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INVESTIGATION OF PROPERTIES OF SEMI-FINISHED PRODUCTS FOR SMOOTHIES DURING LOW-TEMPERATURE STORAGE

Об'єктом дослідження є напівфабрикат для смузі, виготовлений з полуниці, сушених яблук та вівсяних пластівців. Під час низькотемпературного зберігання та розморожування може виникнути погіршення його показників якості (втрата вітамінів та антиоксидантів; зниження органолептичних показників, а саме зміна кольору та втрата аромату). Перспективним є комплексна оцінка кольору та аромату, які формують органолептичні показники напівфабрикату для смузі.

В ході дослідження визначено рН та титровану кислотність методом потенціометричного титрування. Ці показники впливають на колір та стійкість досліджуваних зразків напівфабрикату. Стійкість кольору визначали спектрофотометричним методом, а вміст ароматоутворюючих речовин визначали за результатами окисно-відновного титрування.

Встановлено, що значення рН для свіжого напівфабрикату та напівфабрикату після 270 діб низькотемпературного зберігання мають близькі значення, а саме 3,441 та 3,410. Показник титрованої кислотності у зразках не змінюється протягом терміну зберігання та складає $13,00 \pm 0,02$ ммоль H^+ /100 г. Це свідчить про стабільність органічних кислот та цукрів, які входять до складу напівфабрикату для смузі. Доведено, що наприкінці терміну зберігання інтенсивність кольору напівфабрикату становить 99 % від початкового значення. Визначено, що вміст ароматоутворюючих речовин у свіжовиготовленому напівфабрикаті для смузі становив 43,6 мл $Na_2S_2O_3$ /100 г, а після терміну зберігання дорівнював 22,7 мл $Na_2S_2O_3$ /100 г.

Таким чином під час зберігання протягом 270 діб за температури $-18^\circ C$ та розморожуванні на відкритому повітрі за температури $23 \pm 1^\circ C$ напівфабрикат для смузі залишається стабільним з точки зору фізико-хімічних показників та інтенсивності кольору. Вміст ароматоутворюючих речовин залишається на рівні 52 % від початкового значення.

Виготовлення даного напівфабрикату для смузі надасть можливість розширити асортимент замороженої продукції та збільшити базу місцевої переробної промисловості, розвиток якої сприятиме розвитку сільськогосподарського виробництва регіону.

Ключові слова: напівфабрикат для смузі, низькотемпературне зберігання, натуральний колір, число аромату, функціональний продукт.

1. Introduction

Modern trends in the development of the consumer market require the creation of qualitatively new food products, having a positive impact on the human body. These products include functional foods that can reduce the risk of certain diseases, slow down the aging process of the body and diversify the diet of humans through the content of biologically active substances [1].

One such food is the smoothie, which contains natural ingredients. To improve the nutritional value, smoothie is made from fresh vegetables, berries and fruits [2]. Promising raw material for making smoothie is apples and strawberries, since they contain high enough concentrations of organic acids, vitamin C, folacin, riboflavin, vitamin B6, biotin, minerals. The aroma of apples and strawberries is mainly due to the presence of esters, alcohols, aldehydes, ketones, lactones, terpenoids, etc. The aroma of forming substances is influenced by genetic modification, maturity, environmental conditions, storage conditions [3]. The color of both apples and strawberries is due to the presence of carotenoids, anthocyanins, flavanols. Analysis of the

chemical composition of oat flakes shows that they are rich in sodium, iron, zinc, calcium, containing lipids, is a source of dietary fiber and vitamins [4].

Apples, strawberries, oats are widely cultivated and are traditional for Ukraine raw materials. This gives grounds for the development of new types of food products with their use. One of the rational methods of storing fruit and berry raw materials is the production of semi-finished products from their subsequent low-temperature storage. This way gives an opportunity to get high-quality domestic products that can become a source of BAS during the off-season period, during which prices for fresh berries and fruits rise sharply and certain segments of the population can't afford such expenses, especially given the fall in the standard of living in Ukraine [5].

It should be noted that after low-temperature storage and defrosting, certain deterioration of functional and technological properties is typical for fruit and berries [6]. Freezing is regarded as an important and simple process of preserving plant raw materials, but this is not an ideal process, as it is well known that some nutritional value (vitamins and minerals) can be lost during the process of

freezing and defrosting. According to [7], nutrient losses during freezing and defrosting can be the result of certain physical and chemical processes, for example, leaching.

That is why it is important to assess the organoleptic characteristics of the product – appearance, color, aroma, taste and consistency. From the point of view of the consumer, the color and smell of the product is an essential criterion of the quality of the food product. Stability and intensity of color can be caused by the presence of natural coloring substances, the presence of artificial food dyes as well as the influence of technological parameters of processing of plant raw materials [8]. The smell of the product can also be formed either due to the presence of aroma-forming natural substances, or artificial aromas.

Thus, it is important to study the possibility of using apples, strawberries and oat flakes to produce high-quality semi-finished products with increased nutritional value, natural color and aroma. Realization of the plan will allow expanding the assortment of semi-finished products for smoothie and creating competitive products in the food market.

2. The object of research and its technological audit

The object of research is the properties of the product during storage for 270 days. The subject of research is semi-finished product for smoothie, which is made from strawberries, apples and oat flakes.

Semi-finished product was prepared using strawberry «Dukat» (Ukraine); apples of the «Borovinka» grade (Ukraine), oat flakes «Hercules» of the manufacturer LLC «Firm DIAMANT LTD» (Poltava, Ukraine). This strawberry variety is suitable for processing and storage at low temperatures. Apples of «Borovinka» grade were chosen due to their increased resistance to low temperatures. Crushed oat flakes «Hercules» were introduced into the formulation for enrichment with minerals and vitamins, increasing the viscosity of the product and creating an appropriate texture. The dynamics of freezing of the semi-finished product for the smoothie was studied in [9, 10]. The ranges of crystallization and the amount of freezing moisture of the semi-finished product are established. The results of microbiological studies are given, rational regimes of freezing and smoothie of the semi-finished product are established.

During low-temperature storage and defrosting of the semi-finished product, the food value may decrease due to the loss of vitamins and antioxidants, deterioration of organoleptic parameters (color change, loss of aroma). Therefore, it is important to pay attention to compliance with the conditions of freezing, low-temperature storage and quality indicators after defrosting the semi-finished product.

3. The aim and objectives of research

The aim of research is investigation of the properties of the semi-finished product for smoothie during low-temperature storage at a temperature of $-18\text{ }^{\circ}\text{C}$ for 270 days.

To achieve this aim, it is necessary to solve the following tasks:

1. To determine the physicochemical parameters of the quality of the semi-finished product for smoothie.

2. To investigate the stability of the color of the semi-finished product for smoothie during storage.

3. To investigate changes in the content of aroma-forming substances during storage.

4. Research of existing solutions of the problem

Analysis of literature sources on the issue of low-temperature freezing and storage allows to conclude that the preservation of natural aroma and nutrients in frozen food products depends on the conditions of cultivation and the region, the variety characteristics of raw materials, technological and many other factors [11].

In work [12], deficiencies of vegetable semi-finished products are described, the main one of which is the use of synthetic dyes. Changes in the intensity and stability of the color of the vegetable semi-finished product under various conditions and processing techniques before freezing are also investigated. It is established that after processing operations before freezing, the coordinates of color, color tone, and colorimetric purity change.

In [13], using the instrumental method with the use of color-parametric characteristics, the color of new products made from the radish root is fixed. The method used significantly facilitates the estimation of color and consumer properties in general and can be used in the development of new food products, as well as the effect of storage conditions on their quality.

Specialists [14] investigate the color characteristics of water extracts of berries depending on their pretreatment before storage. It has been established that the process of partial dehydration does not significantly affect the color parameters of gooseberry and blackcurrant, since the change in color tone and colorimetric purity of the prototypes is not significant for carrying out control samples.

To control the quality of raw materials, sensory evaluation is often used. This method is not accurate enough because of the subjectivity of the views of the tasters [15]. Progressive development of digital technology gave impetus to the formation of a new method of computer colorimetry, the essence of which is the description of the color of the object in the color coordinate system based on the results of processing digital images of the sample [16].

For each food product there are characteristic only for it taste and aroma. In their formation, various chemical compounds are involved, which are formed during the growth of plants, in the production of food products under the influence of microorganisms or under the action of enzymes, cooking food [17]. More than 5,000 different aromatic-, taste-forming substances have been isolated from foods [18, 19].

It is established [20] that most fruits and vegetables contain aroma precursors, but not always contain the necessary aromatic-forming enzymes to give the product the desired aroma. The fragrance can be restored after its loss as a result of heat (freezing, canning, drying) of the product. The process of restoring the fragrance is enzymatic. The establishment of aroma depends on the presence of enzymes that form aromatic substances from the precursors. These enzymes must be contained in plant raw materials in sufficient concentrations for the enzymatic formation of the aroma, resulting from sequential hydrolytic and oxidative processes.

The results of the analysis lead to the conclusion that a complex assessment of color and aroma that form organoleptic parameters of the semi-finished product for the smoothie is promising. At the same time, it is known that the pH and the titratable acidity of plant raw materials influence the formation of color and its stability [21], since the color is significantly dependent on the content of anthocyanins and flavonoids. That is why it is expedient not only to limit organoleptic indicators, but also to evaluate individual physicochemical parameters.

5. Methods of research

Quantitative characterization of the quality of the semi-finished product samples for smoothie and their research over the storage period is carried out, based on the basic physical and chemical parameters, namely pH and titratable acidity. These indicators are determined using standard methods [22, 23]. The pH of the samples of the semi-finished product is determined from the results of potentiometric titration. Before the definitions semi-finished product defrosted outdoors at a temperature of 22 ± 1 °C. Thereafter, the sample was taken up in a flask with sufficient number of electrodes for immersion tests, while taking into account the thick consistency of the semi-finished product and, accordingly, the need to dilute it with water in half.

The titratable acidity (T) of the semi-finished product is determined from the results of potentiometric titration [24]. Before the definitions semi-finished product defrosting outdoors at a temperature of 22 ± 1 °C are selected sample of 25.00 g, was added to 50 cm³ of hot water, stirred until a homogeneous consistency and heated to reflux on a steam bath for 30 min. Then the sample is mixed thoroughly, cooled and quantitatively transferred to a 250 cm³ flask, adjusted to the mark with water, stirred and filtered again. Further, a filtrate of 25 cm³ is added to the flask with a stirrer and titratable with 0.1 M sodium hydroxide solution. The titratable acidity is calculated by the formula:

$$T = \frac{250}{m} \cdot V_1 \cdot c \cdot \frac{100}{V_0},$$

where m – weight of the sample of the semi-finished product, taken for analysis, g; V_1 – volume of sodium hydroxide solution consumed for titration, cm³; c – molar concentration of sodium hydroxide solution, mol/dm³; V_0 – volume of aliquot of the filtrate, taken for analysis, cm³; 250 – volume of the volumetric flask, cm³; 100 – conversion factor per 100 g of product.

After that, the calculated value is recalculated into a gram of malic acid, accounted for 100 g of semi-finished product.

The color stability of the semi-finished product for smoothie, which is due to the presence of anthocyanins and flavonoids, is studied by the spectrophotometric method [25]. The color intensity of the sample is determined from the optical density of the aqueous extract of the freshly prepared semi-finished product. To do this, let's take a sample of the unfrozen sample of a semi-finished product with a mass of 5 g to an accuracy of 0.01 g and dissolved it in water heated to 50 °C, after which it is filtered, the filtrate is quantitatively transferred to a 100 cm³

volumetric flask, 2 cm³ of concentrated hydrochloric acid and brought to the mark with distilled water. After that, the optical density of the resulting solution is determined on a SF-46 spectrophotometer (JSC Lomo, St. Petersburg, Russia) at a wavelength of 490 nm in quartz cuvettes with a layer thickness of 10 mm. The initial and repeated (after 9 months) measurements of the optical density of the extracts of the semi-finished samples are carried out under the same conditions. The change in optical density is expressed as a percentage, with the original optical density being taken as 100 %.

The basis for determining the aroma number is the reaction of the interaction of essential oils with the chromium mixture, resulting in their oxidation [25].

The content of aroma substances (x) in the semi-finished product is determined from the results of oxidation-reduction titration. To isolate the substances that cause the fragrance of the semi-finished product, they are distilled with water vapor at a temperature of 98 °C. The substances are distilled into a receiver with a chromium mixture. The resulting distillate is boiled in a water bath for 1 hour, cooled, after which 25 cm³ of 10 % potassium iodide solution is added and left in a dark city for 3 minutes. Iodine, which was then isolated, is titratable with 0.2 N sodium trioxothiosulfate. As an indicator, 1 % starch solution is used. The amount of aroma (in ml Na₂S₂O₃/100 g) is calculated by the formula:

$$x = \frac{(V_0 - V) \cdot K \cdot 100}{m},$$

where V_0 – volume of sodium solution to trioxothiosulfate, consumed for titration in the control experiment, cm³; V – volume of sodium solution to trioxothiosulfate, spent on titration in the main experiment, cm³; m – weight of the sample of the semi-finished product, taken for analysis, g; K – conversion factor.

6. Research results

Shelf life is one of the main characteristics, which determines the competitiveness of any product on the market. During the storage of semi-finished products as a result of physical, chemical and microbiological processes, its quality indicators may change. The nature and intensity of the flow of these processes depends on factors such as formulation composition, manufacturing technology, storage conditions and packaging method. So, the following factors influence the stability of anthocyanins, which determine the color of the semi-finished product for the smoothie: the native chemical structure, the pH of the medium, the temperature, light, the presence of oxygen, enzymes, metal ions, ascorbic acid, flavonoids. Therefore, the study continued for the entire storage period, namely 270 days from the date of manufacture. The semi-finished product was stored in the dark at a temperature of -18 °C, the samples were packaged according to the current requirements [26].

The effect of the method and shelf life on the quality of the new semi-finished product is investigated with changes in individual physicochemical and organoleptic indices.

The obtained results of studies of physicochemical parameters confirmed the quality of the new semi-finished product (Table 1).

Table 1

Physicochemical parameters of the semi-finished product

Sample of semi-finished product	pH	Titrateable acidity, mmol H ⁺ /100 g	Titrateable acidity, mmol, g of malic acid/100 g
Freshly prepared	3.441	13.00±0.02	0.87
After low-temperature storage	3.410	13.00±0.02	0.87

As the data of Table 1, the pH of the fresh half-finished product and the sample, which lasted for 270 days, are almost identical. It is found that after 270 days of storage the titrateable acidity remains unchanged. This indicates the stability of organic acids and sugars entering the product during storage and during defrosting.

Determination of the color stability of the semi-finished product, based on the measurement of the optical density of the solution, is carried out in two stages. The first stage consisted in the spectrophotometric study of an aqueous extract of a sample of a freshly prepared semi-finished product (Fig. 1).

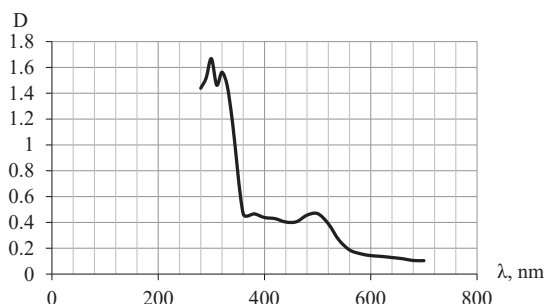


Fig. 1. Absorption spectrum of an aqueous extract of freshly prepared semi-finished product for smoothie

Studies have shown that the absorption spectrum has several maxima, one of which is more pronounced and lies within 290...300 nm, and the other in the range of 310...320 nm, which indicates the presence of flavonol glycosides in extracts.

The maximum absorption, which is observed at a wavelength of 490 nm, indicates the presence in the extract of colorants of anthocyanins of nature [27]. Therefore, further studies of the color stability of the semi-finished product are carried out at this wavelength. The optical density value for the extract of the freshly prepared semi-finished product is 0.467 for the extract of the defrosted sample of the semi-finished product – 0.465.

It is proved that the semi-finished product has a stable color. At the end of the shelf life, the color intensity is 99 % of the initial value.

Table 2 shows the results of determining the content of the aroma of forming substances in a semi-finished product.

Table 2

Results of the determination of the content of aroma-forming substances in the samples of the semi-finished product for smoothie

Sample semi-finished product for smoothie	Aroma number, ml Na ₂ S ₂ O ₃ /100 g
Freshly prepared	43.6±1.3
After storage	22.7±0.6

According to the obtained data, a sample that lasted for 270 days loses 48 % of the substances responsible for the aroma of the semi-finished product.

Thus, during storage for 270 days at a temperature of –18 °C and defrosting in the open air at a temperature of 23±1 °C, the semi-finished product remains stable in terms of physicochemical parameters and color intensity. The content of aroma-forming substances remains at the level of 52 % of the initial value.

7. SWOT analysis of research results

Strengths. The strengths of the developed product include:

- expansion of the range of frozen products;
- consumer's curiosity about a new food product;
- natural components and improved organoleptic characteristics;
- reduction of labor and time spent on making beverages at home and in public catering;
- decrease in the intake of radionuclides into the body and increase of resistance of the organism to radiation actions.

Weaknesses. The weaknesses of the developed product include:

- limited in the component composition of the semi-finished product;
- poor consumer awareness of the new product.

Opportunities. Additional opportunities to achieve the objectives of research, are in great potential of this raw material, which has high antioxidant properties.

Threats. Threats when a new product is released to the consumer market include:

- decline in the purchasing power of the population;
- possibility of the appearance of new analogues.

Based on the SWOT analysis, the following strategic solutions are proposed:

- active role of marketing;
- access to new markets.

When carrying out marketing activities, it is necessary to emphasize the composition and consumer properties of the semi-finished product, its biological and nutritional value, high organoleptic and antioxidant properties, radio-protective properties, and reduce the risk of radionuclide deposition in the human body.

8. Conclusions

1. Physicochemical indicators of the quality of the semi-finished product for the smoothie are determined. The pH of the fresh semi-finished product is 3.441, and after low-temperature storage at a temperature of –18 °C for 270 days – 3.410. It is found that the indicator of titrateable acidity did not change during storage and amounted to 13.00±0.02 mmol H⁺/100 g. This indicates the stability of organic acids and sugars that make up the semi-finished product.

2. It is proved that the semi-finished product has a stable color. At the end of the shelf life, the color intensity was 99 % of the initial value.

3. The content of aromatic-forming substances in the semi-finished product for smoothie is determined. For the freshly prepared semi-finished product, the aroma is 43.6±1.3 cm³ Na₂S₂O₃/100 g, and at the end of the storage period – 22.7±0.6 cm³ Na₂S₂O₃/100 g.

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