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DEVISING MANUFACTURING TECHNIQUES FOR MAKING CULINARY MEALS USING VEGETABLE CONCENTRATES

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It is known that the vegetable concentrates' composition includes dietary fibers, micro-elements, color-forming substances, which can be successfully used as a substitute for the main substance in a formulation. This paper reports the development of a technique to process vegetables into vegetable semi-finished products, the formulations of culinary meals based on vegetable concentrates, as well as the techniques of their heat treatment using electrocontact heating (ECH).

A technique to process vegetables into vegetable semi-finished products using carrot as an example implies the separation of raw materials into juice and pomace followed by separate processing of each component. Depending on the technological tasks, it is possible to obtain a vegetable concentrate by mixing juice and dried pomace. The colorimetric quality assessment has helped establish the parameters for juice and pomace processing. A carrot-based concentrate has been studied in terms of the content of the dried pomace. It was established that adding it improves the quality of the product, namely the brightness and color purity become better.

It has been proposed to use carrot pomace in the formulations for different culinary meals provided the heat treatment process is intensified by combining convective heating and ECH. Carrot pomace was used in formulations for several culinary meals (rice pudding, millet balls, as well as unleavened pastry).

The combined thermal treatment of experimental products involving ECH provided several advantages in terms of the technological indicators, namely: the duration of heat treatment decreases by 20...40 %, the output increases by 10...20 %, and energy consumption decreases by 23...32 %, which is an argument for its application.

Based on the organoleptic assessment, it was noted that, in addition to the taste inherent in these products, the resulting products acquired a kind of pleasant taste of carrot, the increased juiciness and tenderness, which can attract the consumer

Keywords: carrot pomace, vacuum vibration drying, colorimetric assessment, beta-carotene, electrocontact heating

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1. Introduction

Making fruit and vegetable juices, as well as sugar production, are accompanied by a large amount of waste, in particular in the form of pomace. In most cases, this raw material is to be disposed of. However, it should be noted that the vegetable pomace's composition includes dietary fibers, micro-elements, color-forming substances, which can be used quite successfully in the food industry. They are applied as a structure-forming agent, a moisture retainer, a substitute for the main substance in a formulation of, for example, flour or cereals, a source of dietary fibers, a colorant, etc.

However, there is currently no conceptual approach to processing and comprehensive use of vegetable pomace. It is known that pomace is a material that deteriorates quickly enough, resulting in its complicated further processing. In this regard, it is a relevant scientific and applied task to devise a required set of technological procedures for processing vegetables, namely vegetable pomace.

2. Literature review and problem statement

Paper [1] examines processing techniques, investigates the regimes and the influence of drying on the preservation of biologically active substances and color-forming components of beet. The authors of work [2] proposed new unique technology for processing plant raw materials into semi-finished products with enhanced biological value. At the same time, the issues concerning the compliance of the received raw materials with colorimetric quality indicators remain unresolved. A variant to overcome the appropriate difficulties may be to apply a systematic approach to the processing of vegetable raw materials, namely the use of vacuum technology at different stages of processing for storing color-forming components. That is, both liquid fraction and pomace should be processed using certain temperatures (up to 55 °C), without air access. This approach was applied in study [3] but the described processing technique can be used only for liquid fractions. That allows us to argue that it is advisable to conduct a study on the development of a comprehensive low-waste method to process fruit and vegetable raw materials using vacuum technology.

Work [4] confirms the expediency of using concentrated fruit and vegetable pastes in the formulations of confectionery using marshmallows as an example, which could provide consumers with food containing the physiological and functional ingredients of natural origin. Consequently, of scientific interest is the further use of the resulting concentrated raw materials as a substitute for the basic components of the formulation. In addition, a problematic issue is to bring the resulting semi-finished products to culinary readiness at the rational parameters of heat treatment.

It is known from [5] that the positive impact on the intensification of heat treatment processes by reducing the process, by controlling and adjusting temperature regimes, etc. is exerted by the combined techniques involving electrophysical methods. Such methods differ by the oscillation frequency of electromagnetic fields and by the method of influence on the object. Special attention should be paid to the contact influence by an electric current, that is, ECH. Obtaining internal energy when using this method, throughout the entire volume of a semi-finished product, is an important advantage. The application of ECH or "ohmic heating" is described in paper [6] as an alternative way of heating food. From a physical point of view, ECH is based on passing an electric current through a food product that has electrical resistance. At the same time, electric energy is converted into thermal energy directly in the conductive environment [7] at a uniform heating speed [8]. The ECH studies are primarily aimed at establishing the effect of AC frequency on the process implementation [9] and the presence of harmful electrolysis products during such heating [10]. When using an AC low-frequency electric current within 50...60 Hz, no accumulation of electrolysis products is observed. At the same time, there is an increase in moisture retention and, consequently, in the output of finished products, as well as an increase in the specific electrical conductivity, which generally intensifies the heating process. However, the issue, which has not so far been resolved by the authors of the cited studies, is the lack of generalized recommendations on the ECH parameters, in particular guidelines for using a certain value of the electric current voltage for individual culinary meals. This issue can be resolved through a comprehensive study of a wide range of culinary meals at different ECH parameters by selecting their rational values, in particular, voltage and cooking time.

Thus, there is an issue related to the use of concentrated raw materials as a substitute for the basic components in the formulation of culinary meals. It is possible to intensify the heat treatment processes by applying the combined heating technique involving ECH, which has no generalized recommendations on the parameters of such processing. It is advisable to conduct a study into the processes of the heat treatment of culinary meals based on vegetable concentrates at different ECH parameters, which could help achieve the effect of intensification.

3. The aim and objectives of the study

The aim of this work is to devise manufacturing techniques to prepare culinary meals using vegetable concentrates.

To achieve the set aim, the following tasks have been solved:

– to devise a technique to produce a vegetable concentrate from carrot;

– to examine the qualitative indicators of the resulting concentrate: the content of beta-carotene; to conduct a colorimetric assessment of the quality of pomace depending on drying modes, namely the amplitude and frequency; to investigate microbiological indicators;

– to design manufacturing techniques for the preparation of culinary meals using a vegetable concentrate made from carrot;

– to investigate the process of combined heat treatment of culinary meals using a vegetable concentrate with the application of ECH.

4. Methods to study the qualitative characteristics of products and the combined heat treatment

4. 1. A method for studying the β-carotene content in carrot pomace

Samples of carrot pomace were used to determine the total number of carotenoids. A certain amount of crushed fresh plant material using a solvent (hexane) is taken to a porcelain mortar and rubbed with the addition of quartz sand and anhydrous sodium sulfate. The procedure for determining the β-carotene content in carrot pomace is described in [11].

4. 2. A procedure for determining colorimetric characteristics of the resulting concentrates made from vegetable raw materials

One of the issues when storing and processing food products based on natural raw materials is the change in quality properties, especially color. This predetermines the need to analyze techniques for determining the color properties of the raw materials in order to find a cheaper express method [12].

The color characteristics of the samples were determined on the basis of a CIE *XYZ* method (International Coordinate System), underlying which is a tricolorimetric color model. Blue, green, and red are basic colors; other colors are formed by mixing the basic colors in corresponding ratios, which are determined by the coloration coordinates x, y, z. If the sum is $1{:}x+y+z=1$, the color, in this case, is white [13]. At the same time, the colored surface is perceived in its specific color due to the reflection of light at a certain length; all other waves are absorbed.

The method makes it possible to acquire reflection spectra for opaque substances and materials by measuring the spectral coefficient of diffusion reflection R_λ (reflection) [14].

4. 3. A procedure to study combined heat treatment involving electrocontact heating

Our experimental study into the combined heat treatment involving ECH under a heating mode with convection was carried out at a laboratory bench whose principle of operation is given in [15]. The research methodology is as follows. A control unit was used to establish the power of convective heating. A generator set the frequency of changes in the electric current while the regulator set the ECH voltage. Next, the working volume was heated to a temperature of 180 °C. After that, the semi-finished product with the temperature sensor inserted was placed in the body. The closed body was placed in a thermal insulation casing. The ECH was switched on at the control unit. Heating power was measured by a wattmeter connected to the electrical circuit. Heat treatment time was recorded with a stopwatch. At the time of reaching the required temperature inside the product, the heat treatment was stopped; having opened the body, the finished product was removed. At the known processing time, the amount of energy used (determined by the indicators of the wattmeter), and the mass of the semi-finished product, we defined the specific consumption of heat (kJ/kg).

The weight of the semi-finished products was determined before and after the heat treatment by weighing the finished products. The weight difference was used to determine the loss of moisture and the percentage of product output.

4. 4. A procedure to study the quality of finished products

Our study of the microbiological indicators was carried out in accordance with the "Medical and biological requirements". The preparation of nutrient environments, solutions of reagents, colorants, and indicators used in the microbiological analysis was carried out according to [16]. Sampling for the microbiological research was carried out based on [17]. The preparation of samples for the microbiological tests was carried out in accordance with [18]. To obtain the average sample, we selected the samples from three products of the same type and mixed them.

The number of mesophilic aerobic and optional-anaerobic microorganisms was determined according to the standard given in [19]. The presence of Escherichia coli bacteria was determined according to standard procedures. Thus, the detection of golden staphylococcus was carried out according to [20]. The presence of Proteus was determined according to [21]. [22] The detection of pathogenic microorganisms, including the Salmonella genus, was carried out in accordance with [22].

The quality of the finished products in terms of the organoleptic indicators was assessed in accordance with the procedure given in [23] taking into consideration the significance factor of each indicator: appearance, appearance at the cross-section, smell, taste, color, consistency.

5. Results of studying the qualitative characteristics of products and the combined heat treatment

5. 1. Devising a technique to produce vegetable concentrate from carrot

The technique shown in Fig. 1 has been proposed to produce vegetable concentrates from carrots.

The technique includes the following main stages: the preparation of vegetable raw materials, grinding, the separation of the bulk into juice and pomace, juice filtering. Next, the juice is to be concentrated to the content of dry substances $C_{c.p.}$=70 % by boiling under a vacuum. The pomace after separation of juice is subject to grinding and subsequent vacuum drying to the content of dry substances $C_{c.p.}$=90 %. Depending on the manufacturing tasks, the mixing of the concentrated juice with the dried pomace is implied.

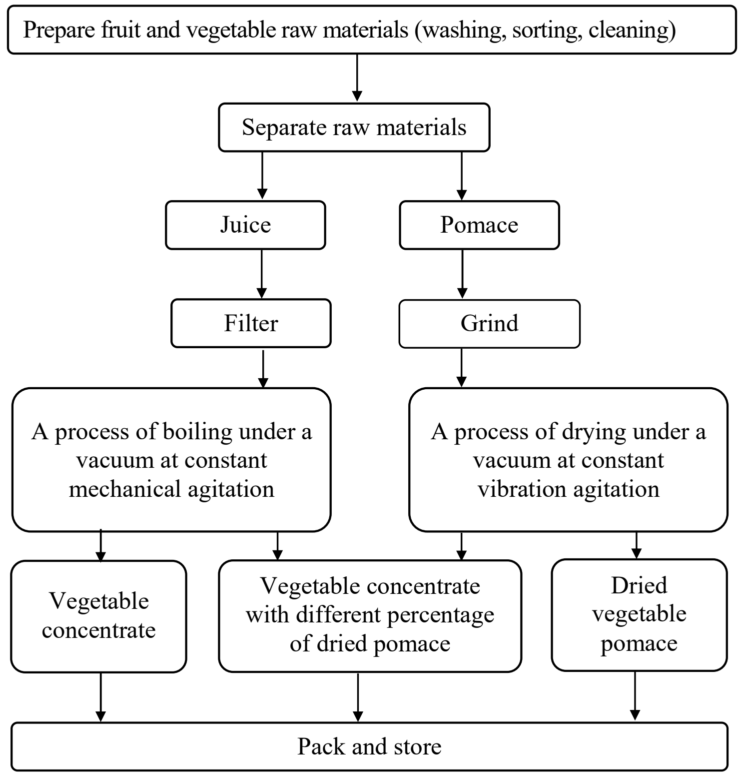


Fig. 1. A technique to produce concentrates from carrot

5. 2. Studying the quality indicators of vegetable concentrate made from carrot

The main result of our study aimed at devising a principal technological scheme is the expansion of the range of vegetable concentrates. By using the rational modes of heat and mass-exchange treatment, we improve the quality of the resulting products by boiling and drying under a vacuum at constant agitation. This approach ensures a high degree of preservation of the organoleptic and colorimetric properties of finished products [3]. The application of vacuum during the drying of pomace provided for the high quality of the resulting product, which was proven by the investigated color, chemical, and microbiological indicators (Tables 1, 2). The mode parameters of drying are given in Table 3.

Table 1

The content of beta-carotene in carrot pomace depending on drying modes

No.	Designation	Amplitude, m	Frequency, Hz	Pressure, MPa	Drying duration, min.	The content of beta-carotene, mg/g
1	Mode 1	0	0	0.1	140	46.4
2	Mode 2	0	0	0.09	110	52.1
3	Mode 3	0.003	6	0.09	100	56.9
4	Mode 4	0.003	8	0.09	96	60.1
5	Mode 5	0.005	6	0.09	88	73.4
6	Mode 6	0.005	8	0.09	82	76.3
7	Mode 7	0.007	6	0.09	85	70.1
8	Mode 8	0.007	8	0.09	80	75.4

Table 2

Colorimetric assessment of carrot pomace quality depending on drying modes

Raw material	Carrot pomace before drying	Dried carrot pomace		
		under mode No. 1*	under mode No. 2*	under mode No. 3*
Dominant wavelength, nm	581.6	575.2	579.4	580.3
Tone purity	85.67	76.97	80.31	83.84
Brightness	45.8689	43.5827	44.4144	44.9401
Spectral color (dominating tone	Red-orange	Yellow	Yellow-orange	Orange

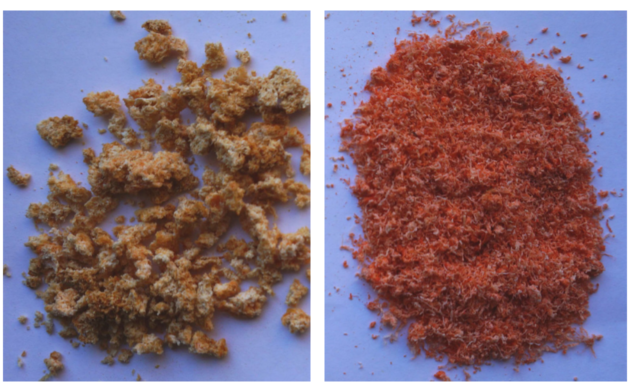
Table 3

Drying modes of vegetable pomace

Designation	Amplitude, m	Frequency, Hz	Vacuum, MPa
Mode 1	0	0	0.09
Mode 2	0.005	6	0.09
Mode 3	0.005	8	0.09

The following drying modes were selected depending on the maximum beta-carotene content.

Fig. 2 shows data on the impact of processing duration and drying mode on the organoleptic indicators of resulting dried pomace. The photographs are presented in two variants; samples with the best appearance (mode 3) and with the worst appearance (mode 1).



a *b*

Fig. 2. Carrot pomace dried under different drying modes: *a* — mode 1; *b* — mode 3

Based on the results of the colorimetric assessment of the quality of the pomace and concentrate made from vegetable raw materials (carrot of the Karotel variety), the defined parameters for the juice and pomace treatment contribute to the preservation of the color of the finished product (mode 3 according to Table 3). According to the main indicators of colorimetry (a dominant wavelength), the samples after the treatment involving drying mode at the vibration amplitude A=0.005 m, the vibration frequency f=8 Hz, were closest to the control. The deviation was 0.3 %. The results of the colorimetric assessment of the quality of carrot concentrate depending on the content of dried pomace indicate that adding it improves the quality of the product. Namely, the brightness and the color purity approach those of the control sample.

5. 3. Devising the technological techniques to prepare culinary meals using a vegetable concentrate made from carrot

The next stage of our study was to establish the possibility of using the resulting vegetable concentrate in the formulations of different culinary meals provided the heat treatment process is intensified. The group of the examined meals included rice pudding, millet balls, and unleavened pastry.

The group of meals to be researched is made using a thermal treatment under the high-temperature heating modes. Such processes of heat treatment are characterized by a long duration for the temperature to reach culinary readiness; by significant heat consumption, and by a low indicator of efficiency, sometimes equal to 60 %. It is possible to improve heat treatment by using electrophysical methods, for example, a combined heat treatment involving ECH. Thus, when ECH is combined with heating by convection, it is possible to reduce the time of heat treatment and the mass loss by the products, improve quality, reduce energy costs, and ensure balanced heating.

The techniques that follow refer to the techniques of baking food products when the convective heating and ECH are combined.

A combined technique to prepare rice pudding with the addition of dried carrot pomace using electrocontact heating. Typically, the preparation of rice pudding implies that milk, eggs whisked with sugar, water, fat are added to the finished crumbly rice porridge and are then stirred. The prepared mince is laid out on a fat-oiled baking plate and baked at a temperature of 180 °C for 20...25 min until a crust on the surface forms.

The proposed technique implies adding carrot pomace to the minced mass of semi-finished products. In this case, the quantitative composition of rice pudding components per 1 kg of mince should match the composition given in Table 4.

Table 4

Quantitative composition of components per 1 kg of mince for rice pudding according to the devised technique

Component	Mass, g/kg
Rice porridge	450
Carrot pomace	250
Milk	100
Egg	40
Sugar	35
Water	90
Fat	35

The products are thermally treated on the basis of the total weight of semi-finished products of 1 kg by the combined heating by convection at a temperature of 180 °C and by the ECH current at a voltage of 36 V. The output of products under this technique is 755 g of finished products, which is 15 % higher than the output of rice pudding prepared conventionally. The duration of the process is 15 minutes, which is 25 to 40 % faster than the conventional treatment only by convective heating.

A combined technique to prepare millet balls with the addition of dried carrot pomace using electrocontact heating. At food companies and in everyday life, the preparation of millet balls involves the formation of products of the appropriate rounded shape made from the mince based on millet porridge. The products, similarly to rice pudding, are laid out on a fat-oiled plate and baked at a temperature of 180 °C for 25...30 min until a crust on the surface forms.

The technique offered implies adding carrot pomace to the minced mass of semi-finished products. In this case, the quantitative composition of the components of millet balls per 1 kg of the mince mass should match the composition given in Table 5.

Table 5

Quantitative composition of components per 1 kg of minced millet balls according to the devised technique

Component	Mass, g/kg
Millet porridge	470
Carrot pomace	260
Egg	40
Water	190
Fat	40

The products are thermally treated based on the total weight of semi-finished products of 1 kg using the combined heating by convection at a temperature of 180 °C and by the ECH current at a voltage of 34 V. The output of products under this technique is 880 g of finished products, which is 20 % higher than the output of millet balls prepared conventionally. The duration of the process is 20 minutes, which is 20 to 33 % faster than the conventional processing only by convective heating.

The combined technique to prepare unleavened pastry with the addition of dried carrot pomace involves the preparation of dough from conventional components. The main of which are flour, sugar, mélange, margarine, and water. It is also proposed to add dried carrot pomace to the dough. The pastries are filled with crushed fresh apples mixed with sugar in a ratio of 4:1. The molded pastries stuffed under conventional technology are subject to heat treatment at a temperature of 180 °C for 40...45 mins until a crust on the surface forms.

The quantitative composition of the dough components per 1 kg of its mass and the amount of filling should match the composition given in Table 6.

The products are thermally treated based on the total weight of semi-finished products of 1 kg using the combined heating by convection at a temperature of 180 °C and the ECH current at a voltage of 36 V. The output of products under this technique is 1,360 g of finished products, which is 10 % higher than the output of unleavened pastry prepared conventionally. The duration of the process is 30 minutes, which is 25 to 33 % faster than the conventional processing only by convective heating.

Table 6

Quantitative composition of components per 1 kg of the pastry dough with the addition of dried pomace made from carrot and a filling

Component	Mass, g/kg
Best grade flour	550
Sugar	27
Margarine	60
Mélange	80
Salt	7
Sodium bicarbonate	8
Citric acid	8
Water	200
Dried carrot pomace	60
Filling	430

5. 4. Studying the process of the combined heat treatment of culinary meals using vegetable concentrate and applying ECH

During our experimental studies of the proposed techniques, we thoroughly measured the energy spent on heat treatment using a wattmeter. The study results are shown in the form of a diagram in Fig. 3.

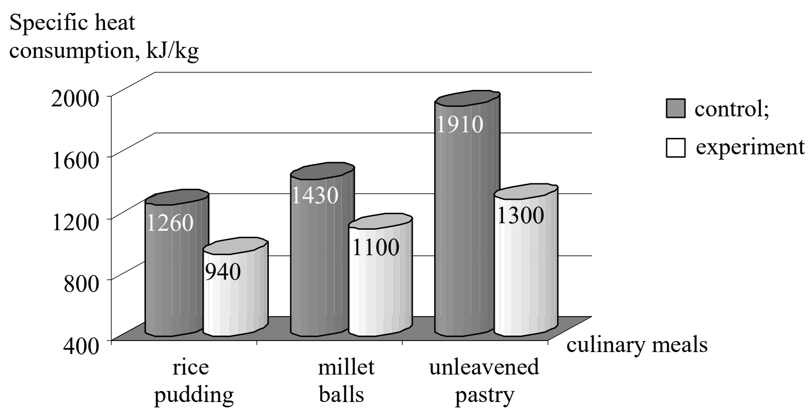


Fig. 3. Diagram of specific heat consumption (kJ/kg) for the conventional and experimental technologies

A common feature of the difference between all experimental processes and control is the reduction of energy consumption. A more pronounced difference is observed for unleavened pastry – by 32 %. As regards the rice pudding based on the experimental technique, the energy consumption is less than that by control by 25 %; and for millet balls, respectively, by 23 %.

Thus, the proposed techniques have a series of advantages in terms of the technological indicators of production. There is a decrease in the duration of heat treatment and an increase in the output of products. Energy consumption under experimental processes is less than that for control. Consequently, these advantages are an argument in favor of the use of vegetable concentrates in the formulations of culinary meals and the combined heat treatment of these meals involving ECH.

According to the organoleptic assessment, it is noted that, in addition to the taste inherent in these products, the products acquired a kind of pleasant taste of carrot, the increased juiciness and tenderness, which can attract the consumer.

6. Discussion of results of studying the quality characteristics of products and the combined heat treatment

The proposed technique for processing vegetables into concentrated products makes it possible to obtain high-quality semi-finished products. This is evidenced by previous studies into determining beta-carotene in dried pomace and their colorimetric score (Table 2). Due to the brightness, the color of the finished products had defined advantages over the control samples (products with conventional formulation). In addition, the increased content of beta-carotene increases the nutritional value of the proposed culinary meals. The peculiarity of a given technique, compared to existing techniques, is the low-waste technology of processing vegetable raw materials into concentrates using a vacuum at the stage of boiling the liquid and dried solid fraction.

Prospects for using the resulting vegetable pomace involve its further application by adding it to the culinary meals' semi-finished products. The result of our study is the devised techniques to bake food products, which made it possible to achieve the effect of improving quality. This is due to the fact that carrot pomace and a balanced ratio of components given in Tables 4–6 are used in the formulations of culinary meals. In conjunction, such high-quality properties can attract the consumer.

A special feature of the proposed techniques is the use during the preparation of these meals of the combined heat treatment by convection at a temperature of 180 °C and ECH at the recommended voltage and cooking time values. The result of studying the relevant processes has established a decrease in the time of heat treatment and the mass loss by products compared to the meals prepared in conventional ways. This is due to the fact that the combined heating provides a balanced thermal impact: the inner layers of the product are heated by ECH while the formation of crust on the surface is due to convection. Thus, the heating time decreases, which, accordingly, reduces the amount of evaporated moisture, and, therefore, of the weight loss.

Experimentally, we have proven a decrease in energy consumption when using the proposed techniques, compared to conventional ones. This is evidenced by the results shown by a diagram in Fig. 3. This is due to the relatively rapid heating of products, the high ECH efficiency, and, as already mentioned, the balanced energy supply from heat sources.

As regards the use of the proposed combined heat treatment, it has limitations due to the ECH parameters for specific culinary meals. Different semi-finished products have different conductivities, so the use of the same voltage is inadmissible. Both the heat treatment time and voltage should be worked out in terms of preventing overheating or not bringing the product to the condition of culinary readiness. The air temperature for convection is 180 °C in most cases but can sometimes be changed to balance the heating.

Some caveats of this study relate to applying our results to pectin-containing fruits and vegetables; earlier studies demonstrated that the presence of pectin in the source raw materials leads to pomace sticking during drying. That requires further research in this area, namely into the possibility of pre-processing of pomace before drying.

The main drawback, which may limit the use of ECH in combined heating, is the critical voltage value of 42 V. Exceeding this value can be dangerous. Thus, at restaurant businesses, most operations are carried out manually, in particular loading and unloading. Therefore, when using ECH, the service personnel must be aware of the risk of electric shock. A solution to this flaw could imply the following. If a voltage of 42 V is not enough during combined heat treatment to achieve the culinary readiness of the product, it is recommended to prolong the heat treatment time while the temperature of convective heating, on the contrary, must be reduced to prevent overheating the crust.

Our study could be advanced by expanding the range of culinary meals based not only on carrot pomace but also a variety of other vegetable concentrates that have not been considered in the current work, as well as determining the rational conditions for their thermal treatment.

7. Conclusions

1. We have devised a technique to produce vegetable concentrate from carrot, which involves the separation of raw materials into juice and pomace followed by separate processing of each component.

2. The qualitative indicators of the produced concentrate have been investigated. Under a drying mode with a vibration amplitude of A=0.005 m, a vibration frequency of f=8 Hz, a vacuum in the apparatus of 0.09 MPa, the basic indicators of colorimetry (a dominant wavelength) are the closest to the control. A greater beta-carotene content has been determined at an amplitude of fluctuations during the drying of pomace of A=0.007 m, at a vibration frequency of f=8 Hz, a vacuum in the apparatus of 0.09 MPa. Our study into the microbiological indicators of dried pomace has found no pathogenic microflora, which proved the need to use a vacuum during drying as a factor that makes the contact with air and pathogenic microflora impossible.

3. We have devised the manufacturing techniques to prepare culinary meals using vegetable concentrate from carrot (rice pudding, millet balls, and unleavened pastry) provided the process of heat treatment is intensified by a combined application of ECH. The combined thermal treatment of products has an advantage over conventional one: the output of products is, on average, larger by 10...20 % while the process duration is, on average, shorter by 20...40 %.

4. The process of combined heat treatment of culinary meals containing vegetable concentrate with the use of ECH was investigated. We have established a decrease in energy consumption, under the experimental technique, by 23...32 % compared to the control. Based on the organoleptic assessment, it was found that, in addition to the taste inherent in these products, the products acquired a kind of pleasant taste of carrot, the increased juiciness and tenderness.

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