# DEVELOPMENT OF A TECHNICAL AND TECHNOLOGICAL SOLUTION FOR THE PRODUCTION OF CARROT NECTAR

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**Abstract:** The modern food market forms a need for two trends for the development, production and sale of products: taking into account the demand of consumers and taking into account lack of irreplaceable (functional) micronutrients in the diet of different population groups. It is advisable to develop technical and technological solutions for innovative ideas at a higher institution, which are tested in business incubators (small innovative enterprises) with the interaction of scientists and production workers. The study objects included: the carrots of different varieties of the crop of 2015–2017 grown in the climatic conditions of the Kemerovo region; the syrup based on Lesovichok plant raw materials; pectolytic, amylolytic and cytolytic enzymatic preparations. Modern research methods have been used in the study. The antioxidant activity was determined using the coulometric method; the content of dry soluble substances – using the refractometric method; the size of carrot particles in the semi-finished products and the finished product – by means of microscopy using a CT-2200 electron microscope; the strength characteristics of raw materials – using Structurometer St-1. As a result of the studies, a product with a high antioxidant activity – carrot nectar developed using hybrid technologies – has been obtained. On the basis of the results of the study of the structural and mechanical properties of carrots, two-stage grinding has been proposed with the subsequent biotechnological processing of raw materials (semi-finished products), which provides specified consumer properties. The high antioxidant activity of the developed nectar has been experimentally confirmed.

**Keywords:** Carrot nectar, nutritional value, antioxidant activity, hybrid technologies, innovative project

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## INTRODUCTION

One of the factors contributing to the development of innovative food technologies is the theory of specialized and functional nutrition. This direction is developed by trial and error, but the level of innovative technologies achieved in this area allows us to conclude that it is unconditionally promising. This trend tends to be broadly differentiated; from the idea of balanced mass nutrition to nutrigenomics [1]. The personal approach to nutrition is also conditioned by the physiological and psychological features of food perception and different sensory sensitivity to the same food products.

Summarizing all the trends for the development of specialized and functional food products, two main groups can be distinguished:

– the technology of mechanistic formation of a set of macro- and micronutrients necessary for human life and its addition to a food product [2, 3]. A classic example of this trend is programs for fortifying food with deficient macro- and micronutrients, while food fortification is determined by Codex Alimentarius [4] as " ... adding one or more necessary nutrients to the foods that contain or do not contain these elements in their natural state , aiming to prevent or correct the demonstrated deficiency of one or more necessary nutrients in the population as a whole or in certain population groups ...";

– the technologies based on studying and taking into account the preferences of consumers in the development of food products. These technologies are developed in close cooperation with sociologists, psychologists, marketers and other specialists who actively study such an area as consumption psychology in general and nutrition psychology, in particular [5, 6, 7].

At present, the first trend has a sufficiently developed theoretical, normative-methodological and socio-psychological basis. The disadvantage of this trend is the mainstreaming of general ideas of nutritional science, without taking into account the interests and preferences of the population.

The second trend is only formed as the basic ideas and trends of its development. Its main task is to develop a technology for designing a food product based on the individual or group preferences of consumers. Herewith, in order to develop a competitive product, special attention should be paid to the so-called "trends" – the most popular, fashionable stereotypes of eating behavior. One of the most popular world trends in nutrition was a "healthy diet", the principles of which include the emphasis on increasing the consumption of vegetables rich in fiber, focusing on local raw materials, reducing the proportion of simple carbohydrates in the diet, etc. Considerable attention is paid to the development of foods with high antioxidant activity [8, 9]. In this trend, the task of forming water-disperse stable systems is urgent, in which all the substances necessary for easy uptake contained in native structures have already been revealed. To this end, the development of modern science-intensive technologies for food production is necessary.

Considering the prospects for the production of functional food products, it is advisable to carry out studies in the conditions of business incubators and small innovative enterprises created on the basis of higher institutions. Business incubators are one of the organizational forms for the development of an innovative activity based on the formation of favorable conditions for the development, testing and implementation of innovative ideas. The development of higher institution business incubators, on the one hand, makes it possible to effectively use the intellectual capital and privileges for scientific institutions, on the other hand, it allows to attract young scientists, students and graduate students to innovative activities. The main objective of a business incubator is to help innovators in the most risky period of the formation and development of business; this means when an innovation came out of a scientific laboratory, but an economic study has not yet been obtained for its commercialization.

Open and closed business incubators are designed to create effective small innovative enterprises that develop and test innovative projects taking into account the resources of local industry, intellectual property, etc.

In the regional context, the projects for processing local raw materials that create food products are urgent for the food industry, taking into account the stereotypes of eating behavior based on the production and processing of agricultural raw materials to meet the demand of different groups of the region's population, create new jobs, etc.

The study aims at developing a technical and technological solution for the production of nectar with a high nutritional value from carrots based on the formation of its conceptual image. The study topic corresponds to the priority areas of science, technics and technology and the critical technology of the Russian Federation "Technologies for reducing losses from socially significant diseases".

Carrot nectar with a high nutritional value was developed within the framework of the START grant (H 5 area) of the Fund for the Promotion of the Development of Small Forms of Enterprises in the Scientific and Technical Sphere in the conditions of the BATAT small innovative enterprise (Kemerovo).

The expediency of such a scheme for developing and introducing new food products to the market corresponds to the "science – production – market" industry / region generally accepted in the conditions of innovative development. Abroad, an analogous model – Triple Helix (the triple helix model) – "state – science – business" is effective [10, 11, 12].

## STUDY MATERIALS AND METHODS

The materials of the study at different stages were:

– garden carrot (lat. *Daucus carota subsp. Sativus*) of the varieties Nantes, Toucheon and Forto collected within the period of 2015–2017 on the fields of the Kemerovo Research Institute of Agriculture *(Novostroyka settlement, Kemerovo district)* according to GOST 32284-2013;

– syrup based on medicinal and vegetable raw materials Lesovichok (based on a mixture of extracts from the herbs of yellow melilot (lat. *Melilótus officinális*), peppermint (lat. *Méntha piperíta*), meadowsweet (lat. *Filipéndula ulmária*), wormwood tarragon (lat. *Artemísia dracuncúlus*) and Siberian larch needles (lat. *Lárix sibírica*) according to STO 10912245-2-2009;

– enzyme preparations – alpha amylase ES 3.2.1.1, endo - 1.3 (4) – beta-gluconase ES 3.2.1.6, fructozym (in the modifications of Master, Color and P6L) – produced by Erbsloh Geissenheim AG, Germany.

**Study methods.** The antioxidant activity was determined using the coulometric method of titration according to Fisher with an Expert-006 – antioxidants precision coulometer developed and serially produced by NPK OOO Ekoniks-Ekspert, Moscow, No. 23192-02 in the State Register of Measuring Instruments of the Russian Federation. The studies were carried out according to the methods for determining antioxidant activity (MVI 01-44538054-07). The methods are used to quantify the total antioxidant activity in terms of a standard sample of food products. The instrument is calibrated with a standard rutin sample.

The content of dry soluble substances in the raw materials was determined using the standard refractometric method.

The size of carrot particles in the semi-finished products and the finished product was determined by microscopy using an ST-2200 electron microscope.

The strength characteristics of raw materials were determined using Structurometer St-1. For the purpose of finding and analyzing the strength characteristics of carrots, the loading diagrams were recalculated by means of compression and cutting in the coordinates y–ε and $P_{spec}$–d. The strain was calculated using the formula:

$$y = F/S, \quad (1)$$

where $F$ is force, N; $S$ is the surface area of the sample, $m^2$.

The relative movement $\varepsilon$ was calculated using the formula:

$$\varepsilon = (l_2 - l_1)/l_1, \quad (2)$$

where $l_1$ is the original length of the element; $l_2$ is the length of the element after deformation.

The specific force $P_{spec}$ was calculated using the formula:

$$P_{spec} = P * l\,, \qquad (3)$$

where $P$ is force, N; $l$ is the length of the sample surface under the blade.

The relative movement $\partial$ was calculated using the formula:

$$\partial = l_2 – l_1\,. \qquad (4)$$

To estimate the organoleptic properties of the finished nectar samples, a 20-point scale has been developed to provide the estimation of such parameters as color, appearance and consistency, taste and aroma.

The experiments were carried out in 5–10 fold replicates, the results were processed with the help of the Statistica software package.

## RESULTS AND DISCUSSION

It is known that vegetable juices and nectars are characterized by a high content of a whole complex of essential nutrients including ballast and mineral substances and vitamins. In the conditions of the growing trend of healthy nutrition, consumers' awareness of a need to preserve health, this product is of special importance due to its dietary and prophylactic properties.

Among the biologically active substances contained in vegetable juices, vitamins C, E and provitamin A, which are natural protectors that protect the human body from oxidative damage, are of particular importance. Due to this, on the one hand, the methods for processing raw materials must be effective for the maximal extraction and transfer of biological active substances into the finished product, on the other hand, the production technology should maximize their preservation.

Carrots are a traditional vegetable raw material throughout Russia and are widely used in public catering as an ingredient of dishes and culinary products, however, the assortment of its derivative products (including juices and nectars) in the market is limited. This is due to a number of reasons:

– the features of the anatomical and morphological structure of carrots. The absence of high-tech methods for providing storage at the enterprises results in the fact that the losses during the storage of fresh carrots reach 40%. A way out of this situation can be the processing of carrots in the shortest possible time after harvest, while the content of vitamins and other biologically active substances is maximum;

– the full production cycle of juice from fresh carrots requires a large number of technological operations, which, in comparison with the production of juice products from concentrates, is more costly both in terms of material and time resources, and therefore less attractive to producers;

– juices and nectars from carrots have specific flavor characteristics, which limits their spread in the mass market. This feature can be eliminated by blending carrot juice with the products the taste characteristics of which are more palatable to the consumer, but this can lead to the additional financial and production costs.

The reasons listed above have led to the fact that in the Russian market, the imported carrot juice for baby food is widely offered, as well as the carrot juice of domestic producers in limited quantities, while the sales volumes and assortment cannot meet the growing demand.

While forming the "conceptual image" of the product being developed, the following was taken into account at the design stage:

– the characteristics and features of the choice of raw materials and ingredients with the specified properties that determine the antioxidant properties of the finished products and their storage stability;

– the specificity of the technological regimes and parameters of processing carrots for the purpose of obtaining the sizes of pulp that promote the stabilization of carrot juice consistency during storage;

– the biotechnological ways of processing carrots (using macerating enzyme preparations);

– imparting competitive advantages by improving the consumer properties of the finished product: functional, social, safety, organoleptic, etc.;

– the prospects for including a new product in the preventive programs at a regional and other levels;

– the presence of the novelty of a technical solution for securing intellectual property as a component of an innovative project.

**Study of the structural and mechanical properties of carrots.** The characteristics of carrots that determine the consumer properties of its derivative products are the higher, in comparison with other vegetables, content of solids and a coarse fibrous structure. In this regard, when developing carrot nectar with pulp, special attention was paid to the formation of the optimal consistency of the finished product.

At the first stage, based on the analysis of literature data, the carrots varieties most suitable for nectar production were selected. The comparative characteristics of the composition, weight and size of root crops of eighteen varieties of carrots and their specific features (a keeping quality, juicy pulp, the high content of carotenoids, vitamin C, etc.) made it possible to choose the most appropriate ones: Nantes, Forto and Toucheon. The structural and mechanical properties of the source raw materials were preliminary determined.

When processing rough vegetable raw materials, one of the main tasks is its disintegration. To this end, it is necessary to destroy the native structure to a state when the insoluble dietary fibers are dispersed to sizes from $10^{-4}$ to $10^{-5}$ m and simultaneously bind solidly with the dispersion medium.

The cubes of freshly harvested carrots with a face size of 10 mm and the carrots after 3 months of storage (the storage conditions are 3 ± 1°C and the relative air humidity of 92 ± 1%) – of the varieties Nantes, Forto, Toucheon – were tested. As a result of experimental studies, the loading curves of carrot samples for compression and cutting have been obtained (Figures 1–4).

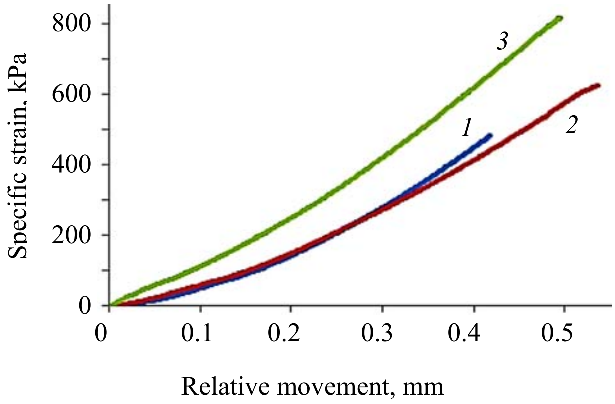



**Fig. 1.** Loading curves for the compression of fresh carrot samples: (*1*) Nantes carrots, (*2*) Forto carrots, (*3*) Toucheon carrots.

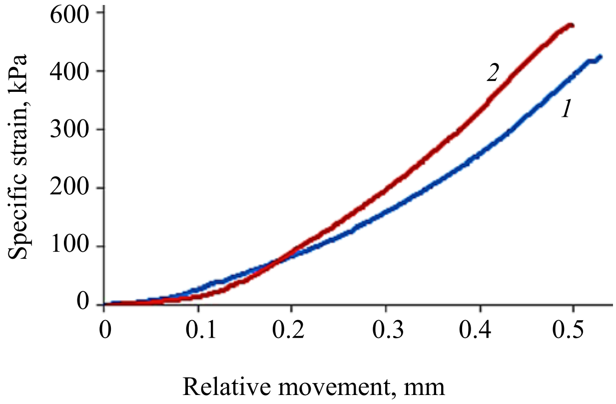



**Fig. 2.** Loading curves for the compression of carrot samples after 3 months of storage (*1*) Nantes carrots, (*2*) Toucheon carrots.

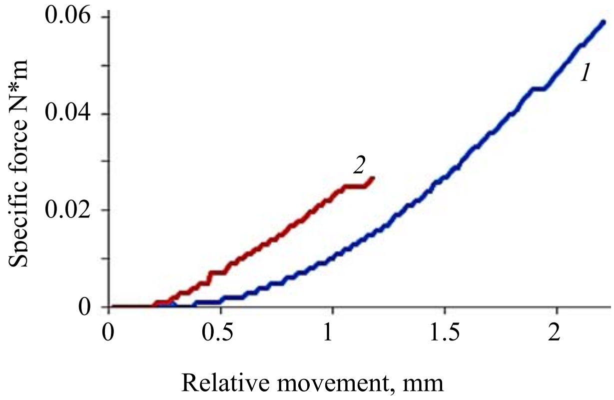



**Fig. 3.** Loading curves for the cutting of fresh carrots samples (*1*) Nantes carrots, (*2*) Forto carrots.

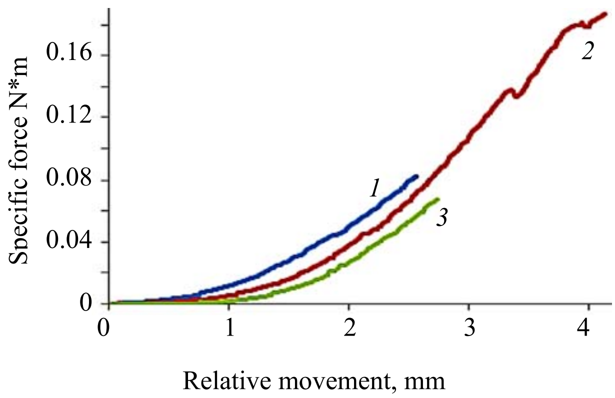



**Fig. 4.** Loading curves for the cutting of carrots samples after 3 months of storage (*1*) Nantes carrots, (*2*) Forto carrots, (*3*) Toucheon carrots.

The nature of graphical dependencies shows that carrots exhibit the nonlinear strength properties described by the Kelvin law regardless of a variety:

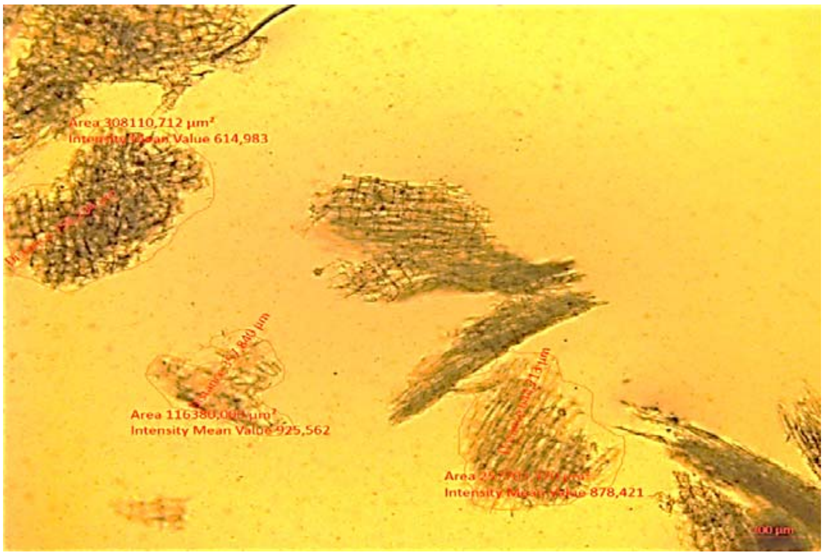
$$\tau_0 = \eta \frac{d\gamma}{dt} - G\gamma , \quad (5)$$

where $\tau = \tau_0 = \text{const}$ is the initial stress applied to the body; $\eta$ is the dynamic viscosity coefficient; $\frac{d\gamma}{dt}$ is the angular deformation velocity; $G$ is the elasticity modulus of the second kind; $\gamma$ is the deformation angle.

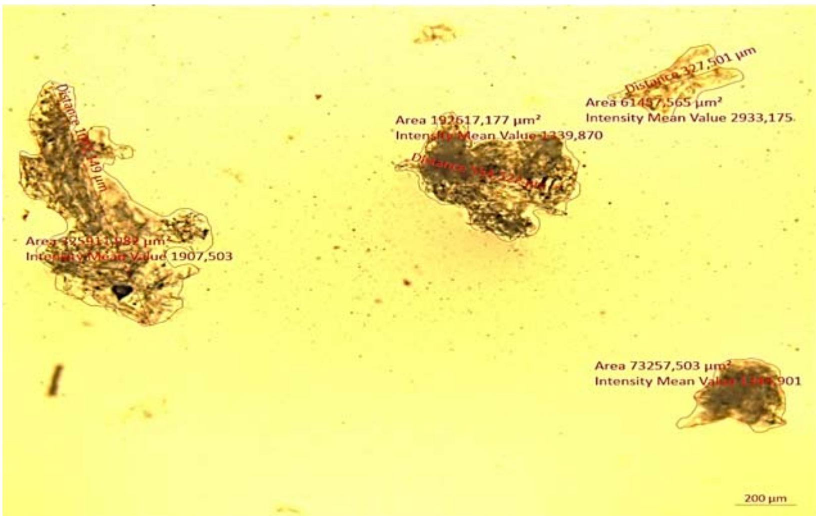
It has also been revealed that carrots exhibit elastic properties with some nonlinearity in individual areas and correspond to a creep curve according to the Kelvin-Voigt model. Herewith, the deviations from the nonlinearity are insignificant and to simplify the calculations, the experimental data were approximated by some linear dependences of the form $y = ax$. Table 1 presents the results of the experiments.

The analysis of the experimental dependences of the strength characteristics of carrots presented in the table allows us to state that, with an increase in deformation velocity, the ultimate failure strain values for carrots increase, reaching their maximum at the average grinding rates, and then decrease, which is explained by the adhesive nature of strength, the presence of natural stress concentrators in the surface interaction zones of material structures both at the micro and macro levels. Thus, the results of carrots study using quasistatic loading allow us to justify the choice of equipment, to reveal the reserves of reducing its material consumption, thereby ensuring significant resources saving, which is of no low importance in the organization of production in the conditions of a small enterprise.

**Determining the carrots grinding parameters.** One of the mandatory technological stages of production of nectars with pulp is the availability of such a technological operation as grinding. The formation of consumer properties of nectars with pulp, especially organoleptic ones, directly depends on a consistency that has a colloidal structure. Such a consistency can be obtained if carrot pulp is ground to a size of 1–10 microns. The available literature data and our own experience show that such a particle size is difficult to obtain using standard grinding methods. The possibility of solving this problem was based on the use of hybrid technologies for processing root crops – combining mechanical grinding and the enzymatic hydrolysis of pulp with the use of pectolytic enzymes.




(a)

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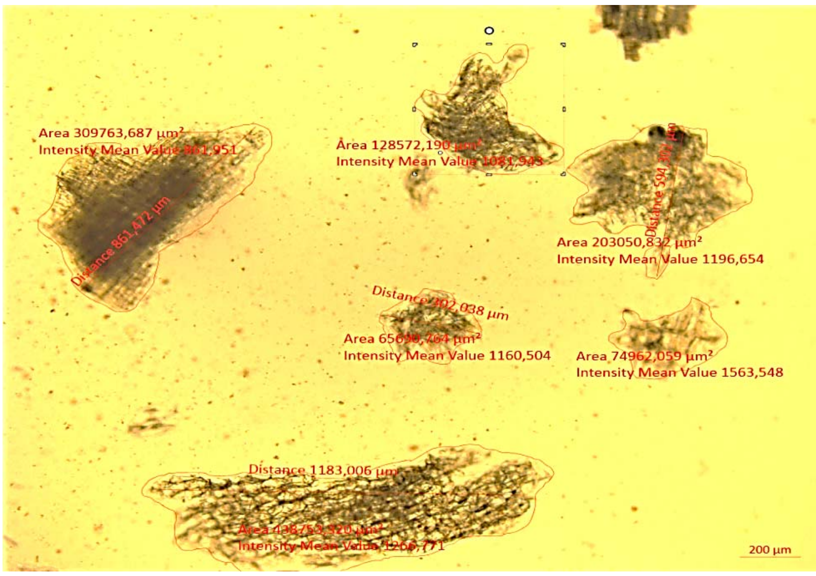



(c)

**Fig. 5.** Nantes, Forto and Toucheon carrots (a, b, c, respectively) after grinding using a centrifugal juicer at a screen rotation rate of 1800 rpm, a 200-fold increase.

**Table 1.** Strength characteristics of carrots

| Variety of carrots | Type of loading | Approximation dependence, y = ax | RMS deviation, $R^2$ | Limiting strain, KPa, | Limiting force, N*m |
|---|---|---|---|---|---|
| *Fresh* | | | | | |
| Nantes | Pressure | y = 955.86x | 0.9128 | 484.0 | – |
| Forto | Pressure | y = 1034.2x | 0.9516 | 628.0 | – |
| Toucheon | Pressure | y = 1505.6x | 0.9757 | 817.0 | – |
| Nantes | Cutting | y = 0.0199x | 0.8281 | – | 0.059 |
| Forto | Cutting | y = 0.0206x | 0.9181 | – | 0.027 |
| *After 3 months of storage* | | | | | |
| Nantes | Cutting | y = 0.0244x | 0.8542 | – | 0.083 |
| Forto | Cutting | y = 0.0355x | 0.8143 | – | 0.187 |
| Toucheon | Cutting | y = 0.0151x | 0.6846 | – | 0.068 |
| Nantes | Pressure | y = 648.9x | 0.9053 | 425.0 | – |
| Toucheon | Pressure | y = 784.24 | 0.8779 | 481.0 | – |

**Table 2.** Structure of carrot pulp of different varieties after grinding using a centrifugal juicer at a screen rotation rate of 1800 rpm

| Variety of carrots | Juice yield, % | % of solids in juice | Average particle length, μm | Average particle area, μm$^2$ |
|---|---|---|---|---|
| Nantes | 55.0 | 9 | 586.3 ± 20.6 | 227397.7 ± 99.3 |
| Forto | 54.5 | 10 | 657.6 ± 39.2 | 163310.5 ± 123.5 |
| Toucheon | 48.0 | 10 | 735.0 ± 37.5 | 203465.0 ± 146.6 |

The algorithm of the carrot processing technology included the initial stage of grinding root crops using a centrifugal juicer at a screen rotation rate of 1800 rpm followed by the separation of pulp and cell sap. Grinding carrots at the indicated parameters promoted the yield of juice from 48 to 55%, depending on a variety. After grinding, the carrot pulp was microscopized at a two-hundred-fold increase, the results are shown in Fig. 5 and in Table 2.

The data presented in the table show that Nantes carrots yield the highest amount of juice – 55%, and Toucheon carrots – the lowest (48%). At the same time, the content of dry substances in carrot juice of different varieties is practically the same and amounts to 9–10%.

The microscopy of carrot pulp after grinding using a centrifugal juicer showed that it was flakes of various shapes. It has been found that the particles most uniform in size and shape are in Nantes carrots, the least uniform – in Toucheon carrots. Thus, various structural and mechanical properties of the carrots of the studied varieties affect juice yield. Since, in the conditions of production, it is practically impossible to process the carrots of only one variety (mixed varieties are used), it is necessary to choose the parameters of a raw material processing technology that level these differences. A hypothesis has been put forward that complex two-step mechanical grinding with the subsequent biochemical effect allows us to obtain nectar with the required organoleptic characteristics.

A rotary disperser (the rotor speed is 1200 rpm) operating in closed mode was used for the fine grinding of carrot pulp. After dispersion, the carrot pulp was microscopized again. When analyzing the results, a reduction in the size of pulp particles to 3–400 microns was established (Fig. 6).

The analysis of distribution of particle sizes of carrot pulp after dispersion showed that 50% of particles have a size of up to 10 μm, the proportion of particles larger than 150 μm is only 5%. Thus, more than 85% of the particles have a size of less than 100 μm. However, in order to form the colloidal structure of pulp to ensure the stability of nectar consistency during storage, it is necessary to increase the number of particles up to 10 μm in size.

**Determination of parameters for carrot pulp maceration.** The efficiency of pulp processing using enzyme preparations in order to increase the yield of juice providing the correct ratio of raw materials: enzyme preparation is confirmed in a number of studies [13, 14]. To achieve the specified level of the particle size of carrot pulp that causes the colloidal stability of the finished product and an increase in the yield of juice from the pulp, it was macerated. It is known that when affected by pectolytic enzymes, the parenchyma tissue cells are partially hydrolized, which contributes to a reduction in the particle size.

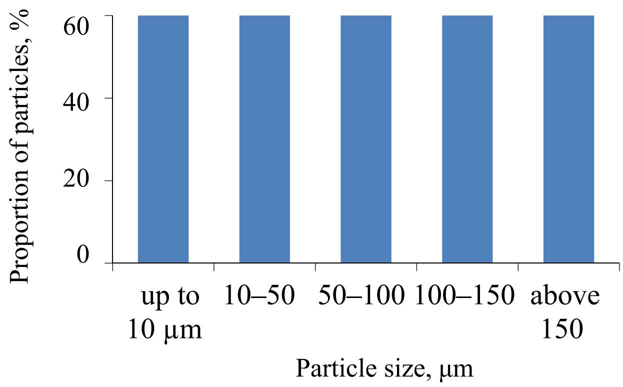



**Fig. 6.** Distribution of particle sizes of carrot pulp after dispersion.

The use of enzyme preparations is a promising research trend in the development of technologies of juice products. The choice of an enzyme preparation in each specific case is determined by the chemical composition of raw materials, their structural and mechanical properties, as well as the desired properties of the finished product. Processing is carried out using both mono preparations and a complex of enzymes that encompass the action of amylolytic, proteolytic, cytolytic, pectolytic and other enzymes. In this case, insoluble high-molecular carbohydrate and protein substances, as well as the substances related to the structural elements of cells, become soluble. The paper studied the effect of five names of enzyme preparations with different characteristics on carrots:

– alpha amylase ES 3.2.1.1 – an enzyme with an endogenous mode of action that catalyzes the hydrolysis of 1.4-glycosidic bonds of starch with the formation of dextrins, oligosaccharides and maltose;

– endo – 1.3 (4) – beta-gluconase ES 3.2.1.6 – an enzyme that catalyzes the hydrolytic cleavage of 1.3-β-D-glycosidic bonds in the structure of β-glucans (the chains of glucose polymers – cellulose and hemicellulose) forming the residues of glucose and oligosaccharides;

– Fructozym Master * – a pectolytic enzymatic preparation used for the maceration of tissue of fruit and vegetable raw materials recommended for puree and juices with pulp;

– Fructozym Color * – a highly concentrated pectolytic enzyme preparation for the production of fruit juices with an intense color, while the dye components are extracted from the pulp and remain stable in juice;

– Fructozym P6L * – an acid-stable pectolytic enzyme preparation (contains pectin esterase, pectin lyase and endo-polygalacturonase) used for the fast and complete destruction of pectin in fruit pulp and fruit juice.

Note: * – the detailed composition of the preparations is a commercial secret of the manufacturer.

To maximize the yield of nutrients from raw materials and accelerate the process of enzymatic hydrolysis of carrots, the optimal processing parameters have been selected: the selection of an enzyme preparation (or complex) has been justified; the optimal pH of the medium has been determined; the temperature mode has been selected; the hydrolysis duration has been established.

As the basic (control) conditions, the conditions recommended for the effective action of enzyme preparations were taken: the temperature is 45–55°C; pH of the medium is 4.8–5.0.

The ground pulp was processed using the abovementioned enzymatic preparations at a concentration of 0.01% of the pulp mass, the incubation was carried out in a thermostat with occasional stirring for 2 hours. The results are presented in Table 3.

As the results show, the maximum yield of carrot juice in comparison with the control sample was obtained using Fructozym Color. A little less was the yield of juice when using the enzymes Fructozym Master and Fructozym R6L. Based on the results obtained for further research, a Fructozym Color enzyme preparation (Erbsloh Geissenheim AG, Germany) has been chosen.

Fructozym Color is a liquid highly concentrated pectolytic enzyme preparation recommended for use in the production of fruit juices with intense color. The experimental studies have shown that the preparation also gives positive results when used in the production of vegetable juices. The advantages of the enzyme preparation is that when using it, the dye components are extracted from the pulp and remain stable in juice, which should be clarified in experimental studies using carrots as an example. The commodity form of the enzyme preparation is liquid concentrate. It has been found that to distribute the enzymatic preparation completely throughout the mass of pulp it should be dissolved in water or juice. In this paper, it was used by diluting it in carrot juice to a concentration of 10%.

When determining the optimal concentration of the enzymatic preparation, 8 samples of the pulp processed with various enzyme concentrations were studied. The processing was carried out at a temperature of 55°C for 2 hours. The enzyme preparation was added at concentrations of 0.001 to 0.1% of the weight of pulp.

The visual estimation of the mass of the fermented pulp allowed us to give a positive estimate, as the appearance became a more homogeneous pureed mass. Based on the complex of organoleptic and instrumental methods for estimation (the yield of solids), the rational concentration of the enzymatic preparation was determined during maceration: 0.005–0.01% to the mass of pulp. The processing was carried out without impairing the organoleptic characteristics of the semi-finished product, a resultant was an increase in the yield of juice. It has been shown that the concentrations of the enzymatic preparation of more than 0.01% make it possible to obtain a pureed pulp consistency, but this is followed by a change in the color of pulp from bright orange to dark orange, the appearance of a bitter aftertaste and unpleasant odor that impair the organoleptic characteristics. This is probably due to the deep hydrolysis of sugars and the formation of oxymethylfurfural.

The established concentration of the enzyme preparation was used during the maceration of samples of the semi-finished carrots of different varieties for 3 hours at a temperature of 55°C. The content of solids in juice was determined every 30 minutes. Fig. 7 presents the results of experimental studies.

**Table 3.** Juice yield from the pulp of Nantes carrots after processing with enzymatic preparations

| Name of the enzyme preparation | Juice yield, % |
|---|---|
| Control | 54 ± 1.2 |
| Alpha amylase | 57 ± 2.0 |
| Endo – 1.3 (4) – beta gluconase | 58 ± 1.4 |
| Fructozym Master | 60 ± 2.1 |
| Fructozym Color | 66 ± 2.1 |
| Fructozym R6L | 61 ± 1.5 |

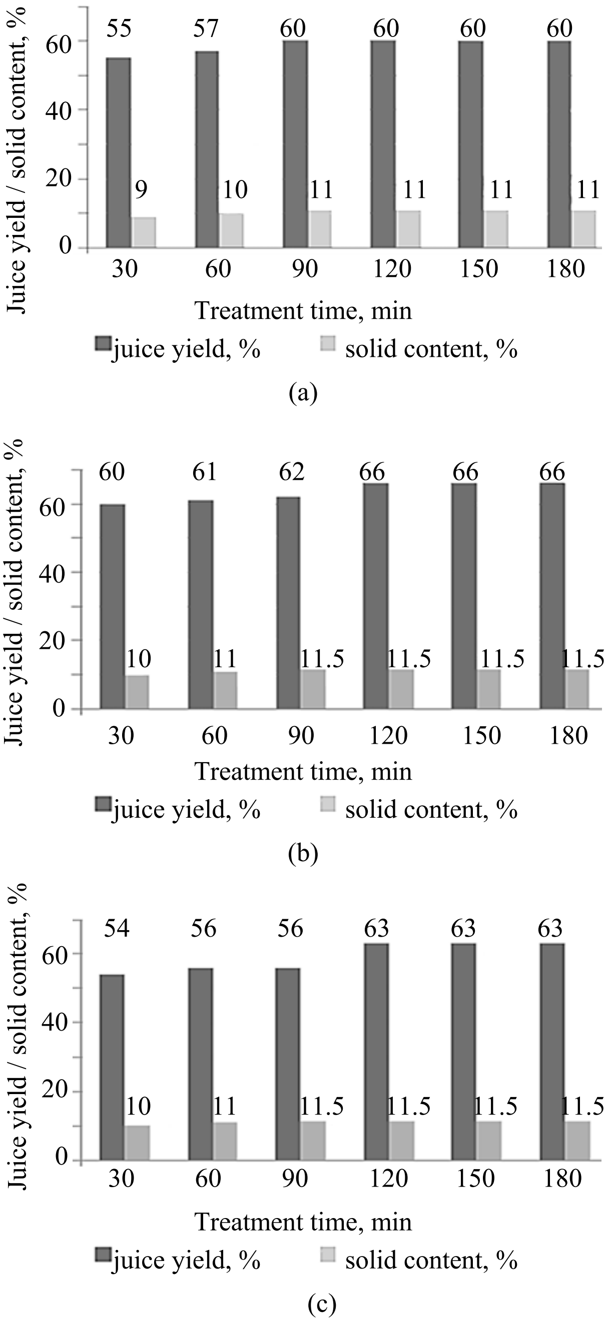



**Fig. 7.** Dynamics of juice yield and solids content during the maceration of pulp of different varieties of carrots using a Fructozym Color enzymatic preparation in an amount of 0.01% of the mass, T = 55°C: (a) Nantes variety carrots, (b) Forto variety carrots, and (c) Toucheon variety carrots.

**Table 6.** Characteristics of the structure of carrot pulp after maceration

| Variety of carrots | Average particle length, μm | Average particle area, $\mu m^2$ |
|---|---|---|
| Nantes | 515.9 ± 18.1 | 200109.9 ± 87.4 |
| Forto | 578.6 ± 34.4 | 143713.2 ± 134.5 |
| Toucheon | 646.8 ± 38.2 | 179049.2 ± 122.9 |

As the provided data show, the increase in maceration duration for more than 120 minutes does not lead to an increase in the yield of juice and an increase in the content of solids. The maximum juice yield is when Forto carrot pulp is processed using an enzymatic product – 66%, processing the pulp of Nantes and Toucheon carrots contributes to the yield of juice of 60% and 63%, respectively. At the same time, the maximum increase in dry substances was in Nantes carrot juice. On average, the use of a Fructozym Color enzyme preparation increases the yield of juice by 6.6 ± 2%, depending on a carrot variety, the growth of dry substances is 1.5– 2.0%.

The use of enzyme preparations in juice production implies their elimination from the finished product by inactivation. To this end, the carrot pulp was heated at a temperature of 90–100°C for 1.5–2.0 minutes and then microscopized using an electron microscope with a two-hundred-fold increase. Fig. 8 and Table 6 present the microscopy results.

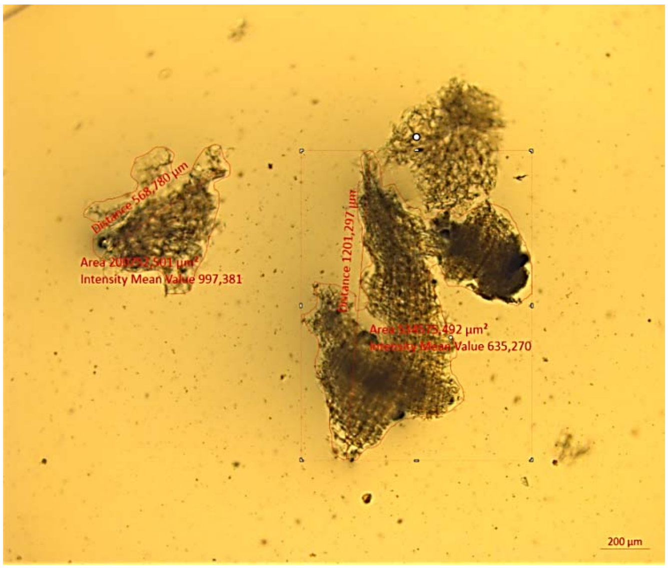
The results show that, as a result of enzymatic processing, the particle sizes of carrot pulp decreased on average by 10–15%. This indicates that in the process of fermentation, there is the surface hydrolysis of parenchyma tissue, which does not significantly affect the size of pulp particles. However, the set parameters are: the increase in juice yield and the increase in solids indicate that hydrolysis is successful. In general, the number of pulp particles with the corresponding specified sizes (less than 10 microns) increased to 75–80%, which indicates the stability of pulp in the finished product.

**Determination of antioxidant activity of the finished product.** Due to the fact that the functional properties of carrots are largely due to the content of carotenoids and vitamin C (soluble biologically active substances excluding cellulose), the high antioxidant activity of carrot nectar due to the complex and synergistic effect of these biologically active substances was initially predicted.

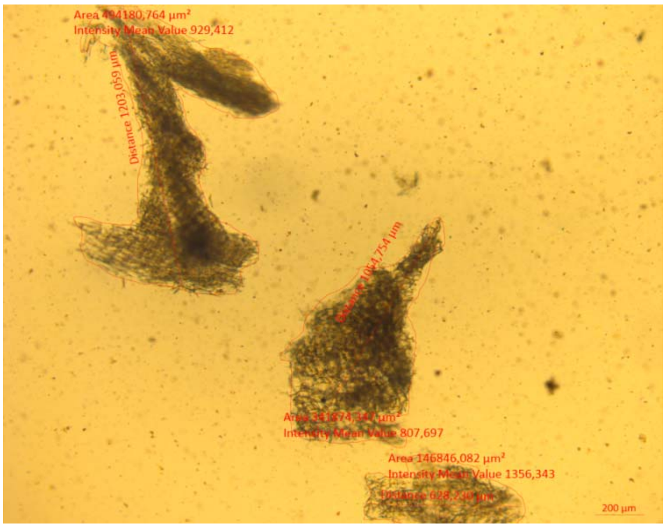
To determine the retention of biologically active substances and confirm the functional orientation of the nectar being developed, the antioxidant activity of carrots was determined before and after maceration, the results of the studies are presented in Table 7.

**Table 7.** Antioxidant activity of carrots before and after maceration

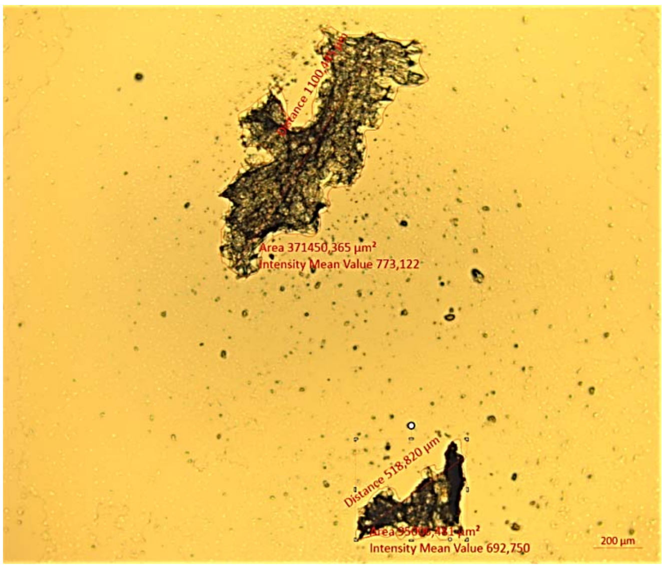
| Variety of carrots | Total antioxidant activity, mg of rutin | Total of carotenoids, mg per 100 g | Content of citric acid, mg per 100 g |
|---|---|---|---|
| *before maceration* | | | |
| Nantes | 161.0 ± 4.4 | 19.7 ± 2.3 | 22.35 ± 0.1 |
| Forto | 129.0 ± 5.4 | 18.3 ± 1.95 | 21.57 ± 0.1 |
| Toucheon | 126.7 ± 7.8 | 18.5 ± 4.6 | 27.43 ± 0.1 |
| *after maceration* | | | |
| Nantes | 172.6 ± 8.3 | 19.8 ± 2.4 | 26.1 ± 0.5 |
| Forto | 144.4 ± 6.85 | 17.9 ± 1.65 | 26.1 ± 0.35 |
| Toucheon | 131.7 ± 7.3 | 18.4 ± 0.41 | 28.1 ± 0.4 |




(a)




(b)




(c)

**Fig. 8.** Fermented carrot pulp, a 200-fold increase: (a) Nantes variety carrots, (b) Forto variety carrots, (c) Toucheon variety carrots.

**Table 8.** Antioxidant activity of ready-made carrot nectar

| Name of the product | Total antioxidant activity, mg of rutin | Total of carotenoids, mg per 100 g | Content of an antioxidant complex, mg per 100 g |
|---|---|---|---|
| *before sterilization* | | | |
| Carrot nectar with Lesovichok syrup | 124.2 ± 6.8 | 15.4 ± 0.56 | 24.8 ± 2.3 |
| *after sterilization* | | | |
| Carrot nectar with Lesovichok syrup | 110.1 ± 4.5 | 12.6 ± 2.1 | 20.2 ± 0.6 |
| *ready-made nectars sold in the market* | | | |
| Tedi carrot nectar, OOO SMP MARK-IV, Russia | 79.8 ± 10.8 | 11.9 ± 2.8 | 18.3 ± 0.67 |
| Gerber apple-carrot juice, Nestle | 81.6 ± 7.3 | 6.3 ± 2.7 | 17.5 ± 1.3 |

Based on the data obtained, it has been established that in the process of maceration, there is a tendency for an increase in the antioxidant activity of the semi-finished product. The basis is the process of hydrolysis when dehydroascorbic acid and other biologically active substances are released from tissue cells. The higher antioxidant activity of Nantes carrots has been noted.

According to the Technical Regulations of the Customs Union TR TS 023/2011 "Technical Regulations for Juice Products from Fruits and Vegetables" the composition of nectar should include at least 25% of puree, and the puree may consist of different proportions of NFC juice and pulp.

The model samples of nectars were prepared from Nantes carrots by mixing the prepared puree with 10% invert sugar syrup in a ratio of 1 : 1, while the puree consisted of different proportions of NFC juice and the prepared pulp, but it was 25% in total. The carrot pulp was added in an amount of 5 to 25% of the volume of nectar, at a pitch of 5%.

The results of the estimation of the expert commission (tasters) made it possible to establish that when pulp is added in an amount of 5–10%, the good organoleptic properties of the finished nectar are formed, the increase in the pulp content from 15 to 25% significantly affects the organoleptic characteristics for the worse. The addition of pulp of 15% and above worsens the consistency of nectar and results in the stratification of mass to a solid and liquid phases. At a pulp concentration of 10% and 15% of NFC juice in the volume of nectar, a stable consistency is formed providing long-lasting resistance.

The demand for juice products from carrots is affected by the specificity of its consumer properties (smell, taste), which necessitates carrot nectar blending. The analysis of the market of juice products in Kemerovo showed that it is mainly carrot juices and nectars that producers blend with apple juice.

In order to provide high consumer properties, it was suggested to use Lesovichok vegetable syrup manufactured at a small enterprise in Novokuznetsk, the Kemerovo region, as an ingredient. The syrup is a mixture of extracts from plant raw materials (yellow melilot herbs, peppermint, Siberian larch, meadowsweet and wormwood tarragon) and sugar syrup with a solids content of 50.5%. The tests carried out earlier in the accredited laboratory of the Rospotrebnadzor territorial directorate in the Kemerovo region confirmed a high content of vitamins and micronutrients, in particular, selenium in the syrup. It was also assumed that the addition of syrup would reduce the sugar laying rate and would have a positive effect on the stability of consistency of the finished nectar.

The choice of the rational amount of the syrup added was carried out on the basis of studying its effect on the organoleptic indicators of the finished nectar. To this end, the syrup was introduced in amounts of 1 to 20% by volume at a pitch of 2.5%, a 20-point scale was used to estimate the consumer properties of samples. The results showed that the syrup content of 5–15% gives the nectar a more pronounced harmonious and mild, nevertheless, recognizable and corresponding to the product name "Carrot nectar" taste. The increase in the proportion of the added syrup to 25% changes the organoleptic properties of nectar towards the predominance of taste qualities of the syrup, there is a change in color along with a change in taste. Given that Lesovichok syrup has a high content of extractives and a specific taste, a syrup sample with a concentration of Lesovichok syrup 15% by volume gained the maximum score – 17.9.

The antioxidant activity (AOA) of the developed product, confirming the functional purpose of nectar before and after heat treatment, was determined. The results are presented in Table 8.

On the one hand, the negative effect of nectar sterilization on antioxidant activity has been established, on the other hand, the sterilization of the product allows to provide microbiological purity and an increase in its shelf life (6 months).

The comparative analysis of the antioxidant activity of the analogues products of different manufacturers sold in the market: Tedi nectar, Gerber apple-carrot juice and the developed carrot nectar showed the advantage of the latter.

Thus, the use of hybrid technologies (the mechanical effect and biotechnological methods for processing raw materials) allowed us to effectively use carrots – vegetable raw materials with complex structural and mechanical properties – to obtain juice products with high consumer properties and functional orientation. The order of methods for affecting carrot pulp using the example of Nantes variety and the size limits of pulp particles ensuring the stability of nectar consistency have been established: the primary mechanical processing of pulp – coarse grinding and dispersion; biotechnological processing – maceration. The novelty of the technical solution is confirmed by Patent No. RU 2493747 "Carrot nectar production method".

It should be borne in mind that the use of multi-level technological methods and methods for processing carrots can lead to the higher costs of the finished products. This makes it advisable to use the search design methods, namely, the functional and physical as well as functional and cost analysis in the development of a technical and technological solution for carrot nectar.

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