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# INNOVATIONS IN FORMING FUNCTIONAL FOOD PROPERTIES BASED ON QUINOA SELECTED IN RUSSIA

Lyudmila V. Donchenko (a), Elene V. Leushkina (b), Natalia S. Limareva (c)*
*Corresponding author

(a) Kuban State Agrarian University, 13, Kalinina Str., Krasnodar, 350044, Russia, niibiotechn@mail.ru
(b) Kuban State Agrarian University, 13, Kalinina Str., Krasnodar, 350044, Russia, niibiotechn@mail.ru
(c) North-Caucasus Federal University, 56, 40 let Oktyabrya Ave., Pyatigorsk, 357500, Russia, nlimareva@pfncfu.ru

## *Abstract*

The study of the nutritional status of the Russian population showed a significant change in the structure of nutrition. Experts in the field of nutrition characterize the detected change as a crisis. Taking into account this observed trend of deficiency of minor compounds with high detoxification and antioxidant properties in the diet of modern people in economically developed countries, the relevance of searching for their natural sources remains relevant. The object of the study was selected samples of leaves of quinoa varieties of Russian selection grown in the South of Russia – on the land of the Krasnodar territory. Quinoa leaves were picked in early June in the juvenile phase, in September in the flowering phase and in the seed maturation phase. It was found that quinoa leaves picked during the flowering period are preferable as a natural source of biologically active substances. The content of pectin substances during this growing season is 5.9 %, protein – 21.1 %, potassium – 3.23 %, calcium – 3.05 %, phosphorus – 0.53 %, carotene – 49.0 mg/kg, vitamin C – 35.0 mg %. A high antioxidant activity is achieved 525.0 mg/l, which is comparable to the activity of Chinese lemongrass and ginseng. At the same time, the amount of flavonoids contained in quinoa leaves exceeds the amount of flavonoids of black Bayh tea by about two times. The results of our experimental studies have shown that quinoa leaves of Russian selection can be recommended as natural source of pectin and antioxidant substances in the production of functional food.



**Keywords:** Pectin, quinoa, leaves, antioxidants, flavonoids, functional food.

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## 1. Introduction

The study of the nutritional status of the Russian population showed a significant change in the structure of nutrition. It should be noted that this is typical not only for Russia, but for almost all economically developed countries. Experts in the field of nutrition characterize the detected change as a crisis (Boye, 2015; Tutelyan, Razumov, & Vyalkov, 2010). It is due to the observed lack of micronutrients in the body, caused by a decrease in their content in traditional food products. Meanwhile, in order to maintain energy consumption at the current pace of life and work, the diet should contain micronutrients of natural origin, such as protein balanced in amino acid composition, pectin and mineral substances, vitamins and other minor compounds.

The observed deficiency of these substances causes the formation of immune-deficient conditions, the development of a number of socially significant diseases, and shorter life expectancy (Donchenko, 2018; Puri, 2017).

No less important is the role in the formation of a high level of health of various groups of flavonoids. It was found that flavanols (quercetin, rutin, etc.), flavones (luteolin, apigenin, etc.), flavonones (naringenin, hesperidin, etc.), dihydroflavanols, proatocyanidins, and catechins can act as protectors for various forms of cancer (Hollan & Grumezescu, 2018).

## 2. Problem Statement

According to the materials of national and foreign literature, all the listed requirements are met by quinoa. Quinoa belongs to the amaranth family (Amaranthaceae). 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"). Three varieties of quinoa Kadi, Seva, Barusa were created.

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. In 2020 the region plans to open a plant and to start industrial processing of quinoa.

The composition of quinoa seeds includes a fairly large variety of basic nutrients that are scarce in the modern human body. Thus, the carbohydrate complex is characterized by starch content – 55.6 %, pectin substances – 3.1 %. Quinoa is rich in phosphorus (3,920 mg/kg), iron (249.3 mg/kg), calcium (983 mg/kg), zinc (32 mg/kg), and potassium (4424 mg/kg). A sufficiently high content of tocopherols (up to 10.0 mg/100 g), as well as the presence of vitamin C (5.46 mg/100 g), niacin (0.92 mg/100 g) in the composition allow talking about high antioxidant activity of quinoa seeds (Kharapaev & Kokoreva, 2017; Merkulova & Nalyvayko, 2015). Despite the high nutritional value, quinoa can be attributed to products that have a low calorie content (360 kcal/100 g) and a low glycemic index.

According to the results of early research, it was found that not only seeds, but also leaves of plants of the Amaranth family, in particular amaranth, are of scientific interest. It was found that the leaves of these plants contain such low-molecular phenolic compounds as rutin, quercetin, and trifolene (Ivanova, Mashchenko, & Kintya, 2013). The results of the conducted research also showed the presence of a significant amount of pectin substances in them (Mironov, 2011). It should be noted that these

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compounds have a fairly high antioxidant activity. For flavonoid compounds, it is due to their inherent ability to bind free radicals and form compounds with metal ions (copper, iron), depriving them of their catalytic action in oxidation processes (Kharapaev & Kokoreva, 2017; Rotimi, 2012). The physiological activity of pectin substances is well-known and is determined by their detoxification and radioprotective ability (Donchenko & Firsov, 2007).

The main natural source of phenolic compounds are black and green Bayh tea. They make up the most valuable part of the tea leaf and are mainly represented by catechins and their Gallic esters. Phenolic compounds include more than 30 closely related compounds and account for up to 25 % of the dry weight of the tea leaf (Bagachi, Lau, & Ghosh, 2010). Catechins account for 60–70 % of the total amount of phenolic compounds. The physiological role of catechins is expressed in the ability to reduce capillary permeability to normal, return elasticity and permeability to their walls. This, in turn, allows regulating blood pressure and contributing to the prevention of hypertension.

The composition of tea leaf phenolic compounds includes flavonoids along with catechins. This group of substances in tea is represented by a set of mono-, di- and triglycosides three aglycones: kaempferol, quercetin and myricetin. These compounds are contained in small amounts, but, as plant antioxidants, are quite resistant to oxidative transformations, so that when processed, they retain up to 80 % of the amount of flavonoids contained in fresh tea leaves.

Taking into account the observed trend of deficiency of minor compounds with high detoxification and antioxidant properties in the diet of modern man the searching for their natural sources remains relevant.

## 3. Research Questions

The object of our research was selected samples of leaves of quinoa varieties of Russian selection (Kadi, Seva, Barusha), grown in the South of Russia – on the land of the Krasnodar territory. Quinoa leaves were picked in early June in the juvenile phase, in September in the flowering phase and in the seed maturation phase.

**3.1.** Study of the dynamics of accumulation and changes in the fractional composition of pectin substances in quinoa leaves of Russian selection throughout the growing season.

**3.2.** Determination of physical and chemical parameters of pectin substances of quinoa leaves.

**3.3.** Study of the chemical composition of quinoa leaves of Russian selection of different phases of development.

**3.4.** Comparative evaluation of the content of flavonoids in the leaves of quinoa and black Pekoe tea.

**3.5.** Study of the effect of the method of harvesting quinoa leaves on antioxidant activity (AOA).

## 4. Purpose of the Study

The purpose of the research is to study the content of pectin substances and phenolic compounds in quinoa leaves of Russian selection.

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## 5. Research Methods

Isolation and physical and chemical characterization of pectin from the dry green mass of quinoa grown in the Krasnodar region was carried out using conventional methods (Donchenko & Firsov, 2007). The method of quantitative determination of pectin substances in plant raw materials is based on extracting pectin from plant raw materials and converting it to a dissolved state. The basis of the study of the extracts of hydropectin and protopectin is the calcium-pectin method and precipitation with ethanol.

Chemical composition studies were performed using standard methods used in complex chemical analysis: the total content of nitrogenous substances – by the Kjeldahl method using the FOSS autogas analyzer; carbohydrate composition and mineral content – by capillary electrophoresis; vitamin content- by HPLC and fluorometry.

Determination of phenolic compounds was performed using the method proposed in the paper (Temerdashev, Frolova, & Kolychev, 2011). Data processing was performed in the environment of the LCSolution program (Shimadzu, Japan). We used the Zorbax SB C18 column (55 microns, 150×2.1 mm, Agilent, USA) and the ZORBAX SB C8 pre-column (5 microns, 20×2.1 mm, Agilent, USA). The mobile phase consisted of eluent A-acetonitrile, eluent B-0.04 M KH2PO4, acidified H3PO4 to pH 2.8. Gradient elution mode: 0–3 min 3 % eluent A, 3–4 min 3–5 % A, 4–8 min 5 % A, 8–15 min 5–20 % A, 15–18 min 20 % A, 18–25 min 20–40 % A, 25–28 min 40 % a. Temperature control of the column at 40 °C. the mobile phase Flow rate of 0.25 ml/min sample Volume 1 µl.

The total antioxidant activity was determined spectrophotometrically with aluminum chloride and Triton X100 using the FRAP method (Lee, 2015).

## 6. Findings

The results of the study of the fractional composition and content of pectin substances in quinoa leaves are shown in figure 1.

From the above mentioned data, it can be seen that the total content of pectin substances changes from 1.36 to 8.3 % throughout the growing season. At the same time, a pattern of simultaneous increase in the mass fraction of soluble pectin and protopect in in the phases of quinoa development was revealed.

The monosaccharide composition of pectin consisted of galacturonic acid – 58 %, arabinose – 5.1 %, galactose – 7.7 %, glucose – 8.6 %, xylose – 3.2 %, rhamnose – 3.5 %, fructose – 5.1 %. Pectin has a molecular weight of 26 KD and a degree of esterification of 62 %.

In order to determine the nutritional value of quinoa leaves, we studied their chemical composition.

The experimental data obtained are shown in table 1.

Quinoa leaves have a fairly high protein content (11.2–22.2 %), low sugar content (1.4–2.4 %) and fat content (0.8–1.5 %), as well as high ash content (18.8–20.7 %) and calcium content (3.05–5.42 %).

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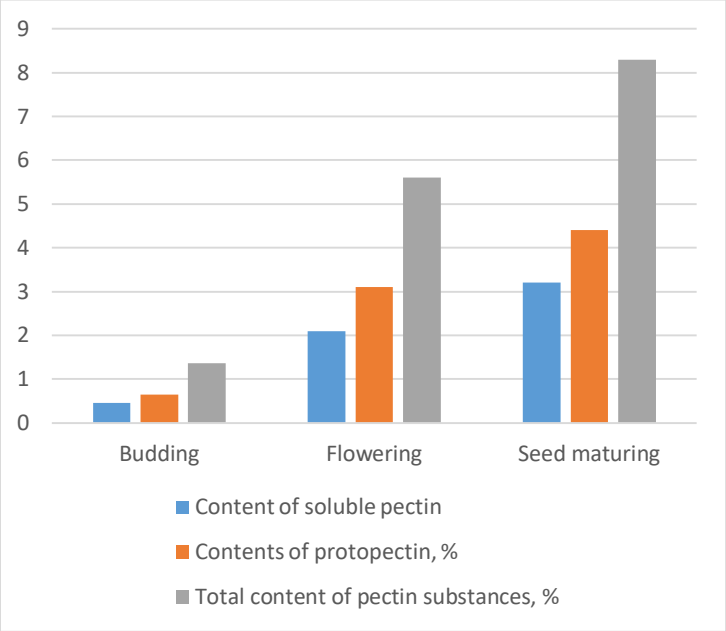


**Figure 01.** Fractional composition of pectin substances of quinoa leaves during the growing season

**Table 01.** Chemical composition of dried quinoa leaves

| Content, % | Budding | Flowering | Seed materation |
|---|---|---|---|
| Dry substances (DS) | 90.9±3.6 | 91.4±3.7 | 92.2±3.9 |
| Nitrogen | 3.28±0.10 | 3.19±0.12 | 2.12±0.07 |
| Protein | 22.20±0,7 | 21.10±0.7 | 11.20±0.4 |
| Fat | 1.5±0.05 | 0.8±0.05 | 1.4±0.03 |
| Saccharides | 1.4±0.05 | 1.6±0.08 | 2.4±0.09 |
| Ash | 18.8±0,7 | 20,7±0,8 | 20.7±1,2 |
| Potassium | 3.70±0.10 | 3.23±0.10 | 3.10±0.1 |
| Calcium | 4.20±0.15 | 3.05±0.16 | 5.42±0.3 |
| Phosphorus | 0.30±0.14 | 0.53±0.01 | 0.55±0.02 |
| Carotene, mg/kg | 75.0±3.3 | 49.0±2.0 | 38.1±1.4 |
| Vitamin C, mg/ % | 17.7±0.5 | 35.0±1.8 | 19.1±0.8 |
| Ruthin | 2.18±0.9 | 2.45±1.1 | 1.83±0.07 |

From the data obtained, it is evident that the highest content of proteins and substances with antioxidant activity (vitamin C, ruthin, carotene) is observed in quinoa leaves during budding and flowering compared to leaves during seed maturation.

Based on the obtained results, we conducted additional studies of the effect of leaf harvesting methods on the antioxidant activity of extracts obtained by water extraction (figure 2).

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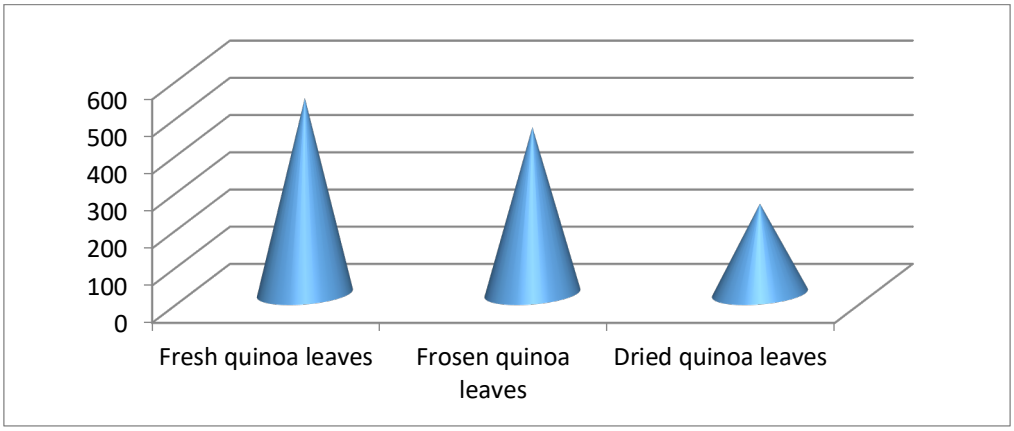


**Figure 02.** Antioxidant activity (AA) of quinoa leaf extracts (standard – quercetin, mg/l)

From the above mentioned data, it is evident that the highest AA is found in the extract from fresh leaves. At the same time, the AA of the extract from frozen leaves is lower by 8.5 %, and from dried leaves by 46 %.

Table 2 presents the results of the comparative composition of flavonoid compounds in the leaves of black tea and quinoa. As can be seen from the table, the amount of flavonoids contained in quinoa leaves exceeds the amount of flavonoids in black tea by almost 2 times. At the same time, it was found that the content of quercetin and its compounds is also higher in quinoa leaves than in black tea.

**Table 02.** Flavonoid compounds in black tea and in leaves of quinoa, % for absolutely dry mass

| Compounds | Dried quinoa leaves | Black tea |
|---|---|---|
| Ruthin | 1.10 | 0.90 |
| Quercetin | 0.68 | – |
| Quercetin-3-0-glucoside | 0.71 | 0.52 |
| Quercetin-3-0-galactoside | 0.30 | 0.18 |
| Quercetin-3-0-rhamnoside | 0.51 | 0.30 |
| Dihydroquercetin | 0.25 | – |
| Amount of flavonoids | 3.55 | 1.90 |

## 7. Conclusion

The results of our research have shown that quinoa leaves of Russian selection can be recommended as natural source of pectin and antioxidant substances in the production of functional food products such as herbal teas, beverages, bakery and other products.

It is most appropriate to use quinoa leaves picked during the flowering period of the plant. The content of pectin substances during this growing season is 5.9 %, protein – 21.1 %, potassium – 3.23 %, calcium – 3.05 %, phosphorus – 0.53 %, carotene – 49.0 mg/kg, vitamin C – 35.0 mg %. In addition, a high antioxidant activity is achieved – 525.0 mg/l, which is comparable to the activity of Chinese lemongrass and ginseng. At the same time, the amount of flavonoids contained in quinoa leaves exceeds the amount of flavonoids in black Bayh tea by about two times.

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