Specific features of aerobic energy exchange in crucian carp females during the spawning season

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Abstract. The article provides the study of the features of aerobic energy metabolism in female crucian carp during the spawning season based on the amount of dissolved in water oxygen consumed according to the methods suggested in fish farming with reference to weight, length and surface area of the body, condition and weight of eggs. It has been shown that aerobic energy metabolism in female crucian carp with oxygen content in the water of the fishing area of 9.5 mg/l and a water temperature of 15 °C during the spawning season is characterized by a high positive correlation of the oxygen amount consumed with the mass, length and surface area of the body, moderate - with the gonads mass and moderately negative with condition, which corresponds to the spawning season and their reproductive potential in favorable environmental conditions.

Among the scientific tasks of modern biology in fish farming, the problems of studying fish adaptation to various environmental factors in connection with the increasing anthropogenic impact on water bodies, the possibility of increasing their immune resistance and a targeted effect on metabolism to increase productivity are noted [1, 2, 3].

Attention is paid to studies of the biological characteristics of energy metabolism and its stages in fish [4, 5]. Biochemical markers for assessing fish energy state are being developed, age characteristics, relationship of metabolism and pubertal development and reproductive systems functioning, energy metabolism enzymes activity and the growth rate and size of fish are studied [6, 7, 8]. It has been determined that the most important indicator of the aerobic (oxygen) universal stage of energy metabolism in fish is the amount of oxygen consumed [9, 10].

Water as a habitat for fish contains dissolved oxygen, and all fish breathe oxygen dissolved in water, so its content in water is of critical importance for them. With its participation, the amino acids, monosaccharides, fatty acids formed at the previous stage of metabolism are oxidized to the final products - H₂O and CO₂, with the release of a large amount of energy and its accumulation in ATP molecules.

It has been shown that fish oxygen consumption depends on the species, age, mobility, stocking density, physiological state and water salinity. Young fish are more sensitive to oxygen content than older age groups. With an increase in their age and weight there is a tendency to a decrease in the level of aerobic metabolism and an increase in the degree of anaerobic metabolism, which is associated with an age-related decrease in oxygen consumption, a decrease in the motor activity of species, an increase in the anabolic component of metabolism, an increase in the synthesis and accumulation of reserve substances. Moving fish consume more oxygen than sedentary ones. Before spawning fish oxygen...
consumption increases by 23-30%, since metabolism increases before the spawn; fish greedily consume food (intensive feeding) containing substances necessary for metabolic processes - proteins, fats, carbohydrates, vitamins and minerals that are used by fish for synthesis of new macromolecules (plastic value of food) and to obtain free energy as a result of oxidation (energy value of food), which allows organisms to respond to conditions and influences [11]. At the same time, during the spawning period, food intake stops which changes not only aerobic energy metabolism, but also the internal organs and the appearance of the fish (color, proportions). During this period, the change in their metabolism shifts towards dissimilation processes, although their reproductive products mature and a complex transformation of the body's reserve substances is carried out (physiological starvation, endogenous nutrition) [12].

In the literature it is noted that the spawning of crucian carp is somewhat different from the spawning of other fish [12]. There are two main differences that are emphasized in the literature: the fish go to spawn only when the reservoir is completely free of ice, the female spawns in several stages (the first one can begin in the spring, and the subsequent ones in the summer) and several times a year. Crucian carp spawns from May to July in portions (from 3 to 5 portions). Spawning is extended (according to some data from 12-15 days, or from 1 to 2 months), which significantly affects the energy and plastic metabolism of the whole organism. Smaller fish may spawn earlier than larger ones. Spawning is closely related to water temperature and weather. According to various studies the optimal temperature should fall within the range from 13 to 18 degrees.

The purpose of our research was to study the features of aerobic energy metabolism in female crucian carp during the spawning season.

The material for our research was the female silver carp, whose habitat was the Belgorod reservoir with a total volume of water at the full supply level equals 76 mln. m³, useful - 67.7 million m³, water surface area - 23 km². The reservoir is located on the territory of the Belgorod and Shebekinsky districts of the Belgorod region. The Belgorod region is ecologically unstable - the coefficient of ecological instability is 0.33, anthropogenic load is 3.52; Shebekinsky - ecologically stable – energy connection coefficient - 0.40, anthropogenic load 3.25. In terms of hydrochemical indicators the water in the reservoir as a whole belongs to the 3rd quality class (moderately polluted). The content of dissolved oxygen in water makes from 3.04 to 12.6 mg / dm³. The average biomass of phytoplankton - 27.6 g / m³, zooplankton - 1.8 gm³, and zoobenthos - 1.4 g / m³.

To study the features of aerobic energy exchange in female crucian carp during the spawning season, the weight, length, body surface area, condition, weight of eggs and the amount of oxygen consumed were determined according to the methods developed in fish farming [13, 14].

During the research we used female crucian carp caught on May 30, 2020. The water temperature in the fishing area was 15 °C, the oxygen content was 9.5 mg / l.

Figure 1. Thermooximeter.
The water temperature, the content of dissolved \( \text{O}_2 \), and the degree of oxygen saturation were determined with a thermodissolver made in Germany (OxyGuard Handy Polaris) (figure 1).

The results of the studies showed that of many factors influencing the intensity of aerobic energy metabolism of fish body weight is paramount (table 1).

Crucian carp females with a maximum mass of 908 and 952 g consumed oxygen of 47.6 and 45.4 mg/kg/h, and with a minimum weight of females obtained in our studies of 352 g, it was 2.66 times less \((r = 0.88)\).

**Table 1.** Oxygen consumption of female crucian carp due to weight, length, body surface and gonadal.

| Indices                               | Lim          | M±m         |
|---------------------------------------|--------------|-------------|
| Oxgen consumption. \( \text{O}_2 \) mg/kg/h | 17.9-47.6    | 33.8±10.44  |
| Weight, g                             | 358-952      | 677.7±208.9 |
| Length, cm                            | 25-36        | 32.4±4.0    |
| Body surface area, dm\(^2\)           | 23.98-63.78  | 45.4±14.0   |
| Eggs weight, g                        | 6-164        | 63.1±59.6   |
| Coefficient of condition              | 2.06-3.86    | 2.71±0.6    |

An increase in the body weight of fish was accompanied with an increase in the surface area, which according to our data was maximum in the same specimen with a mass of 908 and 952 g and amounted to 60.84 and 63.78 dm\(^2\), respectively. At the same time, the regularity in oxygen consumption persisted - the larger the surface area and the longer the body length, the higher the amount of oxygen consumed by females \((r = 0.88 \text{ and } 0.82)\). The oxygen flow index is 0.75 mg/kg/h/ dm\(^2\).

According to M.I. Shatunovsky, in mature fish body weight increases significantly with age, which is explained by an increase in individual absolute fertility and reproductive potential [15].

According to our data the relative weight of eggs in females with a maximum weight was 16.63 and 17.23%, while with a minimum weight of females of 358 g, the relative weight was only 1.67%. This can be explained by the data available in the literature that carp spawns in portions (3-5 receptions with breaks of 10-12 days), as well as the fact that smaller fish can spawn earlier than large ones. Therefore, when interpreting such different data on the content of eggs, it is necessary to take into account the non-simultaneous start of different sized and aged fish spawning. According to our data, oxygen consumption by females during the spawning season was moderately positively correlated with the weight of eggs \((r = 0.67)\).

It is important to note that at the time of spawning, females spawn about 20% of their own weight (according to our data, 1.67-17.23%) of nutrient-rich eggs, which requires significant energy resources in the form of proteins to ensure the next spawning cycles of entry and accumulation in the fish body: carbohydrates, fats and mineral salts. In this regard, during the spawning season changes in metabolism towards the dissimilation side impact the body proportions (eyes enlarge, head sharpens, etc.). So for silver carp, the ratio of depth and body length is typical and equals 1:2.1 and 1:2.7; only in rare cases reaches 1:2.9. In four studied female silver carp this ratio exceeded 1: 2.9 and shifted to 1:3–1:3.2. The ratio of head length to body length also changed significantly and ranged from 1:3.87 to 1:5.1 (Figure 2).

According to some literature sources the head length of the crucian carp makes 25.6% of the body length. As per our data, the head length ranged from 19.4 to 25.8% of the body length. At the same time, shifts in body proportions in most cases are relevant for older specimen and associated with both energy and plastic metabolism stress due to transition to endogenous nutrition and the use of energy resources accumulated over the previous period.

The degree of reserve nutrients accumulation in the body of fish reflects condition determined by the ratio of length and mass. Moreover, the greater this value, the fatter the fish is. According to studies, the body condition of female crucian carp ranges from 2.4 to 5.5. Condition is closely related to all physiological processes in the fish body. Therefore, it can be an indicator of adaptive changes in the
body and is considered as one of the mechanisms of energy "depot" formation when the population is exposed to unfavorable natural factors. E.M. Romanova, E.V. Spirina (2010) suggest the data that crucian carp accumulates fat during winter fasting rather than loses it. Its amount per dry weight increases in adult carps by 10.6-11.3%, in juveniles - by 9.5%. This is due to a sharp decrease in methionine content: in adult fish - by 55-60%, in juveniles - by 26%. Fat accumulation is a consequence of a violation of the liver lipotropic function due to a significant decrease in the number of methionine mobile groups in the body [16]. Spawning is believed to be the main factor causing a decrease in fish body condition (emaciation).

The body condition of the female crucian carp studied averaged 2.7 during the spawning season, with individual fluctuations from 2.06 to 3.86 negatively correlated with the amount of oxygen consumed ($r = -0.72$).

Body condition usually increases with age and for the same-age and uniform-sized fish positively correlate with the accumulation of energy substrates.

When switching to endogenous nutrition during the spawning season energy substrates are consumed, the fatness and quality of the fish decreases. In this regard, it has been shown that fish caught during the spawning period or immediately after spawning usually turns out to be nutritionally deficient. Its meat becomes not only less nutritious, but also flabby, low-persistence, its color fades, the aroma and normal taste disappear, the nutritional value is sharply reduced due to the huge loss of fat, significant loss of protein and strong watering of the meat. It is noted that it takes from 20 to 60 days to restore fat and protein substances in the fish body after spawning, depending on the type of fish, habitat conditions and other factors. So, for the digestion of 1 kg of food, the oxygen consumption of fish is 0.22 kg. In accordance with this, the demand for oxygen also increases to ensure aerobic energy exchange. For an increase in 1 kg of mass, fish feeding must contain 4000-5000 kcal (16760-20950 kJ) of energy.

Thus, the anaerobic stage of energy metabolism in female crucian carp with oxygen content in the water of the fishing area of 9.5 mg / L and a water temperature of 15 °C during the spawning season is characterized by a high positive correlation of the amount of oxygen consumed and weight ($r = 0.88$),
length ($r = 0.82$), body surface area ($r = 0.88$), moderate - with gonad mass ($r = 0.67$) and moderate negative ($r = -0.72$) with condition, which corresponds to the spawning season and their reproductive potential in favorable environmental conditions.

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