Effect of feed composition on the nutritional value of meat of African catfish

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Abstract. The article outlines the results of the research into the influence of feed composition on the amino acid value of African catfish meat. It has been shown that quality characteristics of fish meat depend on protein and fat content. It has been proved that high-protein feed ensures increase in the content of all amino acids in African catfish meat. Nevertheless, protein and fat content in the muscles of the studied fish is more than 2 times higher than the same indicator in the fish on low-protein and low-fat diet. Meat of the African catfish is rich in two amino acids – leucine and lysine. Two amino acids, tryptophan and methionine, are limitative at a high protein diet. At a lower protein diet, isoleucine amino acid is also added. The amino acid composition of African catfish meat is highest at high-protein feeds. The amino acid index of African catfish muscles at high-protein feeds is 0.48, significantly exceeding the index of fish bred on feeds with a reduced protein content. The conducted studies have shown that the use of high-protein feeds in catfish breeding stimulates protein metabolism, enriching the amino acid composition of muscle tissue and increasing the nutritional value of fish as a food product. The research has been funded by the Russian Foundation for Fundamental Research, project No. 18-016-00127.

1 Introduction

Today, in the context of import substitution, the problem of saturation of the food market and meeting the demand of the population in fish and fish products is particularly acute.

Fish is one of the most valuable food products, a source of essential amino acids and high-grade protein. Fish is an essential part of the human diet. According to the WHO standards, consumption of fish by one person should make 18.2 kg per year [1, 2].

Balanced and complete feeding is one of the main keys to the intensification of production of fish and fish products.

Since fish meat contains a significant amount of biologically active substances (polyunsaturated fatty acids, essential amino acids, enzymes, vitamins), this allows referring it to the group of the most popular food products. This also determines its nutritional and biological value [3-5].

Meat of most fish contains a sufficient amount of unsaturated fatty acids, and therefore it can be considered as one of the most important natural components of the anti-sclerotic diet. Thus, the use of fish resources for food, medicinal and other purposes necessitates the study of chemical composition of fish muscle tissue [6-8].

The chemical composition of fish meat differs radically from that of productive animals. The nutritional value of fish meat is influenced by a set of factors, among which the primary importance is given to breed characteristics. In addition, lifestyle (pelagic, bottom-dwelling, passing, semi-passing), habitat (marine, freshwater), metabolic and gender-age features, the physiological state of fish and a number of other factors have a pronounced impact [9, 10].

Fish is the highest quality source of protein. Fish meat has a high nutritional and biological value since its protein contains all essential amino acids. From this viewpoint, fish can be considered as one of the most high-quality sources of protein nutrition.

Fat content is also one of the most important indicators of nutritional and energy value of fish. However, fat content of most fish breeds is subject to strong fluctuations. The fat content of fish directly depends on age and gender, year season, lifestyle features, and the length of migrations [11-13].

This variability is usually conditioned by various factors. For the most part, the primary role is played by breeds differences and availability of food resources, as well as features of metabolism, physiological state and other factors.

This explains an interesting fact that fish of the same breeds caught in different habitats are characterized by different fat content, due to the peculiarities of food supply and abiotic environmental factors, e.g. water temperature. Temperature is one of the important abiotic factors. A direct relationship between the ambient temperature and the fat content in muscle tissue has been scientifically proven. The lower the ambient

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temperature, the higher the fat content in fish muscle tissue [14-16].

Besides, in most cases, the fat content is directly influenced by the morphometric and age characteristics of fish. As the fish grows and ages, the amount of fat in the muscle tissue also increases.

Thus, the economic and biological characteristics and chemical composition of fish muscle tissue are influenced by a complex of factors: habitat, food availability, breeding conditions, season, etc.

In this regard, organization of a complete and balanced feeding ensuring fish with main nutrients, as well as vitamins and microelements, plays a crucial role in improving the productivity of fish and the quality of the products obtained.

The nutritional and biological value of food products is determined by values of their constituent substances [17, 18].

Currently, the range of market feed for fish and aquatic organisms is quite diverse. At the same time, it should be taken into account that complete and balanced nutrition is the key to productivity, safety and health of fish.

It is preferable that fish feed meets the price-quality criterion. The Russian technology of feed production must be developed and improved, but this is impossible in the lack of demand from fish farms. Today, the physical and mechanical properties of most Russian feed for various fish breeds do not always meet modern requirements, which causes significant economic damage to the industry. The factors of economic damage include higher feed costs per kilogram of live weight gain and environmental pollution. This is usually determined by low competitiveness of domestic feed as compared to Western counterparts and is one of the reasons for purchasing expensive imported feed from Western companies by Russian fish-breeding enterprises [19].

A feeding diet is considered complete if it contains all the substances necessary for normal growth and development. Protein, fat and carbohydrates are considered to be energy-containing components of fish diet. However, these components are not sufficient for normal life. The diet should also include the necessary micro- and macroelements, vitamins, and some other biologically active substances. Protein surely plays an important role in the metabolism of fish. It consists of protein and non-protein components. The protein component is broken down to amino acids used for fish growth and replenishment of protein reserves in the body, as well as performs an energy function. Protein containing non-protein forms of nitrogen is biologically less valuable. Fish need 2-3 times more protein than productive animals and poultry. This is due to the fact that the excretory function is performed not only by kidneys, but also by gills. Thus, fish do not get poisoned by ammonia, which is formed during the final breakdown of the protein. For example, the optimal protein level for adult fish is 40-45 %, for juveniles – 50-60%. It is necessary to take into account the fact that the protein must be complete. Such property as the completeness of protein determines the content of amino acids in it, mainly essential ones. The absence or insufficient amount of at least one essential amino acid reduces the growth rate of fish [20, 21].

The research purpose consists in evaluating the effect of fish feed of various Russian producers on nutritional value of African catfish muscle tissue in the laboratory of experimental biology and aquaculture of the Ulyanovsk State Agrarian University named after P.A. Stolypin.

2 Materials and methods

The research object is represented with one-year-old catfish. The duration of the production experience made 2.5 months. Two experimental groups each consisting of 20 fish have been formed from the selected breeds for carrying out the experiment. Catfish from the first group were fed with Limkorm feed (Belgorod, Russia) containing 45% of crude protein and 12% of crude fat. The second group was fed with Akvareks (Tver, Russia) containing 36% of crude protein and 8% of crude fat.

The groups were distributed in 300-liter reservoirs each operated in the autonomous mode. Water temperature in the reservoirs was maintained at the level of 26°C, the oxygen content in the water was at the level of 4 mg/l. Feeding and maintenance of hydrochemical indicators of water quality were carried out in the usual mode.

Quality indicators of African catfish meat have been estimated in accordance with GOST 7631-85 "Fish, marine mammals, marine invertebrates and products of their processing. Acceptance rules, organoleptic methods of quality assessment, methods of sampling for laboratory research". The organoleptic indicators have been used to determine fish color, appearance and condition, smell and taste of fish.

Physical and chemical parameters of African catfish meat have been assessed in accordance with GOST 7631-85 "Fish, marine mammals, marine invertebrates and products of their processing. Methods of analysis". The content of amino acids in the muscle tissue of the African catfish has been estimated using an amino acid analyzer Hitachi AAA 835.

The research has been carried out on the basis of the certified educational, scientific and testing laboratory for determining the quality of food and agricultural products of the Saratov State Agrarian University named after N.I. Vavilov.

3 Results

The results of assessing the organoleptic properties of the African catfish of both groups are almost the same.

The fish were active and their bodies were in good condition. They had natural color, light and bulging eyes, soft abdomen without signs of bloating, color and smell peculiar of healthy fish, tough muscles. Cooking test has also shown good results: the broth was pellucid with a specific fish smell and taste.

The obtained results indicate that the organoleptic parameters of catfish in both experimental groups correspond to the norm.

The nutritional value of African catfish meat has been determined by its relative content of moisture, fat, protein and minerals.

According to the protein content in the muscle tissue, fish are classified as follows:

1) low-protein fish – up to 10% of protein;
2) medium-protein fish – 10-15% of protein;
3) protein fish – 15-20% of protein;
4) high-protein fish – over 20% of protein.

The chemical composition of the muscle tissue of fish in the experimental groups differs significantly (Table 1).

The research results show that the meat of the African catfish of experimental group 1 contains 18.1% of protein, and that of experimental group 2 – 13.7%, which allows attributing it to protein products (Table 2).

According to the fat content in the muscle tissue, fish are classified as follows:

- ✓ low-fat (skinny) – up to 2% of fat (cod, flounder, perch, and many other ocean fish);
- ✓ medium-fat – from 2 to 6% of fat (sword fish, halibut, mackerel, catfish, Baltic herring, etc.);
- ✓ fat – from 6 to 20% of fat (salmon, Atlantic herring, etc.);
- ✓ extra fat – over 20% fat (salmon, saury, eel, carp, etc.).

In the fish under study, the fat content was equal to 6.1%, which makes it possible to attribute them to fat fish breeds.

As a rule, water content in the muscle tissue of fish is directly dependent on fat content. The higher the fat content, the less the water content.

According to the results obtained, the fat content in the catfish muscles of experimental group 1 is more than twice as high as that of experimental group 2.

The amino acid composition of muscle tissue of experimental African catfish has also been studied.

Table 1. Nutritional value of African catfish

Indicators	experimental group 1	experimental group 2
Water, %	63.1 $\pm$ 2.17	78.2 $\pm$ 0.53
Protein, %	18.1 $\pm$ 0.37	13.7 $\pm$ 0.31
Fat, %	6.1 $\pm$ 0.15	2.1 $\pm$ 0.06

Amino acids are the most important structural elements of a living organism. They take part in the synthesis of vital biologically active compounds (proteins, enzymes, hormones). Each amino acid performs its own specific function. Amino acids, not proteins themselves, are the most valuable elements of nutrition.

This is due to the fact that amino acids form proteins that make up all the tissues and organs of the body. Some amino acids act as neurotransmitters and are involved in the regulation of carbohydrate and lipid metabolism. All of the above facts indicate that amino acid metabolism plays a leading role in the metabolism of a living organism [22].

Unique biological functions of amino acids determine the growth and development of a living organism. Amino acids are the main and primary building materials. They are essential in all processes of vital activity of an organism [23].

As a result of the lack of amino acids in the body, various pathological processes may develop. According to the literature data, insufficient content of isoleucine slows down the processes of growth and development. Lack of valine is the cause of impaired osmoregulation in fish. Lack of threonine causes disruption of the synthesis of many biologically active substances, and an imbalance of lipid metabolism is possible with a reduced content of methionine [23].

Lack of amino acids, as a rule, also leads to an increase in feed consumption. In such cases, the action of the "law of the minimum" is manifested. The essence of it in this case is that the lack of even one essential amino acid leads to a violation of metabolism, reduced growth and development, and, ultimately, to an increase in feed costs, which entails economic losses.

Fig. 1 shows the amino acid composition of African catfish muscle tissue. Glutamic acid (8635 and 7527 mg/100 g), aspartic acid (6640 and 5531 mg/100 g), leucine (5767 and 4137 mg/100 g) and lysine (7986 and 5787 mg/100 g) take dominant positions in quantitative terms in the samples of muscle tissue of both groups of fish.

At the same time, it should be noted that the amount of all amino acids at Limkorm diet significantly increases, which makes its introduction into the fish diet the most preferable.

According to the results obtained, a full range of essential amino acids has been found in the samples of fish muscle tissue from both experimental groups.

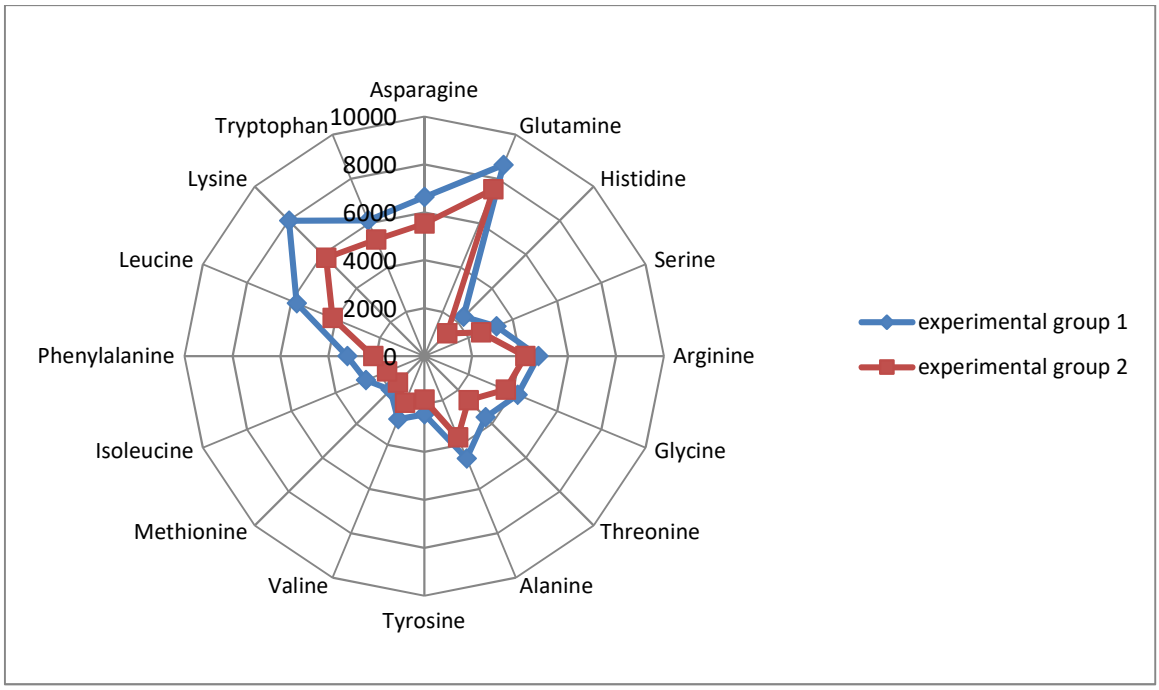

Fig. 1. Amino acid composition of African catfish muscle tissue (in terms of dry matter), mg/100 g

4 Discussion

Analysis of the results reveals that tryptophan (59 mg/100 g) and methionine (1987 mg/100 g) are the limiting essential amino acids in experimental group 1. In experimental group 2, the limiting essential amino acids include tryptophan (21 mg/100 g), methionine (1569 mg/100 g) and isoleucine (1687 mg/100 g).

Leucine and lysine content prevails in both the experimental and control groups (Fig. 2).

The biological value of protein can be estimated using the method of determining the amino acid score. In this regard, at the next stage of our research, we have analyzed the biological value of African catfish meat from both groups.

For this purpose, we have applied the above method of amino acid score of the protein product. This method makes it possible to identify limiting amino acids. The results of score calculation are shown in Table 2.

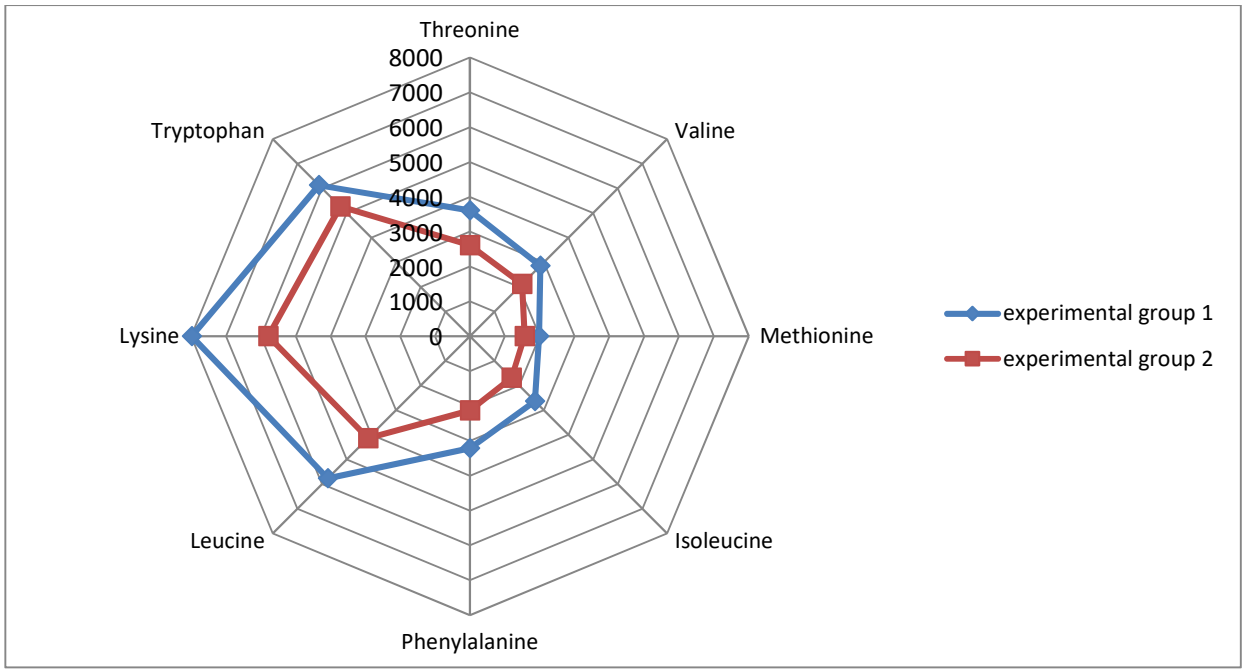

Fig. 2. Content of essential amino acids in the African catfish muscle tissue (in terms of dry matter), mg/100 g

Table 2. Amino acid score of African catfish muscle tissue

Essential amino acid	Perfect protein FAO/WHO		Experimental group 1		Experimental group 2	
	g /100 g protein	SCORE, %	g /100 g protein	SCORE, %	g /100 g protein	SCORE, %
Threonine	4.0	100	3.6	90	2.6	65
Valine	4.5	100	2.8	62	2.1	46
Methionine	3.0	100	1.9	54	1.5	50
Isoleucine	3.7	100	2.6	70	1.6	43
Phenylalanine	3.5	100	3.2	91	2.1	60
Leucine	6.2	100	5.7	91	4.1	66
Lysine	5.5	100	7.9	143	5.7	103
Tryptophan	0.8	100	6.1	762	5.2	650

The results of the analysis of the amino acid score of African catfish meat, presented in Table 2, indicate that it is characterized by an optimal content of essential amino acids, which is as close as possible to the standard.

Two amino acids that meet the requirements of FAO/WHO (lysine and tryptophan) have been found in the muscle tissue of fish of both experimental groups. The other amino acids have a score below 100%.

At the same time, the score of amino acids in the muscle tissue of fish of experimental group 1 exceeds similar indicators of fish of experimental group 2.

To evaluate the biological value of African catfish meat, we have calculated the amino acid index of the ratio of essential amino acids to total amino acids in the muscles of African catfish of both groups. This index has a value of 0.36 for a "standard" protein. In African catfish muscles, this index is 0.48 in experimental group 1, and 0.45 – in experimental group 2. The results obtained indicate the high biological value of African catfish meat, which makes it a very valuable food product.

5 Conclusion

The research results allow concluding the stimulation of protein metabolism accompanied with formation of a full range of amino acids in the muscle tissue of African catfish as a result of introduction of Limkorm feed into their diet.

The use of Limkorm feed allows increasing the content of all essential amino acids in catfish meat, including lysine as one of the most deficient amino acids. Lysine and tryptophan, the level of which has also increased, serve as growth factors in the body. The use of Limkorm has also increased the content of sulfur-containing amino acids, particularly methionine.

Besides, the use of Limkorm is more economically feasible, since it has a lower price as compared to Akvareks feed. And this is important, since the share of feeds makes about 40 % of the cost of fish production.

The conducted research shows that Russian fish feeds Limkorm and Akvareks are highly competitive as compared to expensive imported analogues.

This will significantly contribute to improving the efficiency of domestic commercial fish farming and, ultimately, to solving the most important food problems related to the organization of balanced nutrition of the population.

In this regard, the use of high-protein feed in the diet of African catfish increases the quality characteristics of the fish and is more cost-effective.

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