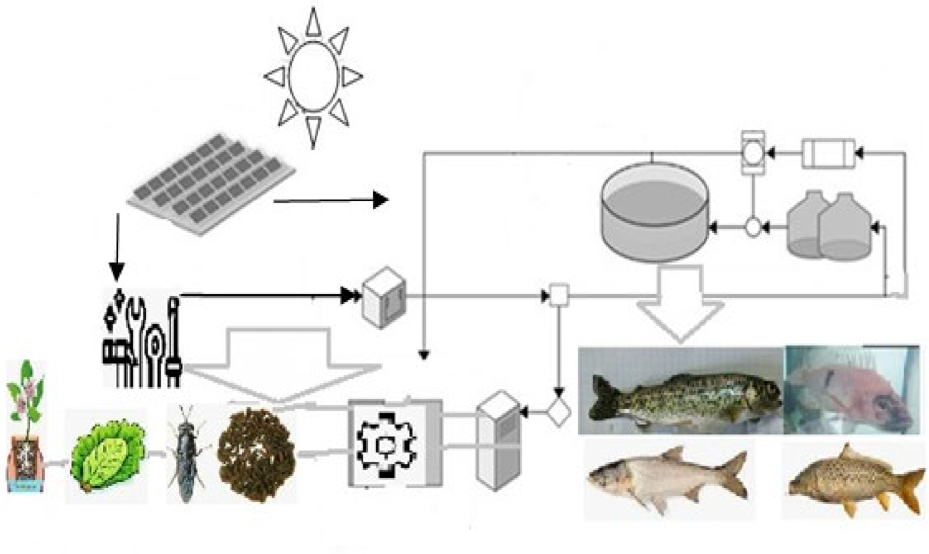

Figure 1 An example of a modular system of recirculation function and the main objects of a scientific research experiment

The results of raising fish in such a modular recirculation system are presented in the following diagrams, Figures 2–8.

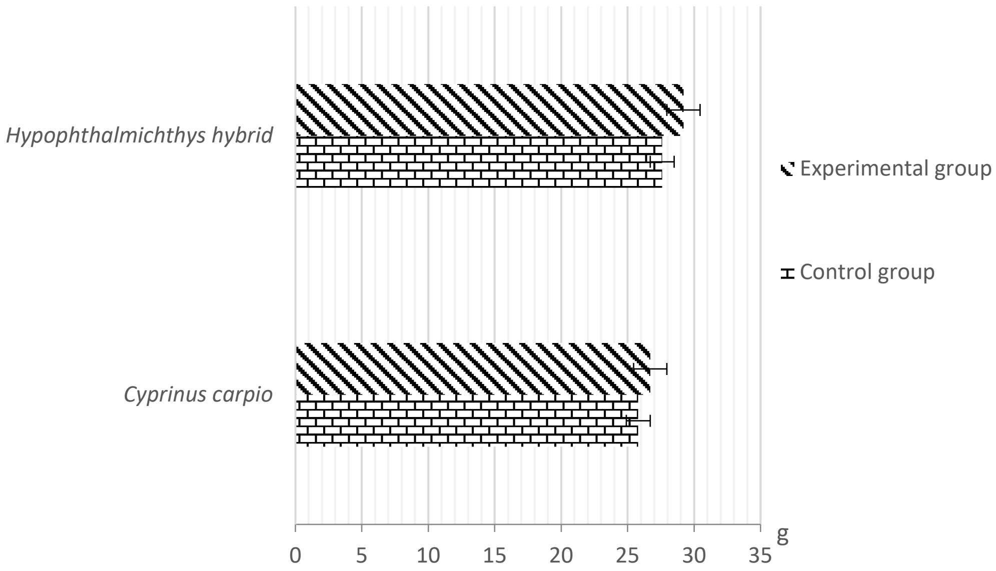

Figure 2 Analysis of the factor of additional growth carpio in RAS with natural components

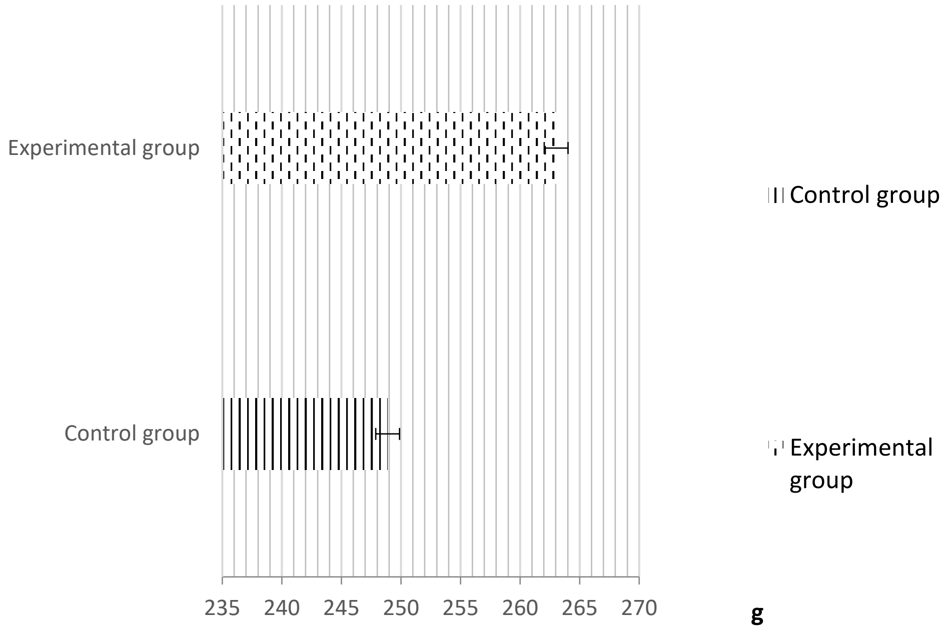

Figure 3 Analysis of the influence of the additional growth factor rainbow trout under conditions of cultivation in RAS

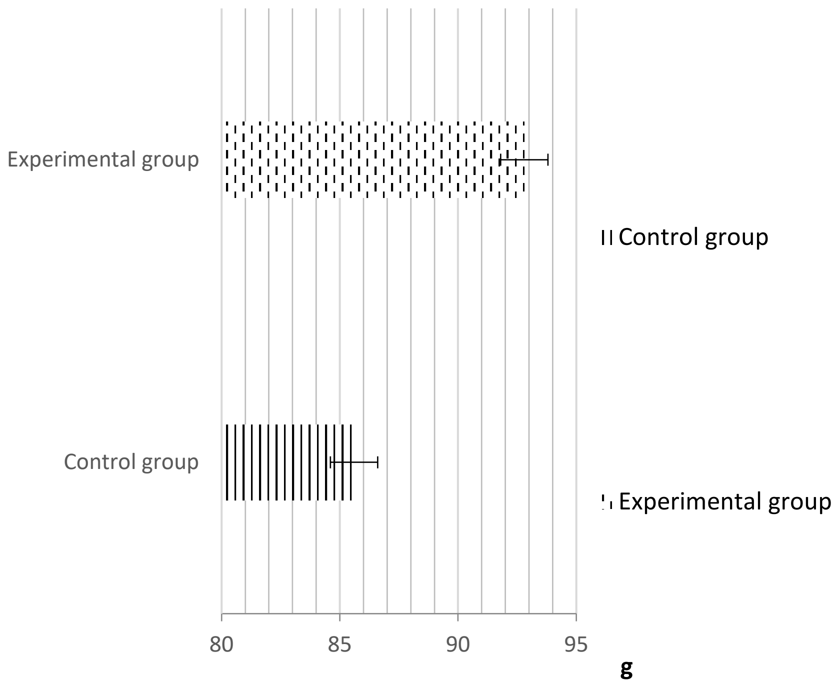

Figure 4 Analysis of the influence of the additional growth factor tilapia under conditions of cultivation in RAS

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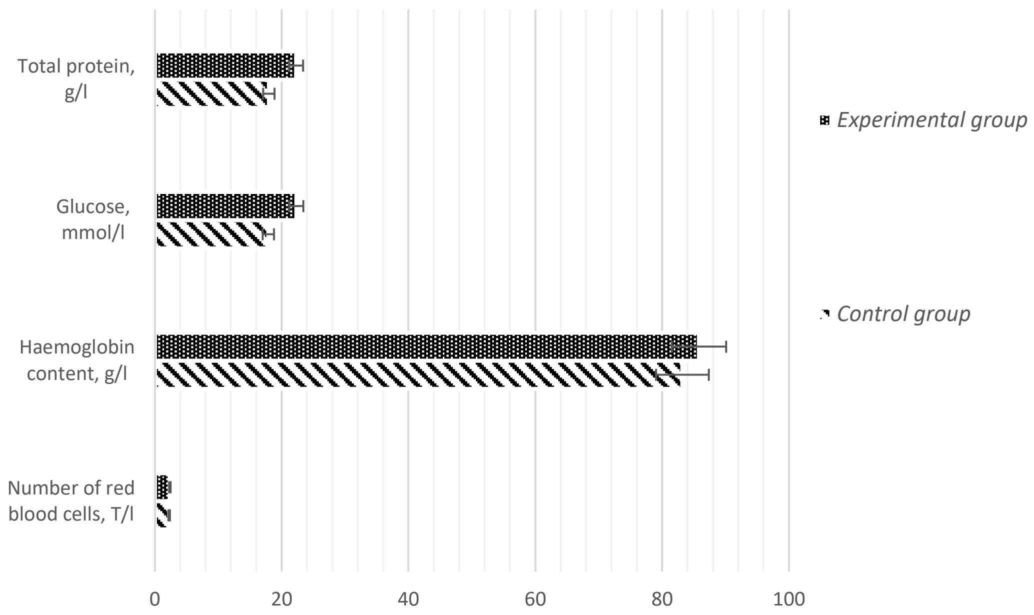

Figure 5 Analysis of morpho-functional blood parameters *Cyprinus carpio* under conditions of cultivation in RAS

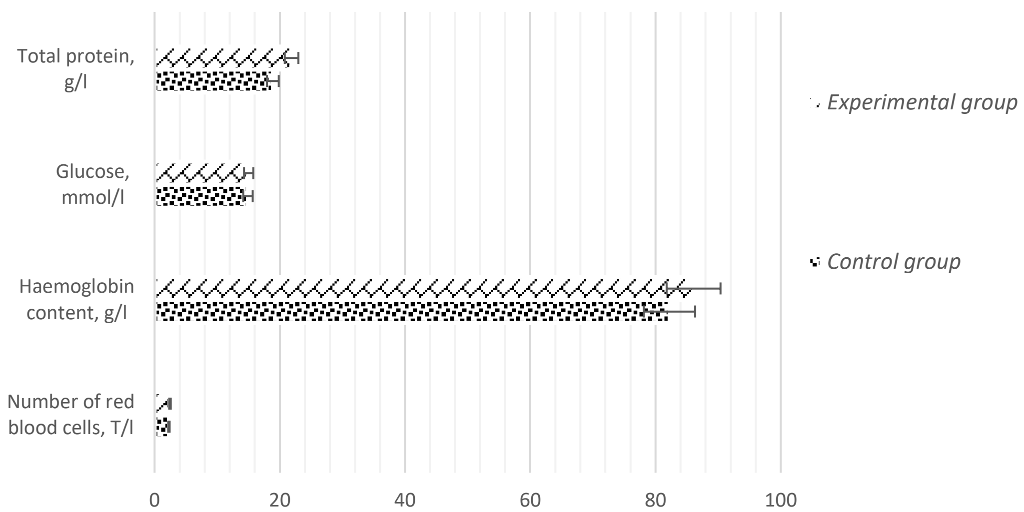

Figure 6 Analysis of morpho-functional blood parameters *Hypophthalmichthys hybrid* under conditions of cultivation in RAS

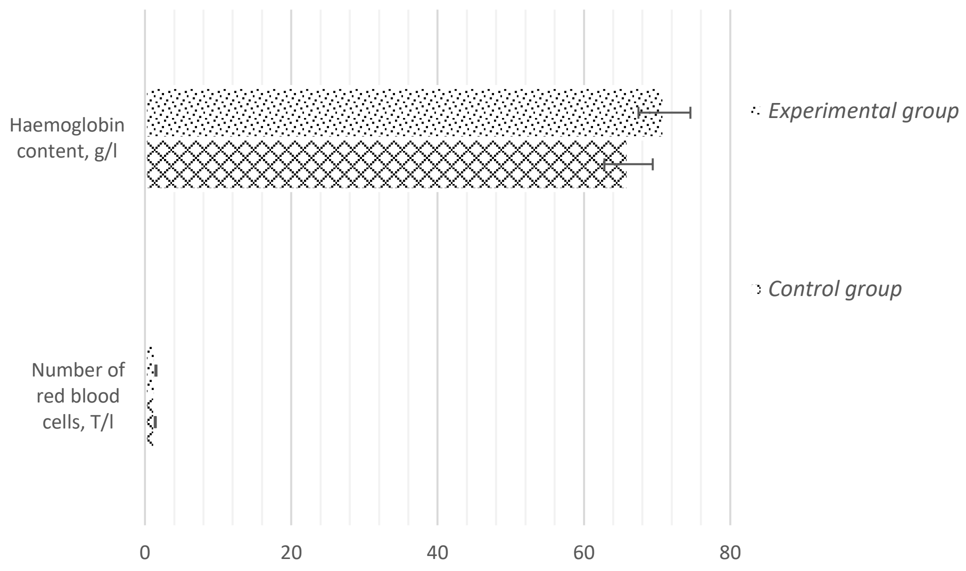

Figure 7 Analysis of morpho-functional blood parameters tilapia under conditions of cultivation in RAS

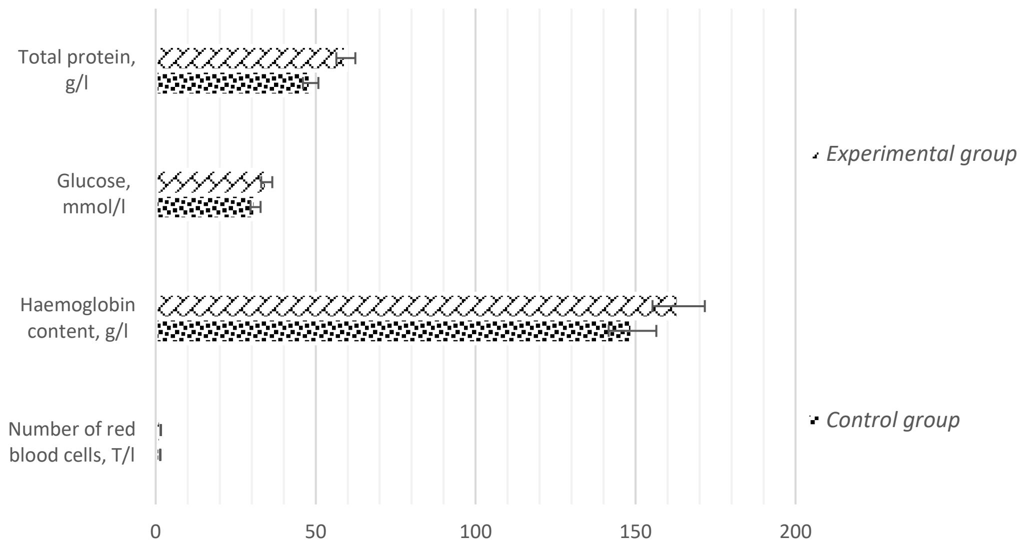

Figure 8 Analysis of morpho-functional blood parameters rainbow trout under conditions of cultivation in RAS

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Summary and conclusions

Using the obtained results of research work as basic aspects, it can be noted that the use of an additional theinological case as an extension in recirculating modular systems (RAS) contributes to the increase of leading parameters in fish farming, in particular, aquaculture. Hydrobionts improve the overall functional status of the organism, activate metabolic processes.

As a result, there is an activation of development processes, the speed of body weight, and an increase in resistance to the influence of factors of abiotic and biotic nature. Such a growth stage can be used as the main one in breeding and growing hydrobionts only in recirculating modular aquaculture systems. And as an additional one at the growth stage for the purpose of stocking water areas with viable young hydrobionts.

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