Study of the chemical composition of quinoa of Russian selection grown in the South of Russia

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Abstract. According to WHO experts, almost all countries have a shortage of dietary protein, which is about 25 million tons. This fact causes a high risk to human health, expressed in changes in the quality of its physiological processes. Most of the world's scientists conduct scientific research to find natural raw sources of biologically complete protein. It is promising to use pseudo-grain quinoa culture as such source, which was awarded the title of the ideal product of the XXI century because of its amino acid composition. We conducted research on quinoa of Russian selection grown in the southern part of Russia. It was found that the coefficient of difference of amino acid scores (CDAS) of quinoa protein, showing an excess number of essential amino acids that are not used for plastic needs, is 9.86 %. With the CDAS evaluated the biological value (BV) of quinoa proteins, which is equal to 90.14%. Experimental data confirmed the nutritional value of quinoa of Russian selection. It can be recommended as a functional source of not only balanced amino acid composition of protein, but also minerals, vitamins, in particular magnesium, calcium, phosphorus, water-soluble vitamins B₁, B₂, C and fat-soluble vitamin β-carotene.

1. Introduction

One of the important problems of the XXI century is the lack of protein. The results of the assessment of the nutritional status of the world's population showed that the total protein deficit is estimated at 10-25 million tons per year. According to experts, there is about 60 g of protein per day per inhabitant of the Earth at a rate of 70 g.

It is known that protein deficiency is a high risk, especially for a growing body. Thus, reducing the quantitative content of protein in the diet to 3% of the recommended norms can lead to such consequences as weight loss, complete stop of growth, changes in the chemical composition of bones, etc.

The described problem is not only economic for modern society, but also serious social and medical. This is due to the fact that the lack of protein, especially balanced in its amino acid composition, does not allow the biological body to develop normally.

To solve this important problem, scientists around the world conduct numerous studies [1]. Most of them are aimed at finding new raw sources of dietary vegetable protein and / or expanding the range of protein-containing foods [2-4].
The results of our analysis of scientific and technical literature have shown that in most studies, in addition to the well-studied proteins of soybeans and other legumes, sunflower seeds, and nuts, the proteins of plants of the Amaranth family (Amaranthaceae), in particular amaranth and quinoa, are considered. These crops were awarded the title of the ideal product of the XXI century due to the amino acid composition of the protein contained in them [5]. Their high biological value is also due to the quantitative content of essential amino acids. However, quinoa is different by the best content. It was recognized by the UN as a culture of global importance in ensuring food security. The UN General Assembly declared 2013 the year of quinoa in order to attract the world community to the role of quinoa in ensuring a healthy diet.

Quinoa is a pseudo-grain crop. Its homeland is considered South America. In the diet of the Incas, quinoa occupied one of the leading places. The Incas called quinoa as “the Golden grain”.

Its main global producers are Bolivia and Peru, which account for more than 80% of the gross quinoa harvest. It should be noted that according to FAO / UNO data, the list of countries that grow quinoa is expanding. Among them, there were such European countries as France, Spain and the United Kingdom, the total area of crops in which is more than 5 thousand hectares.

According to the Federal customs service, in 2018, 867 tons of quinoa were imported to Russia for $2 million, mainly from Peru (98% of the total import volume).

This ancient grain crop has a tall green stem about 1 – 1.5 meters high with rounded leaves and fruits that are shaped in large and Curling clusters. Quinoa grains are similar to buckwheat grains, but have a different color; it can be beige, black or red (figure 1). They have a high protein content of about 20%.

Its nutritional value is also characterized by the presence of polyunsaturated fatty acids of the omega-3 family, as well as vitamins.

![Figure 1. Quinoa is the culture of the Amaranthaceae family](image)

Such properties of this pseudo-grain crop have determined the feasibility of conducting research on its production and processing in Russia.

In March 2017, the Ministry of agriculture of the Russian Federation included quinoa culture in the state register of breeding achievements approved for use in Russia (in the register it is designated as "quinoa"). Created three varieties of quinoa Kadi, Seva, Barusa.

In 2019, about 10 hectares of land in the Krasnodar region (South of Russia) were sown with quinoa seeds, which were not previously grown in Russia. The region plans to open a plant and establish industrial processing.

The purpose of our research was an in-depth study of the chemical composition of quinoa grown in the South of Russia.
2. Methods

We selected the southern region of Russia, in particular the Krasnodar region, as an experimental site. The object of our research was selected samples of quinoa varieties of Russian selection.

To determine the quantitative content of proteins we used the following methods: classical method of Kjeldahl on a FOSS Kjeltec 8200 analyzer, amino acid composition, content of macroelements - method of capillary electrophoresis, trace elements – photocolorimetric, water-soluble vitamins – method of capillary electrophoresis and fluorimetrical, fat-soluble – spectrophotometric.

3. Discussion and results

The results of comparative studies of the amino acid composition of quinoa and wheat protein are shown in Figure 2. Wheat is selected as a comparison object as a grain crop.

![Figure 2](image)

**Figure 2.** Comparative content of amino acids in the protein of quinoa and wheat seeds, g / 100 g of protein

The amino acid balance of quinoa protein was evaluated by a set of indicators: biological value (BV), amino acid score, differences in amino acid scores (CDAS,%).

It was found that the first limiting amino acid of quinoa seed protein is methionine, and that of wheat is lysine.

However, this does not reduce the value of the quinoa culture of Russian selection as a promising raw source of protein in the composition of multi-component food recipes. It should also be noted that according to official medicine, the daily requirement for methionine is on average 1.5 g [6, 7, 8]. According to experimental data, the content of methionine in the protein of quinoa seeds is 2.1±0.07 g/100 g.

We have determined the coefficient of difference of amino acid scores (CRA, %), showing the excess amount of essential amino acids (NAC) that are not used for plastic needs (Figure 3).

![Figure 3](image)

**Figure 3.** Coefficient of difference of amino acid scores (CDAS) of quinoa and wheat proteins, %
The biological value (BV, %) of quinoa and wheat proteins was estimated by the value of CDAS. It was 90.14% and 79.9%.

The experimental data obtained confirm the high biological value of quinoa protein and the prospects for its use in the human diet.

One of the conceptual provisions of rational human nutrition is a balanced intake of not only protein with high biological value, but also minerals that play an important role in maintaining the integrity of cell membranes, in regulating immune processes, and in providing respiration to tissues.

We have conducted research on the mineral composition of quinoa, in particular such basic macronutrients as magnesium, calcium, potassium, phosphorus, and trace elements as iron and selenium [9, 10].

Table 1 provides an estimate of the daily availability of essential macronutrients when consuming quinoa.

| The studied parameters | Value, mg / kg | Satisfaction level, % of adequate daily consumption | Requirements of physiological needs in food substances, mg |
|------------------------|---------------|-----------------------------------------------|------------------------------------------------------|
| Potassium              | 630           | 15,8                                         | 4000                                                 |
| Sodium                 | 19            | 0,4                                          | 5000                                                 |
| Magnesium              | 190           | 63,3                                         | 300                                                  |
| Calcium                | 260           | 43,3                                         | 600                                                  |
| Phosphorus             | 357           | 29,8                                         | 1200                                                 |

From the data presented in table 1, it follows that according to the degree of daily safety, such macronutrients as magnesium, calcium and phosphorus are allocated.

The presence of magnesium in the diet ensures the smooth operation of all systems of our body, in particular the nervous system. It activates the enzymes that are responsible for the body's absorption of protein. In general, this element is very important for the human body: without it, calcium will not be absorbed; with its sufficient content, people are much less likely to suffer from heart diseases.

Calcium is also an essential macronutrient. It is indispensable in nerve processes, cellular structures, and the production of necessary hormones. It affects the functioning of the nervous system, normal blood clotting, and stable heart function.

Phosphorus plays a key role, it normalizes protein and carbohydrate metabolism. Without phosphoric acid, normal chemical reactions in cells are impossible. Phosphorus compounds are involved in maintaining acid-base balance in the body.

The degree of daily supply of the human body with potassium is within the limits regulated for functional food products of about 16%. Potassium supports normal blood pressure levels, participates in the nervous regulation of heart contractions, and improves bowel function. Therefore, in our opinion, quinoa is advisable to include for this reason in the dishes of a healthy diet.

The low degree of daily safety is noticeable in sodium-0.4 %. But this fact, in our opinion, is considered favorable. Since products that have a high sodium content in their composition can not be recommended for people with high blood pressure. If necessary, especially for patients with hypertension, kidney disease and cardiovascular failure, the amount of salt in the diet is sharply limited, and even temporarily assigned to the so-called "salt-free diet".

A study was also conducted to determine the mass content of iron and selenium in quinoa.

In figure 4 data on the degree of daily supply of the human body with basic trace elements when consuming quinoa are presented.
Figure 4. The level of satisfaction with the main trace elements, % of the adequate daily consumption of quinoa
* % of the body’s supply is calculated for the highest daily human need.

From the data presented, it can be seen that the degree of daily availability of iron is 9.2%, selenium – 1.5%.

It is known that iron is involved in the storage and transport of oxygen in the human body, and is also required by many enzymes and proteins that perform various functions in our body. This element increases resistance to diseases and prevents iron deficiency anemia.

Selenium contributes to the production of various antibodies: white blood cells, and red blood cells. It has antioxidant activity. It protects cell membranes and promotes the formation and growth of new healthy and intact cells [10].

Thus, based on the data obtained, it can be concluded that quinoa, in the future, can be considered as a functional source of iron.

However, it should be emphasized that the iron contained in products of plant origin has a chemical form that is practically not absorbed by the body.

The analysis carried out on the study of this crop, as well as the results of research allow us to assert the prospects of using quinoa as a source of minerals. At the same time, magnesium (63.3%), calcium (43.3%) and phosphorus (29.8%) are distinguished by the degree of daily macronutrient availability.

We conducted a comparative analysis of the content of the most important vitamins in the studied sample of quinoa and wheat. The experimental data obtained are shown in Fig. 5.

From the data presented, it is clear that quinoa has the best vitamin composition. In addition to water-soluble vitamins B₁ and B₂, the quinoa sample contains vitamin C, which is not present in wheat. It is known that the average daily dose of vitamin C is 70-100 mg [11]. Therefore, when the vitamin C content of quinoa is 68 mg / 100 g, the satisfaction level will be about 97% of the adequate daily intake.

The content of vitamin B₂ in quinoa is also almost 4 times higher than in wheat. It is known that it is often called "beauty vitamin", since the concentration of this compound in our body depends on the condition of the skin, hair and nails.

A higher content of such fat-soluble vitamin as β-carotene was also found; its amount is 14 times higher than in wheat.
The presence of \( \beta \)-carotene increases the nutritional value of quinoa, since this compound is a good antioxidant, and also has an immunostimulating and adaptogenic effect.

4. Conclusion
Pseudo-grain quinoa culture of Russian selection, grown in the Krasnodar region, located in the South of Russia, is applicable for the production of food of functional significance, which is a trend in the development of modern human society.

The existing shortage of dietary protein in the human diet makes it necessary to expand the range and increase the production of protein-containing foods.

The results of experimental studies have shown that the coefficient of difference of amino acid scores (CDAS) in quinoa is 9.86%. It shows an excessive amount of essential amino acids that are not used for plastic functions, i.e. the lower this value, the more complete the protein of the studied agriculture.

We evaluated the biological value (BV) of quinoa proteins by the value of CDAS, which was 90.14%.

Experimental data confirmed the nutritional value of quinoa of Russian selection. It can be recommended as a functional source of minerals and vitamins, in particular magnesium, calcium, phosphorus, water-soluble vitamins \( B_1 \), \( B_2 \), \( C \) and fat-soluble vitamin \( \beta \)-carotene.

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