IMPROVEMENT OF THE TECHNOLOGY OF MARSHMALLOW WITH THE ADDITION OF PLANT RAW MATERIALS

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Abstract
Every year, the interest in functional nutrition is growing in the world. Consumers are increasingly rejecting products containing sugar, artificial preservatives, dyes, flavorings, flavor enhancers, etc. There is a growing public interest in healthy food products and the ingredients used in these products. Despite the increase in the price of such products, marketing research confirms the demand for them and the willingness of the population to "overpay for naturalness". The article is devoted to the development of the formulation and technology of a pastila-type product with a functional purpose using non-traditional raw materials (coconut sugar, fructose and blueberry powder) instead of sugar. The organoleptic and physicochemical indicators of the quality of new products were determined. The pastila-type products are enriched with protein, dietary fibers, minerals (potassium, calcium, magnesium, zinc) and vitamins (C, PP, groups B, A).

Keywords
marshmallow; additives of plant original; glycemic index; antioxidant capacity; quality indicators of marshmallow; chemical composition.

Introduction
Consumption of low-quality food products (low-quality means a combination of high energy and low nutritional value, as well as a deficiency of dietary fibers and micronutrients) reduces the quality of life and leads to the occurrence of a number of serious diseases. Sugar confectionery products, due to their taste properties, are in high demand among various groups of the population. They are characterized by high caloric content, easy digestibility, are effective suppliers of energy in the human diet, have an attractive appearance, pleasant taste and serve as a supplement to the human diet. But this group of products, as a rule, has a high sugar content and a significant glycemic index, which causes a sharp increase in the level of glucose in the blood [1]. The following is the priority direction for expanding the assortment of whipped confectionery products the use of new raw components that make it possible to change or adjust the functional and technological properties of whipped masses, as well as texture, quality indicators, and extend the shelf life of marshmallow products. In works [2–4], the expediency of using viburnum juice, blackcurrant pomace, pumpkin puree, redcurrant jam, and chicory powder in the technology of enriched pastille products is substantiated. In work [5] it is proposed to use aqueous solutions of anthocyanin pigment of honeysuckle and black currant in the production of marshmallows. The use of red beet juice and puree and physalis juice as natural dyes in the zephyr technology

allows you to enrich it with general phenols and flavonoids and thereby increase the antioxidant properties of the product. It also allows to get a natural product with the same color and aroma that artificial colors and flavors give [6]. Scientists of KhSUFTT developed a fruit and vegetable semi-finished product (apple - 60%, pumpkin - 20%, beetroot - 20%) with a dry matter content of 45% and confirmed the feasibility of using this semi-finished product in the composition of marshmallows by replacing 75% of apple puree [7]. The authors established that the use of plant powder extracts in marshmallow technology (powders obtained using low-temperature technologies) allows to enrich the product with biologically active substances. In addition, the quality indicators of the new product are improved [8]. To expand the range of functional confectionery products and prevent iron deficiency anemia, spinach and tomato extracts (25:75) are added to the marshmallow recipe. This product contains 1.159 mg/100 g of iron and 44 mg/100 g of vitamin C [9]. Semi-finished products from Jerusalem artichoke roots (pure, paste, powder) and concentrated fruit juices (apple and pineapple) are used as enrichment additives in marshmallow technology. This allows to increase the content of vitamin C in marshmallows by 2 - 4 times, potassium by 4 times, magnesium by 7 times, antioxidant activity by 3 - 5 times, compared to the control; enrich with inulin; reduce the energy value [10]. The use of lingonberry enzyme hydrolysate in the production of marshmallows made it possible to obtain a product enriched with physiologically functional ingredients. Also, this marshmallow is characterized by good organoleptic properties due to the appearance of natural dyes - anthocyanins [11]. The authors [12] proposed the use of barberry fruit extract as a natural dye in confectionery technology, including marshmallows. It has been established that barberry extract has greater color stability compared to beet juice concentrate; products with added extract have better antioxidant properties.

A new marshmallow technology based on blackcurrant puree and the addition of basil powder was developed [13]. The composition of marshmallows with Jerusalem artichoke syrup, milk whey, a mixture of apple and blueberry puree is known, which allows to obtain products with reduced sugar content and increased nutritional value [14,15]. A marshmallow technology was developed with a partial replacement of apple puree with a mixture of blueberry and strawberry puree. The product obtained by this technology is characterized by an increased content of dietary fibers, macro- and micronutrients, anthocyanins [16]. The use of new-generation sugar substitutes in marshmallow technology (referring to polyols with prebiotic properties and a low glycemic index) makes it possible to obtain products with reduced sugar content and increased nutritional value [17]. Numerous works are devoted to the use of fructose in the technology of pastila-type products to improve the quality of products, increase the shelf life, reduce the sugar content, obtain products with a functional purpose, and expand the raw material base [18–23]. Scientists [24] improved the formulation of whipped confectionery products by replacing sugar with erythritol and a small amount of sucralose and introducing an active ingredient (a multivitamin mixture or vitamin C or a mixture of B-complex vitamins) into the products. Such products have low energy value and glycemic index, unique structure, extended shelf life and increased nutritional value. The authors [25] studied the influence of sorbitol and sweet potato inulin extract on the physical, chemical and organoleptic characteristics of marshmallows. It was established that the product with the addition of 2% sweet potato inulin extract and 50% sorbitol has the best characteristics.

Numerous studies of sugars, sugar substitutes and sweeteners were carried out at the NUFT under the leadership of Dorohovich. The physico-chemical and physiological properties and the possibility of use in the production of dietary functional confectionery products with reduced glycemic and caloric content were determined [26–29]. Coconut sugar is a sweet product obtained from the juice of the coconut palm and is widely used as an alternative to other types of sugar. This sugar has a subtle, less sweet taste than regular sugar with a caramel aftertaste. Coconut sugar has a low glycemic index of 35 and is rich in nutrients [30]. Cryopowders are environmentally friendly products made from certified plant raw materials without the use of chemical stabilizers. Their feature is a high content of biologically active substances, which during cryomechanical processing preserve up to 95% of the original composition of useful substances. The introduction of cryopowders makes it possible to increase the nutritional value of finished products, to exclude synthetic dyes and flavors from the recipe, to obtain a variety of colors, as well as to improve the structural-mechanical and physico-chemical indicators of finished products [31]. Blueberries contain a large amount of anthocyanins, up to 12% of pyrocatechin group tannins, organic acids (citric, malic, succinic, etc.), vitamins C, PP, B1, B2, carotenoids, minerals: potassium, calcium, magnesium, and iron. Blueberry myrtilin has the property of lowering blood sugar. Pterostilbene provides it with a pronounced cholesterol-lowering effect. Flavonoids are able to successfully fight inflammatory processes and protect the mucous membrane of the stomach, increasing the secretion of mucus. The optimal ratio of vitamins of groups B and C gives blueberries a vaso-strengthening and anti-anemic effect, improves memory and resistance to stress [32]. After analyzing the presented scientific improvements, it was concluded that the creation of new technologies of functional marshmallow is relevant. Marshmallow has a high glycemic index due to the significant content of white sugar and causes a sharp jump in the level of glucose in the blood. And therefore, they cannot be consumed by all sections of the population. In addition, it is poor in vitamins and minerals. This can be corrected by replacing white sugar with alternative types of sugars that have a lower glycemic index and by introducing berry powders obtained by low-temperature technologies, which have better indicators of the content of vitamins, macro- and microelements. In order to solve this problem, we suggested replacing white sugar in the marshmallow (zephyr) formulation with a mixture of coconut sugar and fructose and adding freeze-dried blueberry powder.

Methods of research

Materials

Coconut sugar (manufacturer, VanaVita, Germany), blueberry powder (SOK "Unikrasa", Ukraine), fructose (OOO "Barvysta", Ukraine), agar (ROKO, Spain), apple puree ("Agrana Fruit" Ukraine), molasses starch (PJSC "Dniprovsky starch-molasses plant"), citric acid ("Kharkiv plant of food acids", Ukraine).

Method for determining the content of anthocyanins

It was determined by measuring the optical density of the investigated solution at a wavelength of 490 nm (layer thickness 10^{-2} m). The sample was prepared by diluting 1 cm^3 of the test solution with a buffer solution with pH=1.0 to 10 cm^3. A buffer solution with pH=1.0 was prepared by mixing 0.2 N potassium chloride solution with 0.2 N with a solution of hydrochloric acid in a ratio of 25:67. The amount of anthocyanins was calculated using the formula:

(1)
$$C_A = \frac{A_{490}^{\mathrm{pH}=1,0}}{49}$$

where:

C_A - is the concentration of anthocyanins in the solution, mg/100 cm^3

$A_{490}^{pH=1,0}$ - light absorption at λ=490 nm of the sample of the investigated solution (pH=1.0; layer thickness 10^{-2} m)

49 - is the coefficient calculated from the angle of inclination of the calibration graph [33].

The content of pectin substances was determined according to the universal method [33]. The essence of the method is to determine the content of pure pectin in the form of a uronide component. (0,2…0,5)×10^{-3} kg of powder was moistened with a few drops of ethyl alcohol, 10 - 20 cm^3 of water was added and mixed. Then 1 - 2 cm^3 of 1 N NaOH was added to the resulting mixture and left for saponification for 20x60 seconds. After that, pectinic acid was precipitated with 2 - 3 cm^3 of 1 N HCl, and 50 cm^3 of 0.1 N HCl was immediately added. The total mass of the solution (G) was fixed by adding individual components. The sediment was filtered through a paper filter. 10 - 20 cm^3 of filtrate was taken and titrated with 0.1 N NaOH. The remaining filtrate, the filter cake and the filter were combined and titrated with 0.1 N NaOH. The pectin content was calculated according to the formula:

(2)
$$C = \frac{V \cdot 176 \cdot 0{,}1}{1000}$$

where:

V - is the volume of sodium hydroxide used for the titration of pectic acid, cm^3

176 - molar mass of pectic acid equivalent, g/mol

0,1 - 0.1 is the molar concentration of the sodium hydroxide solution equivalent, mol/l.

Method for determining the content of ascorbic acid

A blue solution of 2,6-dichlorophenolindophenol is reduced in the presence of chloroform to a colorless compound with colored plant extracts containing ascorbic acid (Tilmans reaction) [34].

Method of tannins determination

The method for determining tannins is based on their easy oxidation by potassium tetraoxomanganate in an acidic medium in the presence of indigosulfonic acid [35].

Method of determining the antioxidant capacity (AOC)

The antioxidant capacity of raw materials and finished products was determined by the method of galvanostatic coulometry. To prepare the extracts, a weight of the appropriate crushed sample with a mass of (5.0…6.0)x10^{-3} kg was ground with 10 - 20 cm^3 of the extractant (distilled water) and quantitatively transferred to a 100 cm^3 flask, the volume of the solution was brought to approximately 100 cm^3 and weighed. The contents of the flask were kept for 10x60 s, mixed and filtered. (0.2…5.0)x10^{-3} of the obtained extracts were placed in the coulometric cell and titrated with electrogenerated bromine at currents of 1 - 5 mA depending on the concentration of the solution under study so that the titration time was 300 - 500 s. Bromine was generated from an aqueous solution of 0.2 M potassium bromide in 0.1 M sulfuric acid. Fixation of the equivalence point was carried out by the potentiometric method. AOC (Cl/ 100 g) of herbal supplements and products was calculated according to the formula:

(3)
$$\mathrm{AOC} = \frac{100 \cdot I \cdot t \cdot m_{\mathrm{e}}}{m_a \cdot m}$$

where:
I - current strength, A
t - time to reach the end point of titration, s
m - mass of the sample that was taken for analysis, g
m_e - mass of the extract, g
m_a - mass of the aliquot used for analysis, g.

Methods of assessing the quality of semi-finished products for the production of marshmallows

The foaming ability of the marshmallow mass (%) was determined by measuring the volume of the recipe mixture before and after whipping, then the amount of foaming ability (FA, %) was calculated according to the formula:

(4)
$$FA = \frac{V_2}{V_1} \cdot 100$$

Where:
V_1 - is the volume of the recipe mixture to be whipped, cm^3
V_2 - is the volume of the recipe mixture after mixing, cm^3.

The stability of the foam after whipping was determined within an hour by measuring the foam volume every 15 min and dividing it by the initial volume. The nutritional value was determined by the calculation method [36]. Determination of the content of anthocyanins, pectin substances, low molecular weight phenolic compounds, tannins in finished products was carried out according to the methods given in [33–35].

Statistical analysis

Experimental data were processed with the use of MS Office Excel spreadsheets. Each test or measurement was performed three times. The statistical significance of the obtained results was determined at p <0.05.

Results and discussion

The results of the determination of the quality indicators of coconut sugar are shown in Table 1.

Table 1. Coconut sugar quality indicators. *Source: Authors.*

Indicator	**Characteristic**
Appearance	Brown, free-flowing, uneven in size, there are lumps that fall apart when lightly pressed
Taste and smell	Sweet with a caramel flavor
Purity of the solution	Light brown, clear solution with a slight precipitate in the form of insoluble black inclusions
Humidity,%	0.11

Table 1 shows that coconut sugar is a free-flowing brown product with uneven crystal size, sweet taste and caramel flavor; it gives a clear solution, has a moisture content of 99%. The results obtained will be considered in the development of technology. The results of determining the quality indicators of blueberry powder are shown in tables 2 and 3.

Table 2. Quality indicators of blueberry powder. *Source: Authors.*

Indicator	**Characteristic or value**
Organoleptic indicators	
Appearance	Homogeneous, finely dispersed, free-flowing mass interspersed with berries seeds
Color	Dark pink with a purple tint
Taste	Sweet and sour, typical for blueberries
Smell	Typical for blueberries
Physico-chemical indicators	
Humidity, %	0.5
pH	3.2

It can be seen from Table 2 that blueberry powder is a finely dispersed free-flowing mass, dark pink in color, with a sweet-sour taste, moisture content of 95.0%, pH 3.2. The obtained results will be considered in the development of the technology.

Table 3. The content of biologically active substances in blueberry powder and its antioxidant capacity. *Source: Authors.*

Indicator	**Value**
Anthocyanins, %	2.8±0.2
Pectin substances, g/100 g	9.0±0.5
Low molecular weight phenolic compounds (by routine), g/100 g	11.2±0.1
Tannins (by tannin), g/100 g	5.3±0.3
Vitamin C, mg/100 g	15.0±0.7
Antioxidant capacity, mg AAE/100 g	1092.0±177.6

Studies of the chemical composition of blueberry powder have shown that they contain a significant percentage of biologically active substances (BAS) and have a high antioxidant potential (Table 3). The use of this additive will make it possible to obtain products with increased nutritional value and antioxidant properties. Based on the fact that the structure of marshmallow is a foam - an unstable system, the quality of which depends on the recipe components and their quantity, the influence of coconut sugar, fructose and blueberry powder in the amount of 3, 5 and 7% on the process of foaming in the marshmallow mass was investigated and its stability. During the experiment, 7 samples were prepared: 1 - control sample on white sugar, 2 - sample based on coconut sugar, 3 - sample based on fructose, 4 - sample based on a mixture of coconut sugar and fructose, 5 - sample based on a mixture of coconut sugar and fructose with the addition of 3% blueberry powder, 6 - a sample based on a mixture of coconut sugar and fructose with the addition of 5% blueberry powder, 7 - a sample based on a mixture of coconut sugar and fructose with the addition of 7% blueberry powder. The results of the experiment are presented in Figure 1.

From the obtained results, it can be seen that sample 2 has the highest amount of FC, 53% higher than that of the control sample, which we believe is due to the proteins present in the coconut sugar. Sample 3 also has a fairly high FC value; this is due to the fact that fructose is more soluble compared to sucrose. However, with the introduction of blueberry powder into the marshmallow mass, there is a tendency to decrease FC, and increasing the amount of powder to 7% reduces FC by 114%, compared to the control, which may be related

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to the dispersion of the powder and the presence of seeds. The powder adsorbs egg white on its surface, the amount of foaming agent in the total volume decreases, which leads to an increase in surface tension and a decrease in foam dispersion. When determining the stability of the foam in the semi-finished products for the production of marshmallows, it was noted that 15, 30, 45 and 60 minutes after the end of whipping, the foam resistance in all test samples did not change. It is known that for whipped masses of marshmallows on agar, the amount of foaming capacity should be at least 200%. The obtained results indicate that a concentration of blueberry powder of 3–5% is more acceptable for maintaining quality and obtaining the desired effect.
Replacing white sugar with a mixture of coconut sugar and fructose and adding blueberry powder has a significant impact on the organoleptic and physicochemical quality indicators of the finished product. The results of the relevant studies are shown in Tables 4 and 5.

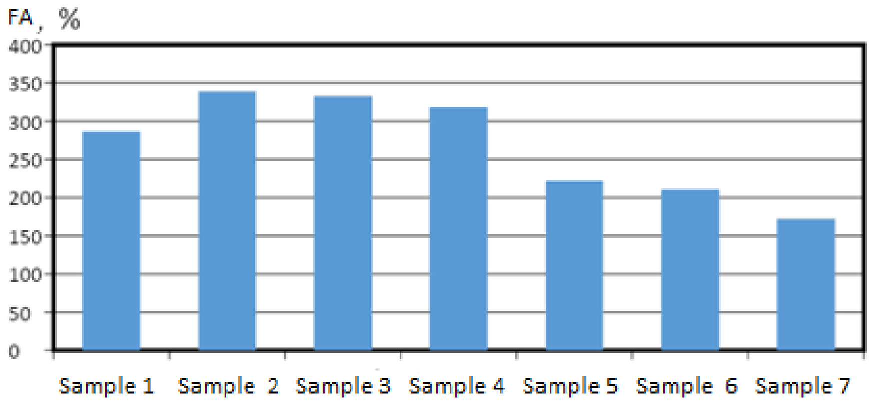

Figure 1. The influence of recipe components on the process of foaming in semi-finished products for the production of marshmallows. *Source: Authors.*

Table 4. Organoleptic quality indicators of marshmallows based on coconut sugar and fructose with different dosages of blueberry powder. *Source: Authors.*

Indicator	**Characteristics of marshmallows**			
	Control sample	Sample based on coconut sugar and fructose with the addition of blueberry powder, % of the total mass		
		3.0	5.0	7.0
Appearance	Round form, corrugated surface with clear outline	Round form, corrugated surface with clear outline	Round form, corrugated surface with clear outline	Round form, corrugated surface
Color	White	Light pink	Pink with red shade	Dark pink with plum shade
Consistence	Elastic, easily broken	Elastic, soft, easily broken		
Texture	Uniform, fine-pored	Uniform, fine-pored		
Taste and smell	Sweet with sour flavor	Sweet with caramel flavor	Sweet with sour and Caramel flavor	Sweet with bright pronounced flavor blueberries

According to the data in Table 4, it can be seen that the research samples of marshmallows have original organoleptic indicators: appearance, color, taste and smell, in contrast to the control sample.

From the table 5. it can be seen that the humidity of marshmallow based on coconut sugar and fructose with the addition of blueberry powder is within the normal range. The acidity of marshmallow increases to 9.0 degrees with an increase in the powder concentration to 7%, which is due to the fact that it contains a significant amount of organic acids. The content of reducing substances in the developed marshmallow samples is increased compared to the control due to the addition of fructose, which is a reducing carbohydrate, and the use of raw materials that also contain reducing substances (coconut sugar and blueberry powder). Based on the research conducted, we believe that a powder content of 5% of the total weight of the product is rational for achieving the set goals. It was established that the introduction of coconut sugar and blueberry powder into the marshmallow recipe made it possible to obtain products with a sweet taste with sour caramel notes, a more delicate color (pink with a red tint) compared to marshmallows with the addition of blueberry puree [14], which has a delicate, pleasant taste with blueberry flavor and dark purple color. The appearance, consistency and structure of the products remained unchanged. The physical and chemical indicators of the products do not differ significantly [14–16] and meet the requirements of regulatory documents.

It has been proven that the quality of the new products meets the requirements of the regulatory documentation for this type of product, and due to the content of biologically active substances, they are significantly superior to the analog product that does not contain such substances (Table 6).

Table 5. Physico-chemical indicators of the quality of marshmallows based on coconut sugar and fructose with different contents of blueberry powder. *Source: Authors.*

Impact	**According to SSTR (state standard technical requirements)**	**Control sample**	**Marshmallow based on coconut sugar and fructose with the addition of blueberry powder, % of the total mass**		
			3.0	5.0	7.0
Mass fraction of moisture, %, no more	24.0	16.4	18.0	19.6	20.3
Acidity, degree, no less	5.0	5.0	7.8	8.2	9.0
Mass fraction reducing substances,%	7.0…14.0	9.75	14.0	13.6	11.9

Table 6. Chemical composition and antioxidant capacity of the developed marshmallow. *Source: Authors.*

Indicator	**Marshmallow control sample**	**Marshmallow “Blueberry Glow”**
Proteins, g	1.14	1.96
Fats, g	0.1	0.3
Carbohydrates, g	89.75	81.05
Dietary fiber, g	0.43	1.33
Anthocyanins, mg/100 g	-	15.0±0.8
Pectin substances, mg/100 g	7.9±1.2	49.5±1.5
Low molecular weight phenolic compounds, mg/100 g	-	33.0±1.0
Tannins, mg/100 g	-	28.8±0.9
Antioxidant capacity, mg AAE/100 g	14.4±2.9	33.6±1.5

According to literature data [14,15] the use of a mixture of apple and blueberry puree in the marshmallow technology led to an increase in dietary fiber (by 5.0-5.6 times), vitamins B1, B2, B6, B9 and C (in 2- 3 times), as well as potassium (1.2 times), calcium (1.04 times) compared to the control. In addition, the products are characterized by a decrease in energy value by 25%, which is associated with a halving of the amount of added sugar. The authors of the paper [16] established that marshmallows based on apple-blueberry-strawberry puree contain 3.6 times more dietary fiber, 1.1 times more sodium, 2.6 times more potassium, 1.4 times more calcium, 1.8 times - magnesium, 3 times - iron. There was also a 5.5 - fold increase in the content of vitamin C and anthocyanins compared to the control sample.

In the proposed product (Table 6), the content of dietary fibers increases by 3.1 times, pectin substances by 6.3 times. The products are enriched with anthocyanins, low molecular weight phenolic compounds, tannins; the antioxidant capacity increases by 2 times. The products are characterized by a decrease in energy value and glycemic index, which is associated with the replacement of white sugar in the recipe with coconut sugar and fructose (Table 7.)

Table 7. Comparative analysis of calculated values of energy value and glycemic index. *Source: Authors.*

Samples of marshmallows	**Energy value**		**Glycemic index**	
	kcal	% decrease	%	% decrease
Marshmallow "Blueberry Glow"	336.60	7.70	36.00	36.84
Marshmallow on isomalt and fructose [28]	343.75	9.73	23.09	58.99
Marshmallow on maltitol and fructose [29]	343.17	9.90	50.07	11.07

The results of the analysis shown in Table 7 indicate the competitiveness of the innovative product among similar products in terms of caloric content and glycemic activity. The use of coconut sugar and fructose allows labeling the product with "reduced calories" and "reduced glycemic index". The proposed product can be used by people who lead an active healthy lifestyle and people with diabetes.

Impact

The implementation of the obtained results will allow to improve the marshmallow technology using coconut sugar, fructose and blueberry powder and to obtain a product with high consumer properties. This will contribute to solving the important social task of improving the health of the population. Due to the sugar content, confectionery products have a high energy value and glycemic index and are not recommended for consumption by people with diabetes. The research described in this article offers a solution to this problem by completely replacing white sugar in the marshmallow recipe with coconut sugar and fructose, which have lower glycemic indices. In addition, in order to increase the nutritional value, the addition of finely dispersed blueberry powder, obtained by low-temperature technology, is proposed. Research data show the effectiveness of introducing new ingredients to lower the glycemic index of marshmallows and increase their nutritional value. The use of coconut sugar, fructose and blueberry powder in marshmallow technology does not have a negative impact on the environment. The introduction into production of marshmallows based on coconut sugar, fructose with the addition of blueberry powder will contribute to the expansion of the assortment, saturation of the world market with high-quality confectionery products with a reduced glycemic index. The innovative product can be used by people with diabetes and people who lead an active, healthy lifestyle. The new product will be more expensive compared to the product based on white sugar. However, considering the reduced glycemic index of the products (36) and the presence in the composition of low molecular weight phenolic compounds, tannins, anthocyanins, an increased amount of pectin substances, this product will have a sustainable competitive advantage among products of the same category.

Conclusions

It was established that replacing white sugar in marshmallow technology with coconut sugar and fructose lowers the glycemic index of products by almost two times. It has been proven that thanks to new ingredients (coconut sugar, fructose, finely dispersed blueberry powder, obtained by low-temperature technology), the organoleptic properties of the product are improved, namely, the marshmallow acquires a pink color with a red tint and a sweet taste with sour, caramel notes. At the same time, dyes and flavorings are completely excluded from the recipe. According to physical and chemical parameters, the new product meets the requirements of regulatory documentation.

Marshmallow based on coconut sugar and fructose with the addition of 5% of blueberry powder from the total mass has an increased protein content (by 72%), dietary fiber (by 209%), reduced calorie content (by 7.7%). Thanks to the introduction of blueberry powder into the product recipe, the nutritional value of marshmallows is significantly increased, namely, the composition includes low molecular weight phenolic compounds, tannins, and anthocyanins. A significant advantage of the product is its antioxidant properties, which is confirmed by an increase in the antioxidant capacity of the products by almost 2 times compared to the control. Further research will be aimed at determining the effect of coconut sugar, fructose and blueberry powder on the organoleptic, physicochemical and microbiological properties of marshmallows during storage.

Conflict of interest

There are no conflicts to declare.

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