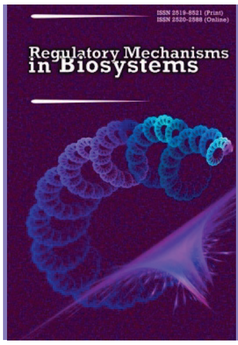

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Influence of winter water temperatures on the physiological state of carp (*Cyprinus carpio*)

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In the winter period, water temperature is one of the main factors influencing the physiological state of fish. Its optimal and stable indicator during the whole winter period guarantees high yield of fish and its quality. To this date, the winter period is characterized by elevated temperatures with acute fluctuations. In this work, the main object of study is carp (*Cyprinus carpio*) at the age of six (young-of-the-year) and ten (one-year) months. The aim of this study was to determine how much the period of the optimal winter water temperatures decreased and how this affected the weight and fatness, hematological profiles, erythrocyte indices and basic biochemical parameters of carp muscle tissue. As a result of research, it was found that optimal winter water temperatures decreased by an average of two months, which affected the physiological state of carp. Consequently, there was a decrease in body weight and fatness. Dissolved oxygen level, pH, nitrites, nitrates and hardness were normal, while oxidation was increased. Muscle fat and protein levels decreased to critical levels, at the same time, moisture and ash levels were noted to increase. The total content of red blood cells decreased, however, the level of hemoglobin, mean corpuscular hemoglobin (MCH), mean cell hemoglobin concentration (MCHC) increased. With increasing hemoglobin content and concentration, mean corpuscular volume (MCV) decreased. After wintering, the number of white blood cells increased. The biochemical profile of carp blood showed a decrease in total protein in blood serum, albumin, triglycerides, cholesterol and glucose. After wintering, there was an increase in creatinine, phosphorus and calcium. Knowing how much the period of optimal winter temperatures has shortened, and how this affects the state of carp at the physiological level, will provide an opportunity to develop recommendations for improving wintering technologies. Considering the dynamics of climate change, the research in this area is promising.

Keywords: starvation, energy reserves, blood serum, biochemical profile, hematological profile, erythrocytes.

Introduction

Water temperature determines the intensity of metabolic processes in fish, which is characteristic of poikilothermic species (Christensen et al., 2021; Chung et al., 2021; Zhu et al., 2021). Thus, changes in temperature are, in many cases, a natural stimulus that triggers the spawning, migration, and other behavioral responses of fish (Angiulli et al., 2020). In fish of low and moderate temperature latitudes, which include the object of the study, intensive metabolism occurs at high temperatures (Aidos et al., 2020; Pilakouta, 2020). Within the optimal temperatures for such species of fish, its increase leads to increased digestion of the fodder aquatic organisms. With the temperature change, the degree of digestibility changes (Hébert & Dunlop, 2020; Volkoff & Rønnestad, 2020). Since fish are adapted to life in a certain temperature range, it is known that its distribution in a water body is closely related to the distribution of water temperature (Nordahl, 2020).

The readiness of young-of-the-year fish for the wintering is largely ensured by the conditions of feeding in the summer growing period, which affects the physiological state of fish before the period of fall in temperatures (Khalko & Sherysheva, 2018). As a result of lower nearby environment temperature, fish begin to concentrate in the lower reaches of the water body bed in search of favourable conditions. Any change in the temperature, hydrological, gas regime and chemical composition of water at this time causes adequate responses of the fish, which leads to increased energy expenditure to support life (Takegaki & Takeshita, 2020). In this regard, in the conditions of fish farming enterprises, much attention is paid to the cultivation of standard carp young-of-the-year fish with an average weight of at least 25 g (Tovstik, 1965; Shumak, 2016).

In recent years, the priority areas in global science research on climate change have been the studies of increase in the average annual temperature of the surface of the atmosphere, which is seen as global warming, combined with continuous and long-term increase in the Ocean level, which are identified by the UN as the most important modern problems of mankind, and the consequences of its impact on the planet as a whole, or on its local parts (Cortès et al., 2019; Jo et al., 2019). From 1880 to 2015, the global average surface temperature increased by about 1.0°C with a range of 0.8 °C to 1.2 °C, this value has been called an increase in global temperature since the pre-industrial era (Stocker et al., 2013; Masson-Delmotte et al., 2018).

The warming, which exceeds the global average, is observed in many regions on land and at different times of the year. According to estimates, it is found that significant warming of most of the non-tropical zone in the Northern Hemisphere, in which Ukraine is located, is observed in the winter-spring period (Boychenko et al., 2016; Bardin, et al., 2020).

Under favourable wintering conditions, which lasts 5–6 months in the south of Ukraine, according to the fishery and biological standards, the survival rate of the one-year carp planted in wintering ponds of the young-of-the-year should be 80–85%, and the average weight loss should not exceed 12%. In young-of-the-year fish, well-prepared for wintering, in autumn, the moisture content in the muscles should be no more than 78%, protein should be about 12%, fat – at 6–8%, ash – at 2–3% (Sakovskaja et al., 1991).

The climate changes described above affect the temperature regime of the wintering ponds create "disturbing" temperatures, and shorten the period of optimal temperatures for the wintering of carp. Such conditions provoke the mobility of fish, which together with the lack of food leads to loss of organism reserves, depletion and increasing of mortality during the process of wintering. Due to this hypothesis, the aim of the article is to determine the dynamics of changes in the main fish farming indicators and biochemical parameters of muscle tissue of carp fish stocked in the period before and after the wintering, under the influence of astatic water temperatures.

Materials and methods

The principles of bioethics were used in the research. Before conducting measurements of carp and blood sampling, fish taken from the pond were immersed in 5 g of NaCl L^{-1} for 5–10 min to alleviate or reduce the osmoregulatory dysfunction by reducing the gradient between water and fish blood during the period of stress (Wurts, 1995; Harmon, 2009). All the described experiments were approved by the Academic Council of Kherson State Agrarian and Economic University and conducted in accordance with the Recommendations of the Council of the European Union (2010/63/EU) for the use of research animals and guidelines principles ARRIVE (NC3R). The object of the research was carp (*Cyprinus carpio* Linnaeus, 1758) at the age of six (young-of-the-year) and ten (one-year) months. The fish farming, biochemical and hematological indicators of fish were the subject of the research. Direct research was carried out at a fish farm in the south of Ukraine in the ponds used for the wintering of carp fish stocking. Carp at the age of six months were placed into a pond with capacity of 1 m^3 for the period of wintering. The density of the fish planting was set at a rate of 450 specimens per hectare, thus, 19 specimens were planted into the pond. To determine the fish farming indicators of fish, biochemical parameters of blood serum, its morphological and functional indicators, and biochemical parameters of muscle tissue in laboratory conditions, 15 specimens of young-of-the-year fish and all one-year fish which have survived the wintering were selected, thus, the total sample was 30 specimens. The processing of experimental material was carried out at the end of the growing season, with a decrease in water temperature to 10 °C, before transferring to the wintering ponds, and in post-winter period, at a water temperature of 10 °C, before transferring fish to the fattening pond. The water temperature was determined twice a day by means of a submerged temperature water sensor with a wireless combination to an automatic professional Ambient Weather WS-2902C meteorological station on the WS-5000 module (China, 2016).

Water samples for hydrochemical analysis were taken every three days, directly from the pond near the water supply, drainage and in the middle of the pond, using samplers (Bessonov & Privezentsev, 1987; Washington, 1999). Using a certified Palintest 7500 (UK, 2018) multiparameter photometer, and with use of Palintest (UK, 2018) reagents, pH, hardness, dissolved oxygen, oxidation, nitrite and nitrate concentration were determined in each sample (Wedemeyer, 1996; Boyd, 2012). To determine the dynamics of changes in the length and weight parameters of young-of-the-year fish in the period before and after the wintering, a morphometric analysis of the object on plastic characters using a caliper, electronic scales with an error of 0.01 g and measuring tape, was performed (Pravdin, 1966). Fatness was determined by the method of calculation according to Fulton's formula (Fulton, 1902). Determination of the main biochemical parameters of muscle tissue was performed by the following methods: the mass fraction of water was determined by drying at 100–105 °C (to constant weight) in ThermoLab (Ukraine, 2010) drying apparatus; the mass fraction of lipids was determined by defatted residue Soxhlet apparatus; the mass fraction of protein (total nitrogen) was determined by the Kjeldahl method; the mass fraction of mineral was determined by burning in a muffle furnace at a temperature of 450 °C (Nikolaenko et al., 2011).

Four blood samples (two before the wintering, two after) were obtained by puncturing the caudal vein with a syringe at a volume of 4 mL and later transferring it to two test tubes, one with 2% heparin for hematology profiles and the other for coagulating and blood serum obtained for biochemical profiles. Evaluation of hematological profiles and erythrocyte indices was performed according to the following indicators: red blood cells (RBC), white blood cells (WBC), hemoglobin (HGB), mean red cell volume (MCV), mean red cell hemoglobin (MCH), mean red blood cell hemoglobin content (MCHC). Hemoglobin (HGB) was determined by cyanmethemoglobin method (Samour et al., 2016) and quantitatively using a UNICO 1201 (USA, 2010) spectrophotometer at 530 nm. MCV, MCH, MCHC were calculated from the total number of red blood cells and hemoglobin. White blood cells were counted and evaluated using the stained blood smears according to Natt-Herrick (Noga, 2010; Grant, 2015). The biochemical profile was determined from blood serum samples, for which the blood coagulation was performed, and centrifuged by 1000 rpm for 10 minutes. Determination of total protein, glucose, albumin, creatinine, triglycerides, cholesterol, calcium and phosphor in the blood serum was performed on Humalyzer 3000 (Germany, 2010) biochemical analyzer using standard unified kits by Human GmbH (Germany, 2019).

Data processing was performed using Past 3 (UK, 2017) statistical software. The tables and figures show the arithmetic mean values and their standard values (x ± SE). The certainty of differences between the samples was assessed using single-factor analysis of variance (ANOVA). Differences were considered certain at $P < 0.05$.

Results

Analysis of the dynamics of water temperature during the winter showed a reduction in the period of optimal temperatures by two months (Fig. 1). The average water temperature in November was 8.1 ± 0.8 °C, and in March 6.2 ± 0.1 °C, while the optimal water temperature range for carp wintering is 2.0–4.0 °C, and it lasted from December to February. The dynamics of air temperature is characterized by a small number of days with temperatures below zero.

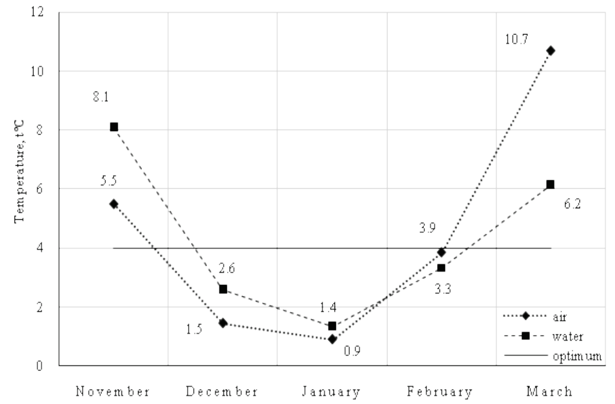

Fig. 1. Graph of the dynamics of changes in air temperature and water temperature during the winter period in the pond where the experiment was conducted; the graph also shows the optimum of winter water temperatures for carp (x ± SE)

During the winter period, the oxygen level was in the range of 6.9–7.4 mg/L, pH – 7.6–8.0, nitrite content was 0.001–0.011 mg/L, nitrate content – 0.16–0.25 mg/L, hardness – 3.2–3.6 mg-eq./L, oxidation – 11.5–17.5 mg/L. The dynamics of the main fish farming indicators of carp reflects a decrease in weight to 31.7% ($P < 0.001$), and the coefficient of fattening to 5.5% ($P < 0.01$) (Fig. 2, 3).

The weight of carp before planting for the wintering averaged 51.9 ± 1.0 g, and the length was 12.0 ± 0.2 cm; after the wintering, the weight decreased on average 35.6 ± 0.5 g, and the length was up to 11.2 ± 0.1 cm ($P < 0.01$). Fulton's fattening coefficients of carp, at the beginning of wintering, was at the level of 2.71 ± 0.04, and after the wintering it was 2.56 ± 0.02. Analysis of the main biochemical parameters of muscle tissue of carp showed a low fat content before the wintering, along with that, the level of moisture, protein and ash in the muscles was within the normal limits (Table 1).

At the end of the winter period, moisture content in carp muscles increased by 20.1%, ash content increased by 30.0%, protein content decreased to 18.2%, fat loss was 28.4%. Based on the obtained data, the dependence of the main biochemical parameters of muscle tissue on body weight was calculated. The obtained pairs of dependences allowed us to determine the maximum dependence between the analyzed indicators (Table 2).

Table 1
Basic biochemical parameters of muscle tissue of carp (*Cyprinus carpio*) before the wintering at the age of 6 months and after the wintering at the age of 10 months (in % of raw material; x ± SE, n = 30)

Biochemical parameters	Before winter (young-of-the-year)	After wintering (one-year)
Moisture	66.6 ± 1.0	83.4 ± 0.9***
Fat	5.2 ± 0.1	3.2 ± 0.1***
Protein	15.4 ± 0.4	12.6 ± 0.6***
Ash	2.8 ± 0.0	4.0 ± 0.1***

Note: in this and the following tables, statistically significant differences compared with indicators at the beginning of the experiment were considered: * – P < 0.05; ** – P < 0.01; *** – P < 0.001.

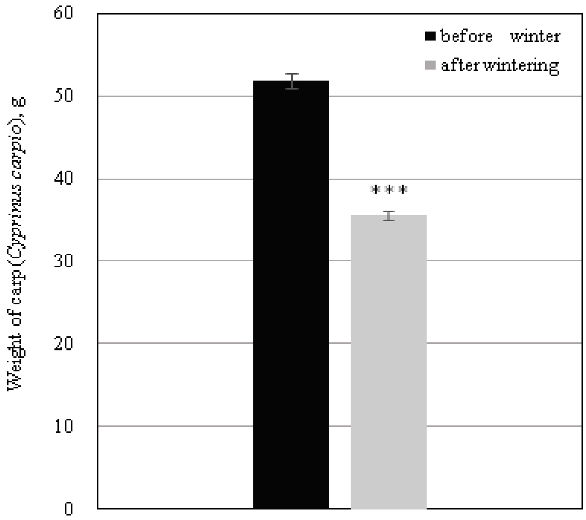

Fig. 2. The dynamics of changes in weight of carp (*Cyprinus carpio*) before the wintering at the age of 6 months (black column) and after the wintering at the age of 10 months (grey column): x ± SE, n = 30; *** – P < 0.001

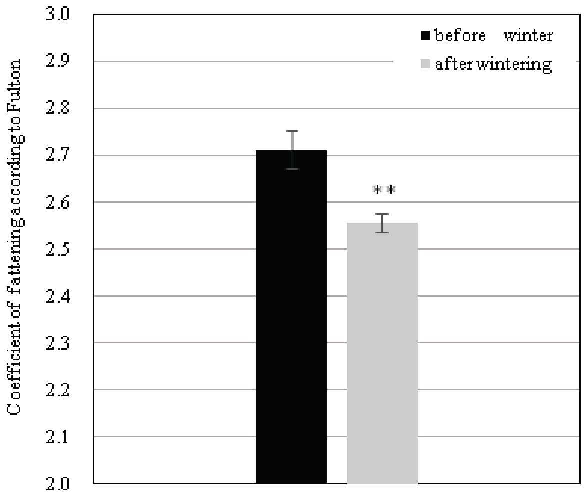

Fig. 3. The dynamics of changes in fattening of carp according to Fulton's coefficient of fattening (*Cyprinus carpio*) before the wintering at the age of 6 months (black column) and after the wintering at the age of 10 months (grey column): x ± SE, n = 30; ** – P < 0.01

The approximation coefficient for polynomial trend model was in the range of 0.78–0.95, for logarithmic model – in the range of 0.63–0.84. This suggests that the degree of conformity of polynomial model to the original data is higher than the logarithmic one. Therefore, it is better to use a polynomial equation to describe the dependency of biochemical parameters of muscle tissue on carp weight.

The seasonality factor and temperature fluctuations affect the intensity of hematopoiesis, and on this basis, on dynamics of morphological and functional parameters of blood (Table 3).

Table 2
The equation of polynomial and logarithmic correspondences for dependence of biochemical parameters of muscle tissue on body weight of carp (*Cyprinus carpio*)

Parameters	Indicators of dependence			
	polynomial equation of connection	coefficient of approximation, R^2	logarithmic equation of connection	coefficient of approximation, R^2
Moisture	$y = 0.0064x^2 - 0.3206x + 54.492$	0.78	$y = 10.788\ln(x) + 15.276$	0.63
Fat	$y = 0.0004x^2 - 0.0201x + 4.9827$	0.85	$y = 0.7267\ln(x) + 2.3761$	0.67
Protein	$y = 0.0006x^2 + 0.0106x + 12.814$	0.91	$y = 2.6133\ln(x) + 4.9955$	0.84
Ash	$y = 0.0006x^2 - 0.0283x + 2.6208$	0.95	$y = 1.0132\ln(x) - 1.0211$	0.76

Note: y – biochemical parameters; x, x^2 – fish weight; R-square for polynomial and logarithmic correspondences.

Table 3
The hematological profile and erythrocyte indices of carp (*Cyprinus carpio*) before the wintering at the age of 6 months and after the wintering at the age of 10 months (x ± SE)

Parameters	Before winter (young-of-the-year)	After wintering (one-year)
Red blood cells, × 10^6/L	3.68 ± 0.14	3.46 ± 0.11
White blood cells, × 10^3/L	31.23 ± 0.48	44.20 ± 0.70***
Hemoglobin, g/L	93.42 ± 0.29	99.59 ± 0.28***
Mean red cell volume, fL	15.29 ± 1.13	12.45 ± 1.23
Mean red cell hemoglobin, pg	29.18 ± 1.70	33.27 ± 2.22
Mean red blood cell hemoglobin content, g/L	241.10 ± 4.41	247.67 ± 6.93

Note: see Table 1.

After the wintering, the number of red blood cells decreased by 6.0% (P > 0.05). As the temperature increased, the number of white blood cells increased by 29.3% (P < 0.001), and also the hemoglobin level increased by 6.2% (P < 0.001). At the same time, the degree of saturation of erythrocytes with hemoglobin (MCH), and the average concentration of hemoglobin in erythrocytes (MCHC) showed an increase with increasing of temperature by 12.3% (P < 0.001) and by 2.6% (P < 0.001). Against the background of increasing of hemoglobin content and concentration, the mean erythrocyte volume (MCV) decreases by 18.5%. Significant changes also occurred in the biochemical parameters of blood serum (Table 4).

Table 4
The biochemical profile of carp (*Cyprinus carpio*) blood before the wintering at the age of 6 months and after the wintering at the age of 10 months (x ± SE)

Parameters	Before winter (young-of-the-year)	After wintering (one-year)
General protein, g/L	55.60 ± 1.66	5.90 ± 0.14***
Albumin, g/L	17.51 ± 0.36	2.70 ± 0.39***
Creatinine, mol/L	0.01 ± 0.00	0.25 ± 0.00***
Glucose, mol/L	3.18 ± 0.05	0.25 ± 0.00***
Triglycerides, mol/L	1.03 ± 0.03	0.56 ± 0.01***
Cholesterol, mol/L	4.79 ± 0.05	3.89 ± 0.01***
Calcium, mol/L	0.17 ± 0.01	0.21 ± 0.01*
Phosphorus, mol/L	0.64 ± 0.01	1.06 ± 0.02***

Note: see Table 1.

As a result of the reaction to the increase in temperature, the content of total protein in the blood serum decreased by 89.4% (P < 0.001) after the wintering. Along with that, there was a significant decrease in albumin content by 84.6% (P < 0.001). After the wintering , in carp blood serum, there was an increase in creatinine by 4.0% (P < 0.001), calcium – by 19.0% (P < 0.05), and phosphor – by 39.6% (P < 0.001). After the wintering, the content of triglycerides decreased by 45.6% ($P < 0.001$), cholesterol – by 18.8% ($P < 0.001$), and glucose – by 92.1% ($P < 0.001$).

Discussion

The results of the wintering depend on many abiotic factors of the environment, among which the water temperature is certainly one of the determinants, taking into account such characteristic as astaticism, which affects the behavioral responses of fish as poikilothermic animals. The ecological significance of water temperature is extremely high, as water is a habitat that directly affects the vital functions and metabolic processes in fish organism (Fang et al., 2010; Correia et al., 2018; Islam et al., 2020). As an environmental factor, temperature affects the speed and nature of various life processes, including respiration, growth, development against the background of dynamic changes in the environment. Studies conducted in previous years and analyzed materials indicate that, in the winter period, there is a slight but steady increase in air temperature, and, therefore, optimal winter water temperatures come quite late: in mid-December, when the water temperature reaches lower 4 °C, while their increase is observed in late February (Tsurkan et al., 2018, 2020). In other words, the period, when the fish is in optimal winter temperatures, lasts only two months. Along with that, the need for food in the range of temperatures above the optimum, to some extent, remains, it means that, throughout the whole of November and March, young-of-the-year experience the period of "starvation metabolism". Under such conditions, against the background of actual lack of food, the mobility of fish begins, which is the cause of active consumption of fat reserves, weight loss and general depletion (Barton, 2002; Gosselin & Anderson, 2020).

To stabilize water temperature and create favourable wintering conditions, the ice cover of ponds is an important factor, playing a significant role in heat exchange between water and atmospheric air (Aslamov et al., 2014; Huang et al., 2019). The ice cover itself ensures stability of the water temperature during the whole winter, which allows young-of-the-year to effectively use the accumulated nutrients without increased energy losses. According to data presented of Tovstyk (1963), the period during which the ponds were covered with ice in the Steppe zone of Ukraine, was 150 days, notably, the thickness of the ice reached 1.0–1.5 m. Nowadays, the period of freezing over has been shortened four times, and the maximum ice thickness rarely reaches 10 cm (Tsurkan, 2021).

Regarding the hydrochemical parameters, we see that the mass fraction of oxygen dissolved in water, the active reaction of water and almost all other indicators meet the requirements for the wintering ponds (Kozlov, 1998). Along with this, the oxidation of water exceeds the optimal values, which is caused by the gradual accumulation of organic matter in the condition of actual absence of such technological component as the summering of ponds.

Planting density is another stress factor that affects the physiological state of carp during the wintering. According to fish farming and biological standards, the optimal planting density of young-of-the-year carp in wintering ponds for the south of Ukraine is 650 thousand specimens per hectare. Planting density affects the biochemical and hematological profiles of fish, as well as the yield of fish, which in the conditions of the modern climate change, astatic water temperatures and long-term starvation metabolism, can significantly reduce the yield of young-of-the-year fish after the wintering (Ashley, 2007; da Costa et al., 2019; Battisti et al., 2020). Therefore, as part of the experiment, the density of carp planting was reduced to 450 thousand specimens per hectare, which allowed us to eliminate the effect of negative factors.

Sufficiently high coefficients of fattening according to Fulton indicate a good physiological condition of carp before the wintering. During period of high temperatures, as a result of prolonged starvation metabolism, the active use of accumulated nutrients by carp leads to a sharp change in physiological state. If in the optimal wintering, the weight loss did not exceed 14%, then, in modern conditions, it is 30–32%, which leads not only to reduced yield of one-year carp after the wintering, but also to a sharp decrease in growth rate, disease resistance, general resistance of fish organism, and increase in mortality up to 40–50% in the second year of life.

During the winter, young-of-the-year fish consume nutrients that have been accumulated over the summer. Reduction of the fat content to 1% and protein to 8–6% leads to mortality of young-of-the-year fish in the ponds. When wintering in satisfactory conditions, protein loss should not exceed 16%, fat – 30%. If during the winter, young-of-the-year fish consume more than 35% protein and 60% fat, then this will lead not only to reduced yields of one-year fish after the wintering, but also to reduce in resistance of fish to diseases, overall endurance of organism, a sharp decrease in growth rate and increase of mortality of two-year fish by 40–50% (Sakovskaja et al., 1991; Emil et al., 2021). During starvation, fish go through three phases: (I) a short transition phase, (II) a long phase of stable protein storage, in which the oxidizing fats are the main source of energy, and (III) a transition to protein mobilization as the main energy source. If the level of fat reserves in fish before the wintering is below the recommended norms, then the transition to the third phase occurs faster. In the carp used for the study, the fat content in the muscles before the wintering was lower than the recommended norms require, which caused a rapid transition to the third phase. As a result, the loss of protein and fat in one-year carp reaches critical values, which clearly affects the overall physiological state of carp after the wintering and the overall yield (Cargnelli & Gross, 1997; Bar & Volkoff, 2013; Bar, 2014).

However, changes in erythrocyte level may be due to changes in the planting density as well as the effects of starvation metabolism and water temperatures (Dai et al., 2011; Pinho et al., 2016; Paredes-López et al., 2021). As a result of hematological studies, there is a tendency to decrease or increase in the parameters of erythrocyte indices in accordance with the erythrocyte profile of circulating blood of fish before and after the wintering. The value of erythrocyte volume index (MCV) in carp blood was lower after the wintering by 19% relatively to the parameters before the wintering. This demonstrates the activity of adaptive and compensatory processes and the level of neurohumoral regulation of carp organism (Hassan et al., 2022).

The number of leukocytes in blood is one of the indicators of the norm of physiological state of fish. In the spring, there is an increase in the number of leukocytes in carp blood. This may be due to the reaction of the fish to deterioration of living conditions, the presence of diseases, as well as rising water temperatures.

After the wintering, there is a significant decrease in protein content in the blood of carp, which indicates a decrease in the intensity of protein metabolism due to the cessation of feeding. Significant protein losses are associated with reduced vital capacity and may be accompanied by fish death. Low values indicate depletion, infectious diseases and kidney damage (Desmet & Blus, 2001).

Glucose is one of the most important components of the internal environment of vertebrates, it is consumed by the body directly, or being stored in organs and tissues as a reserve in the form of glycogen. Significant reduction of glucose in carp blood after the wintering indicates a lack of proper nutrition, reduced metabolism and high energy expenditure (Biktasheva, 2010).

Albumin, which is synthesized in the fish liver, is needed to maintain the osmotic balance, which provides the normal distribution of fluid between the blood vessels and extravascular space. The significant decrease of albumin in the blood of the studied fish, which is observed during the research, is due not so much to increased catabolism, but rather to reduced synthesis as a result of the use of necessary substrates for energy needs for fish adaptation to extreme environmental conditions. This situation leads to increased accumulation of water in tissues. Such condition, which is associated with protein deficiency, can be considered as starvation edema (Desmet & Blus, 2001).

The decreasing level of cholesterol in carp blood indicates the energy expenditure of body. Since triglycerides perform structural and energy function in cells, the dynamics of their changes in blood of the studied fish are similar to the dynamics of cholesterol.

Creatinine concentration increased significantly after the wintering, so this allows us to suggest that, due to early rise in water temperature in the wintering ponds, the motion activity (search for feed) increases in young-of-the-year fish (Hemingway & Scarnecchia, 2018).

Phosphorus in the blood serum is an indicator of phosphorus metabolism; the increase in its concentration indicates the need for optimal nutrition of fish during the first year of life in the breeding ponds. During the research, in the carp organism, there is a tendency to increase the content of calcium in the blood after the wintering, which may be due to its accumulation in the bones against the background of starvation edema (Havird et al., 2020).

Conclusion

Under the influence of the climate change, there is a reduction in the period of the optimal water temperatures for carp. As a result of the research performed, it was found that, during the wintering, carp fish actively use the accumulated energy reserves, consequently, the percentage of fat and protein in the muscles was much lower than recommended. As a result of such changes, carp weight and fattening rate after the wintering have reached critical values. Hematological profile and erythrocyte indices point to the influence of starvation metabolism and the course of adaptive and compensatory processes, along with this, an increase in the number of leukocytes in the blood of carp indicates a deterioration of living conditions and rising water temperatures. The biochemical profile of the blood is characterized by a decrease in glucose, cholesterol and triglycerides, which indicates the active use of energy reserves of the organism.

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