Vitamin content in meat when growing African catfish with probiotics

L A Shadyeva, E M Romanova, V V Romanov, E V Spirina
Ulyanovsk State Agrarian University named after P.A., Stolypin, 1, Novy Venets Blvd., Ulyanovsk, 432017, Russian Federation
E-mail: vvr-emr@ulsau.ru

Abstract. The article presents the results of the analysis of the content of vitamins in the meat of the African catfish Clarias gariepinus from the Clariidae family, which are widespread in the world's industrial aquaculture. Studies have shown that African catfish meat contains water- and fat-soluble vitamins. Fat-soluble vitamins are represented by vitamins A and E. The group of water-soluble vitamins consisted of vitamins PP, C, and B vitamins (B1, B2, B5, and B6). Studies have shown that the meat of the studied fish species has a high biological value. It contains functional food ingredients - vitamins A, PP, B1, B5, B6 in an amount of at least 15% of the daily physiological requirement. According to the results obtained, the content of all water-soluble vitamins in the muscle tissue of males exceeds that of females. During the study, it was revealed that the introduction of the probiotic Sporothermine into the fish diet based on the spore forms of the bacteria Bacillus subtilis and Bacillus licheniformis causes a significant increase in the content of some vitamins. In particular, the content of vitamins B5, B6, nicotinic, and ascorbic acid increases. Fat-soluble vitamins showed increased content of vitamin E.

1. Introduction
In modern society, a rational and healthy approach towards one's diet is being promoted. A balanced diet of nutrients, microelements, and vitamins is not only a guarantee of health, but it also reflects the improvement in the quality of life of the population. The degree of the nutritional and biological value of food products is determined by their ability to meet the nutritional needs of a living organism in the first place.

Fish is traditionally considered to be one of the irreplaceable foods. It is essential for children and people with cardiovascular disorders. [1, 2]. Eating fish and its processed products helps to increase mental activity, prevent various groups of diseases, it has a beneficial effect on the activity of the organs of the reticulo-endothelial system and regenerative processes. The content of proteins, fats, carbohydrates, vitamins in fish meat is not constant. It directly depends on species, sex-age characteristics, time and place of catch, and mental state. The most important condition for intensifying the production of fish and fish products is the organization of rational and adequate feeding of aquatic organisms [3, 4].

Currently, the assortment of the fish feed market is quite diverse. At the same time, the composition of feed has a pronounced effect on the productivity, safety, and health of fish [5, 6]. Adequate feeding leads to an increase in fish productivity and the quality of the resulting product. In addition to the main nutrients - proteins, fats, carbohydrates, the fish diet requires the introduction of biologically active substances, for example, probiotics [7, 8]. The nutritional and biological value of food products is
determined by the value of their constituent substances. The biological value is characterized by the presence of biologically active substances in products: vitamins, macro- and microelements, essential amino acids, and polyunsaturated fatty acids. These food substances are not synthesized in the body; therefore, they cannot be replaced by other food substances.

The meat of various fish species contains fat and water-soluble vitamins. The group of fat-soluble vitamins is represented, as a rule, by vitamins A, D, E, K. Traditionally, the depots of these vitamins are organs where fats accumulate. Of the parenchymal organs, this is usually the liver. The liver of various fish species is used to obtain fish oil. Fish oil is a valuable nutritional supplement that contains a large number of vitamins. The most valuable is cod and shark liver [9].

Fish oil is a source of essential fatty acids (linoleic, linolenic, arachidonic), which form vitamin K. It is believed that this vitamin is a prophylactic agent against cancer, lowers cholesterol in the liver, and provides elasticity of blood vessels. The muscle tissue of fish contains vitamins B1 (thiamine), B2 (riboflavin), and B12 (cyanocobalamin). In addition, vitamin B12 is deposited in the internal organs of fish. Lack of cyanocobalamin can lead to pernicious anemia [10].

2. Materials and methods
Our study aimed to analyze the nutritional value of African catfish meat, which was based on the assessment of the vitamin content when using the probiotic Sporothermine in the cultivation technology based on the spore forms of the bacteria Bacillus subtilis and Bacillus licheniformis.

The work was carried out in the laboratory of experimental biology and aquaculture of the Ulyanovsk State Agrarian University named after P.A. Stolypin, the content of vitamins in the meat of African catfish was produced in the laboratory of the Federal State Budgetary Educational Institution of Higher Education "Ulyanovsk State University".

The object of the study was the African catfish, which belongs to the category of the fastest-growing fish in the world. The fish was 6 months old at the beginning of the experiment. The experiment lasted 2.5 months. For the experiment, the fish were divided into 2 groups of 20 individuals each.

The fish of both groups were fed with Aqarex extruded food. The probiotic Sporothermine was introduced into the feed of the fish of the experimental group. The feed was irrigated with a probiotic at the rate of 0.2% of the feed weight. Feeding was performed 3-4 times a day by hand as the food was consumed. The water temperature in the fish pools was maintained at 26 °C.

The quantitative content of riboflavin, nicotinic acid, vitamin A was determined by spectrophotometry, thiamine by the fluorometric method, vitamin E, pyridoxine by the photocolorimetric method, and vitamin B5 by chromatography. The determination of ascorbic acid was carried out by titration with the Tillmans reagent.

3. Results
Vitamins are vital substances that a living organism needs to maintain its vital functions. In this connection, the consumption of food that is balanced in vitamins is extremely important.

To assess the biological value, we conducted a study of African catfish meat for the content of vitamins. According to the results obtained, fat- and water-soluble vitamins were present in the meat of the African catfish (Table 1). Fat-soluble vitamins were represented by vitamins A and E. The group of water-soluble vitamins consisted of vitamins PP, C, and B vitamins (B1, B2, B5, and B6). Our results indicate that the meat of the African catfish has a high biological value.

This is since it contains functional food ingredients - vitamins A, PP, B1, B5, B6 in an amount of at least 15% of the daily physiological need, which can provide a scientifically substantiated and confirmed effect on one or several physiological functions, processes metabolism in the human body with the systematic use of a functional food product containing them.

The content of vitamin A in the meat of the studied fish species (1.07 mg / 100 g) is more than twice that in sterlet meat (0.5 mg / 100 g in sterlet meat).

The actual content of vitamin PP exceeds 15% of the daily physiological requirement by more than double (6.3 mg / 100 g). The decisive role of nicotinic acid is its active participation in redox reactions.
Vitamin PP helps lower cholesterol levels, promote tissue growth, and convert fat into energy. The systematic intake of this vitamin helps prevent cardiovascular diseases.

This biologically active substance ensures the normal functioning of the gastrointestinal tract, improves the functioning of the pancreas and liver.

Table 1. Vitamin content of African catfish meat

| Vitamins | Daily intake, mg | 15% of the RDA | Fact. content, mg / 100g |
|----------|-----------------|----------------|-------------------------|
| PP       | 20              | 3              | 6.3 ± 2.07              |
| B1       | 1.1-1.2         | 0.18           | 0.27 ± 0.07             |
| B2       | 1.7-1.8         | 0.27           | 0.09 ± 0.02             |
| B3       | 4-7             | 0.6-1.05       | 0.75 ± 0.08             |
| B6       | 1.6-1.8         | 0.27           | 0.5 ± 0.05              |
| C        | 75-100          | 15             | 0.24 ± 0.05             |
| A        | 0.7-0.9         | 0.13           | 1.06 ± 0.34             |
| E        | 15              | 2.25           | 1.08 ± 0.12             |

It should also be noted that vitamin PP is involved in the production of hormones and the synthesis of hemoglobin and erythrocytes [11]. The actual vitamin B6 content in 100 g of African catfish meat (0.5 mg) is more than 1.5 times higher than 15% of the daily requirement (0.27 mg). This fact also makes it possible to classify vitamin B6 as a functional food ingredient [12]. Taking vitamin B1 helps prevent cognitive impairment of brain activity. With the participation of thiamine, the activity of the gastrointestinal tract is stabilized by normalizing the acidity of gastric juice. Vitamin B1 activates the processes of digestion and assimilation of carbohydrates, it is necessary for the tone of the muscles of the digestive tract. Thiamine in combination with other B vitamins and ascorbic acid takes part in the body's immune response. It has antioxidant properties, i.e., prevents cell destruction due to age characteristics and bad habits. This vitamin lowers blood cholesterol levels, has a wound-healing effect, actively participating in cellular metabolism [13]. The actual content of vitamin B1 in the meat of the studied fish also exceeds 15% of the daily value (0.27 mg / 100g).

Encouraging results were obtained when studying the effect of the probiotic *Sporothermine* on the vitamin content in African catfish meat. Two groups of fish - experimental and control were formed for the experiment. Each of the groups included twenty African catfish.

The fish of both groups were fed with Aquarex extruded food. The probiotic *Sporothermine* was introduced into the feed of the fish of the experimental group. The probiotic was added to the feed by irrigation in an amount of 0.2% of the feed weight. The basis of any probiotic, as a rule, is a living symbiotic microbiota that is not pathogenic for humans. They contribute to the displacement of opportunistic and pathogenic microorganisms from the intestinal microbiocenosis while potentiating the growth of beneficial microflora. Probiotics can produce enzymes, vitamins, and have a beneficial effect on the health of animals. The present study showed that when the probiotic *Sporothermine* is introduced into the diet of the African catfish, the content of several vitamins in its muscle tissue increases (Table 2).

Table 2. Comparative assessment of the content of water-soluble vitamins in the meat of the African catfish when the probiotic *Sporothermine* is introduced into the diet

| Vitamins | control group | experimental group |
|----------|---------------|-------------------|
| PP       | 6.1           | 6.6               |
| C        | 0.23          | 0.25              |
| B1       | 0.34          | 0.25              |
| B2       | 0.11          | 0.08              |
| B3       | 0.68          | 0.76              |
| B6       | 0.4           | 0.5               |
There was an increase in the content of niacin, ascorbic acid, and vitamins B5 and B6 in the group of water-soluble vitamins (Table 2). Also, there is an increase in vitamin E content in the group of fat-soluble vitamins (Figure 1).

![Figure 1](image1.png)

**Figure 1.** The content of fat-soluble vitamins in the meat of the African catfish when the probiotic *Sporothermine* is added to the diet.

Vitamin E is not produced in the human body, the body receives it only with food. The biological significance of vitamin E is that it is a powerful antioxidant. With the participation of vitamin E, hemoglobin synthesis occurs. Vitamin E is traditionally referred to as cardioprotective agents because it has antiplatelet and vasodilator properties [14].

The introduction of the probiotic *Sporothermine* into the diet contributes to an increase in the content of vitamin E in African catfish meat, which leads to an increase in its biological value. The article analyzed the content of vitamins in African catfish meat depending on gender. The results are shown in Figure 2. The content of all water-soluble vitamins in the muscle tissue of males exceeds that of females. This is explained by the fact that sexual maturation of females occurs much earlier than in males and their female organism is much earlier included in a generative exchange.

![Figure 2](image2.png)

**Figure 2.** Content of water-soluble vitamins in the meat of males and females of African catfish.
The dynamics of fat-soluble vitamins in the muscle tissue of males and females looks somewhat different (Figure 3).

![Bar chart showing content of fat-soluble vitamins in the meat of males and females of African catfish](image)

**Figure 3**. Content of fat-soluble vitamins in the meat of males and females of African catfish

The meat of African catfish males contains more vitamin E (1.26 mg / 100 g) compared to females (1.06 mg / 100 g). Female meat contains more vitamin A (1.26 mg / 100 g) than male meat (0.8 mg / 100 g) (Figure 3).

4. Discussion

In the discussion of the results obtained, we will focus on the importance and physiologically functional significance of vitamins that were found in the meat of the African catfish when assessing its nutritional value.

Let us start the discussion with vitamin A. The importance of this vitamin can hardly be overestimated. It plays an important role in human life. Vitamin A ensures the normal activity of the visual analyzer, being included in the composition of the visual pigment rhodopsin, which provides photoreception on the retina. Vitamin A plays a fundamental role in the development of skin and bone cells; has an immunomodulatory effect. Being an organic substance, this vitamin strengthens the mucous membranes and makes them resistant to viruses and infections, thereby preventing respiratory and gastrointestinal diseases. Vitamin A prevents the development of infertility and normalizes sexual function, it also has keratoplastic and wound healing effects and pronounced antioxidant properties: slowing down the aging process and reducing the risk of developing cancer [15]. According to the results obtained, the content of vitamin A in 100 g of the studied fish species is 1.06 mg, which is 1.3 times higher than the daily requirement.

B vitamins have been identified in African catfish meat. All B vitamins work in "mutual cooperation" and vitamin B1 is no exception. Thiamine plays one of the important roles in the human body, exerting a regulatory effect on its most important functions. Vitamins B1 and B6 are called trophies of the nervous system. Thiamine is required for synaptic transmission, usually by participating in the synthesis of acetylcholine. It improves the functioning of the nervous system. A dietary intake of this vitamin can improve mental health. In this connection, vitamin B1 is sometimes called the vitamin of optimism.

Vitamin B1 has a pronounced effect on the course of metabolic reactions in the human body. Thiamine takes part in hematopoiesis, regulates hemodynamics.

With the direct influence of vitamin B1, there is a decrease in the level of homocysteine, an amino acid, the high content of which contributes to the development of heart attacks and strokes.
100 g of African catfish meat contains 0.27 mg of vitamin B1. Since the daily requirement for it is 0.18 mg, this allows it to be classified as a functional food ingredient.

Vitamin B5 (pantothenic acid) is necessary for the full functioning of a person. He takes part in hematopoiesis, the transformation of food into energy.

Pantothenic acid is an element necessary for the synthesis of coenzyme A. It takes part in the formation of fatty acids. Coenzyme A converts food into "good" cholesterol.

The presence of coenzyme A ensures the normal functioning of the gastrointestinal tract, promotes the course of detoxification processes.

Vitamin B5 coordinates several important physiological processes in a living organism. Pantothenic acid takes an active part in the synthesis of hormones of the endocrine glands. During formation, all hormones of the adrenal cortex are associated with coenzyme A. It has been scientifically proven that the adrenal cortex can produce hormones for up to six hours a day. In this connection, there is a need for significant reserves of calcium pantothenate. Glucocorticoids have anti-inflammatory, anti-allergic effects, have a pronounced effect on all types of metabolism.

Vitamin B5 coordinates the synthesis of fatty acids. Polyunsaturated fatty acids support normal brain activity. Vitamin B5 stabilizes metabolism and activates human mental activity [15, 16].

The derivative of pantothenic acid provides the formation of hormones, neurotransmitters, which are of exceptional biological importance. The biological role of these substances is that they ensure the correct development of the nervous system in children, adolescents, and adults. A daily intake of 5 mg of vitamin B5 prevents the onset of Alzheimer's disease and dementia. With the participation of pantothenic acid, the transformation of choline into acetylcholine is carried out, through which synaptic reactions occur.

Unlike vitamins A and E, which have antioxidant properties, the biological role of pantothenic acid is in the synthesis of antibodies. The deficiency of vitamin B5 leads to a sharp decrease in the number of immunoglobulins, as a result of which the body becomes most vulnerable to various kinds of pathogens.

With the participation of pantothenic acid, lipolysis is triggered in the body. At the same time, triglycerides are released from fat cells, followed by their burning. These reactions are accompanied by the production of additional energy, which is necessary both with intense physical exertion and increased mental activity. Vitamin B5 has a wound healing and regenerating effect, prevents the development of dysbiosis.

The intake of pantothenic acid during stress is extremely important. With the participation of its components, other stress hormones, mainly glucocorticoids, are released, which increases the body's resistance to various kinds of adverse effects.

Based on our results on the content of vitamin B5, which meets the requirements for functional food ingredients, African catfish meat can be classified as functional food products. This is since its content in 100 g of meat of the investigated fish exceeds 15% of the daily requirement.

The content of vitamin B5 in the meat of the studied fish species was 0.75 mg / 100g. The lower limit is 15% of the daily requirement of 0.6 mg. This also makes it possible to classify vitamin B5 as a functional food ingredient.

Vitamin B6 (pyridoxine), identified by us in the meat of African catfish, plays the role of a metabolic stimulant. It is a coenzyme of proteins that are involved in the processing of amino acids and regulate protein absorption. Pyridoxine takes part in hematopoiesis, namely the production of erythrocytes and hemoglobin, participates in the uniform supply of cells with glucose.

Vitamin B6 has a cholesterol-lowering and lipotropic effect. Adequate amounts of pyridoxine are essential for normal liver function.

Vitamin B6 has a pronounced effect on mineral metabolism. Pyridoxine takes an active part in the correction of metabolic processes in the liver, performing glucose-regulating and antitoxic functions. It has a beneficial effect on the functional state of the central nervous system.

According to the literature, pyridoxine stimulates the function of the organs of the reticuloendothelial system. It maintains the sodium-potassium balance of body fluids, which ensures the normal functioning
of the nervous system, memory, and brain performance. Vitamin B6 is involved in the synthesis of neurotransmitters, including serotonin, a substance that lowers the body's pain threshold. Pyridoxine has a beneficial effect on mood, appetite, and sound sleep.

Vitamin B6 promotes the formation of antibodies, providing the body's immune defenses. Pyridoxine stimulates leukopoiesis, especially in leukopenia, which has developed as a result of chronic intoxication caused by certain drugs, X-rays, and several industrial ecotoxicants [16, 17].

The content of vitamin B6 in the meat of the studied fish species was 0.5 mg / 100g, which is more than twice the 15% of the daily requirement. This allows vitamin B6 to be classified as a functional food ingredient.

People prone to the development of cardiovascular pathology need pyridoxine in large quantities: it improves the rheological properties of blood, prevents the formation of atherosclerotic plaques, prevents heart attack and stroke, and stabilizes blood pressure.

5. Conclusion
Currently, one of the important components of the diet of most of the world's population is fish. Fish has a pleasant aroma and taste. Fish meat is suitable for making canned food, smoking, and various delicacies.

The chemical composition of fish meat is represented by essential amino acids necessary for the life of the human body, fat, including both saturated and irreplaceable polyunsaturated fatty acids, extractive substances, water, and fat-soluble vitamins and mineral elements. All this together determines the high nutritional, biological, and energy value of this food product.

The meat of the studied fish species is distinguished by a high biological value since it includes in quantities that meet the requirements of a physiologically functional food ingredient - vitamins A, PP, B1, B5, B6, which is 100 grams of African catfish meat exceed 15% of the daily requirement.

The positive global trend that has developed in recent years towards an increase in the level of consumption of fish and fish products by the population requires new approaches to solving the problems of further increasing production and improving the quality of fish products. To solve these problems, it is necessary to use modern intensive technologies of reproduction, rearing, and feeding of fish, based on ensuring adequate feeding and widespread use of a variety of environmentally friendly means that stimulate the productivity of industrial aquaculture.

Studies by several authors have shown that one of the ways to improve the quality of fish produced in aquaculture is to include probiotics in the diet. We have shown that the inclusion of the probiotic *Sporothermine* in the diet of African catfish increases the content of water-soluble vitamins necessary for the human body in its meat. This is one of the important modern directions for solving the most important food problem - providing the population with nutritious food.

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