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INNOVATIVE TECHNOLOGY FOR HIGH–QUALITY DIETARY COLD SWEET DISHES USING PLANT POWDERS FROM BEETROOT AND BLUEBERRIES

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Abstract. The article presents the results of a study devoted to the development of innovative technology for cold sweet dishes of increased quality for dietary and functional purposes, using the example of whipped creams with the addition of beetroot and blueberry powders as natural sources of biologically active compounds. The relevance of the work is determined by the need to expand the range of dietary products with increased nutritional and biological value, as well as the search for effective technological solutions that ensure stable rheological and high sensory properties of finished products in accordance with modern concepts of nutrition, preventive nutrition, and functional product design. The research was carried out taking into account the philosophy of technologies as a system of conceptual principles aimed at minimizing intensive technological influences, preserving the natural biological value of raw materials, forming a stable product structure without heat treatment, and harmonizing technological, nutrition, and sensory characteristics. This approach made it possible to consider technology not only as a set of operations, but as a holistic model for creating a functional food product. The aim of the study is to scientifically substantiate the recipe composition and technological parameters for the preparation of cold sweet dietary dishes – whipped creams using beetroot and blueberry powders as sources of natural functional ingredients. The object of the study is the technology of cold sweet dishes, in particular whipped creams, and the subject is the influence of plant powders and gelling agents on the formation of their structural–mechanical, physicochemical, and organoleptic characteristics. In the course of experimental research, the recipe composition was optimized based on Greek yogurt with a fat content of 3%, cream 33%, beetroot and blueberry powders, agar–agar, and highly esterified pectin using natural sweeteners. It was established that the rational ratio of active components is 6.81 g of vegetable powders and 4.64 g of gelling agents per 100 g of recipe mass, which ensures the achievement of the maximum integral quality index. Physical and chemical evaluation confirmed the formation of an optimal product consistency with a viscosity of up to 680 mPa·s, minimal syneresis, stable acidity, and shape retention for 48 hours at a temperature of 4 ± 2 °C. The results of infrared spectroscopy and thermogravimetric analysis indicate the formation of a heat–resistant protein–polysaccharide structural matrix that is stable at temperatures up to 120 °C. Chemical analysis has shown a significant enrichment of the product with dietary fiber, minerals, and vitamins, as well as a high content of anthocyanins and betaines, which determines the pronounced antioxidant potential and functional activity of the developed creams. The proposed technology can be recommended for implementation in restaurants and food industry enterprises focused on the production of dietary and functional products.

Keywords: cold sweet dishes, whipped creams, vegetable powders, gelling agents, antioxidant activity, nutritional and biological value, structural stability, IR spectroscopy, dietary nutrition, technology philosophy.

Introduction. Formulation of the problem

In light of consumers' growing interest in healthy eating, there is an increasing demand for products that not only meet gastronomic expectations but also demonstrate high functional properties and promote health [1, 36].

Current trends in the food industry are focused on the use of natural raw materials, minimising the addition of synthetic components, and reducing sugar and fat content, which is driving the search for the development of food products with increased biological value [**2–4, 40**]. One of the promising categories in this area is cold sweet dishes, in particular whipped creams, which, thanks to their soft consistency and minimal heat treatment, better preserve nutrients and biologically active substances [4, 5, 6].

The use of powdered forms of plant raw materials, in particular beetroot and berries such as blueberries, plays an important role in the technology of such whipped creams. These ingredients act as natural colorants and are also sources of biologically active compounds [11–13, 18, 19]. The results of domestic studies confirm that beetroot is a valuable raw material for obtaining natural dyes – betalains, which have a pronounced antioxidant effect and can successfully replace synthetic analogues in food systems [11–14, 17]. Similarly, blueberries are a source of anthocyanins, water–soluble polyphenols with high antioxidant potential and coloring ability [2, 18–20].

In addition to their coloring and functional roles, the use of plant–based raw materials has a positive effect on the structural and mechanical characteristics of the final product. Modern production practices increasingly involve the rejection of animal–derived gelatin in favor of natural plant–based gelling agents such as agar–agar and pectin. Such components not only form a stable texture, but also increase the biological safety and acceptability of the product for consumers with dietary, vegetarian, or religious restrictions in nutrition [7–10]. Domestic scientific sources indicate the effectiveness of combining beetroot coloring components with polysaccharide stabilizers to obtain stable structural systems in dessert products [10–12, 14].

Thus, the scientific justification and development of technology for dietary whipped creams based on beetroot and blueberry powders in combination with natural gelling agents is a relevant and appropriate direction for modern research in the field of functional nutrition. Such a new product will combine high antioxidant activity, structural stability, attractive natural color, high consumer value, and compliance with the requirements of healthy, children's, and preventive nutrition.

Analysis of recent research and publications

At the current stage of food technology development, the priority direction is the implementation of solutions in the production of functional and dietary products. Technologies for creating cold sweet dishes with increased biological value are becoming particularly relevant due to the growing prevalence of metabolic disorders, obesity, and deficiencies resulting from an unbalanced diet [1, 2, 36]. In this regard, considerable attention is paid to the use of plant raw materials as a source of natural bioactive substances – antioxidants, dietary fiber, natural dyes, etc. [3,4, 36, 37].

One of the effective ingredients that combines technological and functional expediency is beetroot powder (Beta vulgaris L.), which contains betalains – water–soluble pigments with pronounced antioxidant, anti–inflammatory, and detoxifying properties. Scientific research data show that the use of beetroot powder increases the nutritional and biological value of cream products, while providing intense natural colouring and improving texture due to its high moisture retention capacity [11–15, 17, 41].

Blueberry powder, made from freeze–dried or dried berries, is characterized by a high content of anthocyanins, flavonoids, B vitamins, ascorbic acid, and other nutrients with antioxidant activity. Anthocyanins, as secondary plant metabolites, not only provide characteristic color, but also have angioprotective, neuroprotective, anti–inflammatory, and antibacterial effects. The use of blueberry powder in whipped creams significantly improves the sensory characteristics, storage stability, and functional orientation of the finished product [2,18–20,38].

The structure–forming properties of whipped creams largely depend on the composition of gel formers. In this context, it is advisable to use natural stabilizers such as pectin and agar–agar, which, unlike gelatin, are of plant origin and have high thermal stability and gel–forming ability. The results of experimental studies show that the synergistic use of these hydrocolloids ensures the formation of a homogeneous cream structure that is resistant to mechanical and thermal stress [7, 8, 10, 12, 39].

The combined use of beetroot and blueberry powders in combination with agar and pectin contributes to the creation of formulations that combine optimal organoleptic properties with high biological activity. In particular, it has been established that such products can contain up to 185 mg/100 g of anthocyanins, up to 95 mg/100 g of betalains, a significant amount of minerals (iron, magnesium, potassium), vitamins, and dietary fiber, which exceeds the corresponding indicators of traditional sweet dishes.

Purpose and objectives of the study. The study aims to develop and scientifically substantiate the recipe and technology for preparing cold sweet dietary dishes – whipped creams using beetroot and blueberry powders as sources of natural functional ingredients. The main focus is on creating a product with high biological value, stable structural properties, natural color, and pronounced antioxidant activity.

1. Review scientific sources on the use of beetroot and blueberry powders in functional whipped creams.

2. Investigate the physicochemical characteristics of beetroot and blueberry powders and evaluate their suitability for use in whipped creams.

3. Justify the use of agar–agar and pectin as natural gelling agents to stabilize the structure of cold dishes.

4. Develop an experimental recipe for whipped cream, determining the optimal proportions of ingredients to achieve the best organoleptic and functional properties.

5. Conduct a comprehensive assessment of the quality of the finished samples based on physicochemical, organoleptic, microbiological, and structural–mechanical indicators.

6. Determine the content of biologically active substances—anthocyanins and betalains—in cream samples and analyze their effect on the functional properties of the product.

Materials and methods.

The study used beetroot (Beta vulgaris) and blueberry (Vaccinium myrtillus) powders obtained by drying to a moisture content of ≤ 6% and subsequent grinding. The base of the whipped cream consisted of 3% Greek yogurt and 33% drinking cream.

Agar–agar and highly esterified pectin were used as gelling agents, stevia was used as a sweetener, and natural essences were used for flavoring. The manufacturing technology included cooling the components, hydrating the gelling agents, whipping the base, adding functional ingredients, and cooling the finished product.

The recipe was optimized using a second–order central composite design, varying the content of plant powders (X_1) and gelling agents (X_2), taking into account a comprehensive quality indicator (Y).

The physicochemical properties (viscosity, pH, moisture content, syneresis, shape stability) were determined by standard methods. IR spectroscopy, thermogravimetry, and gas chromatography allowed the identification of structural stability and aromatic profile. The content of anthocyanins and betalains was determined spectrophotometrically.

Organoleptic evaluation was performed on a 5–point scale (DSTU 4285:2004), and microbiological safety was evaluated in accordance with DSTU ISO 4833:2006. All studies were performed in a food technology laboratory in compliance with sanitary requirements.

Results of the research and their discussion

In order to develop the nutritional value of whipped creams and bring them into line with modern healthy eating requirements, a comparison was made between the classic recipe based on cream and sugar and the developed version, which includes the use of vegetable powders and natural functional ingredients, in line with modern trends in rational and dietary nutrition [1–4, 36]. Comparative characteristics are presented in Table 1.

This approach to using plant powders in sweet food technology is in line with current scientific trends, as fruit and berry powders can simultaneously increase the biological value, antioxidant activity, and consumer appeal of sweet foods [18, 21, 35, 37]. Data analysis shows that the updated recipe for whipped cream, which uses Greek yogurt, beetroot and blueberry powders, natural gelling agents, and non–caloric sweeteners, helps reduce the energy value of the product while increasing its biological activity. This approach is scientifically justified from the point of view of nutrition science, which is consistent with the results of domestic studies that substantiate the feasibility of using functional ingredients of plant origin in cold sweet dishes [14, 19, 21, 39, 43].

The effectiveness of using plant raw materials in cold sweet dishes has been confirmed by the results of research conducted by the National University of Food Technologies, which substantiates the feasibility of introducing plant components to improve the functional and structural properties of desserts [19]. In order to select the appropriate components for the development of a whipped cream recipe, an analysis of the functional, technological, and physiological properties of each ingredient was carried out (Table 2). The feasibility of using Greek yogurt, plant–based gelling agents, and natural sweeteners is confirmed by scientific research in the field of cold dessert and cream product technologies.

Thus, each component of the developed recipe not only plays a technological role in shaping the structure and stability of the product, but also significantly enriches its nutritional value.

Table 1 – Characteristics of Formulation Changes in the Base and Developed Whipped Cream Recipes

Parameters	Traditional whipped vanilla cream recipe	Developed whipped cream recipes with plant powders
Main ingredients	35% cream, white sugar, food–grade gelatin	Greek yogurt, agar–agar, citrus pectin, beetroot or blueberry powder
Gelling system	Food–grade gelatin	Agar–agar, citrus pectin, milk whey
Sweetener	White crystalline sugar	Stevia sweetener
Additional components	Vanilla (powder)	Lavender, cardamom, lemon juice concentrate
Energy value	High	Reduced due to lower fat and sugar content
Bioactive compounds	Minimal amount	Antioxidants, vitamins, dietary fiber
Nutritional orientation	High–calorie cream	Low–calorie product adapted for healthy and dietetic nutrition

Table 2 – Scientific justification for the selection of innovative ingredients in the formulation development

Ingredient	Technological and functional role	Physiological significance
Greek yogurt 3%	Promotes a soft texture, replaces high–fat cream, stabilizes foam	Contains probiotics, improves digestion, enhances calcium absorption
Dairy cream 33%	Provides fat content and creamy consistency	Source of fatty acids and fat–soluble vitamins
Food–grade agar–agar 1.5%	Forms a stable cream structure, ensures heat resistance	Contains dietary fiber, improves intestinal peristalsis
Citrus pectin	Improves dispersion system, reduces risk of phase separation	Lowers glucose levels, normalizes gut microflora
Beetroot and blueberry powders	Natural colorants, enhance antioxidant activity	Source of anthocyanins and betalains; neutralize free radicals
Stevia sweetener	Natural sweetener, reduces energy value of the product	Does not raise blood glucose, suitable for diabetic nutrition
Vanilla extract	Enhances aroma and taste appeal	Has calming (sedative) properties
Chicken eggs (powdered)	Improve foam formation and structural stability	Source of complete protein and B–group vitamins
Cardamom	Provides pleasant aroma, enhances organoleptic properties	Has antibacterial effect, stimulates digestion
Dried lavender	Natural flavoring agent, adds aroma without artificial additives	Calming effect, promotes relaxation
Lemon concentrate	Regulates acidity, stabilizes protein system	Source of vitamin C, exhibits antioxidant activity
Organic milk whey (0.1%)	Enhances texture, binds moisture, stabilizes consistency	Source of protein, calcium, magnesium; promotes beneficial gut microbiota growth

This recipe concept ensures the creation of a whipped cream with an optimal combination of organoleptic advantages and functional benefits that meets modern requirements for healthy, rational, and preventive nutrition.

The use of beetroot and blueberry powders in whipped creams is justified by their high content of biologically active substances, in particular betaines and anthocyanins, which exhibit antioxidant activity and the ability to stabilize the structure of food systems. The use of agar–agar and pectin as gelling agents ensures the formation of a stable protein–polysaccharide matrix and meets modern requirements for plant–based and dietary products.

In order to study the nature of the interaction of beetroot and blueberry powders with various dispersion media, a microscopic study of model systems was carried out. Fig. 1 shows the microstructure features of the components both in dry form and in combinations with distilled water, glycerin, and cream.

Fig. 1 shows the microstructure of beetroot and blueberry powders in different environments at a magnification of ×200.

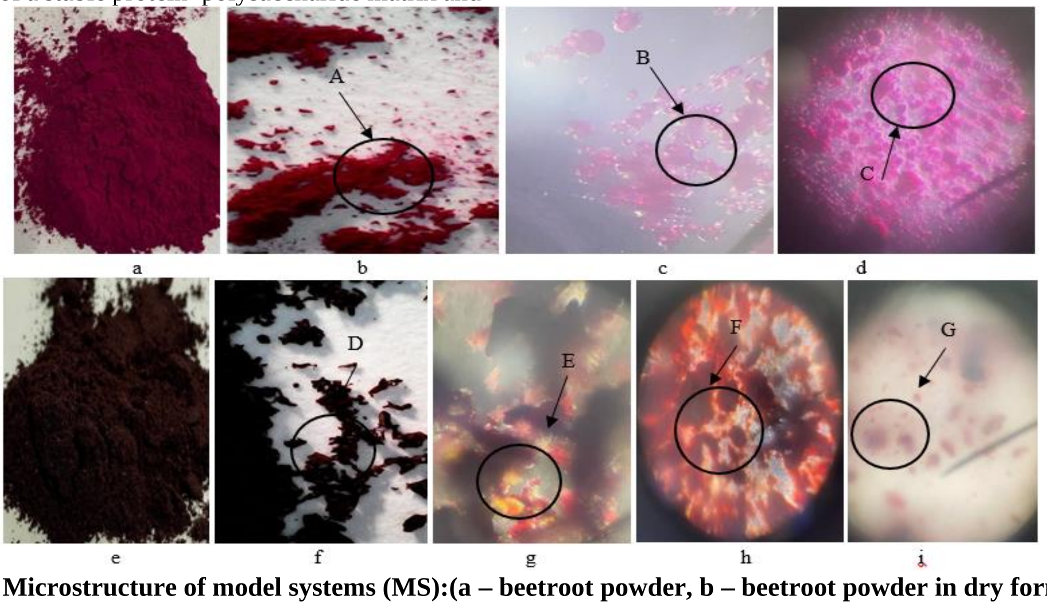


Fig. 1. Microstructure of model systems (MS):(a – beetroot powder, b – beetroot powder in dry form, c – beetroot powder + distilled water, d – beetroot powder + glycerol, e – bilberry powder, f – bilberry powder in dry form, g – bilberry powder + distilled water, h – bilberry powder + glycerol, i – bilberry powder + 33% cream)

Sample (a) demonstrates the finely dispersed dense structure of beet powder, while in the dry state (b) particle agglomeration (A) is observed. In an aqueous environment (c), hydration shells (B) form around the particles, indicating the initial phase of hydration. In a glycerol environment (d), beet powder shows uniform dispersion with clearly defined particle boundaries (C). Blueberry powder (e) has a fine–grained structure with a rich dark hue, and in dry form (f) it exhibits the ability to aggregate (D). When distilled water is added (e), anthocyanins are partially released (E), while in a glycerin medium (f), a stable and homogeneous dispersion is formed (F). When interacting with cream (c), blueberry powder is partially distributed in the lipid phase (G), which indicates its high ability to interact with fatty components.

Thus, the highest stability and homogeneity of the dispersed phase were found in model systems (c) and (e), respectively for beetroot and blueberry powders in an aqueous medium. The highest functional suitability for use in whipped creams was recorded for samples (g) and (h), where a stable fine–dispersed structure was formed, capable of maintaining the physicochemical and organoleptic characteristics of the finished product for a long time. Microscopic examination of model systems (Fig. 1) confirmed the high hydration capacity of plant powders and their active interaction with aqueous, glycerin, and fat environments, which is consistent with the literature data on the functional and technological properties of powdered plant raw materials.

One of the key indicators determining the functional and technological properties of plant powders is their water absorption capacity. It is this parameter that plays a significant role in the formation of the structural and mechanical characteristics, viscosity, and stability of whipped creams. Fig. 2 shows the results of a comparative analysis of the water absorption capacity of beetroot and blueberry powders.

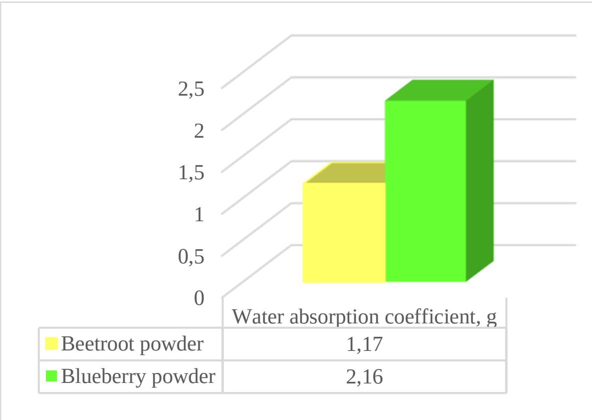


Fig. 2. – Comparative analysis of the water absorption capacity of beetroot and blueberry powders

Analysis of the water absorption capacity of beetroot and blueberry powders (Fig. 2) showed that blueberry powder is characterized by a higher level of hydrophilicity, which is due to the content of soluble dietary fiber and anthocyanins. Similar patterns are described in works devoted to the use of berry raw materials in food technologies.

It was determined that the water absorption index of beet powder is 1.17, and that of blueberry powder is 2.16, which is explained by the difference in their chemical composition and functional properties. The average level of hydrophilicity of beet powder is due to the presence of pectin compounds, fiber, and natural sugars, which contribute to the formation of a gel–like mass and a slight increase in the viscosity of the system. At the same time, the high water absorption capacity of blueberry powder is associated with the content of soluble dietary fiber, anthocyanins, and organic acids, which ensure better moisture retention, foam stabilization, and the formation of a thick, homogeneous, cream–like structure.

Fig. 3 shows the results of a study of the sedimentation stability of model dispersed systems containing beetroot and blueberry powders in combination with whey.

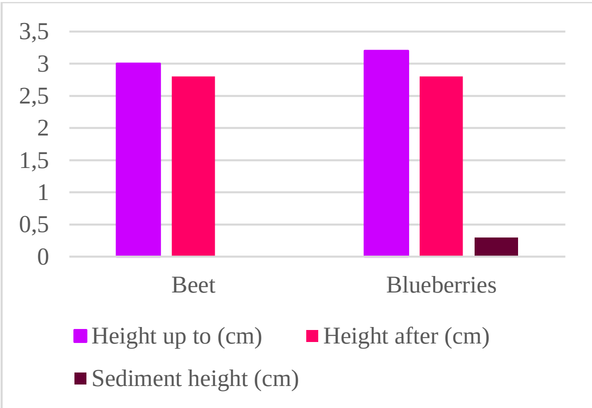


Fig. 3 – Sedimentation capacity of model systems

The sedimentation data recorded over 24 hours allow us to objectively determine the level of aggregate stability and the probability of phase separation in such systems. During the experimental study, it was found that during 24 hours of storage of model systems with the addition of plant powders, a slight decrease in the height of the liquid phase was observed.

Thus, in the variant with beet powder, the initial height of the dispersion was 3.0 cm, and after 24 hours it decreased to 2.8 cm.

No sediment formed in the system, indicating good solubility of the components and high sedimentation stability of the system under study. In turn, in the sample with blueberry powder, a decrease in the height of the liquid phase from 3.2 cm to 2.8 cm was observed, with a sediment 0.3 cm high forming. This indicates slightly poorer particle dispersion and lower stability compared to beet powder. Thus, beet powder is characterized by better sedimentation properties, which gives reason to recommend it as an effective stabilizer in the formation of homogeneous food systems that are resistant to phase separation.

To assess the colloidal stability of whipped creams, the aggregate stability of systems containing beetroot and blueberry powders was also analyzed. According to the results shown in Fig. 4, a relationship was established between the volume of the fat phase and the level of aggregate stability, confirming the technological feasibility of using these ingredients.

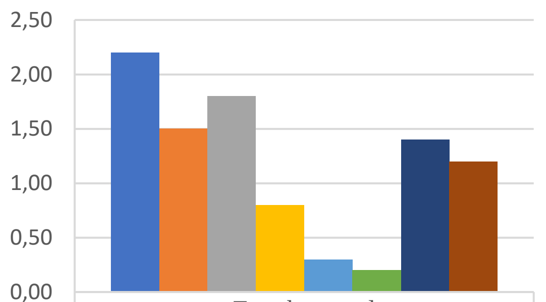
During the experimental study, the stability of eight model samples of cream systems was assessed by centrifugation for 10 minutes at a speed of 1000 rpm. The lowest level of aggregate stability, 78%, was recorded in the sample consisting only of eggs, milk, and sugar, which is associated with the lack of natural emulsifiers in the composition. The addition of gelatin improved stability to 85%, but in the absence of combined stabilizers, the system was still prone to phase separation.

The highest stability of 97–98% was demonstrated by samples with Greek yogurt, egg yolk, stevia, agar–agar, pectin, and beetroot and blueberry powders. This result is explained by the synergistic interaction of protein components, gelling agents, and bioactive substances of plant origin, which ensure the formation of a stable colloidal matrix with dense intermolecular bonds.

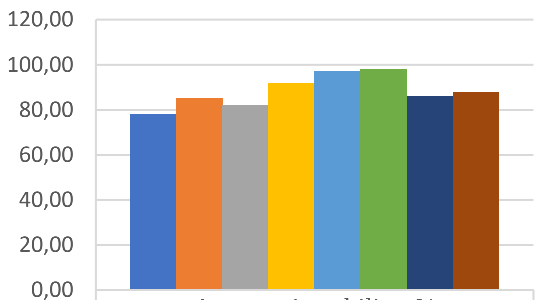
The results of the study of sedimentation and aggregate stability of model systems (Figs. 3, 4) show that beet powder has better stabilizing properties, while blueberry powder has a more active effect on the viscosity characteristics of systems. The synergistic effect of plant powders, protein bases, and gelling agents confirms the effectiveness of combined stabilization systems described in works on the technology of cream and emulsion products [12, 15, 17, 41].

Analysis of model systems has shown that plant–based powders have a pronounced ability to hydrate, thanks to which they effectively bind and retain moisture, increasing the resistance of the cream structure to delamination and sedimentation. The formation of a dense protein–polysaccharide network further stabilizes the dispersed phase, preventing the coalescence of fat globules. This emphasizes the advisability of including plant powders in the formulations of dietary emulsion products in order to increase their technological and consumer stability.

In order to study the rheological properties of whipped creams, the viscosity indicators of model samples were analyzed, since this parameter is decisive for assessing the structural stability and quality of finished products. The data obtained allowed us to trace the influence of the concentration of gelling agents and plant components on the density, homogeneity, and consistency of the samples. Figure 5 shows a graph illustrating the change in the viscosity characteristics of non–thickened creams depending on variations in the formulation of structure–forming ingredients.



	Fat phase, ml
a	2,20
b	1,50
c	1,80
d	0,80
e	0,30
f	0,20
g	1,40
h	1,20



	Aggregation ability, %
a	78,00
b	85,00
c	82,00
d	92,00
e	97,00
f	98,00
g	86,00
h	88,00

Fig. 4. Aggregative stability of model systems (a – fat phase, ml; b – aggregative capacity, %): a – centrifugation process; b – chicken eggs + pasteurized milk 2.6% + white crystalline sugar; c – chicken eggs + pasteurized milk 2.6% + sugar + diluted gelatin; d – Greek yogurt 3% + stevia + chicken egg yolk; e – Greek yogurt 3% + stevia + egg yolk + gelling agents; f – the same mixture with beet powder; g – similarly with blueberry powder; h – variant without gelling agents with powder

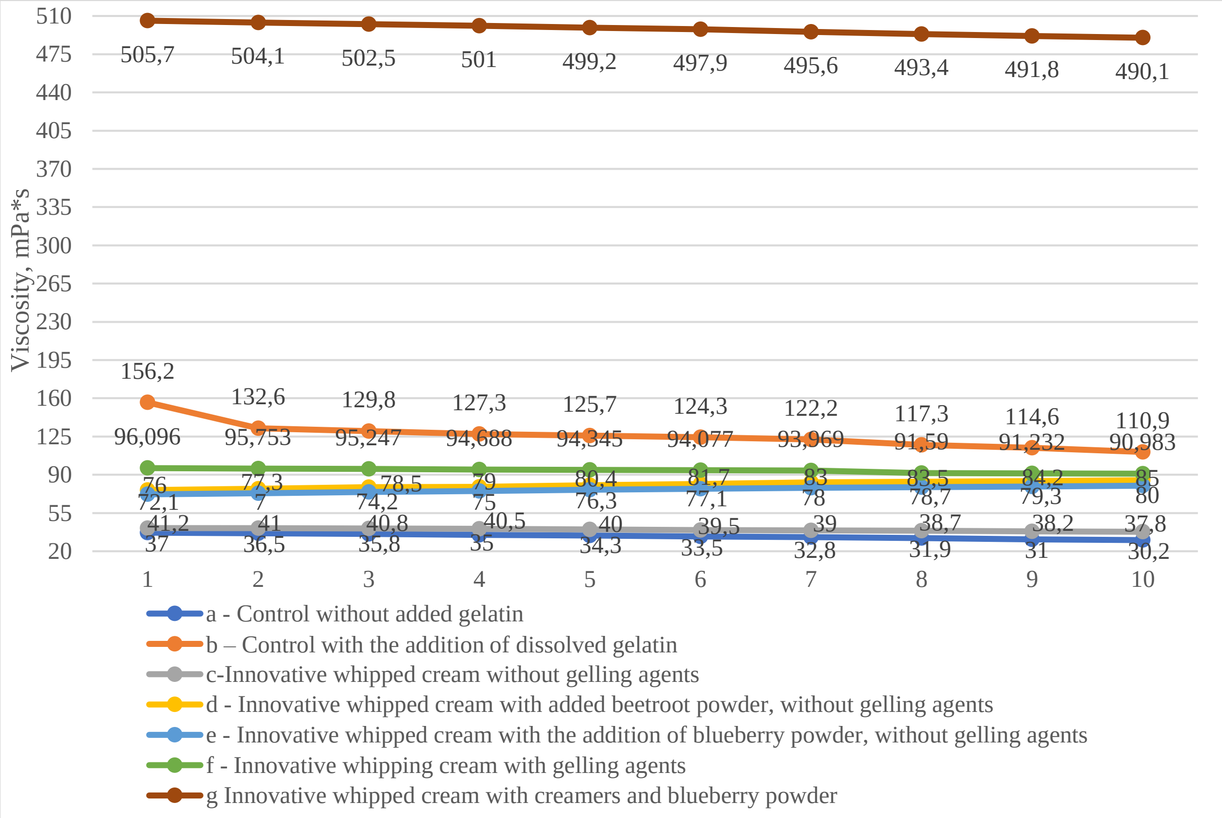


Fig. 5 – Dynamics of viscosity of model whipped cream systems at different recipe ratios

Analysis of rheological properties (Fig. 5) showed that an increase in the concentration of agar–agar, pectin, and plant powders contributes to an increase in viscosity and the formation of a stable gel structure, which corresponds to modern ideas about the mechanisms of gel formation in hydrocolloid systems.

During the study, it was found that the viscosity level of model systems is closely related to an increase in the concentration of structure–forming components. The lowest viscosity values were observed in the control sample, which consisted only of eggs, milk, and sugar, indicating the absence of a formed gel structure. The addition of agar–agar and pectin caused a significant increase in density, which is due to the formation of a three–dimensional polymer network characteristic of systems with hydrocolloids.

The highest viscosity values were recorded in samples supplemented with beetroot powder, and especially blueberry powder.

This is due to the high moisture retention capacity and content of natural polymers in these ingredients, in particular dietary fiber, anthocyanins, and polyphenols. Thus, the inclusion of plant powders in the formulation contributes to the formation of a stable whipped cream structure, reducing the need for synthetic thickeners.

In order to fully assess the sensory characteristics of the cream development, an organoleptic analysis of model samples with different combinations of protein–fat base, gelling agents, and plant additives was carried out.

Fig. 6 shows a profile of sensory properties, demonstrating the effect of recipe components on the overall organoleptic evaluation of whipped creams. The data of the tasting evaluation, conducted on a five–point scale, taking into account criteria such as appearance, color, aroma, taste, and consistency, are presented.

In order to confirm the effectiveness of the development, a technological scheme for the production of dietary whipped vanilla creams with the addition of beetroot and blueberry powders was created. For a visual comparison of the control and model samples, a generalized histogram was constructed in Fig. 7, which demonstrates a set of physicochemical quality indicators of the studied whipped creams.

Fig. 7 shows how the mass fraction of protein increases in the developed samples, which was made possible by the inclusion of ingredients with a high protein content – egg protein, 3% Greek yogurt, and powdered vegetable raw materials.

The use of beetroot and blueberry powders, which are sources of dietary fiber, made it possible to significantly increase the fiber content. The gel structure strength index, which characterizes the stability of the cream, was 131.6 units in the control sample, while in the samples with enriched composition it was significantly higher. This confirms the effectiveness of gel formation achieved through the interaction of agar–agar, pectin, and plant–based functional additives.

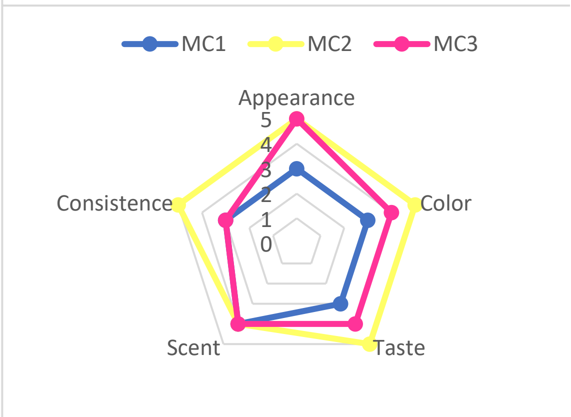


Fig. 6. Profilograms of the texture-structural characteristics of model whipped cream systems with plant powders in combination with various protein-fat bases and gelling agents: a – plant powders + whey; b – plant powders + Greek yogurt; c – plant powders + 33% cream; d – agar-agar and pectin + whey; e – agar-agar and pectin + 33% cream; f – 33% cream + egg white (foam formation assessment); g – 33% cream + egg white + gelling agents (combined effect)

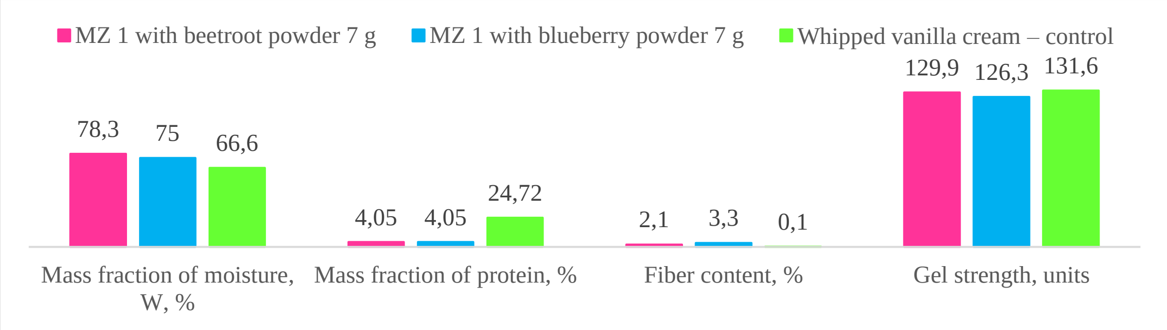


Fig. 7. Comparison of physicochemical characteristics of whipped creams with the addition of plant powders and the control sample – whipped vanilla cream

The study found that the model sample with the addition of 7 g of plant powder (MZ 1) is optimal for creating a functional whipped cream. It is characterized by an attractive appearance, balanced taste, and delicate texture, which ensures high consumer ratings. The results obtained can serve as a basis for the development of new types of cold sweet dishes with increased nutritional value and distinct sensory appeal. Similar technological approaches aimed at improving the quality, structural stability, and functional orientation of cold sweet dishes through the use of plant-based ingredients, natural stabilizers, and bioactive compounds are reported in recent conference and applied research studies, which confirms the relevance and scientific validity of the proposed technological solutions [27, 31, 32].

The process of developing the technology was based on experimental studies on the optimal composition of model systems that provide the necessary structural stability, uniform consistency, stable foam, and high organoleptic characteristics of the finished product. Testing of the proposed technology confirmed its effectiveness in creating creams with enriched structural and sensory characteristics]. The addition of beetroot and blueberry powders has a positive effect on the color, density, and shine of the cream. The sample with beetroot powder acquires a delicate pink hue and has a light caramel–vegetable aroma, while the cream with blueberry powder is characterized by a deep purple color, stable controllable texture, and rich berry flavor. The control sample has a lighter shade and a less pronounced aroma, which indicates the advisability of using plant additives. To assess the effect of plant ingredients on the organoleptic characteristics of creams, a comparative study of samples with beetroot and blueberry powders was conducted. The improvement in the taste, aroma, and texture characteristics of sweet dishes when using natural plant additives is consistent with the results of studies on improving the quality of functional sweet products. The shape, appearance, color, smell, taste, consistency, and appearance when cut were evaluated. The results are presented in Table 3.

Organoleptic evaluation showed that both versions of whipped cream have high quality characteristics. The cream containing beetroot powder has distinct vegetable and spicy notes in taste and aroma, a denser consistency, and a rich pink color.

At the same time, the sample with added blueberry powder has a more delicate texture, a distinct berry aroma, and a uniform light purple color, which makes it more attractive to consumers. Both creams hold their shape well, have a shiny, even cut surface, and show no signs of structural damage, confirming the successful combination of ingredients and the effectiveness of the technological process.

Table 3 – Indicators of organoleptic quality of whipped creams enriched with beetroot and blueberry powders

Indicator	Cream with beetroot powder	Cream with blueberry powder
Shape	Proper, well–defined; maintains shape after removal from the mold	Proper, stable; does not deform when served
Appearance	Uniform, light, delicate texture without inclusions	Uniform, light, and soft texture free of foreign particles
Color	Delicate pink, evenly distributed throughout the mass	Delicate violet, uniformly colored throughout
Aroma	Light vegetal–fruity aroma with notes of beetroot and cardamom	Fresh berry–floral aroma with characteristic blueberry scent
Taste	Moderately sweet, balanced, with a light beetroot juice note and a hint of spices	Light sweet–and–sour taste with a distinct blueberry note and floral nuances
Consistency	Whipped, elastic, jelly–like, soft to the touch	Airy, uniform, soft, stable
Cross–sectional view	Smooth, glossy surface without voids	Uniform, even structure without cavities, with a glossy finish

To evaluate the internal structure of the creams, a microscopic analysis of the sample cuts was performed. The microstructure study made it possible to determine the uniformity of the texture, the degree of porosity, the stability of the air–dispersion system, and the nature of the distribution of components in the final product. Figure 9 shows comparative images of the microstructure of vanilla whipped creams supplemented with vegetable powders.

a

b

Fig. 9. Microstructure of whipped vanilla creams with the addition of plant ingredients: a – cream with beetroot powder; b – cream with blueberry powder

The cream with beetroot powder has a pleasant pale pink hue and a light vegetable–spicy aroma, while the sample with blueberry powder is distinguished by its deep purple color and delicate berry scent. Both cream options have a uniform, smooth texture without air bubbles, which indicates that the whipping and gel formation modes were selected correctly. The use of natural ingredients ensures purity of taste and meets the requirements of healthy eating.

Fig. 10 shows examples of the design and presentation of whipped vanilla creams enriched with beetroot (a) and blueberry (b) powders, as well as a control sample without plant additives (c). The use of natural ingredients gives whipped creams a bright color, distinct texture, and attractive appearance, which significantly affects the perception of dishes in the restaurant service industry.

The visual samples of whipped vanilla creams shown in Fig. 10 clearly demonstrate the significant effect of adding plant powders on the appearance of the finished product. Enriching creams with beetroot and blueberry powder helps to create a rich, uniform color, enhances the contrast of the presentation and overall visual appeal, which is an essential aspect in the sensory analysis of food products. Compared to the control sample, the modified creams are characterized by a more pronounced texture and aesthetic combination with decorative elements (berries, mint, sauces), which emphasizes their functional orientation and compliance with modern standards of food presentation in restaurant service.

Visual appeal, determined by color intensity and compositional harmony, greatly influences the consumer's initial perception of the product, which, in turn, determines the overall impression of quality. Thus, the results of visual analysis confirm the feasibility of using natural dyes and antioxidants of plant origin to improve the presentation characteristics of functional cold sweet dishes. In order to confirm the structural changes, Fig. 11 shows the results of infrared spectral analysis of cream recipes with the addition of beetroot and blueberry powder compared to the control, which made it possible to establish the nature of the interaction of biopolymers and the stability of the product structure.

a b c

Fig. 10. Examples of whipped cream designs: a – vanilla cream containing beetroot powder; b – vanilla cream with the addition of blueberry powder; c – control sample of vanilla cream without additives

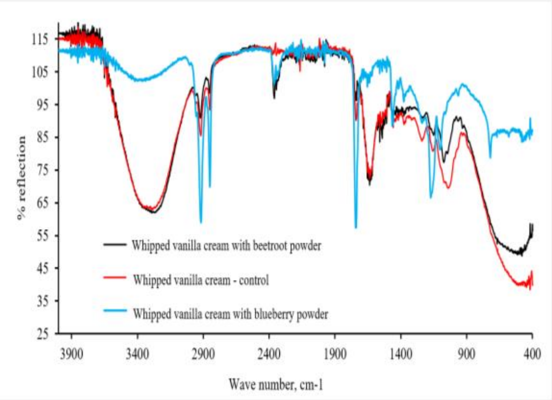


Fig. 11. IR spectra of creams with the addition of beetroot and blueberry powders compared to the control sample

The IR spectra of whipped vanilla creams were analyzed using the attenuated total internal reflection (ATIR) method, using a Nicolet Nexus 470 spectrometer (Thermo Scientific) with a diamond crystal at an angle of 45°, in the spectral range of 4000–400 cm^{-1} at a resolution of 4 cm^{-1}.

A comparative study of IR spectra of samples of formulations with the addition of beetroot and blueberry powders with a control cream showed significant differences in the structural and chemical composition. Within the range of 3600–3200 cm^{-1}, an increase in the bands of valence vibrations of O–H groups was noted, indicating an increase in the concentration of hydrophilic compounds, in particular polysaccharides, phenols, and fiber, which improve moisture retention. A decrease in the intensity of the bands at 2920 and 2850 cm^{-1}, associated with the vibrations of C–H groups of lipids, probably indicates their interaction with dietary fiber. The increase in amplitude in the 1740 and 1650 cm^{-1} regions indicates the presence of carbonyl groups (C=O) characteristic of polyphenols, anthocyanins, and protein molecules, which contribute to the enhanced biological activity of creams. Signals characteristic of phenolic compounds and pectin residues were recorded in the spectral range of 1500–1200 cm^{-1}, while vibrations of C–O–C bonds characteristic of natural polysaccharides were recorded in the range of 1150–900 cm^{-1}. The so–called "fingerprint region" (<900 cm^{-1}) shows unique peaks that indicate the presence of beetroot and blueberry components in the creams studied. The results of the analysis confirm the structural enrichment of innovative formulations with biologically active substances, which provide them with higher functional value compared to the control.

In order to generalize the influence of technological and formulation factors on the quality of whipped creams, a parametric model for process optimization was constructed based on experimental data. This model allows for a systematic presentation of the relationships between input, controlled, disturbance, and output variables that form the quality properties of the product. A schematic illustration of these interactions is shown in Fig. 12.

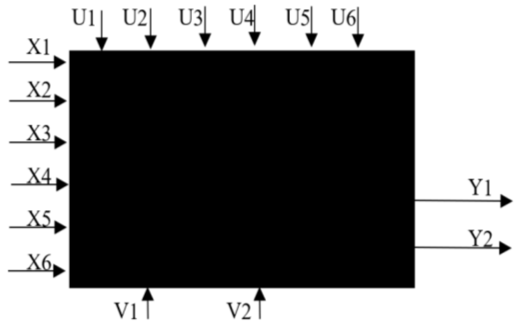


Fig. 12. Structural and parametric scheme for optimizing the recipe composition and technological parameters of whipped cream production, indicating the input, controlled, perturbing and output variables

To improve the quality of whipped creams, a cybernetic modeling method was used, which made it possible to generalize the influence of the main parameters of the technological process. Two controlled factors (X_1, X_2) and one output indicator (Y), which is an integral assessment of the target property of the finished product, were selected. Using two–factor optimization and mathematical modeling in Mathcad, an experimental matrix was formed in Table 4, which made it possible to determine the optimal conditions for the process.

Table 4 – Experimental data for optimizing the formulation of whipped vanilla creams with the addition of beetroot or blueberry powder

	X_1							
X_2		**2**	**3,5**	**4,5**	**5,5**	**6**	**6,5**	
	4	402,13	456,48	481,7	498,13	503,05	505,76	
	4,5	405,99	459,74	484,56	500,6	505,31	507,83	
	5	407,39	460,53	484,97	500,59	505,11	507,43	
	7	388,39	439,14	461,96	476,0	479,71	481,23	
	9	330,03	378,38	399,61	412,03	414,95	415,67	
								Y

As a result of modeling, an equation was established describing the dependence of the integral indicator of structural and mechanical stability of whipped creams (Y) on the concentration of vegetable powder (X_1) and the amount of gelling agents (X_2):

$$Y = 173{,}03 + 63{,}63X_1 + 51{,}14X_2 – 4{,}40X_1^2 – 0{,}80X_1X_2 – 4{,}92X_2^2$$

The model is statistically reliable $R^2 = 0.94$; $F_e = 80.26 > F_{кр} = 2.62$ at $\alpha = 0.05$. The optimal parameter values at which maximum stability $Y_{max} = 508.38$ is achieved are $X_1 = 6.81$ g, $X_2 = 4.64$ g. The reliability of the calculations is confirmed by the close value of Y = 508.14 at $X_1 = 7$ g and $X_2 = 4.5$ g.

The results obtained determine the rational conditions for the formation of the gel–foam system and ensure an improvement in the quality of the finished product. Figure 13 shows the response surface illustrating the complex influence of controlled factors on the target indicator.

The model that was constructed illustrates the nonlinear nature of the influence of variables X_1 and X_2 on the stability index of the cream structure. Under conditions of low dosage of both components X_1 within 2–4 g, X_2 within 2–3.5 g, the lowest stability level Y = 438.8–458.5 is observed, which is associated with a deficiency of dry substances and gel–forming agents. The maximum stability value $Y_{max} = 508.38$ is achieved at $X_1 = 6.81$ g and $X_2 = 4.64$ g, which contributes to the formation of a homogeneous and stable structure with minimal syneresis and adequate viscosity. A further increase in the concentrations of X_1 to 8 g and X_2 to 6–9 g causes a decrease in Y to 470.2–494.6 due to matrix oversaturation, which negatively affects the organoleptic characteristics.

Table 5 presents a comparative analysis of the chemical composition of new whipped creams with the addition of plant powders and a control sample. An increased content of dietary fiber, mineral elements, vitamins, essential amino acids, unsaturated fatty acids, and total energy value was found in the modified recipes, which indicates their higher nutritional and biological value.

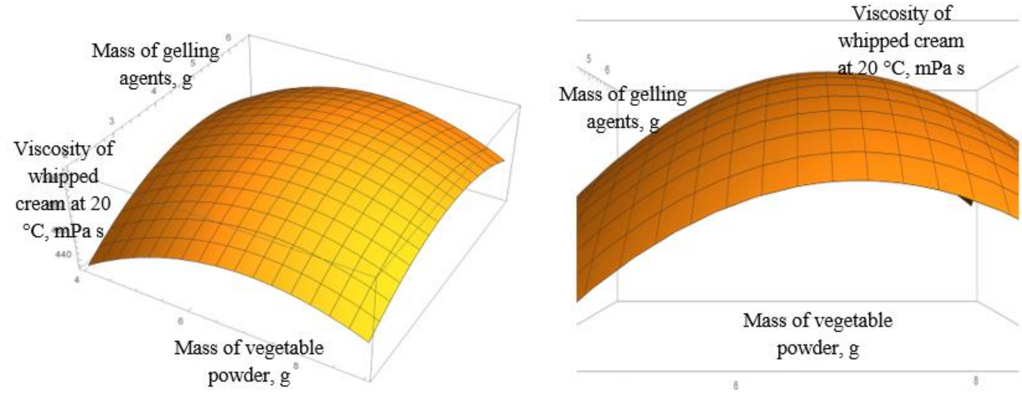


Fig. 13. Response surface illustrating the effect of plant powder (X_1) and gelling agent (X_2) concentrations on the structural stability of whipped creams (Y): top view (a) and side view (b)

Table 5 – Comparative characteristics of the chemical composition of whipped creams with the addition of beetroot and blueberry powders as functional components

Indicators	Basic vanilla whipped cream	Whipped vanilla cream with added beetroot powder	Whipped vanilla cream with added blueberry powder
Proteins, g	16,48	4,21	2,70
Fats, g	7,43	6,28	6,25
Carbohydrates, g	16,90	19,54	11,73
Total number of NAC, g	7,39	31,12	29,45
Total content of NFA, g	6,21	8,23	6,62
Fiber not less than, %	0,1	2,1	3,3
Ash	0,10	0,15	0,20
IS, %	P = 49,45 %	P = 12,63 %	P = 8,11 %
	F = 15,91 %	F = 13,46 %	F = 13,39 %
	C = 9,75 %	C = 11,27 %	C = 6,77 %
Energy value (theoretical), kcal	198,46	148,87	112,89
Energy value (practical), kcal	233,30	141,92	106,86

A comparative analysis of the chemical composition (Table 5) confirmed an increase in the content of dietary fiber and biologically active compounds and a decrease in the energy value of the developed creams. The reduction in calorie content and increase in functional value is consistent with the concept of creating sweet diet foods and recommendations for healthy eating [2, 3, 4].

The results of the study showed that the addition of plant components leads to a decrease in protein content to 4.21 g and 2.70 g, respectively, but at the same time significantly increases the level of dietary fiber to 2.1–3.3% and the total amount of NAA to 31.12 g and 29.45 g compared to 7.39 g in the control cream.

The increase in ash content, as well as the enrichment with vitamins and minerals in the improved creams, confirm their functional value. The energy value of creams with the addition of beetroot and blueberries decreased: theoretically to 148.87 and 112.89 kcal, respectively, compared to 198.46 kcal in the basic recipe, and actually to 141.92 and 106.86 kcal. This indicates the advisability of including such cold sweet dishes, namely whipped creams, in the diet of consumers who need to control the energy value of food. The results obtained correlate with international studies that have proven the positive effect of vegetable purees and infusions on the antioxidant activity and quality of functional sweet dishes.

Conclusion

Based on the conducted research, a scientifically substantiated recipe for whipped creams for dietary purposes was developed using beetroot and blueberry powders as sources of natural biologically active substances, which is consistent with modern trends in the creation of functional cold sweet dishes and the concept of rational nutrition [1, 4, 36]. The proposed recipe and technological solutions are consistent with patent developments in the field of cream products production, which confirms the practical feasibility and technological feasibility of the developed product [23, 33].

The optimal ratio of ingredients – 6.81 g of plant powders and 4.64 g of gelling agents per 100 g of product – contributes to the formation of a stable, homogeneous structure with high rheological and sensory properties. The introduction of functional components provided a significant enrichment of the nutritional value of the creams: the content of anthocyanins reached 185 mg/100 g, betalains – 95 mg/100 g, and dietary fiber – up to 3.3%. The reduced energy value of the samples to 106.86 kcal indicates their suitability for diets with controlled energy intake and dietary nutrition.

The obtained results of spectroscopic and microstructural studies confirm the formation of a heat–resistant protein–polysaccharide matrix, which ensures the stability of whipped creams during long–term storage and is consistent with the ideas about the synergistic interaction of proteins, polysaccharides and plant bioactive components in creamy food systems [12, 15, 16, 41]. The developed whipped creams meet modern requirements for functional cold sweet dishes, are distinguished by their natural composition, pronounced organoleptic characteristics and are promising for use in healthy and preventive nutrition systems, as well as in restaurant establishments with an orientation towards dietary and specialized diets [2, 3, 35, 40, 43].

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ІННОВАЦІЙНА ТЕХНОЛОГІЯ ХОЛОДНИХ СОЛОДКИХ СТРАВ ДІЄТИЧНОГО ПРИЗНАЧЕННЯ ПІДВИЩЕНОЇ ЯКОСТІ З ВИКОРИСТАННЯМ РОСЛИННИХ ПОРОШКІВ БУРЯКУ ТА ЧОРНИЦІ

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Анотація. У статті наведено результати дослідження, присвяченого розробці інноваційної технології холодних солодких страв підвищеної якості дієтичного та функціонального призначення на прикладі збивних кремів із додаванням рослинних порошків буряку та чорниці як природних джерел біологічно активних сполук. Актуальність роботи зумовлена необхідністю розширення асортименту дієтичної продукції з підвищеною харчовою та біологічною цінністю, а також пошуком ефективних технологічних рішень, що забезпечують стабільні реологічні та високі сенсорні властивості готових виробів відповідно до сучасних концепцій нутриціології, профілактичного харчування та функціонального продуктового дизайну. Дослідження виконано з урахуванням філософії технологій як системи концептуальних принципів, орієнтованих на мінімізацію інтенсивних технологічних впливів, збереження природної біологічної цінності сировини, формування стабільної структури продукту без термічної обробки та гармонізацію технологічних, нутриціологічних і сенсорних характеристик. Такий підхід дозволив розглядати технологію не лише як сукупність операцій, а як цілісну модель створення функціонального харчового продукту. Метою дослідження є наукове обґрунтування рецептурного складу та технологічних параметрів приготування холодних солодких страв дієтичного спрямування – збивних кремів із застосуванням порошків буряку та чорниці як джерел натуральних функціональних інгредієнтів. Об'єктом дослідження є технологія холодних солодких страв, зокрема збивних кремів, а предметом – вплив рослинних порошків і гелеутворювальних агентів на формування їх структурно–механічних, фізико–хімічних та органолептичних характеристик. У процесі експериментальних досліджень оптимізовано рецептурний склад на основі йогурту по–грецьки жирністю 3 %, вершків 33 %, порошків буряку і чорниці, агар–агару та високоетерифікованого пектину з використанням натуральних підсолоджувачів. Встановлено, що раціональне співвідношення активних компонентів становить 6,81 г рослинних порошків і 4,64 г гелеутворювачів на 100 г рецептурної маси, що забезпечує досягнення максимального інтегрального показника якості. Фізико–хімічна оцінка підтвердила формування оптимальної консистенції продукту з в'язкістю до 680 мПа·с, мінімальним синерезисом, стабільною кислотністю та збереженням формостійкості протягом 48 годин за температури 4 ± 2 °С. Результати інфрачервоної спектроскопії та термогравіметричного аналізу свідчать про утворення термостійкої білково–полісахаридної структурної матриці, стабільної до температури 120 °С. Хімічний аналіз засвідчив суттєве збагачення продукту харчовими волокнами, мінеральними речовинами та вітамінами, а також високий вміст антоціанів і бетаїнів, що визначає виражений антиоксидантний потенціал і функціональну активність розроблених кремів. Запропонована технологія може бути рекомендована для впровадження у закладах ресторанного господарства та на підприємствах харчової промисловості, орієнтованих на виробництво дієтичної та функціональної продукції.

Ключові слова: холодні солодкі страви, збивні креми, рослинні порошки, гелеутворювачі, антиоксидантна активність, харчова та біологічна цінність, структурна стабільність, ІЧ–спектроскопія, дієтичне харчування, філософія технологій.

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