

## Applying beetroot as food ingredient in ice-cream production

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**Abstract.** The development of new food products with functional ingredients of plant origin is highly promising and relevant direction in food industry. Assortment of products, including ice cream is constantly expanding due to the introduction of various plant ingredients into its composition, enriching the product with health beneficial nutrients. In this study, beetroot (*Beta vulgaris*) was selected as a plant component for ice cream production. The roots of common beets contain many useful inorganic and organic substances, such as carbohydrates, proteins, organic acids, mineral salts, betalaines, vitamins, folic acid and betaine. The influence of different thermal treatment techniques of beetroots on the content of dry substances and organoleptic properties of beetroot puree have been compared and analyzed. The heat exposure technique recommended for beetroots is microwave processing for 9 minutes at a power of 800 watts. This method of heat treatment ensures the culinary readiness of vegetable raw materials while preserving dry substances in it, including betanin. The effect of the beetroot puree dose on the formation of the ice cream quality was studied. The recommended dose of the beetroot puree was established as 20%.

**Key words:** ice cream, beetroot puree, betanines.

### INTRODUCTION

Currently, the food production industry features a trend to produce functional food products, which reduce the risk of diseases and drug loading. The important tasks of food industry science include the development of original technologies for new products that improve the condition of the gastrointestinal tract, support the functioning of the cardiovascular, and immune systems.

The trend of scientific research in this area is clearly traced in meat industry (Bazarnova et al., 2019; Zinina et al., 2019), dairy industry (Zabodalova et al., 2014; Skripleva & Arseneva, 2015; Evstigneeva et al., 2016; Dubrovskii et al., 2019; Hurda et al., 2019), baking industry (Nilova & Malyutenkova, 2018; Dubrovskaja et al., 2019), as well as in cheese making (Iakovchenko & Silantjeva, 2014; Nadtochii et al., 2015; Chechetkina et al., 2016). Designing new food products involves the addition of plant extracts of high nutritional value and dietary fiber (Zinina et al., 2019). To obtain extracts, vegetable raw materials with prominent functional properties are used, for example, chlorella microalgae (Bazarnova et al., 2019), fennel (Dubrovskii et al., 2019), green tea (Evstigneeva et al., 2016). Powders from rowan berries (Dubrovskaja et al., 2019) and sea buckthorn (Nilova & Malyutenkova, 2018) increase the nutritional value of bakery products. Biologically active substances isolated from natural raw materials

are used as functional additives in the preparation of yogurt, for example, curcumin, grape seed oil, hyaluronic acid and chondroitin sulfate (Hurda et al., 2019).  $\beta$ -Carotene, which is included in liposomes to improve technological characteristics, is recommended for dairy formulations (Zabodalova et al., 2014).

Among many food products, ice cream is in great demand. A sweet frozen dessert is made from dairy raw materials with the addition of various ingredients that form the consistency and taste characteristics of the product. Traditional types of ice cream are characterized by high calorie content, due to the high content of sugar and fat, which reduces its physiological value and increases its price. New types of ice cream with therapeutic, prophylactic, functional, and dietary properties and developing technologies are promising (Serova et al., 2016).

Today, there exist types of ice cream that can assist in restoring of the cardiovascular system, slowing the aging process, and reducing the likelihood of inflammatory and oncological diseases (Petash, 2013). For example, an ice cream with low-calorie ingredients and special substances (L-carnitine) was developed for overweight people (Hausmanns & Kovalchuk, 2006). An ice cream recipe is proposed for people suffering from diabetes with amaranth flour (Yakovleva, 2012).

The use of an amino acid complex in ice cream formulas allows to recommend a product to reduce fatigue. The original composition of calcium and magnesium ions with vitamin A in ice cream makes it prophylactic against depression and insomnia (Melnikova et al., 2012).

The types of ice cream have a therapeutic and dietary orientation, when vegetable raw materials are used as fillers. A promising source of plant materials with a unique set of food and biologically active substances are pine nuts kernels and their processed products. Cedar flour as a protein supplement, and cedar oil as a source of essential fatty acids, offer great opportunities for creating dairy products with a given nutritional and biological value (Artyukhova, 2006).

The technology for therapeutic ice cream with stevia extract and lingonberry juice was also developed (Chaika et al., 2009). Ice cream was obtained from goat milk with hawthorn, which had high nutritional, biological value and antioxidant activity (Drevin et al., 2012). There is a method to enrich a frozen dessert with milk and soy proteins, dietary fiber, natural vitamins and minerals (Tikhomirova, 2013).

The formula and technology for the preparation of ice cream with various additives are described: with cereal concentrates (Eremina & Ivanova, 2008), chicory powder and wheat bran (Shambulova et al., 2016), with a microparticulate whey protein and Maxilact, a purified lactase (Stanislavskaya, 2012), with citrus fibers (Gubina, 2013).

The analysis of publications revealed two main trends to obtain new types of ice cream that are more beneficial for health than traditional ones. The first one is the decrease in calorie content, and the second one is the introduction of various functional components in the form of berries, nuts, fruits and vegetables, and the addition of probiotics and prebiotics as well.

Beetroot is a rich source of healthy ingredients for the human body. It contains a significant amount of vitamins and minerals (Prokopets et al., 2014). Beet fiber, interacting with cholesterol, prevents its absorption into the blood (Kurguzova et al., 2012). There are many phenolic compounds in beetroots, mainly free catechins and flavonol glucosides (Sidorenko & Shtonda, 2013). Beetroots are rich in betalaines, which have a lipotropic effect, and are used in the treatment of diseases associated with

impaired fat metabolism (Lechner & Stoner, 2019). Betalaines combine yellow pigments - betaxanthines and pigments with a red and purple color - betacyanins, which are rich in red beets. In addition to their coloring ability, betacyanins are wide and diverse biologically active. Their high antioxidant properties contribute to the assimilation of food proteins. Betacyanins are actively involved in the formation of choline, which increases the activity of liver cells, and inhibit the proliferation of cancer cells, preventing the onset of malignant tumors (Saenko et al., 2012). The most investigated betacyanin is a betanin pigment, which is called the Beetroot Red (E162). There is evidence that betanin is also a hepatoprotector, participating in the neutralization of toxins in the human body (Frank et al., 2005; Lee et al., 2005). Substances responsible for beetroot pigment reduce blood pressure, alleviate spasms and strengthen capillaries; they also inhibit the development of malignant tumors. As beetroot contains macroelements of potassium and magnesium, and trace elements iron, it is recommended for the prevention and treatment of hypertension, atherosclerosis, other cardiovascular system diseases, as well as for the prevention of iron deficiency anemia (Kurgusova, 2013). Studies on the composition of biologically active substances of Bordeaux 237 confirmed the beetroot to be a source of dietary fiber with antitoxic, antioxidant, radioprotective, hypocholesterolemic and lipid-correcting properties, as well as a source of vitamins C and B9, P-active substances with antioxidant properties (Gorash et al., 2015).

There exist various processed beet root products in food compositions. Beetroot powder was added to wheat flour in pasta production (Grazyna, 2015). Studies show that along with other herbal supplements, beets have a positive effect on the nutritional and energy value of noodles, while giving the product a burgundy color. Beet cryopowder was used as a herbal supplement in the production of oil paste (Podkovko & Rashevskaya, 2015). The authors consider red beetroot to be a potential source of immunomodulation, radioprotection and antioxidant effects. Beet fiber of the 'DIVINKA' company in minced meat product allows to increase the protein content, lower the fat content, increase the yield of finished products by 10-12% on average. Compared to wheat bran, it contains twice as much dietary fiber, as well as pectin and hemicellulose, which positively affect metabolism. It has the unique ability to bind water and fat in ratio 1: 8: 8 (Nikitin et al., 2016).

All of the above determines the prospects of applying beetroot in the production of functional products.

This work was aimed to develop the composition and identify the technological parameters for manufacturing of ice cream using Bordeaux table beet.

## **MATERIALS AND METHODS**

The objects of the study were Bordeaux beetroot (*Beta vulgaris*), beetroot puree, ice cream mixtures, control and experimental samples of soft and hard ice cream.

### **Determination of betanin content in beetroot**

We used a method based on the extraction of beet betanin in an acidic medium, measuring the optical density of the extracts obtained and comparing the values obtained with the optical density of a standard solution, which is 1% aqueous solution of cobalt sulfate (Bazarnova, 2013).

Experimental samples of beetroots were crushed into a puree using mixer grinder Bosch MSM 2650B. Weighed portions of the beet puree were 1 g each with accuracy of 0.001 g, they were placed into glass beakers with a capacity of 50 cm<sup>3</sup>, and the weighed portions were transferred to volumetric flasks with a capacity of 250 cm<sup>3</sup>. Then, 10 cm<sup>3</sup> of concentrated hydrochloric acid was poured into each flask, and the volume of the contents of the flask was adjusted to 250 cm<sup>3</sup> with distilled water. The contents of the flasks were thoroughly mixed for 1 min and then filtered through paper filters. The extracts obtained were further used to determine the concentration of betanin.

The optical density of the extracts obtained and a standard solution of cobalt sulfate was determined on photocolimeter KFK-3-01 at a wavelength of 535 nm using a 10 mm thick cuvette.

The content of betanine was calculated by the formula (1)

$$X = \frac{0.022 \cdot D_1}{4m \cdot D_2} \cdot 10^5, \quad (1)$$

where  $X$  – content of betanine, mg per 100 g; 0.022 – mass of betanine, which in color corresponds to 1 dm<sup>3</sup> of a standard solution, g;  $D_1$  – optical density of the test solution, rel. units;  $D_2$  – optical density of the standard solution, rel. units;  $m$  – mass of the sample, g.

#### **Determination of the mass fraction of solids in beets**

The method consists of drying a product sample distributed over an absorbing surface under heating (GOST 28561-90).

Metal cups with weighed samples of filter paper weighing 4–5 g were dried together with lids at 100–110 °C for 1 h, cooled for about 20 min in a desiccator, and weighed. A portion of beetroot puree weighing about 5.0000 g was placed in a glass with filter paper and the product was evenly distributed on the filter paper. The product was kept in a drying cabinet at temperature of 105 °C. Periodically, the cups were closed with lids, cooled for about 20 min in a desiccator and weighed. Drying of the samples continued in the given mode, conducting control weighings at time intervals equal to approximately 10% of the total drying time. The change in the sample weight was determined during each of these drying periods, and the test was terminated if the weight change was less than 0.0020 g.

Mass fraction of moisture in the product ( $W$ ) as a percentage was calculated by the formula (2)

$$W = (M_1 - M_2) \cdot 100 / (M_1 - M_3), \quad (2)$$

where  $M_1$  – mass of the cup with a lid, filter paper and a sample before drying, g;  $M_2$  – mass of the cup with a lid, filter paper and a sample after drying, g;  $M_3$  – mass of the cup with a lid and filter paper, g.

The percentage of mass fraction of solids in the product (DS) was calculated by the formula (3)

$$DS = 100 - W. \quad (3)$$

#### **Thermal treatment of beetroot**

We used the following methods of heat exposure: cooking in boiling water for 1 h; roasting in the oven at temperature of 150 °C for 1.5 h; microwave processing at a power of 800 W for 3–12 min in increments of 3 min. The results to determine the mass fraction

of solids in beetroot puree during various heat treatment techniques were analyzed in statistical program Minitab 19.

#### **Manufacturing of ice cream**

The test and control samples of ice cream were manufactured from a mixture of fresh cow milk, cream, skimmed milk powder, granulated sugar, and a stabilizer. The mixture of components was pasteurized at a temperature of 85 °C for 5 min, cooled to 4–6 °C, and kept for 2 h for protein swelling. Then, for the control sample, the ripened milk mixture was processed on the brand freezer Miken MK-25FTB. In the production of the test samples, beetroot puree prepared from beets subjected to microwave processing for 9 min at a power of 800 W was introduced into the ripened milk mixture. The milk-vegetable mixture was thoroughly stirred, and then also placed into the freezer. At the output of the freezer the product was soft ice cream with the temperature from minus 4 to minus 6 °C. Soft ice cream was packed in plastic cups of 150 cm<sup>3</sup> and frozen to a temperature not exceeding minus 18 °C to become hardened ice cream.

#### **Determination of the conditional viscosity of an ice cream mixture**

The nominal viscosity of the ice cream mixture was determined on a VZ-246 viscometer. The method is based on determining the expiration time of 100 cm<sup>3</sup> of the mixture through an opening with a diameter of 4 mm.

#### **Evaluating of titratable acidity**

The method is based on neutralization of acids in the product with 0.1 mol dm<sup>-3</sup> sodium hydroxide solution with a phenolphthalein indicator. Five g of the product were placed into a flask of 250 cm<sup>3</sup>, then 80 cm<sup>3</sup> of distilled water was added followed by 3 drops of phenolphthalein addition. The mixture was agitated and titrated with alkaline solution until pink color appearance stable for 1 min. Acidity in Turner degrees (°T) was calculated by multiplication of volume (cm<sup>3</sup>) of the sodium hydroxide solution used for titration by 20 (Olenev et al., 2004).

#### **Determination of ice cream overrun**

The method is based on measuring the masses of a fixed volume of the mixture entering the freezer, and the same volume of the air-saturated mixture (ice cream) leaving the freezer, and calculating the overrun of ice cream (Olenev et al., 2004). A glass of 100 cm<sup>3</sup> was filled to the brim with ice cream mixture and weighed with the result recorded up to 1 g. Similarly, the dried glass was filled with the ice cream leaving the freezer. A glass of ice cream was weighed with a record of the result up to 1 g. The percentage of ice cream overrun (O) was calculated by the formula (4)

$$O = (M_2 - M_3) 100 / (M_3 - M_1), \quad (4)$$

where  $M_2$  – mass of a glass filled with a mixture, g;  $M_3$  – mass of a glass filled with ice cream, g;  $M_1$  – mass of glass, g; 100 – conversion factor of the ratio in percent.

**The size of air bubbles in ice cream** was determined by the microscopic method. An ice cream sample was applied to a calibrated mesh, covered with a coverslip on top and examined under a microscope at 600 magnification. Knowing the price of mesh divisions, the size of air bubbles was determined (Olenev et al., 2004).

### Determination of the resistance of ice cream to thaw

The method is based on measuring the duration of the melting of ice cream (Olenev et al., 2004). A sample of soft or hard ice cream (temperature minus 6 or minus 18 °C, respectively) was taken with a special probe in the form of a hollow cylinder with a diameter of 35 mm and a height of 50 mm and placed in a glass with holes along the edge/bottom for free draining of the thawed mixture. The resistance of ice cream to thawing is characterized by the accumulation time of 10 cm<sup>3</sup> of the mixture obtained by melting the ice cream in a thermostat at a temperature of 25 °C.

### Examination of organoleptic characteristics

Organoleptic evaluation was conducted using 5-point scale using the sensory analysis method (Kantere et al., 2001). The samples were evaluated by a trained panel of 12 members. Twelve panelists (age 22–38 years) qualified for sensory evaluation techniques and regular consumers of products estimated the sensory properties of the samples.

All experiments were performed with at least three replicates; data was processed by methods of mathematical statistics with 95% confidence level. The confidence interval was calculated according to the standard procedure using Student coefficient for confidence level of 0.95.

## RESULTS AND DISCUSSION

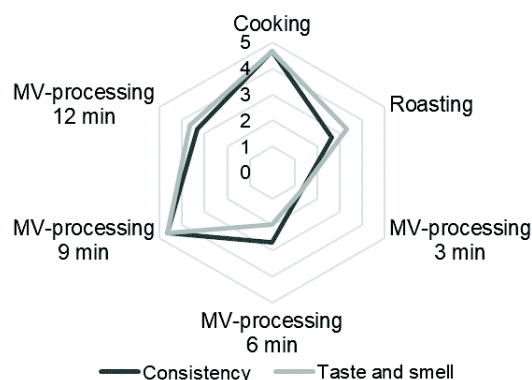
### The choice of filler preparation method

As previously assumed, since a beetroot filler in a puree form is the most appropriate to be added to the ice cream mixture before freezing, its introduction has no noticeable effect on the process. In this case, to ensure the microbiological safety of ice cream, it is necessary to heat the beetroot puree.

A comparative evaluation of the samples was conducted according to the processing technique. The samples of puree were obtained from medium size beetroots of one batch with the same mass, which were subjected to various heat treatment techniques.

Heat treatment was performed until the required degree of readiness of beetroot was achieved. After heat treatment beetroots were cooled, and then processed with mixer grinder to obtain a puree consistency. The organoleptic evaluation of the puree samples prepared was conducted according to the developed point scale, where the mark '5' characterizes a well-defined taste and smell inherent in beets without extraneous smacks and odors and a homogeneous puree-like consistency without the presence of solid particles.

The results of the organoleptic evaluation of the samples of beetroot puree are shown in Fig. 1.



**Figure 1.** Organoleptic characteristics of beetroot puree for various heat treatment techniques.

The two puree samples obtained from beetroots cooked and 9-min microwave processed have a well-pronounced beetroot taste and smell, as well as the best consistency.

Another criterion for choosing a heat treatment method was the mass fraction of betanin in the beetroot puree (Table 1).

The study results revealed the minimal losses of betanin, which were observed in the case of heat treatment of beetroots in a microwave for 3–9 min. A longer treatment led to a noticeable decrease in the content of betanin because of overheating of beetroots and their partial drying. When cooking, part of the coloring matter goes into water, as evidenced by the decoction intense color. Exposure to high temperatures during prolonged baking in the oven significantly reduced the content of betanin in red beets.

The results of the analysis of heat treatment technique influence on the mass fraction of solids in the samples are presented in Fig. 2.

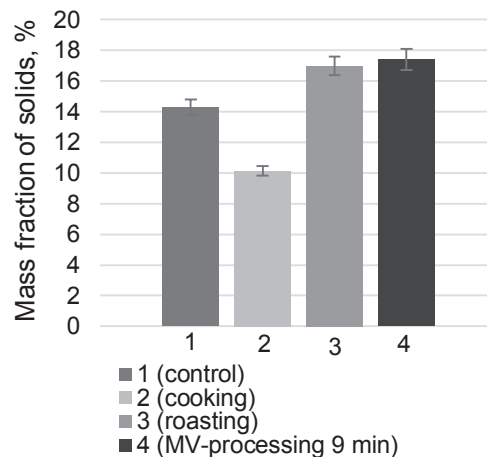
The data analysis shows that among the samples studied, the largest amount of solids was lost during cooking (up to 30% compared with the control sample), which is associated with their extraction into water. When roasting and MV-processing, the mass fraction of solids in beetroot puree increases due to moisture evaporation.

The results to determine the mass fraction of solids in beetroot puree during various heat treatment techniques were analyzed in statistical program Minitab 19. For the analysis we have chosen a standard level of significance alpha equal to. To compare treatment techniques variance analysis (ANOVA) was applied. The evaluation of input values quality for the variance analysis showed normal data distribution. The analysis was based on Anderson-Darling test.

The fact that the value of p-probability (0.000) is less of any reasonable alpha-level proves the treatment techniques significantly influence on the content of solid mass fraction. The model obtained is highly valid as it accounts for 99.61% of dispersion. Table 2 outlines average indicators of solid mass fraction in beetroot puree with a standard deviation, as well as confidential intervals, and grouping of treatment methods according to Tukey's honestly significant difference test.

**Table 1.** The influence of the method of heat treatment on the content of betanin in the beetroot puree

Heat Treatment Technique	Content of Betanin, mg per 100 g
Control	654 ± 42
Cooking	348 ± 40
Roasting	366 ± 71
MV-processing, 3 min	602 ± 42
MV-processing, 6 min	595 ± 53
MV-processing, 9 min	513 ± 70
MV-processing, 12 min	410 ± 62



**Figure 2.** Mass fraction of solids in beetroot puree during various heat treatment techniques.

**Table 2.** Results of statistical analysis in Minitab 19 for the indicator of solid mass fraction in beetroot puree during various heat treatment techniques

Technique	Number of measurements	Average values for solid mass fraction	Standard deviation	Confidential intervals	Grouping
1	5	14.3270	0.1869	14.1337; 14.5203	B
2	5	10.1248	0.2025	9.9315; 10.3181	C
3	5	17.0660	0.0958	16.8727; 17.2593	A
4	5	17.3970	0.2850	17.2040; 17.5910	A

To establish statistically significant differences between the four treatment techniques the dispersion analysis of data was performed with Tukey's range test.

The comparison of the treatment techniques and 3 (roasting) and 4 (microwave) revealed there is no statistical difference between these methods, therefore, they belong to the one group, which is A group. Technique 1 (raw beetroot) and technique 2 (cooking) differ from each other and techniques 3 and 4 belonging to groups B and C. Calculated values of probabilities proved the application of treatment techniques 3 and 4 results in equal solid mass fraction in beetroot puree with 98.87% accuracy. The corrected p-probability indicator for the difference between techniques 3 and 4 is 0.086.

As a result of the studies, it was found that the most delicate method of processing beetroot crops is microwave processing for 9 min (power 800 W), at which their culinary readiness is achieved with minimal loss of dry substances, including betanine.

#### The choice of a rational dose of beetroot filler

Ice cream formulations with various mass fraction of the beetroot puree are developed. In all samples, the mass fraction of fat (MFF) was 3.0%, dry skimmed milk residue (DSMR) – 11.5%, the mass fraction of sucrose (MFS) – 15.5% in accordance with GOST 31457-2012 'Ice cream milk, cream and ice cream. Technical conditions'. The dose of beetroot puree was 15, 20 and 25%. An example formulation with 20% excipient is presented in Table 3.

**Table 3.** Ice cream recipe per 1,000 g of mixture

Rawmaterials	Mass, g
Whole milk: MFF = 3.2%; DSMR = 8.2%	547.1
Skimmed milk powder: DSMR = 96%	70.8
Cream: W = MFF%; SOMO = 6.12%	35.7
Beetroot puree: MFS = 6.8%; DS = 17.4%	200.0
Sugar: MFS = 100%	141.4
Stabilizer: DS = 96%	5.0
<b>TOTAL</b>	<b>1,000.0</b>

We studied the effect of the filler dose on the physicochemical parameters of the finished ice cream with beetroot puree addition (Table 4).

**Table 4.** Physico-chemical characteristics of the finished ice cream

Indicators	Control sample	Mass fraction of beetroot puree,%			
		15	20	25	
Conventional viscosity of the mixture for ice cream, c	23±1	26 ± 1	32 ± 1	36 ± 1	
Ice cream overrun, %	71 ± 2	59 ± 1	46 ± 2	35 ± 1	
Resistance to melting, min	soft ice cream	16 ± 0.5	18 ± 0.5	15 ± 0.4	10 ± 0.5
	hardened ice cream	40 ± 0.5	60 ± 0.4	53 ± 0.5	49 ± 0.5
Air bubbles size, mcm	33 ± 2	38 ± 3	50 ± 2	61 ± 2	
Titrateable acidity, ° T	20 ± 1	21 ± 1	22 ± 1	24 ± 1	



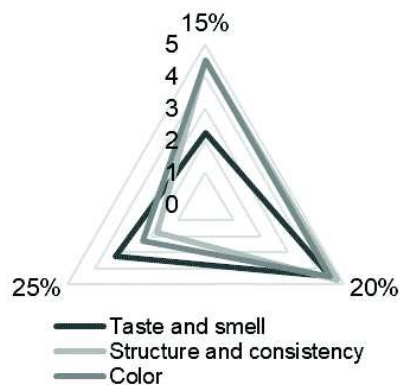
It was noted that an increase in the mass fraction of beetroot puree was accompanied by an increase in the conditional viscosity of the mixture, a decrease in ice cream overrun, an increase in the size of air bubbles, and a decrease in resistance to melting. Neither clear deterioration or improvement was observed.

The decisive criterion in determining the rational dose of beetroot puree was the organoleptic characteristics of the finished product. The results of the organoleptic evaluation of the test samples are presented in Fig. 3.

The ice cream sample with a mass fraction of beetroot puree of 20% received the highest score. Ice cream with a puree mass fraction of 15% is characterized by a less pronounced color, and beetroot taste and smell were practically not felt. An excessively dense consistency was noted in ice cream with 25% puree, beetroot flavor and odor were too pronounced. According to the results of organoleptic studies and physico-chemical indicators, a rational dose of beetroot puree in an ice cream mixture was chosen – 20%.

The studies conducted allow to conclude that the use of Bordeaux beet broadens the horizons in the production of ice cream with original taste characteristics enriching its composition with valuable nutrients.

In literature available there is no research data on application of beetroot products in ice-cream industry.



**Figure 3.** Organoleptic evaluation of hardened ice cream with beetroot puree.

## CONCLUSIONS

Based on the studies conducted the following conclusions have been made:

1. Literature data analysis showed that Bordeaux red beet is a biologically valuable product, the addition of which enriches ice cream with the beneficial ingredients beet roots possess.
2. The heat exposure technique recommended for beetroots is microwave processing for 9 minutes at a power of 800 watts. This type of heat treatment ensures the culinary readiness of vegetable raw materials while preserving dry substances in it, including betanine.
3. The study how the filler dose influences on the formation of the ice cream quality determined 20% as a rational dose of beetroot puree.

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