UDC 664.075
DOI: 10.15587/1729-4061.2021.247669

COMPARATIVE ASSESSMENT OF THE EFFECT OF THE DEGREE OF GRINDING OF VEGETABLES (CARROTS) ON THE YIELD OF JUICES AND PUREE

Shakir Aliyev
Corresponding author
Doctor of Philosophy in Engineering, Associate Professor
Department of "Machine Engineering and Logistics"*
E-mail: shakiraliyev@mail.ru

Rasim Saidov
Doctor of Technical Sciences, Professor
Department of Engineering and Applied Sciences
Azerbaijan State Economic University
Istiglyaliyat str., 6, Baku, Azerbaijan, AZ 1001

Gabil Mammadov
Doctor of Technical Sciences, Professor**

Musfiq Khalilov
Doctor of Philosophy in Engineering, Associate Professor
Department of "Food Engineering and Expertise"*

Gahira Allahverdiyeva
Doctor of Philosophy in Engineering, Associate Professor**
*University of Technology of Azerbaijan
Sh. I. Khatai ave., 103, Ganja, Azerbaijan, AZ 2011
**Department of "Agricultural machinery"
Azerbaycan State Agrarian University
Ataturk ave., 450, Ganja, Azerbaijan, AZ2000

Some vegetables and fruits are indispensable for the production of a wide range of food, juice and confectionery products, because of their chemical composition and biochemical properties. One of the factors hindering their widespread use in the food industry is the insufficient study of their functional and probiotic properties in the mentioned technological areas. The mechanical properties (approximated dependence, standard deviation, and limit stresses) of the carrot varieties Nantes-5 NABA and Chantenay-2461 intended for juice production have been studied. The enzymatic hydrolysis parameters have been determined based on the parameters of the optimal effect of enzyme preparations. As a result of experimental studies, by determining the extreme loads of squeezing and crushing carrots, the power consumption for grinding carrots was determined.

The structure of the carrot pulp was revealed. The highest juice out yield put was observed in the Nantes-5 NABA variety. To increase the juice yield from the pulp, maceration was applied and parameters of enzymatic hydrolysis were determined. Complex two-stage mechanical grinding allowed the production of juice with high organoleptic properties. Antioxidant activity was determined before and after the maceration of carrots. The mode and parameters of the juice production technology were corrected during the research.

Ready-made pulpy juice samples were tasted and evaluated. The safety of carrot puree during storage has been verified by analytical research data

Keywords: technological processes, approximate dependency, technical means, safety indicators, carrot puree

Received date 26.10.2021
Accepted date 10.12.2021
Published date 28.12.2021

How to Cite: *Aliyev, S., Saidov, R., Mammadov, G., Khalilov, M., Allahverdiyeva, G. (2021). Comparative assessment of the effect of the degree of grinding of vegetables (carrots) on the yield of juices and puree. Eastern-European Journal of Enterprise Technologies, 6 (11 (114)), 60–67. doi: https://doi.org/10.15587/1729-4061.2021.247669*

1. Introduction

The provision of the population with necessary food products is one of the main directions of the social and economic policy of the state. To solve the problems raised in this area, the development of conservation technologies, increasing efficiency based on scientific and technological progress, developing new technological processes and introducing them into production are needed.

Developing new varieties and hybrids, which contain high levels of sugar, protein, vitamins and other substances essential for the human organism, wider use of agricultural plants, and the development of technologies that minimize the loss of biologically active substances in raw materials are the first priorities. From this point of view, attention should be paid not only to the popular fruits, berries, and vegetables but also to the expansion of the range of their products [1]. Canned products provide the population with a more varied, balanced diet. The provision of adequate nutrients to the human organism (to a certain extent, proteins, carbohydrates, and fats) is necessary for normal life activity [2]. The average physiological norm of proteins, fats, and carbohydrates in the daily diet should meet a condition 1:1:4. Vegetables play a crucial role in nutrition along with other nutrients. They provide our organisms with valuable nutrients such as carbohydrates, proteins, fats, vitamins, mineral salts, and organic acids.

It should be noted that many carrot varieties have not yet been studied in terms of their application to existing technological processes. Their use can enhance dietary diversity leading to enrichment of products by biologically active substances or replacing chemical preservatives with natural supplements. The spread of carrot varieties and their comprehensive study contribute to the psychophysiological adaptation of humans to the environment [3].

Carrot is one of the most common root vegetables. Fresh carrot is used in culinary without any processing, in juice production, canned vegetables and carotene production. However, the production of canned products (juice, paste, etc.) from this valuable raw material has not been studied enough. The surface of the carrot is covered with a thin layer of crust. There is a pulp under the crust, rich in nutrients. There is a core in the center of the carrot. The core is relatively less delicious compared with the pulpy section. Carrot contains 4–12 % sugar, 0.4–2.9 % pectin, 2.3–5.6 % nitrogen-free extract, including dextrin and starch, 0.6–1.7 % ash. The total amount of dry matter is about 8–20 %. Carotene and xanthophyll provide different shades of orange to the carrot. The carotene content is 8–10 mg on average and 5.4–19.8 mg in red carrot. Purple carrot is also rich in anthocyanins, while carrots having a green part are rich in chlorophyll pigments.

The content of vitamins per kg of fresh weight is as follows: B1 – 0.3–1.8 mg/kg; B2 – 0.2–0.62; PP – 2.0–14.7; B6 – 1.2–1.4; E–12, pantothenic acid – 2.5–3.5; biotin – 0.025–0.033; folic acid – 1.0–13; ascorbic acid – 20–100. The chemical composition of the carrot depends on its varieties, cultivation conditions, maturity, and other factors. Botanical varieties differ in shape and size, the color of the pulp, the size of the core, the surface condition, the shelf-life and the ripening period.

Depending on the size, carrots are divided into 3 groups: carrots of 3–6 cm length are included in the short or Karotel group, medium-length carrots are 8–20 cm in length, and long carrots are 20–45 cm in length. Most of the varieties belong to the medium-length group. The Karotel group includes Paris Karotel and Khibin varieties. They are easily digested because their pulp is delicate. But they have a short shelf-life. Medium-length varieties – Nantes, Guerande, Guerande 1129, Ukrainian Guerande, Chantenay, and Moscow are late-ripening varieties. They have a cylindrical and conical shape and a good taste. Nantes and Chantenay varieties are long, symmetrical, the pulpy part is delicate and delicious. They have a long shelf-life. The fruit of the Chantenay variety is large, the fruit mass can be up to 400 grams. The Guerande variety has a long shelf-life. The long variety is Flakkee and it is late-ripening, the color is cinnamon red, the shape is conical, the root is smooth.

Deterioration of the ecological situation in the world and the associated level of contamination of food with radionuclides, toxic chemicals, biological agents, microorganisms lead to increasing negative trends in public health. Improving the health of all age groups through high-quality, safe food is a major goal of all governments. Unfortunately, it should be noted that the modern use of agricultural technologies in the cultivation of carrots contributes to their pollution with xenobiotics. Given this circumstance, our technology for processing carrots allows you to reduce the content of such harmful substances in the finished product.

Such technologies, providing the required sterility of the finished product, allow the product to be processed in more moderate heat treatment modes. The development priorities of this field have been chosen as the way of mastering and improving new technologies on the basis of scientific and technical achievements. This way ensures the high quality and reduced safety of canned vegetables based on fundamental research in the field of biochemistry, food chemistry, microbiology, as well as food hygiene. The importance of the results of applied research and some experimental design work on the creation of advanced technology and technical means for the processing of agricultural products should be noted.

The most promising and developed direction of the 21st century is the fast-food industry. At present, a range of "fast" products are processed in the dairy, confectionery, and meat industries. However, in the field of vegetables, the range of such products is very small and additional funds are required for their preparation. Quick to use vegetable products are one of the main priorities of the processing industry. Vegetable products are an important source of vitamins, minerals, amino acids, dietary fiber, and other useful substances. Regular use of them normalizes metabolism, cleanses the body of toxins, carcinogens, and toxic substances.

However, the improvement of production technology and technical means, ensuring high quality, following and management of technical regimes and parameters at all stages of the production process with the extensive use of local raw materials and their inclusion in technological processes are still important problems.

Thus, the improvement of the technology of canning vegetables depends on the solution of a large-scale urgent scientific problem. And this makes it possible to reduce the content of various xenobiotics in the finished product, and the product becomes less hazardous to health.

2. Literature review and problem statement

The paper [4] convincingly demonstrates the perspective of macerating FP Enzyme Preparations for the production of pulpy juices. The authors provide information only on future development prospects. However, no research has been conducted on the technology of maceration of vegetable juices. Throughout the world, most of juice production technologies use concentrated materials [5]. This affects the quality of the finished product in different ways. The authors of this paper use only technology for concentrated vegetables to produce juices. However, the authors do not describe the process of obtaining natural fresh juices.

The methods of mechanical crushing, steam blanching for the production of vegetable juice have been studied in [6]. The main problem here is the degree of grinding. The authors do not disclose how vegetables (carrots) have been ground. Steam blanching is used to produce juices. In steam blanching used for juicing, temperature and pressure play a great role and their regulation is still a problem.

The paper [7] reports the production of concentrated vegetable juices from the original products by thermal concentration with partial removal of water under gentle conditions. The main problem in the production of concentrated vegetable juices is the choice of the sterilization temperature. The temperature should be chosen so as to avoid the caramelization of the products, and the main problem is the regulation of the temperature.

The author has conducted research [8] on some technological operations of production technology to improve the canning of vegetable products. The parameters and prices for maceration, heating, homogenization, and hot filling technological components have not been studied in the research.

The study [9] has been conducted on the extraction of juices from raw materials by high-frequency electrical pulses. During the extraction of juices in this way, the condensers are overloaded, which leads to their failure.

Although the development of technology for fruit and vegetable juices with antioxidant effects has been studied [10], their analytical safety indicators have not been presented. These indicators are important for human health.

3. The aim and objectives of the study

The aim of the study is to substantiate the methods of technological improvement of the production of functionally valuable products in order to expand the processing of vegetable products, on the example of carrots. This will allow expanding the range of food products with a functional purpose, which is very necessary for the rational nutrition of the population.

To achieve this aim, the following objectives are accomplished:

– to study the structural-mechanical properties of raw material (carrots);

– to determine the antioxidant activity of the carrot before and after maceration to find the level of retention of biologically active substances in the production process;

– to improve the mode and parameters of juice production technology in the research process;

– to taste the prepared juice and work out the recommended recipe. To study analytical research indicators when storing carrot puree and analytical research indicators of carrot puree safety.

4. Materials and methods

The main investigated biological product was carrot, its juice, puree, and pulp. The auxiliary products were various fruit juices, pectin, enzyme preparations, and, finally, products made from carrots. The mentioned vegetable products were prepared under laboratory conditions.

Starch is composed of small, rounded and colorless granules in the tissues, located most commonly between the core and the pulp.

There is no starch in the core. Sugars include sucrose (3.5–6 %), glucose (1–2 %) and fructose (0.2–1.9 %). The sugar content is lower at the core in comparison with the outer layer.

To prepare carrot juice, large and juicy carrots were chosen, washed clean under running water, the stalks were cut and carrots were put in a sieve. Carrots were passed through a juicer and filtered out using cheesecloth. The extracted juice was heated to a temperature of 60–70 °C in an enameled pot, filtered through cheesecloth and filled in jars. The juice was then pasteurized in half-liter jars for 20 minutes, in liter jars for 30 minutes, and in three-liter jars for 45–50 minutes.

The intact carrots selected for the puree were well washed, steamed and then peeled.

Peeled carrots were crushed with a grater and cooked. The cooked mass was squeezed and the juice was separated from the solid mass. Apple, quince, cherry and tomato juices were used for blending.

The product was also assessed depending on the components of the raw material (chemical composition and nutritional value). The technological characteristics of the raw materials were also assessed.

Thus, the biological and technological objects of the research were raw materials based on carrots, the used ingredients, their technological characteristics.

The aim was to reduce material loss and increase production efficiency. The selection of varieties for using them as raw materials also plays an important role. Diversity in varieties, raw material transport, temporary storage, processing capacity, nutritional value based on chemical composition, disease resistance and size were considered as critical factors. Different characteristics of the cultivation of the same species in different regions were also detected.

To solve the set tasks in the research work, the following methods were used: analysis, comparison and generalization, modeling, the expert assessment method, and description. Organoleptic, physicochemical, and special research methods were applied for studying the chemical composition of raw material, semi-finished products, and finished products. The antioxidant activity was determined using the coulometric titration method according to Fischer.

The operation principle of the analyzer is based on the application of Faraday's law, according to which the mass of the analyzed substance is determined by the amount of electricity spent in the reaction. The analyzer records the electrolysis time and calculates, according to Faraday's law, the amount of the determined substance contained in the sample introduced into the coulometric cell. The analyzer is designed for coulometric analysis of the analyte amount at a constant current strength (coulometric titration). In this case, a substance is added to the electrolyte, from which, during electrolysis, a certain intermediate component is obtained, capable of relatively quickly and stoichiometrically reacting with the determined substance. The technique is intended for quantitative chemical analysis of the total antioxidant activity under laboratory conditions in terms of a standard sample of food products: vegetable and fruit juices, dried vegetables, fruits, etc. The method is developed in accordance with the State standard.

The content of dry soluble substances in the raw material was found using the refractometric method. The particle sizes of the semi-finished and the finished product were found by the CT-2200 electron microscope. The strength characteristics of the raw materials were determined using a Structure meter device. The organoleptic characteristics of the beverages (appearance, color, taste, aroma) were assessed by a tasting committee following the State standard (GOST R 52474-2005) of the Gabala Cannery (Azerbaijan). The content of beta-carotene in raw materials, semi-finished products, and the finished product was determined by hexane extraction following the protocol.

Microbiological indicators of extracts and beverages. Maximum Allowable Concentration of toxic elements met the requirements of Sanitary rules and regulations (SanPiN 2.3.2.1078-01). Vitamin C was determined by titration with the Tilman's reagent according to GOST 24556-89. The principle of the method is based on the oxidation-reduction reaction between ascorbic acid and the indicator 2,6 dichlorophenolindophenol (Tilman's reagent). The test results were processed using Microsoft Office Excel (USA) and STATISTICA 7.0 software (USA).

5. Results of the effect of grinding degree of vegetables (carrots) on the yield of juices and puree

5. 1. Study of structural-mechanical properties of raw material (carrots)

One of the main operations when producing food from plant raw materials is grinding. The methods of the equipment choice for grinding root vegetables are based on the availability of information on the structural and mechanical properties of raw materials. In this regard, the structural and mechanical properties of carrots were studied for designing the technological line to produce juice. Experimental studies revealed the dependence on loading type during carrot squeezing and cutting. For experiments, 10 mm cubes were taken from fresh and stored carrots. The main objects of the study were Nantes-5 NABA and Chantenay-2461 varieties. The analysis of the study results is presented in Table 1.

Table 1

Toughness characteristics of carrot

No.	Carrot	Impact types	Approximate dependency, $y=ax$	Mean squared deviation, σ	Pressure limit, y, kPa
1	Fresh Nantes-5 NABA	Squeezing	y=956.76x	0.9218	476
2	Fresh Nantes-5 NABA	Cutting	y=0.02x	0.8072	0.061
3	Fresh Nantes-5 NABA	Squeezing	y=649.1x	0.8870	427
4	Fresh Nantes-5 NABA	Cutting	y=0.0264x	0.9047	0.085
5	Fresh Chantenay	Squeezing	y=1034.3x	0.97236	629
6	Fresh Chantenay	Cutting	y=0.0217x	0.9291	0.03
7	Stored Chantenay	Squeezing	y=784.38x	0.888	479
8	Stored Chantenay	Cutting	y=0.0367x	0.8245	0.200

Table 2

The structure of carrot pulp

No.	Carrot	Juice yield, %	Dry matter in juice, %	Average length of particles, μm	Average area of particles, μm^2	Average light transmission
1	Nantes-5 NABA	54.8	9	586.4±21.0	227398.8±99.4	805.7±167.3
2	Chantenay	54.3	10	657.6±38.9	163311.3±122.9	1880.5±750.2

After identifying tension limits in both squeezing and cutting, studies continued to determine the power consumption for carrot grinding. The studies were performed on a laboratory device (cutter). It was found that the maximum power consumption for carrot grinding was 508 W. The rate of rotation of the working part with a knife varied between 1,000 and 1,170 cycles per minute. These results were used in the selection of a grinder for juice production.

To obtain the juice with stable consistency, the carrot pulp should be reduced to 1–10 micrometers. In this regard, a comprehensive approach to grinding vegetables, in other words, mechanical-enzymatic hydrolysis of the pulp→homogenization is recommended.

The selected carrot samples were used in the experiments. To separate the pulp from the juice, the working part of the centrifugal juicer rotated at the rate of 1,800 cycles/minute. The juice yield was 48–55 % depending on the variety.

After grinding, the pulp was observed under a 2x magnification microscope. The results of the study are presented in Table 2.

The highest juice yield was observed in the Nantes variety. The content of dry matter in the carrot juice was 9–10 %. While juice production was high in the Nantes variety, the content of dry matter was relatively low. After grinding, the carrot pulp resembles a straw in various shapes and lengths. The length of the particles in the pulp of the Nantes variety was 586.4±21.0 μm and the area was 227398.8±99.4 μm^2. The average light transmission intensity inversely correlated with the thickness of the particles. Thus, the light transmission intensity of the particles in the Nantes pulp varied between 805.7±167.3. The average length of particles of the Chantenay pulp was 657.6±38.9 μm, the area was 163311.3±122.9 μm^2, and the average light transmission intensity was 1880.5±750.2.

5. 2. Determination of the antioxidant activity of the carrot before and after maceration

We have tested the pulp maceration technology to increase the juice yield. Three different enzyme preparations were used for the experiment. The parameters of enzymatic hydrolysis were determined according to the optimal enzymatic effects (temperature of hydrolysis – 45–55 °C; medium pH – 4.8–5.0). The results of the experimental studies are presented in Table 2.

A maximum juice yield was obtained when using Fructozym Color. Therefore, this preparation was used in subsequent experiments.

The maximum juice yield was obtained from the pulp of the Chantenay variety (67 %), whereas, in the Nantes variety, the juice yield was 60 %. The increase in dry matter was 1.5–2 %. Maximum dry matter growth was observed in the juice of the Nantes variety. In general, maceration increased the juice yield by 6.7±2 % (Table 3).

Subsequent grinding of the carrot pulp was carried out with a cutter. To determine the water ratio, water was added to the crushed mass and grinding was conducted. The volume of the added water increased until the mass of suspended particles form turbulency. The water ratio was 1:3. The ground particles were in the rounded form with a diameter of 3–17 μm. This size of the particles allows forming the colloidal structure of the carrot pulp.

Table 3

Juice yield during enzymatic hydrolysis

No.	Enzyme	Maceration time, min	Juice yield, %
1	Alpha amylase	120	59
5	Fructozym Color	120	67
6	Fructozym P6L	120	63
7	Control	120	55

The complex 2-stage mechanical grinding and biochemical effects enable the production of the juice with high organoleptic quality. The results of the dispersion analysis of the carrot pulp particles ground using this method are shown in Fig. 1.

The analysis of the dispersion of particles after using a cutter showed that the size of 50 % of the particles was up to 10 μm. Thus, the pulp had a colloidal structure. These results of the study form the basis of the technological unit selection for the juice preparation line.

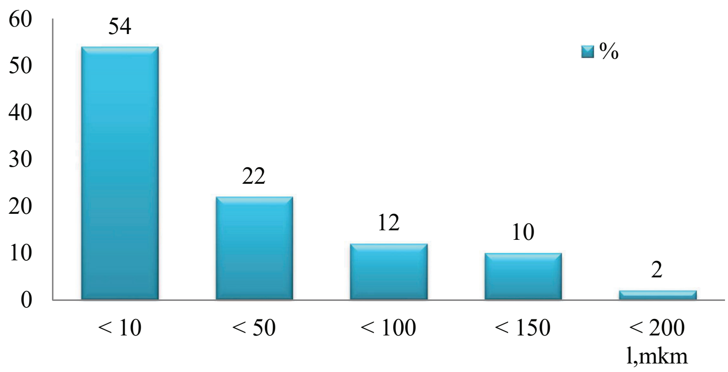

Fig. 1. Dispersity of the carrot pulp particles

To determine the preservation level of biologically active substances in the production process, antioxidant activity was determined before and after the maceration of the carrot. The results of the study are given in Table 4. In the research process, the increasing tendency in antioxidant activity due to releasing biologically active substances was observed.

To preserve biologically active raw materials in the industrial environment, the juice was filled in containers in the hot condition. Under laboratory conditions, the juice samples were sterilized in an autoclave at 100–110 °C for 3 min (Table 4).

Antioxidant activity and preservation of biologically active substances in the finished product are presented in Table 5.

Table 4

Antioxidant activity before and after maceration of the carrot

No.	Product	Total antioxidant activity, per mg rutin		Total carotenoids, mg/100 g	Vitamin "C", mg/100 g
		X	E_n		
1	Nantes before maceration	163±10.3	9.1	26±2.31	24.1±0.14
2	Nantes after maceration	173.4±22.9	17.4	8.2±4.4	25.2±0.6
3	Chantenay before maceration	130±6.6	4.1	13.7±5.1	22.1±0.08
4	Chantenay after maceration	125.6±7.9	6.1	9.1±0.7	26.9±0.42

Table 5

Antioxidant activity in the finished product of juice

No.	Product	Total antioxidant activity, per mg rutin		Total carotenoids, mg/100 g	Vitamin "C", mg/100 g
		X	E_n		
1	Carrot juice with sugar syrup (before sterilization)	125±7.1	9.9	16.5±0.6	25.2±2.2
2	Carrot juice with sugar syrup (after sterilization)	111.2±4.6	3.9	12.94±2.4	21±0.81
3	Carrot juice with orange syrup (after sterilization)	94.7±10.9	9.7	10.3±3.01	20.01±0.6
4	Russian-made carrot juice (nectar)	79.94±11.01	7.9	12.3±3.01	18.5±0.59

The results of the experiments showed that the carrot juice (nectar), processed with sugar syrup and fruit syrup, had 10–15 % more antioxidant activity compared to its foreign analog.

5. 3. Correction of modes and parameters of juice production technology

The modes and parameters of juice production technology were corrected during the research process (Table 6).

The regimes and parameters given in the table have been determined based on the results of the literature analysis and can be clarified under production conditions.

Table 6

Basic modes and parameters of production technology

No.	Technological operations	Modes		
		Parameters	Units	Values
1	Steam peeling	vapor pressure	MPa	0.6–0.8
		effect duration	sec	180
2	Extracting juice	diameter of the hole in the grinder	mm	0.4
		rotation frequency	turn/min	1,800
3	Maceration	temperature	°C	55
		effect duration	min	120
4	Heating (inactivation of enzymes)	temperature	°C	100
		effect duration	sec	2
5	Homogenization	rotation frequency	turn/min	3,000
		temperature	°C	75–115
6	Hot filling	temperature	°C	75
		effect duration	sec	300

5. 4. Study of storage of carrot puree and analytical research of safety indicators

To make the model solution (nectar), carrot puree (Nantes variety) was mixed with 10 % sugar syrup in the 1:1 ratio. In this case, puree contained the juice obtained without squeezing and crushed mass (Table 6).

The analysis of the evaluation results of the tasting commission showed that adding 10–15 % puree to the juice improved the organoleptic properties of the juice (nectar). A 15–25 % increase in the pulp amount leads to the worsening of organoleptic indices. In the case of more than 15 % of the pulp content, the juice was divided into solid and liquid fractions. The juice containing 5 % of the pulp had a more stable concentration (17.6 points) (Table 7).

The syrup was added based on the organoleptic properties of the finished product, that is, 2.5 ml each time, from 1 ml to 20 ml. The optimal amount of the syrup that conferred high organoleptic properties to the final product was 15 %. Further increasing the syrup amount (up to 20–25 %) negatively changed the organoleptic properties of juice-nectar. Given these, the following recipe for carrot juice (Table 8) is recommended.

Not only the taste but also nutritional value and, above all, safety should be included in the evaluation of the finished product. The puree used in the juice was studied in terms of nutrition and safety as it plays an important role in the quality of the final product. The results of the study are presented in Tables 9, 10.

During the storage, the nutritional value of the puree and its biologically active substances were within the limits required by the standard.

During the period of storage, safety control was also performed according to the current regulations. The results are presented in Table 10.

The results of the study of puree obtained from selected carrot varieties show that in view of the quality and safety, the product meets the requirements of the International Fruit and Vegetable Juice Association of juice producers.

The carotenoid content was found to change during puree preparation. Carotenoids include α and β-carotene, lycopene, lutein, cryptoxanthin, etc. The most active among them is β-carotene. It is found in the green parts of the plant, orange fruits and vegetables, aquatic plants, fungi, and bacteria.

Biologically, carotene production depends on some nutritional factors, in particular the structure of food products, and the physical form of carotenoids within the food matrix. The absorption of carotenoids from the raw materials of food can be very low. However, heat treatment, grinding and other methods increase their absorption, facilitating the release of carotenoids from the food matrix. In most varieties, carbohydrates and carotene are accumulated near the crust, which is well developed in carrots.

The daily requirement of the organism for vitamin A is 1.0–2.5 mg or 25.000 IU (international unit). This is equivalent to 6 mg of carotene. The norm of the utilization of vitamin “A” is expressed in IU like all fat-soluble vitamins. 1IU equals 0.3 μg of retinol or 0.6 μg of β-carotene. The amount of β-carotene in carrot puree was determined (Table 11).

Table 9

Indices of the analytical research when storing carrot puree

Carrot species	Months	Soluble dry substances, %	β-carotene	Sucrose, g/dm³	Glucose, g/dm³	Fructose, g/dm³	Citric acid, mg/dm³	L-malic acid, g/dm³	Na, mg/dm³	K, mg/dm³
Nantes	Dec.	8.72	7.61	28.6	10.23	11.87	1.89	1.76	291	1,597
	March	8.64	7.87	27.39	10.32	11.76	1.98	1.72	291	1,596
Chantenay	Dec.	8.81	6.91	27.7	11.69	11.9	1.89	1.75	292	1,595
	March	8.76	6.75	25.79	11.8	11.91	1.97	1.8	303	1,601

Table 10

Analytical indicators of carrot puree safety

Carrot variety	Months	NO_3, mg/kg	Cadmium, mg/kg	Lead, mg/kg	Mercury, mg/kg	Arsenium, mg/kg	Pesticides, mg/kg	Radionuclides, BK
Nantes-5 NABA	Dec.	128.1	none	none	none	none	none	none
	March	126.3	none	none	none	none	none	none
Chantenay	Dec.	162.7	none	none	none	none	none	none
	March	164.4	none	none	none	none	none	none

The amount of β-carotene in the varieties studied corresponds to the nutritional norms of both children and adults.

According to the indices, Chantenay can be considered suitable for use in products that are needed to be enriched with nutrients. Despite the relatively low β-carotene content in Nantes-5 NABA, it corresponds to the daily dietary norm. The daily norm of an adult person for dietary fiber is 25–30 g. The main source of food fibers is cereals, vegetables, and fruits. Food fibers affect the function of the large intestine. They improve the digestive process and the secretion of bile and play an important role in the treatment of constipation and hemorrhoids. Food fibers are able to absorb the products of the metabolism of microorganisms, bile acids, and salts of heavy metals.

The amount of food fibers in the selected carrots is shown in Table 12 and Fig. 2.

Table 7

Tasting points of the pulpy juice samples

Sample number	Amounts of components, %: Inverted sugar syrup, 10 %	Finished puree	Directly extracted juice	Total evaluation points
1	50	5	45	16.6±1.5
2	50	10	40	16.8±0.91
3	50	15	35	14.07±0.5
4	50	20	30	13±1.8
5	50	25	25	12.21±2.75

Table 8

Recommended recipe for carrot juice (nectar)

No.	Components	Unit	Amount	Amount of the dry matter, %
1	Extracted carrot juice	dm³	450	9.2
2	Carrot puree	dm³	50	12.3
3	Sugar syrup	dm³	62	65.3
4	Orange syrup	dm³	15	51
5	Water	dm³	423	0
	Total	dm³	1,000	18

Table 11

Amount of β-carotene in carrot fruit and puree, %

No.	Carrot variety	Fruit	Puree
1	Nantes	11.7	7.61
2	Chantenay	12.8	8.8

As seen in Fig. 2, similar amounts of fiber were found in the carrot varieties.

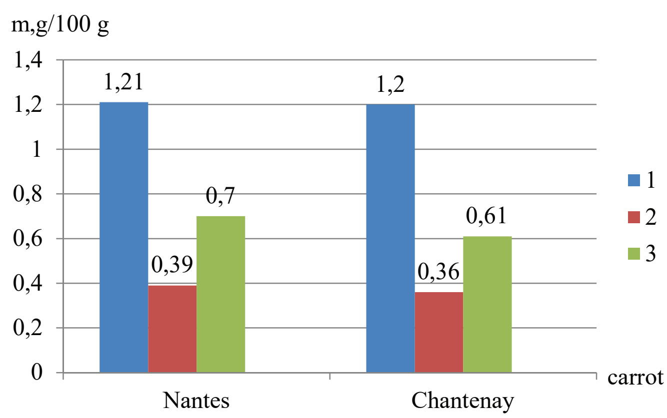

Fig. 2. Amount of fiber in carrot puree: 1 — cellulose; 2 — hemicellulose; 3 — pectin

Table 12

Amount of fiber in carrot, g/100 g

No.	Amount of fiber	Nantes-5 NABA	Chantenay
1	Cellulose	1.21	1.2
2	Hemicellulose	0.39	0.36
3	Pectin	0.7	0.61

6. Discussion of experimental results on the effect of the grinding degree of carrots on the yield of juices and puree

The results obtained are explained by the enrichment of food products with biologically active additives, in particular, carotene-containing raw materials – carrots (Table 12). Providing the population with functional food is known to be a priority for all states today. The choice of grinding equipment based on the study of the structural and mechanical properties of the raw material is a peculiarity of the proposed method. According to the results (Tables 1, 2), this method can also be applied to the processing of various raw materials. The research was carried out with only two varieties of carrots Nantes-5 NABA and Chantenay grown in different places. Therefore, depending on the growing medium of different varieties, the results could differ slightly. In general, the applied method can be considered effective. Although grinding raw materials solved the problem, the results with grinding can be further improved in the future. Based on the study of the structural and mechanical properties of carrots and the selection of parameters of maceration, a complex approach to the formation of sizes of pulp particles is proposed.

This approach includes mechanical and biochemical (enzymatic hydrolysis) effects on the carrot pulp. As a result of the experimental studies carried out by quasi-static loading, the strength characteristics of plant raw materials have been determined (Table 3). The analysis of the obtained experimental dependences of the strength characteristics allows us to suggest that with an increase in the deformation rate, the limiting fracture stresses of materials of plant origin increase, reaching a maximum at average grinding rates, and then decrease, which is attributed to the adhesive nature of strength in plant raw materials, the presence of natural stress concentrators in the surface zones of interactions of material structures at both micro and macro levels. Vegetable juices and nectars, depending on the content of suspended particles, can exhibit true viscous, structurally viscous, or plastic properties, and occupy an intermediate position (Fig. 1). Thus, vegetable juices clarified to a transparent state have truly viscous properties, that is, they are Newtonian fluids, and unclarified juices with pulp lose their true viscosity while acquiring structural and plastic properties to a certain degree (depending on the suspension content). The stability of the suspension in such juices with pulp is achieved with great difficulty and depends on the content of suspended solid particles in the liquid phase, as well as on the ratio between the amounts of pulp and liquid phase. Instability, expressed in the formation of suspended associates of dissolved colloidal particles, which then sediment more or less quickly, often occurs at the stage of conservation. The shape of dispersed particles, their size distribution, hydration shells on the surface of particles, the nature, and content of plant colloids –all these affect the stability of the suspension.

The results obtained on the structural and mechanical characteristics of carrots in order to obtain juice from them according to the described method have advantages over the methods of processing raw materials of other authors [2, 3]. The use of physical and chemical methods of processing raw materials improves both the appearance and the chemical composition of the juice, thanks to the use of gentle processing modes.

The experiments carried out took into account the missing elements of early research. The main feature of obtaining juice from carrots is a high degree of grinding of raw materials, as well as the use of enzymatic hydrolysis (Table 3), which contribute to obtaining a finished product with good quality.

The study of the composition of carrot puree by dietary fiber once again proves the unsurpassed usefulness of raw materials and juice (Fig. 2). Technological processing of carrots in the modes established by us makes it possible to have less impact on the environment. The results of the analyses of the authors [8] show that such operations as homogenization, maceration, hot filling have not been fully investigated.

The problem with the above technology is the long blanching of raw materials, since any heat treatment negatively affects the quality of the product.

Comparative analysis of the antioxidant activity of both raw carrots and finished carrot juice (Tables 4, 5) in terms of the content of carotenoids and ascorbic acid showed the importance of using the above method to obtain a quality product.

It should be noted that the limitation of the above-described technology is the long blanching of raw materials, since any heat treatment negatively affects the quality of the product, the results of which is a decrease in the amount of biologically active components. The successful practical application of this method consists in further improving the corresponding technological parameters of the production of the finished product to achieve greater preservation of useful substances with lower energy consumption.

The best indicator is an excellent product. The characteristics of equipment in terms of the degree of grinding should be improved taking into account the physical and mechanical structures of raw materials, as well as enrichment of products using various raw materials for limiting biologically active components. This variety will make it possible to further expand the range of the product. The development of new technological methods for gaining enriched products will allow modernizing the existing technologies for providing the population with rational nutrition.

7. Conclusions

1. The complex two-stage mechanical crushing and biochemical effect were found to allow the preparation of juice with high organoleptic properties. Pulp maceration was examined to increase the juice yield from the pulp. Using six different enzyme preparations, enzymatic hydrolysis parameters (hydrolysis temperature regime – 45–55 °C; ambient pH – 4.8–5.0) were determined according to the parameters of the optimal effect of the enzyme preparations.

2. To assess the level of retention of biologically active substances in the production process, the antioxidant activity was determined in both carrot varieties up to (163±10.3

and 130±6.6 per mg rutin, respectively) and after maceration (173.4±22.9 and 125.6±7.9 per mg rutin).

3. In the course of the research, the regime and parameters of the juice production technology were adjusted. It was found that the maximum yield of juice (67 %) is provided when using Fructozym Color. Therefore, this preparation was used in subsequent experiments. In terms of carrot varieties, most of the juice is obtained from Chantenay (67 %). The use of maceration increased the juice yield by 6.7=2 % (Table 3).

4. Both nutritional and safety aspects of the studied foodstuffs were investigated and formulated. Considering that the method of processing raw materials according to the outlined technological approach makes it possible to reduce the loss of antioxidant activity of valuable components such as carotenoids and ascorbic acid (Tables 4, 5). And also research to study the content of dietary fiber showed that in carrot puree both types of cellulose are more (1.21 and 1.2/100 g, respectively) than hemicellulose (0.39 and 0.36/100 g) and pectin (0.70 and 0.61/100 g).

Acknowledgments

I would like to thank the Department of Food Engineering and Expertise of the Azerbaijan University of Technology and the Gilan Gabala Cannery (Azerbaijan) for their support in conducting the research.

References

1. Abasov, İ. D. (2013). Azərbaycanin və dünyaölkələrinin kənd təsərrüfatı. Bakı: Elm vətəhsil, 712. Available at: http://anl.az/el/Kitab/2013/Azf-273080.pdf
2. Fətəliyev, H. A., Əsgərova, İ. Ə. (2017). Meyvə və tərəvəzlərin emalı texnologiyası. Dərsvəsaiti. Bakı: Ecoprint, 368.
3. Aamodt, A., Magnus, E. M., Færgestad, E. M. (2004). Effect of Protein Quality, Protein Content, Bran Addition, DATEM, Proving Time, and Their Interaction on Hearth Bread. Cereal Chemistry Journal, 81 (6), 722–734. doi: http://doi.org/10.1094/cchem.2004.81.6.722
4. Rimareva, L. V., Serba, E. M., Sokolova, E. N., Borshcheva, Yu. A., Ignatova, N. I. (2017). Enzyme preparations and biocatalytic processes in the food industry. Problems of Nutrition, 86 (5), 62–74. doi: https://doi.org/10.24411/0042-8833-2017-00078
5. Cassano, A., Drioli, E., Galaverna, G., Marchelli, R., Di Silvestro, G., Cagnasso, P. (2003). Clarification and concentration of citrus and carrot juices by integrated membrane processes. Journal of Food Engineering, 57 (2), 153–163. doi: http://doi.org/10.1016/s0260-8774(02)00293-5
6. Omarov, M. M., Islamov, M. N., Abdulkhalikov, Z. A. (2013). Tekhnologiia proizvodstva kupazhirovannogo soka iz morkovi i stolovoi svekly. Pivo i napitki, 5, 30–31.
7. Harshul, M. V., Kyle William S. A., Small Darryl, M. (1999). Acomparative study of three blanch ingmet hodson whole carrot (Daucuscarota L) processing. Journal of Food Science, 21 (5), 122–134.
8. Əliyev, Ş. H. (2016). Tərəvəz məhsullarının konservləşdirilməsinin təkmilləşdirilməsi. Beynəlxalqelmi – praktik konfransın materialları. Gəncə: AKTA nəşriyyatı, 258–261.
9. Aliyev, Sh. G. (2014). The energy intensity of leakage of juice from vegetables. Ahrarnaia nauka, 10, 31–32. Available at: www.elibrary.ru/item.asp?id=22477770
10. Kornen, N. N., Lukianenko, M. V., Shakhrai, T. A. (2017). Antioksidantnaia aktivnost pischevykh dobavok, poluchennykh iz vtorichnykh rastitelnykh resursov. Nauchnyi zhurnal KubGAU, 126 (2). Available at: https://cyberleninka.ru/article/n/antioksidantnaya-aktivnost-pischevyh-dobavok-poluchennyh-iz-vtorichnyh-rastitelnyh-resursov