Assessing the processability of Russian varieties and hybrids of root crops

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Abstract. Biochemical and organoleptic properties of varieties and hybrids of carrots and beets after their processing were studied. Minchanka and Marlinka carrot varieties, as well as Gazpadynya and Nesravnennaya beet varieties were the best for making of vegetable purees. In terms of preservation of vitamin C, the best indicators were characteristic of the F₁ Nadezhda hybrid and the Minchanka variety. Preservation of carotenoids is the greatest in the F₁ Nadezda hybrid and Marlinka varieties.

1. Introduction
Russian-made vegetables are rivals in taste and nutritional qualities and even superior to those imported from foreign countries, however, when sold both in fresh and processed form, they most often do not withstand competition with imported products, both in terms of presentation and assortment. Losses during storage and transportation exceed 40 % of the average annual production. Most of the vegetables grown are consumed fresh (the processed share is only 2.5 %), while in industrialized countries of the world this indicator does not fall below 50 % [5, 14].

One of the main conditions for the production of high-quality canned fruits and vegetables is the high quality of raw materials in relation to the physicochemical composition and organoleptic properties and their safety. The selection of varieties preserving their properties and nutritional value during processing, and in some cases enriched with biologically active substances, is important [10, 11, 13, 17, 18].

Of the most promising methods that allow quickly inhibiting the biochemical and microbiological processes in the fruits and preserving the initial quality indicators of fresh fruits for a long time: color, aroma, taste, carbohydrate content and in general, everything that determines the biological value of fruits and vegetables, is the freezing method. In addition, this method of canning allows successfully using vegetables for delivery to remote areas at a lower cost than its delivery in fresh or processed form. Freezing is widely used in the practice of preserving fruits and vegetables, depending on the processing regimes and varieties of vegetables [18].

The aim of the work is to evaluate and improve the technologies for processing garden root crops, including for obtaining functional food products.

At a freezing temperature of –40–60 °C (shock freezing), the least loss of valuable substances occurs than at a temperature of –5–10 °C. There are three groups of varieties of vegetable crops during freezing. The first one includes varieties suitable for freezing, where the product is almost no different from fresh after seven months of storage. The second group is varieties that retain the primary taste,
although the consistency of the starting material is violated. And finally, the third is the varieties that partially lose their taste and biochemical parameters, especially ascorbic acid and carotenoids [5].

2. Methods and materials

Root crops of garden carrots and beets were grown in 2015-2017 on the experimental fields of the Federal Scientific Center for Vegetable Production in Moscow Region (55°39'23"N, 37°12'43"E). The soil was sod-podzolic, pH was 6.8, the organic matter content was 2.1 %, the content of nitrogen was 108 mg/kg, the content of P$_2$O$_5$ was 450 mg/kg, the content of K$_2$O was 357 mg/kg, total exchangeable bases amounted to 95.2 %.

The biochemical composition of root crops was studied by the following indicators: the total content of water-soluble antioxidants was determined by the method from [7, 12], gallic acid was used as the standard. Carotenoids in the roots of carrots were extracted with 96 % ethanol and the result was determined on a UNICO UV-2804 spectrophotometer using the procedure from [2]. The dry matter content was determined by drying the sample to constant weight at a temperature of 70 °C for 72 hours, the level of sugars was measured using the cyanide method from [15]. The content of Vitamin C was determined by titration of samples with Tillmans reagent (2,6-dichlorophenol with sodium indophenolate) [1]. Betanins were determined spectrophotometrically using formic acid [16].

Root crops were frozen before freeze drying at a temperature of –45 °C in a Haier Biomedical UK DW-40L508 Laboratory Freezer. The lyophilization of crops was performed in a DELTA 1-24 LSCplus laboratory freeze dryer. The purees were prepared in a WAC-47 autoclave [3].

3. Results

Carrot roots used for processing had a high marketability (Table 1). On average, for three years, the smallest yield of commodity root crops (73.1 %) was typical for the F$_1$ Nadezhda, the highest one (84.7–85.6 %) was demonstrated by the F$_1$ Zvezda and Olimpiets hybrids. At the same time, the smallest root crop mass was detected in the F$_1$ Zvezda and Olimpiets hybrids (102–104 g), the largest one (148 g) was characteristic of the Marlinka variety.

| Crop samples         | Average root mass [g] | Marketability [%] | Commercial yield |
|----------------------|-----------------------|-------------------|-----------------|
| Nantskaya 4 (st)     | 113±13                | 80.8              | 39.3            |
| Mars F$_1$           | 121±14                | 84.2              | 43.8            |
| Rif F$_1$            | 105±11                | 83.2              | 37.6            |
| Olimpiets F$_1$      | 104±12                | 85.6              | 38.3            |
| Zvezda F$_1$         | 102±10                | 84.7              | 37.1            |
| Nadezhda F$_1$       | 132±14                | 73.4              | 41.7            |
| Marlinka             | 148±15                | 78.5              | 50.0            |
| Minchanka            | 135±12                | 73.1              | 42.4            |
| Minor                | 122±10                | 80.2              | 42.1            |
| NIIOKh 336           | 129±14                | 79.5              | 44.1            |
| Losinoostrovskaya 13 | 106±9                 | 81.3              | 37.0            |
| HCP$_{05}$           | 10                    |                   | 3.3             |

A high solids content is necessary to obtain a product with high nutritional value. F$_1$ Rif and Zvezda hybrids were characterized by the highest dry matter content, the least value was demonstrated by the Losinoostrovskaya 13 variety and the F$_1$ Mars hybrid (Table 2). Shantane 2461 and NIIOKh 336 (7.1–6.8 %) were distinguished by the maximum content of the sum of sugars, the Losinoostrovskaya 13 variety and the F$_1$ Rif hybrid (5.6–5.4 %) had the lowest. The highest carotenoid content was typical for the Losinoostrovskaya 13 variety (24.0 mg %), the lowest value was characteristic of the F$_1$ Nadezhda hybrid (11.1 %).

Lack of vitamins negatively affects human health: their well-being worsens, their overall performance decreases, resistance to various diseases degrades, the negative impact on the body of
harmful working conditions and the environment is aggravated, treatment of any diseases is aggravated, the body's sensitivity to the effects of increased radiation background is increased, the risk of cancer is increased [4, 6]. According to the content of vitamin C, the best indicators (53.5–58.1 mg/100 g) were characterized by F1 Zvezda and Nadezhda hybrids, the lowest values were shown by the NIIOKH 336 variety and the F1 Rif hybrid (36.0–38.8 mg/100 g).

| Crop samples     | Dry matter [%] | Total sugars [%] | Carotinoids [mg/100 g] | Vitamin C, mg/100 g |
|------------------|----------------|------------------|-------------------------|---------------------|
| F1Olimpiets      | 11.84          | 6.9              | 18.3                    | 52.1                |
| F1Zvezda         | 13.04          | 6.4              | 18.6                    | 53.5                |
| F1Nadezhda       | 10.56          | 5.8              | 11.1                    | 58.1                |
| F1Mars           | 11.41          | 6.0              | 18.2                    | 47.1                |
| F1Rif            | 12.63          | 5.4              | 22.9                    | 36.0                |
| NIIOKh 336       | 11.66          | 6.8              | 14.3                    | 38.8                |
| Losinostrovskaja | 11.02          | 5.6              | 24.0                    | 53.2                |
| -4               | 11.83          | 6.3              | 20.1                    | 43.6                |
| Marlinka         | 11.82          | 6.1              | 13.1                    | 53.2                |
| Minchanka        | 12.10          | 6.1              | 17.2                    | 43.3                |
| Shantane 2461    | 12.16          | 7.1              | 14.7                    | 46.7                |
| НСР05            | 1.09           | 0.6              | 2.6                     | 5.9                 |

Minerals are an indispensable vital food component that perform important physiological functions in the body. An analysis of the chemical composition of carrot root crops showed that they significantly differ in the content of ash and water-soluble minerals. The highest content of ash substances (13.8 %) was detected in the Nantskaya 4 variety, the lowest one (5.2–6.0 %) was in the F1 Zvezda and Olimpiets hybrids. The Minor, Nantes 4 varieties and the F1 Mars hybrid had the highest content of water-soluble minerals (52.1–53.5 mg/kg), and F1 Star and Hope hybrids had the smallest one (36.0–38.8 mg/kg).

In terms of nitrate content, only Nantskaya 4 variety insignificantly (5 mg/kg) exceeded the maximum permissible concentration; in other varieties and hybrids, the content of this toxicant was within the normal range.

Mashing carrots induces profound changes in the biochemical composition of the products. For instance, the dry matter content reduced by 15.6–28.3 %, with the largest dry matter losses typical for the Minor variety. The smallest value was in the F1 Nadezhda hybrid (Table 3). Changes in the content of the amount of sugars are approximately at the same level: the reduction is 10.3–20.9 % against the initial content. It should be noted that the main changes occur due to disaccharides. As for monosaccharides, their content remains almost at the initial level, or even increases (by 53 % in the Minchanka variety).

As a positive fact, it should be noted that the content of nitrates in the process of making mashed potatoes in all studied variety samples is reduced by 32.0–40.4 %. The most important indicator determining the quality of the finished product is the content of vitamin C. Regardless of the variety, no more than 10–13 % of ascorbic acid is preserved in the finished product, which indicates that this type of processing does not contribute to the preservation of vitamins in the finished product.

Organoleptic evaluation of the quality of the puree carried out after its preparation showed that all varietal samples have high indicators: purees have a homogeneous mass, without extraneous tastes and have an orange color.

The tasting confirmed the high quality of the resulting carrot puree. The best quality indicators were characterized by the product obtained from the Minchanka variety, and the lowest average score (4.2) was given to the F1 Nadezhda hybrid.
Table 3. Chemical composition of garden carrot puree

| Crop samples | Dry matter [g/100 g] | Sugars [g/100 g] | Nitrates [mg/kg] | Vitamin C [mg/100 g] |
|--------------|-----------------------|-----------------|-----------------|----------------------|
| Nadezhda F | 8.91 | 3.13 | 4.59 | 155 | 3.8 |
| Minor | 9.66 | 3.38 | 5.04 | 154 | 4.2 |
| Minchanka | 9.82 | 3.67 | 5.47 | 168 | 4.3 |
| Marlinka | 9.51 | 3.29 | 5.14 | 177 | 3.9 |

Note. The numerator is the content in the puree, the denominator is % of the initial content in root crops.

Beetroot for fresh consumption and for industrial processing must meet the following quality requirements: in appearance, the root crops must be whole, healthy, clean, without damage by agricultural pests, without excessive external moisture, uncracked, typical for the botanical variety of shape and color, with the length of the remaining petioles of leaves no more than 2 cm or without them; smell and taste should match the botanical variety; the pulp of the root vegetable is juicy, dark red in different shades depending on the characteristics of the botanical variety [5].

Table 4. Biochemical composition of garden beet samples, 2015–2017

| Variety | Dry matter [%] | Total sugars [%] | Betain [mg%] | Ascorbic acid [mg%] | Antioxidants [mg GAE/g] | Nitrates [mg/kg] |
|---------|----------------|------------------|-------------|---------------------|-------------------------|------------------|
| Bordo odnosepmannaya | 16.4 | 13.9 | 126 | 6.5 | 0.78 | 570 |
| Lyubava | 16.3 | 12.4 | 103 | 6.0 | 0.74 | 769 |
| Bordo 237 | 16.2 | 13.5 | 184 | 7.0 | 0.66 | 670 |
| Nesravnennaya A–463 | 15.3 | 13.2 | 103 | 6.5 | 0.63 | 824 |
| Gaspadynya | 15.9 | 12.6 | 66 | 5.5 | 0.58 | 787 |
| Gribovskaya ploskaya | 14.9 | 12.4 | 57 | 5.5 | 0.56 | 843 |
| Nezhnost | 15.9 | 12.6 | 72 | 6.0 | 0.55 | 805 |

A biochemical assessment of the roots of beetroot revealed that the largest amount of dry matter (Table 4) is characteristic of the single-seeded and Lyubava varieties (16.4–16.3 %), the lowest value was in the Gribovskaya ploskaya variety (14.9 %). A similar picture was revealed in relation to the content of the total sugars and betain.

Tasting evaluation of beetroot puree showed the prominence of the product obtained from Bordo odnoseymannaya (4.9 points), which received 0.2–0.33 more points than the puree from Lyubava and Nesravnennaya A–463 varieties.

In the process of making puree, the dry matter content decreased by 17.3–25.6 %, the amount of sugars reduced by 11.4–32.9 % (Table 5). Moreover, the greatest losses are typical for the Lyubava variety, the smallest are for the Gaspadynia variety. The greatest losses (7.9–10.5 times) are characteristic of the content of vitamin C.

Table 5. Biochemical composition of garden beet puree

| Crop samples | Dry matter [%] | Sugars [%] | Vitamin C [mg/100 g] |
|--------------|----------------|-----------|---------------------|
| Bordo odnoseymannaya | 15.4 | 0.75 | 9.17 | 2.3 |
| Lyubava | 75.6 | 11.5 | 68.8 | 12.6 |
| Gaspadynya | 17.4 | 0.92 | 11.7 | 1.8 |
| Lyubava | 82.7 | 14.6 | 88.6 | 10.2 |
| Nesravnennaya A–463 | 13.2 | 0.81 | 8.86 | 2.1 |
| Lyubava | 74.4 | 12.6 | 67.1 | 10.8 |
| Nesravnennaya A–463 | 15.8 | 0.83 | 9.88 | 1.8 |
| Lyubava | 79.7 | 12.8 | 72.6 | 9.5 |

Note. The numerator is the content in the puree, the denominator is % of the initial content in root crops.
Thus, based on the results of studies of the chemical composition of the selected raw materials, it can be concluded that it is advisable to develop functional food products on its basis.

A food product can be classified as a functional food product, if the content of a certain functional ingredient in it is at least 15% of the daily requirement.

In our studies, it was found that carrot puree can be attributed to functional food products in relation to vitamin A, vitamin C and sodium, the need for which using 100 g of puree is satisfied by 80.0–29.2% (Table 6). When using beetroot puree as a functional product, the consumption of organic acids, sodium and potassium can be considered.

### Table 6. Biochemical composition of puree and degree of satisfaction of daily demand in physiologically necessary ingredients

| Component              | Unit | Dietary reference intake | Content in 100 g of carrot puree * | Content in 100 g of beet puree * |
|------------------------|------|--------------------------|-----------------------------------|---------------------------------|
| Digestible carbohydrates | g    | 100                      | 5.5                               | 5.5                             |
| Proteins               | g    | 55.1                     | 0.8                               | 1.4                             |
| Fats                   | g    | 66.6                     | 0.1                               | 0.15                            |
| Organic acids          | g    | 2                        | 0.2                               | 10.0                            |
| Water                  | g    | 2200                     | 89.0                              | 4.0                             |
| Vitamin A (PE)         | μg   | 9.0                      | 7.2                               | 80.0                            |
| Vitamin C              | mg   | 70                       | 4.5                               | 64.3                            |
| Calcium                | mg   | 1000                     | 45                                | 4.5                             |
| Magnesium              | mg   | 400                      | 30                                | 7.5                             |
| Sodium                 | mg   | 1300                     | 380                               | 29.2                            |
| Potassium              | mg   | 2500                     | 160                               | 6.4                             |
| Phosphorus             | mg   | 800                      | 65                                | 8.1                             |

Note. * is the Dietary reference intake for a person with 100 g of product

Freeze drying, being one of the most promising methods of processing vegetable products, contributes more to the conservation of biologically valuable components of the raw products (Table 7). In this case, the largest amount of vitamin C is preserved in the varieties Marlinka and NIIOKh 336 (32–34 mg/100 g of dry matter), the smallest value is in the Minor variety (21.6 mg/100 g). The storage method also has a certain effect on the safety of ascorbic acid: regardless of the variety of samples, vacuum packaging promotes preservation of vitamin C by 4–5 mg/100 g.

### Table 7. Chemical composition of garden carrot after freeze drying, (1-month storage)

| Crop samples     | Content of Vitamin C [mg/100 g] | Content of carotenoids [mg/100 g] |
|------------------|---------------------------------|-----------------------------------|
|                  | no package | vacuum package | no package | vacuum package |
| Nantskaya 4 (st) | 30.4       | 34.3           | 42.6       | 41.8           |
| Mars F1          | 29.6       | 35.2           | 56.4       | 56.6           |
| Rif F1           | 31.3       | 37.6           | 69.9       | 57.7           |
| Olimpiets F1     | 29.6       | 29.8           | 68.1       | 52.3           |
| Zvezda F1        | 28.0       | 29.6           | 57.9       | 53.1           |
| Nadezhda F1      | 27.2       | 31.8           | 52.3       | 48.4           |
| Marlinka         | 32.0       | 32.2           | 52.4       | 51.9           |
| Minchanka        | 29.6       | 33.6           | 49.6       | 48.4           |
| Minor            | 21.6       | 21.7           | 38.8       | 29.6           |
| NIIOKh 336       | 34.5       | 41.6           | 65.3       | 61.4           |
| Losinoostrovskaya 13 | 25.6     | 37.6           | 74.1       | 60.4           |

In terms of the content of carotenoids during freeze drying, the best hybrids were F1 Rif and Olimpiets and the NIIOKh 336 variety (35.3–69.9 mg/100 g), the worst varieties are Minor and Nantes 4 (38.8–42.6 mg/100 g). The use of vacuum packaging reduces the content of carotenoids by 3–4 mg/100 g of the finished product.
In the process of sublimation, the content of vitamin C reduces by 9–20 times in comparison with the initial amount. At the same time, the largest decrease (20.3 times) is characteristic of the Minor variety, the smallest is for the F1 Zvezda hybrid and the NIIOKh 336 variety (8.9–9.3 times). It should be noted that the greatest losses of ascorbic acid occur not during the processing of the raw products (root crops of carrots), but during storage, especially with an increase in shelf life of more than one month.

The content of carotenoids in the processing process does not change so significantly, compared with vitamin C. The products obtained from the NIIOKh 336 and Marlinka varieties are characterized by the best preservation; the worst are the Minor and Nantskaya 4 varieties. It should be noted that it short-term (within one month) storage practically does not affect the preservation of carotenoids. The greatest losses are observed during 1 to 6 months of storage.

4. Conclusion
Based on studies conducted in 2015–2017, varieties and hybrids of garden root crops were identified, which are distinguished by the best quality indicators: garden carrots F1 Zvezda and Rif, the worst varieties are Losinoostrovskaya and F1 Rif. Among the beetroot those are varieties Bordo odnosemyannaya, Lyubava, and Gribovskaya ploskaya, respectively.

In terms of the preservation of sugars during the preparation of puree from table carrots, the best indicators are characterized by varieties Minchanka and Marlinka, garden beets are Gaspadynya and Nesravnennaya A 463.

In the freeze-drying process of canteen carrots, the least destruction of vitamin C is characteristic of the F1 Nadezhda hybrid and the Minchanka variety, the largest is for the F1 Mars and Rif hybrids. The preservation of carotenoids is greatest in the F1 Nadezhda hybrid and Marlinka varieties, the least is in varieties Minchanka and Nantskaya 4.

Thus, for preparation of puree, the best carrots are Minchanka and Marlinka, the best beets are Gaspadynya and Nesravnennaya A 463, for freeze drying, the F1 Nadezhda carrot hybrid is the best.

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