Запропоновано удосконалену технологію виготовлення цукатів із столових і цукрових буряків, моркви, пастернаку, селери кореневої та брукви. Технологія базується на підвищенні осмотичного тиску в клітинах рослинної сировини шляхом збільшення концентрації сухих речовин. Удосконалена технологія передбачає використання процесу осмотичної дегідратації в 70 % цукровому розчині температурою 50 °С, як альтернативи процесу бланшування. Це забезпечує скорочення часу сушіння до 1 години за рахунок часткового переходу води з клітин коренеплодів у цукровий розчин. Інактивація ферментів, яка відбувається при дегідратації, позитивно впливає на органолептичні показники якості цукатів. Цукати мають хороший аромат, характерний природній колір і можуть використовуватися як готова десертна страва та наповнювачі у виробництві кисломолочних продуктів і кондитерських виробів.

Проаналізовано вплив традиційних способів обробки рослинної сировини на її харчову та біологічну цінність. Досліджено способи виготовлення овочевих цукатів та виявлено недоліки цих способів. Отримано комплекс даних щодо режимів ведення процесів дегідратації та сушіння. Запропоновано технологію, яка включає: подрібнення сировини, осмотичне зневоднення, сушіння у вакуумних сушарках. Технологією передбачено подрібнення сировини кубиком розміром 5/5/5 мм. Осмотичне зневоднення сировини відбувається у пересиченому цукровому розчині протягом 2,5 годин при температурі 50 °С з подальшим сушінням у вакуумних сушарках протягом 1 години при температурі 50 °С.

Розроблено конструкцію апарату для проведення осмотичної дегідратації, який забезпечує підтримання заданого температурного режиму, приготування і перемішування цукрового розчину, постійне перемішування сировини з метою інтенсифікації масообміну.

Проаналізовано органолептичні (зовнішній вигляд, консистенцію, смак, запах, колір) та фізико–хімічні показники (масову частку сахарози, вологи, загальної золи) якості цукатів із столових буряків, виготовлених за удосконаленою технологією. Встановлено їх відповідність вимогам ДСТУ 6075:2009

Ключові слова: осмотична дегідратація, вакуумні сушарки цукати із столових буряків, коренеплідні овочі, масова частка сахарози

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THE APPLICATION OF OSMOTIC DEHYDRATION IN THE TECHNOLOGY OF PRODUCING CANDIED ROOT VEGETABLES

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1. Introduction

The value of fruits and vegetables includes their containing, first of all, vitamins and mineral substances. Fruit and vegetable raw materials are widely used in the production of various food products, including sour-milk products. Fruits and vegetables are usually used as fillers in the form of powders, pastes, jams, candied vegetables, etc. Physical and chemical, organoleptic, and structural-mechanical properties of sour-milk products depend on the properties of fillers. Candied vegetable manufacturing technology involves significant transformations of plant raw materials. During mass exchange and heat processes, there is not only the loss of moisture, minerals, and vitamins but also a change in the structure and organoleptic properties of raw materials. That is why the choice of the method for processing vegetable raw materials, which best preserves its native properties, is an important task for manufacturers of candied vegetables.

The traditional methods for processing the plant raw materials can include:

– thermal treatment under the influence of high temperatures (blanching, boiling, warming, frying);

– thermal treatment under the influence of low temperatures (cooling, freezing);

– dehydration;

– enzymatic conservation.

Blanching and dehydration are the most common and suitable for the production of candied fruit and vegetable raw materials. When choosing a method for making candied vegetables and fruits, it is important to choose the most effective method for preserving their nutritional and biological value and technological suitability.

Given this, the task of the study is to substantiate the choice of the technological parameters of the production of candied vegetables, specifically, the time and temperature of processing raw materials, as well as the concentration of sugar syrup.

2. Literature review and problem statement

Paper [1] presents the information about the loss of nutritional and biological value of fruit and vegetable raw materials during the drying process. This is proved by the changes in structural and mechanical, physical-chemical, biochemical, chemical, microbiological, and organoleptic properties of raw materials. The reason for this is the use of irrational modes of high-temperature thermal processing of fruit and vegetable raw materials.

The method for drying raw material of plant origin, which is presented in research [2] provides for its long-term storage and can be used in the production of various foodstuffs. However, high temperatures that are used in this study lead to a partial loss of mineral substances, which reduces the biological value of the output products.

In article [3], the importance of solar energy as an environmentally friendly technology and the most reliable energy source is discussed. This technology of drying allows obtaining the products with high biological potential. However, there are economic risks that prevent these drying technologies from being widely used. The main drawback of the technology is high production costs.

Paper [4] presents the structure of the solar dryer for drying agricultural products with a unique design that ensures efficient use of energy sources. This design allows obtaining dried products with the assigned quality indicators. However, its manufacture and launching require considerable investments.

The international register of patents contains a new method for vacuum-spray drying [5], as well as the developed apparatus for drying thermolabile food and medicinal raw materials exposed to denaturation. This method is unconventional, so there are difficulties in its implementation in the technological process. This is due to the lack of specialists capable of servicing such plants.

The new non-traditional technology of spray-sublimation drying by frosting, which enables obtaining powdered products, including organic ones, while retaining the merits of traditional dry products, was explored in paper [6]. Despite all the merits, this technology is hardly used due to the high production costs.

Article [7] is devoted to freezing vegetables and by-products under conditions of constant temperature, humidity, and gas composition inside the storage that extends their shelf life. In this case, the product does not lose color, gloss, and texture. But after vegetables are defrosted, the condensate, which negatively affects the quality of sour milk products, is formed.

Paper [8] deals with the storage of frozen fruits and vegetables that uses vacuum packaging. This method not only prevents fruit and vegetables from oxidation and fermentation but also stabilizes the enzyme of fruits and vegetables. However, this method does not allow storing products for a long time.

Research [9] proves that frozen vegetables by the content of basic vitamins are more useful than fresh ones in the winter-spring period. However, their use without pretreatment as fillers for the production of sour milk products is inappropriate, because this method leads to the loss of structural and mechanical properties.

In studies [10], the quality of baby foodstuffs containing fresh, frozen, and canned organic carrot was assessed. However, the obtained findings have a series of differences in physical and chemical composition and organoleptic properties. That is why they cannot be taken as a basis for fundamental research.

The efficiency of NIR-spectroscopy for the control of physical and chemical changes during convective drying of organic carrot slices was proved in paper [11]. The main drawback of the method is that the product obtained using the presented technology is characterized by low organoleptic properties.

Papers [12, 13] present the results showing that dried foods have lower weight, occupy a significantly smaller volume, with considerably higher energy value compared to fresh and products canned in other ways. This greatly facilitates transportation and storage. That is why a certain effect of intensification of different ways of drying and improving product quality is achieved as a result of the preliminary preparation of raw materials.

One of the ways of preliminary preparation of raw materials is described in papers [14]. This method is osmotic dehydration. The osmotic method for dehydration is increasingly often gaining recognition as an alternative to improving the quality of dried products. Osmotic dehydration is a process used to partially extract water from plant tissues by immersion into a hypertonic solution to decrease the moisture content before the drying process. This method is widely used in the development of new products because it has a positive effect on the nutritional and sensory properties of fresh fruits and vegetables [15–18].

Candied fruits are confectionery products of whole or cut fruits and berries cooked with sugar, dried and powdered with sugar or glazed. The assortment of candied products in the Ukrainian market is limited. There prevail candied fruit and berry made by foreign manufacturers, which have a large content of artificial dyers, which reduces their biological value. In addition, they are not available to a wide range of consumers due to the high costs [19]. The high cost is associated with the high costs of raw materials and other raw components.

The traditional technology of manufacturing candied vegetables includes: preparation and crushing raw materials, blanching with steam or water, boiling in syrup, and drying. Based on traditional technology, a number of improvements that differ in the ways of thermal treatment, and accordingly, the properties of the finished product, were developed.

The known method for the preparation of candied potatoes is represented in research [20]. The method includes preparation of sugar syrup, preparation of vegetable raw materials, cutting it into pieces, boiling in sugar syrup, separation of candied vegetables from sugar syrup, and their drying. Before cooking, pieces are additionally kept for 15...30 minutes in the 5.0...6.0 % solution of acetic acid. Candied potatoes, made by this method, have good organoleptic properties, but only at the cutting thickness of 1.5 cm. The parts with these dimensions do not have a wide range of application even after drying. For example, they can not be used as fillers for the production of sour-milk products. However, this technology does not ensure the highest physical and chemical and organoleptic characteristics.

The method of production of candied Jerusalem artichoke, which is presented in article [21], involves crushing the prepared raw materials and boiling at the temperature of 98–100 °C for 53–55 min in the 50–51 % syrup of fructose with the content of 0.9–1 % of citric acid. The disadvantage of this method is that drying is carried out at two stages, one of which is regulated (2–2.5 hours) and the other is limited to the residual moisture, but in the process of re-drying, it is necessary to determine the moisture content, which causes complexity and increases the production time.

There is a method for getting candied pumpkin and carrot, which is presented in the paper [22]. At the first stage, the method involves cutting raw materials, covering with sugar, and settling at room temperature to the abundant release of juice. It is followed by primary boiling at the temperature of 60–70 °C, which is carried out in the electromagnetic field with a frequency of 20,000 Hz. Basic cooking is performed once for 2.5–3 hours.

The known method for the production of candied parsnip root is presented in paper [23]. In accordance with the proposed technology, prepared parsnip roots are blanched by steam for 8–12 min. Then they are boiled in the 50–52 % sugar syrup with the 0.9–1 % content of citric acid. The drawback of this method is that the biological value of this product is lost during blanching and boiling, which is not limited by developers to a certain period.

Since consumers of sour-milk products are oriented not only to trends determining a healthy lifestyle but also to flavor properties of a product, when manufacturing combined dairy products, it is necessary to use as fillers the fruits and vegetables in the form, which will maximally preserve the biological potential of food raw materials and give the product the desired taste characteristics. With this in mind, candied fruits are optimal raw materials.

Thus, the development of the technology of candied fruit manufacturing from inexpensive regional raw materials, which will maximally preserve its taste and functional properties, is promising.

3. The aim and objectives of the study

The aim of the research is to develop improved technology of candied root vegetables, which can reduce the duration of drying due to the use of osmotic dehydration.

To achieve the set goal, the following tasks were performed:

– to develop the technology of production of candied root vegetables, which includes osmotic dehydration and allow maximum preservation of the biological potential and taste properties of the product;

– to study the organoleptic and physical and chemical indicators (mass fraction of moisture, the mass fraction of total sugar, the mass fraction of total ash) of candied vegetables, manufactured according to the improved technology;

– to develop the apparatus for osmotic dehydration in the production of candied root vegetables.

4. Materials and methods for studying yogurt with fillers

4. 1. Studied materials and equipment used in the experiments

The research was carried out at the Department of Milk and Meat Technology, SNAU (Sumy, Ukraine), at the “Educational-scientific laboratory of innovative technologies and safety and quality of food” with the application of liquid thermostat MLW-16 (Germany) for osmotic dehydration (Fig. 1, *a*). Candied vegetables were dried in the laboratory vacuum dryer (Fig. 1, *b*).

a *b*

Fig. 1. Equipment for the implementation of improved technology for obtaining candied root vegetables: *a* – device for osmotic dehydration, *b* – vacuum dryer

To determine the mass fraction of solids in the candied vegetables, we used the thermal treatment chamber MLW WS-100 (Germany).

A series of experiments on the production of candied carrot, white roots, celery, table beet, and their application in the manufacture of various dairy products was conducted [24, 25]. The final parameters of the process of primary thermal treatment (osmotic dehydration) and drying modes were established according to the results of the processing of table beet Bordeaux 237.

4. 2. Methods for determining the indicators of studied samples

The organoleptic analysis of the finished product was carried out by a certain number of descriptors applying the profile method with the use of a ten-point scale by the averaged data.

To determine the physical and chemical indicators, we used a commonly accepted standard method of research: the mass fraction of moisture content was determined according to GOST (State Standard) 28561–90 [26]. To do this, a crushed batch of hard candied fruit of the weight of 5 g was weighed in a pre-dried and weighed weighing bottle with a glass stick, lid, and sand. The open weighing bottle with the batch is placed in the drying chamber, heated to the temperature (105±2) °C. When the weighing bottle is brought into the chamber, the temperature in it drops slightly, so the timing of drying was performed from the moment when the thermometer showed 105 °C. Drying was carried out for 40 minutes. At the end of drying, the weighing bottles with the batch were loosely covered with lids and placed in the exicator for 20 min., and then were weighed after being tightly closed with lids.

Mass fraction of moisture (X) in percentage was calculated from the following formula:

$$x = \frac{m_1 - m_2}{m_1 - m_3} \times K \times 100, \tag{1}$$

where m_1 is the mass of the weighing bottle with the lid, stick, sand and the batch before drying, g; m_2 is the mass of the weighing bottle with the lid, stick and sand and the batch after drying, g; m_3 is the mass of the weighing bottle with the lid, stick and sand, g; K is the correction coefficient.

The mass fraction of total sugar was determined by DSTU 4954:2008 [27]. The batch of the experimental solution was taken calculating so that the mass concentration of sugars in the finishing solution was 2–6 g/dm^3. The batch mass m in grams was calculated from the following formula:

$$m = \frac{\rho_s \times V \times 100}{10 \times \omega_s}, \tag{2}$$

where ρ_s is the mass concentration of sugars in resulting solution, g/dm^3; V is the volume of measuring flask, cm^3; 100 is the coefficient of converting into percent; ω_s is the mass fraction of sugars in the studied product; 10 is the conversion factor of sugar content per content 1 cm^3.

The batch of the studied product was weighed in a glass with the 0.0001 precision. The batch was transferred into the measuring flask of the volume of 250 cm^3, washing the glass with 120 cm^3 of distilled water. Organic acids of the batch were neutralized with the solution of sodium carbonate up to a pH of 7.0, applying the litmus paper for control. After neutralization, the flask with the solution was heated in a water bath for 15 min at the temperature of 80 °C while stirring frequently. After that, the contents of the flask were cooled to room temperature, and the substances that prevent the determining of sugars were deposited by the solution of lead acetate.

Before determining the content of total sugar, sucrose inversion was performed. In order to achieve this, 50 cm^3 of the filtrate was transferred into a flask with a volume of 100 cm^3 using a pipette, 5 cm^3 of hydrochloric acid were added, and stirred. The flask with a thermometer was placed in the water bath heated to 70 °C. The temperature of the solution in the flask was brought to 70 °C and kept for 5 minutes. After the inversion, the solution was immediately cooled by a stream of running cold water to room temperature. The thermometer had to be removed and rinsed. One drop of methyl orange solution was added and carefully neutralized; sodium hydroxide solution was added by droplets. The mass concentration of sodium hydroxide, in the beginning, should be 200 g/dm^3. At the completion of neutralization, sodium hydroxide concentration should be 10 g/dm^3 until the yellow-orange color appears. Then the neutralized solution was brought by distilled water up to the volume of 100 cm^3. Total sugar content was found by the same method as the one for determining the mass fraction of reducing sugars in the percentage of the mass:

$$\omega = \frac{m_1 \times V}{m \times V_1} \times 10^{-1}, \tag{3}$$

where m_1 is the mass of reducing sugars found from tables, mg; V is the volume of the experimental solution prepared from the batch, cm^3; m is the mass of the product batch, g; V_1 is the volume of the solution used for determining sugars, cm^3; 10^{-1} is the factor of conversion into percent.

The mass fraction of total ash was determined using the gravimetric method of GOST 15113.8–77 [28]. The batch of candied fruit of the weight of 5 g was ashed in a muffle furnace in the usual way. 30 cm^3 of the solution of hydrochloric acid with the mass concentration of 100 g/dm^3 were poured into the crucible with the resulting total ash, heated in a water bath for 30 min. and filtered through an ash-free filter. The crucible and sediment on the filter were washed with hot distilled water until the reaction to chlorine-ion with the solution of silver nitrate disappeared. The filter with sediment was dried on the funnel in the drying chamber for 30 min., then transferred to the same crucible, burned and fried in a muffle furnace at the temperature of 500–600 °C. The crucible was cooled in an exicator for 35 min. and weighed with an error of not more than 0.001 g. Frying was repeated until the constant mass was obtained. The ash share, non-dissolved in hydrochloric acid X_1 was calculated from the following formula:

$$x_1 = \frac{m_1 - m_2}{m} \times 100, \tag{4}$$

where m is the mass of the batch of the studied product, g; m_1 is the mass of the crucible with residue, g; m_2 is the mass of the crucible after frying and the ash of the ash-free filter, g.

The results are represented as the arithmetic mean of two parallel measurements, taking into account the standard deviation.

5. Results of studying candied vegetables

5. 1. Development of the technology for manufacturing candied root vegetables using osmotic dehydration

The production of candied vegetables according to the technological circuit presented in Fig. 2 was proposed.

According to this scheme, raw materials (root vegetables) are thoroughly washed with warm running water and peeled. The roots with peeled skin are crushed to pieces in the form of cubes of dimensions of 5×5×5 mm. The resulting pieces are placed into the plant for osmotic dehydration.

First, granulated sugar and filtered drinking water in the ratio of 7:10 are fed to the dehydration plant. The mixture is thoroughly stirred and heated to complete the dissolution of crystals. The resulting sugar solution is pasteurized at the temperature of 65 °C with keeping for 10 min, and then pieces of vegetables are put into it.

Vegetables are kept in the sugar solution with the mass fraction of sucrose of 70 % at the temperature of 50 °C for 2.5 hours. Then candied vegetables are separated from the sugar solution and dried in a vacuum drying chamber for 1 hour at the temperature of 50 °C. Dried candied vegetables are powdered with sugar and packaged.

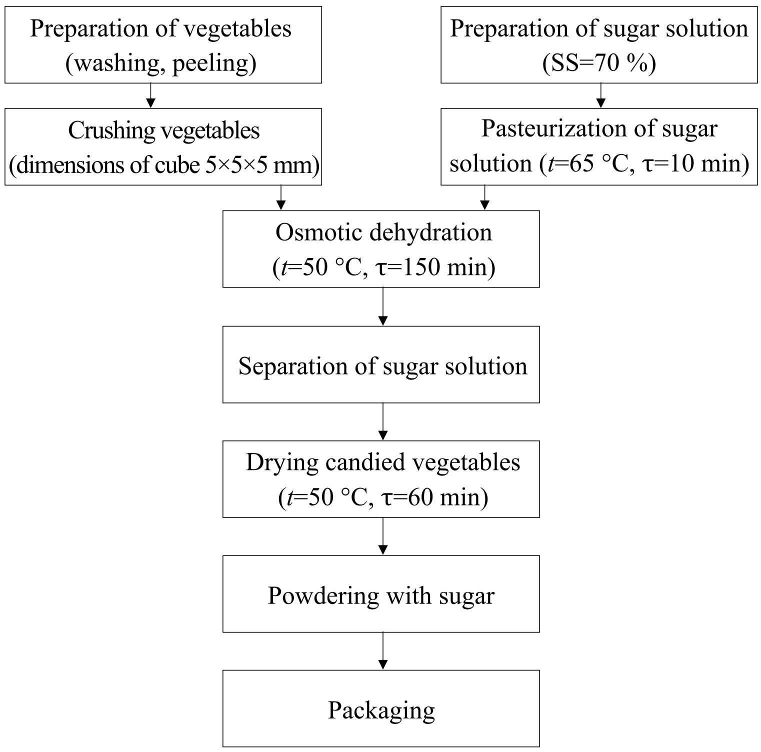

Fig. 2. Technological circuit of manufacturing candied vegetables

The improved technology is universal for the production of candied vegetables made of table beet and sugar beet, carrot, parsnip, root celery, and rutabaga. The specific feature of the developed technology for manufacturing candied vegetables is the use of osmotic dehydration as an alternative to blanching. The dehydration process is based on elevated osmotic pressure in cells by increasing the concentration of solids. This ensures a partial transition of water from roots' cells into the sugar solution and, consequently, inactivation of enzymes.

Drying in vacuum at the temperature below 50 °C is based on the fact that a significant amount of moisture is removed from the product. This creates unfavorable conditions for the development of microorganisms, while the biological value of vegetables is preserved.

This method for manufacturing candied vegetables makes it possible to extend their shelf life, reduce the volume mass, and enhance energy value. Candied vegetables have a good smell, characteristic natural color, and can be used as a finished dessert and fillers in the production of sour milk products and confectionery.

5. 2. Results of studying the organoleptic and physical-chemical indicators of candied vegetables manufactured according to the improved technology

The modes of osmotic dehydration and drying are presented in the proposed technology of manufacturing candied root vegetables. The series of experimental research revealed the optimum concentration of the sugar solution, dehydration time, and drying time. Table beet of the Bordeaux 237 variety was used as the object of research.

The task of the research was to create candied vegetables not only with the preserved biological potential but also with high flavor properties. That is why the data obtained during the organoleptic assessment of the candied vegetables were crucial for the establishment of technological modes. The results of the experimental data are shown in Table 1. The results of experimental research revealed that an increase in the mass fraction of sucrose in sugar solution has a positive effect on organoleptic indicators of candied vegetables, specifically, smell and taste. These indicators were almost the same, regardless of the duration and temperature of dehydration, which was established taking into account the already known studies [15–18].

Table 1

Results of experimental research

Mass fraction of sucrose in solution, %	Duration of dehydration, h	Temperature of dehydration, °C	Temperature of drying, °C	Duration of drying, h	Organoleptic indicators of candied vegetables
1	2	3	4	5	6
50	2	40	45	2	Wine-color cubes, slightly wrinkled, homogeneous in size and shape. Dry consistency. Tangible beet smell and flavor. Not sweet flavor
	2,5				
	3				
	2	50	50	1	Wine-color cubes are not wrinkled, homogeneous in size and shape. Consistency is not dry. Tangible beet smell and taste. Not sweet flavor
	2,5				
	3				
60	2	40	45	2	Wine-color cubes, slightly wrinkled, homogeneous in size and shape. Consistency is dry. Tangible mild beet smell and flavor. The taste is moderately sweet
	2,5				
	3				
	2	50	50	1	Wine-color cubes are not wrinkled, homogeneous in size and shape. Consistency is not dry. Mild smell and flavor of beet. The taste is moderately sweet
	2,5				
	3				
70	2	40	45	2	Wine-color cubes are a bit wrinkled, homogeneous in size and shape. Consistency is dry. Smell of sugar, harmoniously sweet taste
	2,5	40	50	1,5	Wine-color cubes are not wrinkled, homogeneous in size and shape. Consistency is not dry. Smell of sugar, harmoniously sweet taste
	2,5	50	50	1	Wine-color cubes are not wrinkled, homogeneous in size and shape. Consistency is not dry. Smell of sugar, harmoniously sweet taste
	3	50	50	1	Wine-color cubes are not wrinkled, homogeneous in size and shape. Consistency is not dry. Smell of sugar, harmoniously sweet taste

These indicators were practically the same, regardless of the duration and temperature of dehydration, which was established taking into account the already known studies [15–18]. When using sugar solutions with the mass fraction of sucrose of 50 and 60 %, there was pronounced beet flavor and smell regardless of the drying mode. At an increase in the mass fraction of sucrose and the solution temperature, the duration of dehydration decreases. At an increase in the temperature of the solution by 10 °C (from 40 to 50 °C), the drying time is decreased by 30 minutes.

The increase in dehydration duration by 30 minutes (from 2.5 to 3 hours) at the same temperature of the process does not result in the reduction of the drying time.

Given the above, the following parameters are appropriate:
– mass fraction of sucrose in sugar solution – 70 %;
– the temperature of a solution – 50 °C;
– duration of dehydration – 2.5 hours;
– drying temperature – 50 °C;
– duration of drying – 1 hour.

Based on the obtained results of the organoleptic assessment, we carried out the research into the physical and chemical indicators of candied vegetables, manufactured according to the above mode. Research results are given in Table 2.

Table 2

Physical and chemical indicators of candied table beet according to the research results

Indicators, units of measurement	Admissible values	Actual values
Mass fraction of sucrose, %, not less	72	75
Mass fraction of moisture, %, not more	20	13.1
Mass fraction of total ash, %, not more	10	2.7

The results of physical and chemical research showed that candied vegetables manufactured according to the improved technology with osmotic dehydration meet the requirements of the DSTU 6075:2009 standard [29].

5. 3. Development of the apparatus for osmotic dehydration in the production of candied root vegetables

The structure of the apparatus for osmotic dehydration, the housing 1 of which is made of stainless steel, was designed. Space 8 of the apparatus is filled with a sugar solution. To heat the sugar solution, spiral 4 is fitted. Uniform heating of the syrup is ensured by stirrer 3, and stirring of candied vegetables – by stirrer 6 that rests on tripod 7. The specified temperature in the apparatus is maintained by thermometer 2. The dehydration process is performed using control board 5. The grate to keep candied vegetables 9 is placed inside the housing.

Grate 9 performs several important functions at a time: keeping candied vegetables inside the housing and their uniform immersion into the sugar solution; separation of the sugar solution from vegetables after osmotic dehydration.

Due to stirrer 6, the osmosis process is accelerated, which results in the reduction of dehydration time and the total duration of the process of manufacturing candied vegetables.

The circuit of the apparatus for osmotic dehydration is shown in Fig. 3.

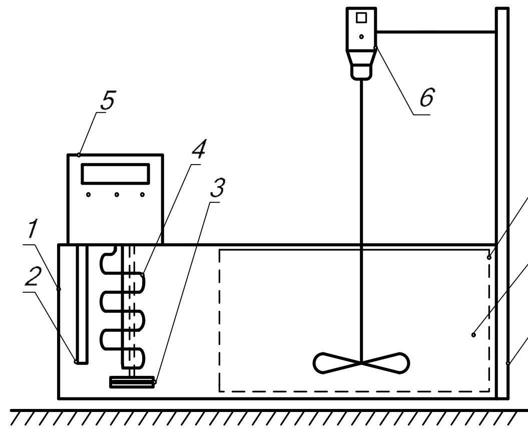

Fig. 3. Circuit of the apparatus for osmotic dehydration

Water and sugar are fed to the dehydration apparatus, both stirrers and the device for heating the sugar solution are switched on using the control board. The washed, peeled, and crushed vegetables with the dimensions of 5×5×5 mm are immersed in the pasteurized sugar solution. Due to this, the temperature of the solution decreases, the operating temperature of 50 °C is set by the control board. When it is reached, the beginning of the dehydration process is recorded. Raw materials are kept in the saturated sugar solution at the temperature of 50 °C for 2.5 hours. Then the grate with candied vegetables is taken out and they are separated from the sugar solution and sent to be dried.

6. Discussion of results of studying the improved technology for manufacturing candied root vegetables

The known methods for making candied products from vegetable raw materials allow obtaining the product, characterized by good organoleptic properties, but lead to a decrease in their biological value.

The proposed technology for manufacturing candied vegetables, which involves the preliminary thermal treatment of vegetables by osmotic dehydration, allows retaining the content of vitamins, macro- and microelements in their composition due to the economical mode of thermal treatment (t=50 °C).

The obtained results of the experimental research showed that an increase in the mass fraction of sucrose in the sugar syrup up to 70 % has a positive effect on the organoleptic characteristics of candied root vegetables, specifically, the smell and taste of candied vegetables are sweet or sour-sweet, inherent in this type of root crops. They have wine color, close to the natural coloration of root vegetables used for making candied products. Candied vegetables after osmotic dehydration and drying look like uniform cubes, not wrinkled, homogeneous in size and shape, not stuck together. The consistency is not dry.

The data given in Table 1 prove the validity of the selected technological parameters, specifically, time and temperature of processing raw materials, as well as the concentration of syrup. The developed apparatus for osmotic dehydration of root vegetables (Fig. 5) can ensure the necessary parameters of the dehydration process. The design of the device allows the automatic regulation of the process parameters, and the use of the stirrer leads to the intensification of the process of osmotic dehydration of root vegetables. The device structure allows leveling the identified shortcomings of the existing devices and solving the set task, specifically, maintaining the temperature of the sugar solution at the level of 50 °C for 2.5 hours.

It should be noted that the use of a vacuum drying chamber in the process of drying candied vegetables is more appropriate in terms of energy efficiency compared with the convective drying method [30]. The vacuum drying chamber (Fig. 1, *b*) was used to dry candied root vegetables. When using this drying method, heat losses with the used-off drying agent decrease, volatile substances from the material are easily trapped. As a result, dried candied root vegetables retain the initial properties: the size of pieces, flavor, color, and smell.

The physical and chemical parameters of candied vegetables were studied and their compliance with the standard indicators was established. Thus, the content of residual moisture in candied vegetables is 10 %, the drying time is reduced by 5 times, compared with the existing methods. The application of temperatures below 50 °C allows maximal retaining the biological value and organoleptic indicators of the product.

The circuit of the apparatus for osmotic dehydration was developed. The apparatus for osmotic dehydration is fully automated, the stirrer for the uniform temperature control and the stirrer for mixing the product were mounted.

Mounting the water stirrer and the product stirrer makes it possible to regulate the apparatus productivity, maintain the assigned temperature without damaging the product structure.

Thus, the range of the conducted research proved the possibility of intensification of the process of manufacturing candied vegetables due to the use of osmotic dehydration and vacuum drying.

The change in the chemical composition of vegetables during their processing using osmotic dehydration was not analyzed in the article.

The results reported in the paper are the intermediate stage of the complex study of the optimization of the technological process. Based on the development of the design and substantiation of the operation modes of the dehydration apparatus, it was possible to reduce energy consumption and to increase the biological and energy value of candied vegetables. The obtained results will be useful to improve the technology and equipment for making candied root vegetables.

The next stage of research is the analysis of the chemical composition of candied vegetables depending on the mode of osmotic dehydration.

7. Conclusions

1. The technology of manufacturing candied root vegetables, which involves the use of osmotic dehydration allowing the retention of the biological potential and taste properties of the product, was developed. The effect is achieved due to the optimum dimensions of parts (5×5×5 mm), osmotic dehydration in sugar solution with the mass fraction of sucrose of 70 % at a temperature of 50 °C for 2.5 hours and subsequent drying in vacuum drying chambers for 1 hour at a temperature of 50 °C.

2. It was experimentally proved that the organoleptic and physical and chemical indicators of candied vegetables, obtained according to the developed technology meet the requirements of DSTU 6075:2009. Their actual values improve at the compliance with the established optimal parameters of the process of manufacturing candied vegetables. The parameters are the following: mass fraction of sucrose in sugar solution – 70 %, solution temperature – 50 °C, dehydration duration – 2.5 hours, drying temperature – 50 °C, duration of drying – 1 hour.

3. The developed apparatus of pre-treatment of root vegetables in the production of candied vegetables was developed. It allows controlling not only the process of stirring the crushed particles but also the dehydration time and the exposition, which positively influences the biological value and taste properties of the finished product.

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