The influence of freeze drying on the quality indicators of potato tubers

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Abstract. In Russia, there is an active development of the Arctic, the Northern regions, the supply of which with food is difficult. The production and supply of freeze-dried vegetables and potatoes is an important task, given that the need for potatoes in terms of nutritional standards is higher than all other vegetables combined, and cargo deliveries are by weight, reducing the weight of the supplied potatoes by four times, taking into account the increase in shelf life by dozens of times and resistance of the freeze-dried product to frost, this is an extremely important area of research. The purpose of the research is to study the quality indicators before and after freeze-drying of potato tubers of domestic and foreign varieties, including varieties with pigmented pulp and skin. The measurements were carried out in the laboratory of the A.G. Lorch" using standard techniques. According to the results of biochemical analysis, the total content of alcohol-soluble flavonoids in terms of quercetin in tubers was 0.08-1.13 mg/g in wet weight, in freeze-dried samples - 0.22-1.46 mg/g in dry weight. The content of low molecular weight antioxidants in fresh potato pulp varied from 0.12 to 1.92 mg/g wet weight, the total content of phenolic compounds in sublimated samples varied from 0.55 to 4.63 mg/g dry weight in gallic acid equivalents. A significant advantage of this drying is the ability to restore freeze-dried potatoes in 60 minutes. The conducted studies confirm that the content of antioxidants in different varieties of potatoes is different and remains after freeze-drying, which makes it possible to select potato varieties for creating healthy food products. Freeze drying of vegetables is an energy-intensive operation. However, according to domestic and foreign manufacturers of freeze-dried products on an industrial scale, the high quality of finished products, the absence of costs for creating a special temperature and humidity storage regime, and a low specific gravity offset the costs of drying.

1 Introduction

Currently, agriculture, energy, food industry and pharmaceutical companies are among the main drivers of Russia's development. It is in these industries that special technologies have

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become objectively in demand to ensure the long-term preservation of raw materials and food products without reducing their quality.

The health of the nation is becoming one of the main priorities in the Russian Federation. The task is to increase the competitiveness of domestic production technologies through the transition to highly productive and environmentally friendly agricultural production and the use of the biological potential of plants to create safe and high-quality, including functional, food products from potatoes [1].

Potato as a food product containing starch, proteins, amino acids and antioxidants has a beneficial effect on human health. Increasing interest in the use of potatoes as a valuable source of natural antioxidants is observed in clinical nutrition [1-3]. This is primarily due to the content in the pulp of tubers of an increased level of carotenoids of the xanthophylls group (lutein, zeaxanthin, violaxanthin) and especially anthocyanins of a flavonoid nature (catechin, epicatechin, glycosides: pionidine, petunidine, malvinidin, etc.). a range of potato products (colored fries, crispy potatoes, mashed potatoes, a new salad direction) and use flavonoid pigments as natural dyes for the food and chemical industries [4-6].

The scientific and technical development of society is faced with the task of preserving useful properties in the process of food preparation of tubers [7, 8]. Since potatoes are consumed in a processed form (mashed potatoes, powder), a number of valuable components are lost during heat treatment. One of the promising ways to prepare tubers is freeze-drying. The principal feature of freeze drying is the removal of water from the tubers by direct transition of water from the solid state (ice) to vapor, thus eliminating the liquid state, and then desorption of water from the "dry" layer. Advantages of freeze-drying over classical methods of preservation: product quality - preservation of nutritional value, vitamins, enzymes, aroma, polyunsaturated fatty acids, amino acids, nutrients in products. If water is added to the dried product, the structure of sublimated products is quickly restored to fresh ones, along with this, all other properties return. Food sublimation is a technology that improves the quality of life of a person in difficult conditions. Freeze drying of products reduces the weight of the finished product by 80% and increases the shelf life, according to some sources, up to 30 years [9-11]. Taste, smell and content of various nutrients do not change [12, 13]. The removal of water by sublimation results in a highly porous structure of sublimated products that are easily transported over long distances. In total, 602.9 tons of freeze-dried products (vegetables, mushrooms, berries and fruits) were produced in 2021 [11, 14]. The advantages of freeze drying are generally recognized. In the food industry of the USA, leading European countries, and in the last 15-20 years in China, India and many countries of Southeast Asia, freeze-drying enterprises have been established and are successfully operating. According to the American company "Mordor Intelligence", engaged in the study of global markets, the global market for dry freeze-dried food products grows by an average of 7.4% every year. It is expected that in 2021 it will reach 66.5 billion dollars, and by 2024 it will already be about 85 billion US dollars. Fruits and berries make up the largest part of the world market of freeze-dried products - 32 ... 55% [14, 15], and vegetables - 39% [16].

Freeze drying of vegetables is considered an energy-intensive operation, but as practice shows, the use of such equipment, energy costs do not exceed 10% of the total costs [9, 16].

In Russia, there is an active development of the Arctic, the Northern regions, the supply of which with food is difficult. The supply of freeze-dried vegetables and potatoes is an important task, given that the need for potatoes in terms of nutritional standards is higher than all other vegetables combined, and cargo deliveries are by weight, reducing the weight of the supplied potatoes by four times, taking into account the increase in shelf life by dozens of times and resistance of the sublimated product to frost, this is an extremely important line of research.

The purpose of the research is to study the quality indicators before and after freeze-drying of potato tubers of domestic and foreign varieties, including varieties with pigmented pulp and skin.

2 Materials and methods

The objects of the study were potato tubers with different pigmentation of both the peel and the pulp. The measurements were carried out in the laboratory of the A.G. Lorch using standard methods: carbohydrates were measured by the spectrophotometric method GOST 31669-2012. Potato sublimation was carried out at the Russian Biotechnological University (ROSBIOTEKH) using a USS-5 vacuum sublimation unit.

Varieties were selected according to the following criteria: skin color (white, beige, yellow, blue, red); flesh color (white, yellow, blue, purple).

For research with raw tubers, samples of 13 potato varieties were used. At the same time, the skin color of the Lilac, Vasilek and Violet varieties is blue (violet); in varieties Yubiley Zhukova, Kolobok, Udacha, Nevskiy, Sineglazka and Veloks - white (beige); in varieties Zhigulevskiy ranniy, Kolette and Gala - yellow; in the Red Scarlett variety - red. In turn, varieties Siren', Yubiley Zhukova, Vasilek, Udacha, Nevskiy, Veloks and Sineglazka have white flesh; varieties Zhigulevskiy ranniy, Kolette, Kolobok, Gala and Red Scarlett have yellow (light yellow) flesh; in the Violet variety, the flesh of the tubers is purple. To conduct research on tuber sublimation, samples of 3 potato varieties (Gala, Sineglazka and Violet) were used.

Analysis of data on the recovery of potatoes after sublimation was carried out according to Nezgovorov and Solovyov [9]. For this, plates of sublimated potato of the Sineglazka variety were immersed in water at room temperature and periodically removed, and weighed after 5, 20, 60, 600, 1000 minutes.

The sublimation technique for potato samples includes the following steps:

- Selection of intact healthy varietal potato tubers: with white and colored skin; white and pigmented pulp. Thorough washing and cutting into plates 2-3 cm thick. The samples of potato tubers cut into plates were placed in trays of a laboratory freeze-dryer and the operating mode was set.
- The freezing process includes rapid freezing - shock freezing down to -30°C, which contributes to the maximum preservation of the original properties of the potato. The duration of the first stage of freeze-drying of food products is 4 hours. At a temperature of minus 25 degrees, the “ice-steam” phase transition occurs.
- Potato heating temperature is set to +50°C. The duration of this period of removal of bound moisture (after drying) is 2.5 hours,
- Sublimated samples were placed in a container and hermetically sealed to avoid exposure to air, light, moisture, and the appearance of foreign odors.

The measurement of antioxidants, phenols, and flavonoids was carried out in the laboratories of the A.G. Lorch using standard methods - spectrophotometric method GOST R 54037-2010.

The total content of antioxidants (SSA) in different varieties of potatoes was determined by the amperometric method on a liquid chromatograph TsvetYauza 01-AA, designed to determine the total content of antioxidants in foods, alcoholic and non-alcoholic beverages, biologically active additives (BAA), drugs, extracts of medicinal herbs [17]. Used portions of raw materials of 5 grams.

The biochemical composition of potato tubers, the conditions for its cultivation and processing are presented in books and reviews [2, 18]. However, the research questions of antioxidants, polyphenols, flavonoids are topical, since these components, as recently established, are important in human nutrition and further study is required [8, 12, 13,19].

3 Results and Discussion

The total content of antioxidants in potatoes varies depending on the variety in the range of 16-192 mg/100 g (standard - gallic acid). The greatest amount of antioxidants, phenolic compounds and flavonoids is accumulated in potato varieties with colored pulp. Moreover, there is a clear correlation between the total content of antioxidants, phenols and flavonoids. Varieties with colored skin, yellow and white flesh were distinguished by a high content of soluble phenolic compounds in the skin and pulp, despite the absence of anthocyanins [3]. The main contribution to the total content of phenolic compounds of such varieties is probably made by phenolic acids and other groups of flavonoids.

Varieties with white and yellow flesh may well be comparable in terms of the content of phenols and flavonoids with varieties with colored pulp. This is due to the presence of groups of uncolored phenolic compounds, such as phenolic acids and lignans.

It has been experimentally confirmed that the total content of phenols, flavonoids, anthocyanins in varieties with colored pulp is on average higher than in potato tubers with white pulp. It has been established that for potato varieties with purple pulp, the main contribution to the total content of flavonoids is made by anthocyanins, for varieties with white and yellow pulp, other groups of flavonoids, such as catechins, leucoanthocyanides, flavanones, flavanonols, and other groups that do not have color.

Anthocyanins (pigments responsible for the blue, red and purple colors of plants) are widely distributed among plants and have a number of beneficial properties for human health, primarily acting as antioxidants through various mechanisms [15-17]. The content of anthocyanins generally correlates with their antioxidant activity.

In potato cultivars, flavonoid concentrations ranged from 0 to 191 μg/g ww for rutin, while tubers of the Phureja group contained up to 3000 μg/g dry wt. Advanced breeding lines have been reported containing more than 430 μg/g dry weight of flavonoids. The content of flavonols increases in tubers up to 140 μg/g ww, suggesting that the use of certain processing methods may be a way to increase flavonols in tubers [18-20].

Analysis of the results of our studies of the antioxidant activity of potato varieties corresponds to the data obtained by other researchers [18-20].

According to the results of measurements of the content of antioxidants 0.16 mg/g-1.92 mg/g (Table 1), the samples with the most contrasting content of antioxidants (Gala, Sineglazka, Violet) were selected and sublimated.

On Figure 1 shows samples of freeze-dried potatoes. Analysis of the data shows that sublimation makes it possible to preserve the shape of the dried object.

Fig. 1. Sublimated samples with white potato pulp.

According to the results of biochemical analysis, the total content of alcohol-soluble flavonoids in terms of quercetin in tubers was 0.08-1.13 mg/g wet weight, in sublimated samples 0.22-2.46 mg/g dry weight (Table 1). The content of low molecular weight antioxidants in fresh potato pulp varied from 0.12 to 1.92 mg/g wet weight, the total content of phenolic compounds in sublimated samples varied from 0.55 to 4.63 mg/g dry weight in gallic acid equivalents.

Table 1. The total content of soluble phenolic compounds and flavonoids in freeze-dried (lyophilic) and fresh potato samples.

Sample, grade	Total content of soluble phenolic compounds, mg/g in terms of gallic acid	Total content of flavonoids, mg/g in terms of quercetin
Potatoes Sineglazka, freeze-drying	0.60±0.18 mg/g dry weight	0.22±0.09 mg/g dry weight
Potato Sineglazka, fresh tubers	0.16±0.12 mg/g wet weight	0.08±0.02 mg/g wet weight
Gala potatoes, freeze drying	0.55±0.11 mg/g dry weight	0.48±0.11 mg/g dry weight
Gala potatoes, fresh tubers	0.12±0.02 mg/g wet weight	0.11±0.02 mg/g wet weight
Violet potatoes, freeze drying	4.63±0.18 mg/g dry weight	2.46±0.12 mg/g dry weight
Violet potatoes, fresh tubers	1.92±0.31 mg/g wet weight	1.13±0.12 mg/g wet weight

Analysis of the obtained data shows that the content of phenolic compounds and flavonoids in sublimated samples remains at the same level as in fresh potato samples. The advantage of sublimated samples is that when transported over long distances, 4 times more payload can be transported.

Analysis of the data (Table 2) shows that after sublimation, plates of sublimated potato of the Sineglazka variety are saturated with moisture when immersed in water at room temperature for 60 minutes.

Table 2. The characteristic level of moisture absorption by sublimated slices of Sineglazka potato tubers when immersed in water at room temperature. Average weight of samples of sublimated potato tubers (35.40+0.2), g.

Exposure time, min	Average weight of recovered samples, g	Mass of absorbed moisture, g	The proportion of absorbed moisture,% of the total mass
0	35.40±0.2	0	0
5	75.2±0.2	39.80±0.2	52.9
20	81.1±0.2	45.7±0.2	56.5
60	82.5±0.2	47.1±0.2	57.1
600	82.6±0.2	47.2±0.2	57.1
1000	82.6±0.2	47.2±0.2	57.1

The developed capillary-porous structure of dry freeze-dried slices of potato tubers provides them with a quick and fairly high degree of rehydration, as evidenced by the data given in Table 2. After recovery, sublimated raw tubers become like the original raw tubers. 20 minutes at room temperature is sufficient for recovery.

Along with the preservation of the appearance, shape and size of sublimated fruits, berries and vegetables, the maximum preservation of the chemical composition is an important indicator of the quality of the finished product [20].

Our studies confirm that in the studied potato varieties, the amount of antioxidants, which are an important food component, is different and can be used in the selection of raw materials for healthy foods. In our country, they are already successfully working - the plant A.N. Mazurin in the city of Borovsk, as well as new enterprises are being built in the

Crimea and the Krasnodar Territory, focused on freeze-drying of plant materials, including potatoes and beets [9]

4 Conclusions and further prospects of the study

According to the results of biochemical analysis, the total content of alcohol-soluble flavonoids in terms of quercetin in fresh tubers was 0.08-1.13 mg/g wet weight, in freeze-dried samples 0.22-2.46 mg/g dry weight. The content of low molecular weight antioxidants in fresh potato pulp varied from 0.12 to 1.92 mg/g wet weight, the total content of phenolic compounds in sublimated samples varied from 0.55 to 4.63 mg/g dry weight in gallic acid equivalents.

Freeze-dried potatoes retain a maximum of antioxidants and do not change the properties and structure of the product. Sublimated raw potatoes, after recovery, retain the properties of the original product. The recovery time for freeze-dried potatoes is 20 minutes. As experience shows, the cost of electricity is no more than 10% of the total cost of production and is completely covered by the dignity of the products, which have a long shelf life.

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