Запропоновано стратегію розроблення замороженої десертної продукції (ЗДП) на основі нежирної молочної та рослинної сировини. Визначено вміст у білково-вуглеводних напівфабрикатах (БВН) основних інгредієнтів, серед яких білково-вуглеводний згусток (БВЗ), ягідне пюре та цукор. Встановлено, що сумісне використання модифікованої молочної та рослинної сировини за умов науково-обґрунтованого ведення технологічного процесу здатне надавати системі нових властивостей піноутворюючого та стабілізуючого характеру

Ключові слова: білково-вуглеводний згусток, кизил, терен, гарбуз, обліпиха, заморожені десерти, піноутворювальна здатність, стійкість пін, глікемічний індекс

Предложена стратегия разработки замороженной десертной продукции (СДП) на основе нежирного молочного и растительного сырья. Определено содержание в белково-углеводных полуфабрикатах (БУП) основных ингредиентов, среди которых белково-углеводный сгусток (БУЗ), ягодное пюре и сахар. Установлено, что совместное использование модифицированного молочного и растительного сырья в условиях научно-обоснованного ведения технологического процесса способно придавать системе новые свойства пенообразующего и стабилизирующего характера

Ключевые слова: белково-углеводный сгусток, кизил, терн, тыква, облепиха, замороженные десерты, пенообразующая способность, устойчивость пен, гликемический индекс

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RATIONALE FOR THE USE OF PROTEIN-CARBOHYDRATE MIX IN THE TECHNOLOGY OF DISPERSE PRODUCTS

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1. Introduction

Production of ice cream and frozen desserts is one of the most promising segments of the dairy industry. Ice cream is an available digestible complete product, a valuable source of important functional nutrients [1]. Analysis of the nutrient composition of Ukrainian ice cream and frozen desserts shows its inadequacy to the requirements of modern dietetics due to excessive saturated fats and digestible carbohydrates, which causes the need to improve formulations of dessert products with the focus on increasing the content of complete protein and dietary fiber and reducing saturated fat and sugar. A modern approach to making desserts is certainly linked to the compliance with the concept of the glycemic index and glycemic load [2].

The presence of simple sugars in ice cream causes a high glycemic index, which makes consumers limit the intake of it significantly, and patients with diabetes, cardiovascular disease or obesity – exclude ice cream at all. This problem can be solved in two ways: to produce savory ice cream or use sweeteners or fructose instead of sugar [3, 4]. Savory ice cream is very popular in Europe and in Japan, where ice cream is made with flavors of meat, seafood (shrimp, octopus, cuttle-fish), sea kale, beer, and vegetable ice cream – tomato, pumpkin, carrot, garlic, onion, cucumber with herbs, beet, potato etc. However, this type of ice cream is not popular and never produced in Ukraine. Ukrainians perceive ice cream as a dessert. So today the problem of reducing the glycemic index of ice cream can only be solved through the use of sweeteners or fructose. Thus, the scientific and practical task of creating new-generation frozen desserts with a low glycemic load, enriched with functional ingredients, is relevant and timely.

2. Literature review and problem statement

The food industry is rapidly developing new product platforms and introduces new categories of products to the market. The main purpose is the growth of economic entities; therefore, most foods contain large amounts of food additives that form nature-identical structure, flavor, color etc. However, the bulk of food additives is of synthetic origin or undergoes profound physical and chemical treatment in production, which leads to harmful effects on human health.

In the segment of frozen dessert products, characterized by multi-stage production process and the need for special equipment, all modern technologies involve the use of foaming and structure-forming food additives to form whipped and stable structure [5].

Dairy industry experts note that the sphere of producing low-calorie ice cream due to vegetable fat substitutes is well-developed, but regular consumption is harmful to health, so more and more consumers refuse such a dessert and prefer more useful products. However, this segment of frozen products is blank in Ukraine unlike Europe, the USA, and Asia. Therefore, production engineers face an actual problem of developing new technologies and adjusting the prescription of ice cream and frozen desserts in order to increase the content of protein [6] and dietary fibers [7] while reducing fat and sugar [8].

A promising solution to this problem is to use fat-free secondary dairy raw materials, such as whey [9] and whey concentrates [10], soy isolates and vegetable protein [11], curd cheese [12], skim goat milk [13], concentrated milk protein, etc. [14] as a basis for ice cream.

One way to increase the content of dietary fibers is the use of vegetable (pumpkin, carrot, tomato) [15], fruit (apple, quince, etc.) [16] and berry [17] purees as a filler in raw milk or ice cream basis. The researchers note that due to the content of pectin and dietary fiber, fruit-berry and vegetable purees act as water-retaining and emulsifying components in food systems and the presence of digestible sugars (mainly fructose and glucose) allow excluding or limiting sugar [18].

The solution to the problem is proposed by reducing the glycemic index of ice cream due to sweeteners (stevia, lactitol, sorbitol, aspartame) and fructose [19], which also act as water-retaining components and improve the functional and technological properties of the disperse ice cream system [20].

The innovative direction in the formation and stabilization of disperse food systems is implementing the principles of evidence-based use of dairy and vegetable raw materials that are carriers of functional and technological components, namely protein in skim milk and pectin in infrequent vegetables – pumpkin, dogberries, sloes and sea buckthorn berries. A new approach to the application of unused natural properties of raw materials may allow maximum implementation of their functional properties (foaming capacity of milk protein and stabilizing effect of fruit pectin), which improves the economic efficiency of technologies by reducing the use of food additives and sugar, and increases the nutritional and biological value of finished products.

In view of the above, it can be concluded that dairy technologists perform fairly intense research work on searching for new ways to improve ice cream formulations and technologies towards the development of new-generation products. Promising raw material for frozen disperse products is a protein-carbohydrate mix (PCM), which is a valuable source of essential substances. Previous studies indicate that the PCM can be used in the production of sweet dishes with foam structure [21]. This allows predicting the specific functional and technological properties of the mixes in frozen disperse systems and the feasibility of using it as a basis in technologies of frozen dessert products.

3. Research goal and objectives

The goal of the research is to justify the feasibility of using the protein-carbohydrate mix (PCM) in the technology of disperse products as a stabilizing base.

To achieve this goal, the following tasks are set:

– to determine the sequence of the production process of a system consisting of a protein-carbohydrate clot and berry puree;

– to investigate the functional-technological and structural-mechanical properties of the PCM compositions;

– to determine the production process parameters and investigate the chemical composition of the PCM.

4. Materials and methods of the quality study of whipped systems

The content of total nitrogen in vegetable samples was determined by chloramine method, the factor of 6.25 was used for conversion to crude protein. The mass fraction of soluble sugars in vegetable samples was determined by the Bertrand's titration method. The amount of fat was determined by the weight of dry fat-free residue by the Rushkovsky's method. The mass fraction of the "crude" fiber was determined by the gravimetric method after successive boiling in the medium of sulfuric acid, sodium hydroxide, and sample drying. The mass fraction of pectin was determined by the photometric carbazole method by galacturonic acid with separation into soluble and insoluble fractions using the photoelectrocolorimeter FEC 56M. The mass fraction of macro- and microelements in vegetable samples was determined by the X-ray fluorescence method using the spectrometer "Spectroscan".

The quality of whipped systems was investigated using the following parameters: foaming capacity (FC), foam stability (FS), surface tension (σ), active acidity (pH), relative and effective viscosity (η).

The foaming capacity of the samples was determined by the Lurie method. The FC calculation was performed using the formula:

$$FC = \frac{V_п}{V_c} \cdot 100,$$

where FC is the foaming capacity, %; $V_п$ is the system volume after whipping, 10^{-3} dm^3; V_c is the system volume before whipping, $\cdot 10^{-3}$ dm^3.

The stability of the foam structure of whipped samples was determined by the Lurie method. The foam stability calculation was performed using the formula:

$$FS = \frac{h_2}{h_1} \cdot 100,$$

where FS is the foam stability, %; h_2 is the foam height after holding,$\cdot 10^{-3}$ m; h_1 is the initial foam height, 10^{-3} m.

The study of the rheological parameters of the samples (effective viscosity, shear stress) was carried out on a rotary viscometer with smooth coaxial cylinders "REOTEST 2". The system of cylinders S 2 with the radial clearance of $1.13 \cdot 10^{-3}$ m and the radii ratio of 1.06 was used. The surface tension was determined on the Rehbinder device by the pressure that is necessary for the air bubble separation from the capillary at the "air – liquid" interface. Active acidity was determined by the potentiometric method according to GOST 26180 – 84 on the device "Ionometer I16 – 0M".

5. The results of studies of the production process of dairy-vegetable disperse food systems

To justify this technology, the innovative strategy of developing a new type of frozen dessert products was determined.

The technologies of milk-based frozen dessert products with pectin, starches, alginates, gums, etc. for the structure formation and stabilization have become increasingly widespread in recent years. The feasibility of using raw milk in technologies of whipped products is caused by the foaming capacity of the milk protein. Raw milk is used in a variety of milk protein concentrates. The disadvantages of this product include the use of food additives, which reduces the nutritional and biological value of finished products. Today it is partly compensated by the use of biologically active substances, dietary fiber, complete proteins, mineral salts and synthesized vitamins in conventional technologies. But the development of technologies using natural vegetable fillers that allow expanding the range of products, meeting the needs of the body not only in essential micro- and macronutrients but also in necessary minor food components is the most promising.

Typically, the functional properties of raw materials are not used to their fullest potential in the production process of dairy-vegetable disperse food systems, hence the need for additional structure formation and stabilization elements in the form of food supplements.

Vegetable raw materials are mainly used in the technologies of disperse products as a flavoring component, a filler, a source of biologically active substances etc. Less use is made of the stabilizing properties of vegetable raw materials, which is caused by chemical composition, namely the content of hydrocolloids. When considering the vegetable raw materials in terms of the content of functional and technological substances, infrequent berries from the south-eastern Ukraine – dogberries and sloes, which are the source of many important nutrients, including protopectin were noted.

Currently, the resources of these raw materials are used for the production of a limited range of products, although the annual yield is sufficient for industrial processing. Consequently, many valuable substances contained in infrequent berries and fruits are lost.

Implementation of the principles of the evidence-based use of raw materials that are carriers of functional and technological components such as protein in skim milk (SM) and pectin in infrequent berries, on one hand, allows implementing the functional properties of the components, which increases the economic efficiency of technologies due to reduced application of food additives and, on the other hand, increases the nutritional and biological value of finished products.

However, because of the technological properties inherent in the SM, including coagulation and denaturation in an acidic medium, and vegetable raw materials - high acidity, heterogeneity, color dependence on the pH, their joint use in the formulation is virtually impossible. Current limitations lie in the plane of denaturation and coagulation of the milk protein under the influence of organic acids of vegetable raw materials, structural breach of SM, coloring change and instability of vegetable raw materials due to the increased pH of the systems.

Functional and technological substances in the skim milk, dogberries and sloes are inactive, so for the implementation of the functional properties of the components of dairy and vegetable raw materials in the formation of whipped structure, it is necessary to activate them, and at the structure stabilization stage – to transfer from the active state to inactive protein-carbohydrate complexes. Pectin of berries should contribute to the foam stabilization, but efficient foaming is possible only in the presence of water-soluble pectin. Berries, along with the soluble pectin, contain a significant amount of inactive protopectin, which can be by hydrolysis, effective catalysts of which are hydrogen and hydroxyl ions. However, bivalent metals that make up the protopectin structure should be withdrawn from the system to prevent reverse complex formation. This can be achieved in hydrolysis at pH above 7.0.

The use of skim milk as a source of functional materials and technological substances in technologies of disperse products has several disadvantages, including the protein concentration insufficient for air dispersion. In addition, casein is in the form of inert caseinate-calcium-phosphate complex that exhibits surface active properties only after treatment with sodium caseinate as alkali. This ensures the casein solubility and release of calcium ions from the complex, which under certain conditions can react with soluble pectins to form pectates. Maximum foaming capacity (FC) and foam stability (FS) are in systems with 10...16 % protein. Accordingly, proteins should be concentrated to activate the SM casein proteins and implement their foaming properties before alkali treatment.

However, conventional and modern methods of concentration, separation and processing of raw milk protein have several disadvantages such as the lack of complex protein precipitation, application of expensive coagulants, high-temperature treatment, foreign flavor and odor of the clot, dense texture of the clot, reducing its functional and technological properties. Therefore, the development of the modified method of complex precipitation of SM proteins, which would increase the protein precipitation degree and obtain products with new functional and technological, consumer properties, is appropriate and promising.

Thus, the aim of developing the modified method of complex precipitation of SM proteins is to obtain the protein clot with the desired properties, namely it must contain whey proteins, have foaming-optimum solids content, certain titratable and active acidity.

In the theoretical justification of the modified method of complex precipitation of SM proteins, the berries were examined in terms of protein coagulant, explained as follows: berry acids provide the conditions for coagulation; the use of pectins allows the formation of protein-carbohydrate complexes; when combined with casein, berry calcium ions form phosphate-calcium "bridges"; berry proteins can be additional coagulation centers.

Based on the protein-carbohydrate clot and berry puree after the activation of their functional substances in their joint whipping due to the presence of surface-active sodium caseinate and stabilizing properties of pectin, it is possible to obtain a high-quality whipped system. The stability of this system can be significantly increased by the complex formation at certain pH between proteins and soluble pectins due to calcium ions. As a result of the controlled interaction of these substances, calcium pectate, and protein-carbohydrate complexes are formed, which can significantly increase the viscosity and cause gelation.

The sequence of the process of obtaining the above system is as follows:

– precipitation of skim milk proteins due to berry puree acids;

– solubilization of protein-carbohydrate clot proteins;

– solubilization of berry puree pectin;

– mixing of the modified products-carriers of the functional and technological substances at temperatures which prevent chemical interaction.

The mixes can be used in technologies of disperse products in case of performing a number of operations:

– tempering of the mix to a temperature above the gelation point;

– saturation of the mix with gas by whipping or aeration;

– addition of the acidic pH regulator at the final stage of whipping or aeration to provide optimum conditions for interaction between the protein and pectin;

– cooling and freezing of finished products to the storage temperature.

Thus, it can be concluded that the combined use of modified dairy and vegetable raw materials under the evidence-based conduct of the process provides new foaming and stabilizing properties of the system, different from the simple mixing of raw materials.

The above provisions are the basis of the innovative development strategy of frozen disperse dessert products based on low-fat dairy and vegetable raw materials.

As a result of experimental studies according to innovative strategy, the data are obtained which allowed justifying the production process parameters of frozen dessert products based on low-fat dairy and vegetable raw materials.

The chemical composition of dogberries and sloes, containing 1.20 % and 1.01 % of pectin substances, including water-soluble – 0.68 % and 0.53 % respectively was determined.

The use of berry raw material in the form of puree in the FDP technologies is efficient, so the next stage was to investigate the patterns of influence of hydrothermal treatment on the functional and technological state of the puree pectin. It was found that the production of the berry puree with a maximum content of soluble pectin requires a three-stage treatment of berry raw materials: hydrothermal treatment of dogberries at 85...87 °C for 60...80 s and sloes at 90...92 °C for 165...180 s, and the subsequent wiping of the berries at 80±2 °C to obtain the puree (stage I), heat treatment of puree in the presence of water at 80±2 °C for 10...12 min (stage II), heat treatment in the presence of whey at 80±2 °C for 30...35 min (stage III), which provides an increase in the share of soluble pectin by 2.5...3.0 times.

According to the innovative strategy, the SM in the mixes for the FDP is supposed to be used after the precipitation of proteins in the form of milk protein concentrate with high FTP. In the development of the modified method of complex precipitation of SM proteins due to berry puree acids, process conditions of SM preparation to precipitation and treatment conditions of the clot were determined: pasteurization temperature of SM – 91...93 °C for 10 min, cooling to 80 P...82 °C, introduction of the dogberry or sloe puree to the SM at 80...82 °C, coagulation, cooling to 12...14 °C, filtering of the clot and subsequent self-pressing for 20...30 min.

The influence of the mass fraction of the puree introduced (Fig. 1), temperature (Fig. 2) and duration of coagulation (Fig. 3) on the degree of complex precipitation of the SM proteins was investigated.

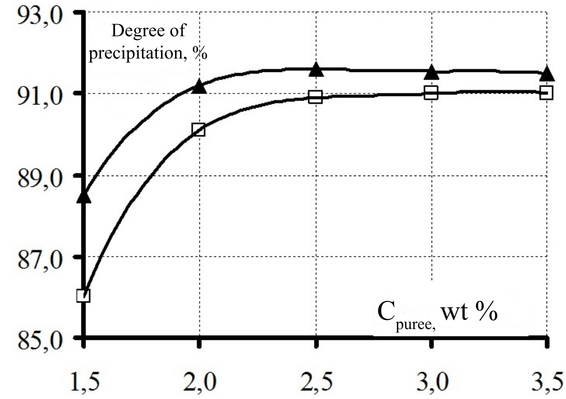

Fig. 1. The degree of precipitation of SM proteins depending on the share of the puree introduced, %:
–▲–, –□– – the composition of skim milk with dogberry and sloe puree respectively

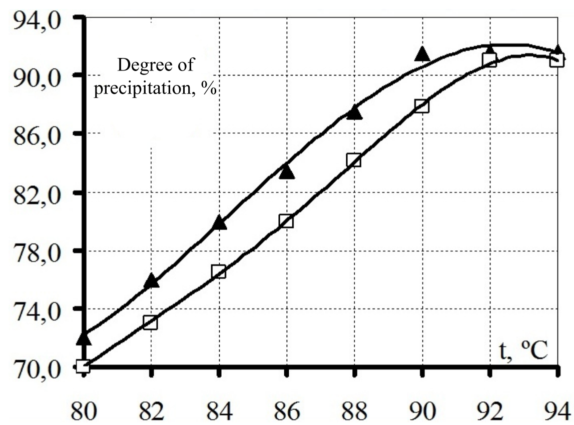

Fig. 2. The degree of precipitation of SM proteins depending on the treatment temperature, %:
–▲–, –□– – the composition of skim milk with dogberry and sloe puree respectively

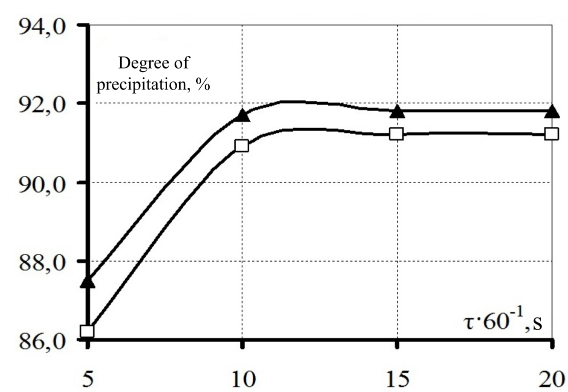

Fig. 3. The degree of precipitation of SM proteins depending on the coagulation duration at 92±1 °C, %:
–▲–, –□– – the composition of skim milk with dogberry and sloe puree respectively

It was found that the maximum precipitation of SM proteins occurs with the introduction of 2.5…3.5 % berry puree at a coagulation temperature of 90…94 °C and coagulation duration of 10…15 min.

The increase in the precipitation temperature from 80 °C to 94 °C leads to a decrease in moisture content of the clots from 80.1 % and 79.5 % to 68.3 % and 67.14 % for compositions with dogberry and sloe puree respectively. The effective viscosity of the clots (ε=1.8 s^{-1}) obtained at the precipitation temperature of 92 °C is 118.0…119.8 Pa·s, and at 94°C, due to reduced protein-carbohydrate interaction through the protein denaturation decreases to 102.6…101.9 Pa·s (Fig. 4, 5).

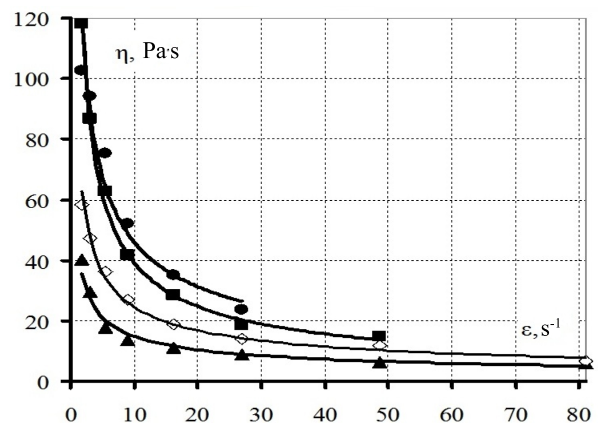

Fig. 4. The dependence of the effective viscosity (η) of the shear rate (ε) of compositions of SM with the dogberry puree: —▲— — at the precipitation temperature of 80 °C; —■— — at 92 °C; —●— — at 94 °C; -◊- — the control (low-fat curd cheese with a moisture content of 70.0 %)

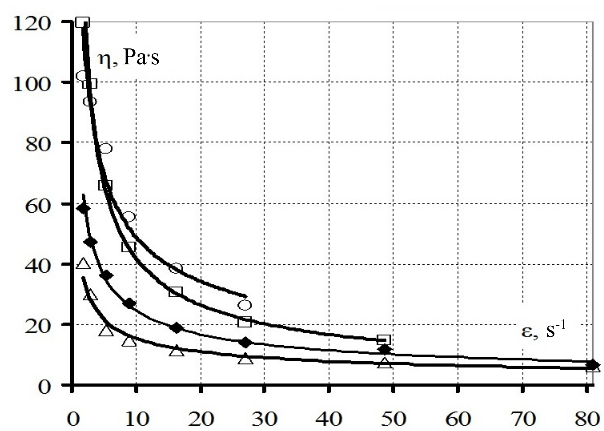

Fig. 5. The dependence of the effective viscosity (η) on the shear rate (ε) of compositions of SM with the sloe puree (B): —△— — at the precipitation temperature of 80 °C; —□— — at 92 °C; —○— — at 94 °C; —♦— — the control (low-fat curd cheese with a moisture content of 70.0 %)

The structural and mechanical properties of the clots, obtained at optimum parameters were investigated. It was found that the maximum effective viscosity of the clots (ε=1.8 s^{-1}) increases due to the pectin and the stabilizing effect of protein-carbohydrate complexes by 2.62 and 2.66 times compared to the control (low-fat curd cheese) for the clots with the dogberry and sloe puree.

Along with the viscosity increase, the strength growth is observed in the samples. Thus, the initial shear stress R_0 that determines the force at which the system extremely collapses, and the shear stress in the creep area R_1 that determines the force at which the system begins to collapse is 2.53…2.63 times higher in the clots than in the control.

The effect of the alkaline pH regulator on the solubility degree of caseinate-calcium-phosphate complex (CCPC) of the clots was investigated to increase the FTP of protein-carbohydrate clots (PCC). The surface tension was the criterion of the CCPC decalcination process and accumulation of soluble proteins. For this, the clot with a certain concentration of phosphate was subjected to heat treatment, then centrifuged, the supernatant solution was collected and its surface tension was determined. The maximum accumulation of surfactants by the PCC protein solubilization is achieved in heat treatment of the clot with the addition of 0.90 % phosphate mix “Biofos 90” at 80±2 °C for 10…12 min.

The next stage was to determine the efficient ratio of the PCC and berry puree by investigating the FC and FS of the systems. To prevent the irreversible formation of calcium pectates and protein-carbohydrate complexes, mixing of components was conducted at temperatures above 70 °C, which do not allow chemical interaction. The compositions were heated to 80…82 °C, cooled and whipped.

After analyzing the data, it can be concluded that the maximum FC and FS values for the compositions “PCC – dogberry puree” and “PCC – sloe puree” are observed in compositions with the content of the modified berry puree of 15…20 %. These concentrations decrease pH by 0.61…0.56 units, which raise the surface tension by $1.20 \cdot 10^{-3}$ N/m and $1.40 \cdot 10^{-3}$ N/m (for compositions with dogberry and sloe puree, respectively). This ensures the maximum implementation of surface properties of milk protein, which is reflected in the FC increase by 57.2 % and 56.1 %, respectively

The effect of sugar on the functional-technological and structural-mechanical properties of the compositions of the PCC with the optimum puree content was examined (Fig. 6, 7).

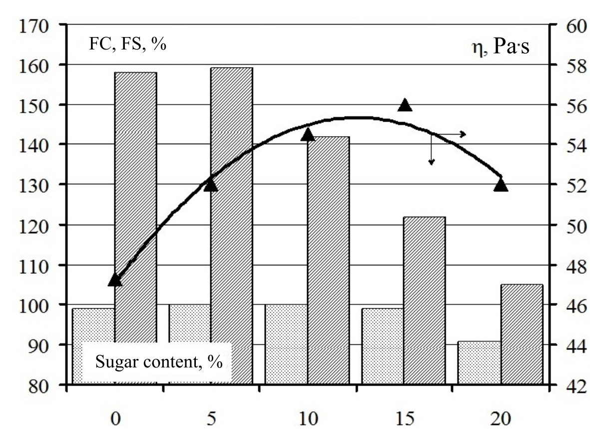

Fig. 6. The effect of sugar on the functional-technological and structural-mechanical properties of the composition of the dogberry PCC with the dogberry puree: ▨ — foaming capacity; ▩ — foam stability; —▲— — effective viscosity

It was found that the viscosity (ε=1.8 s^{-1}) of compositions of the PCC with dogberry and sloe puree with the addition of up to 15 % of sugar increases by 18.39 % and 20.27 %

respectively. A further increase in the sugar content leads to syneresis with a visible fluid release and reduction of the structural and mechanical properties of the compositions. Thus, viscosity decreases by 7.14 % and 3.92 % respectively at the sugar content of 20 %.

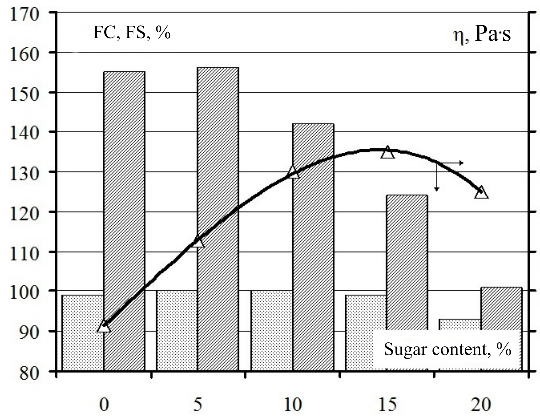

Fig. 7. The effect of sugar on the functional-technological and structural-mechanical properties of the composition of the sloe PCC with the sloe puree: — foaming capacity; — foam stability; —Δ— — effective viscosity

The foaming capacity (FC) of the compositions of PCC with dogberry and sloe puree with the addition of 5...20 % of sugar decreases by 33.54 % and 34.84 % respectively. At the same time, the compositions are characterized by high stability with the sugar content of up to 15 %. As a result of sugar content optimization by the conjugate gradient method and organoleptic research, the efficient sugar content in the composition of the dogberry PCC with dogberry puree is 7.5...8.0 %, in the composition of the sloe PCC with the sloe puree – 7.8...8 0 %.

Thus, the content of the basic ingredients, including PCC, berry puree, and sugar in the mixes was determined and optimized. The developed mixes can be used as mixes for FDP without foaming and structure-forming food additives due to the presence of surface-active sodium caseinate in the PCC, the pectin in the berry puree and provided their interaction to form calcium pectate and protein-carbohydrate complexes.

The mixes can be used in the FDP technologies in case of performing a number of operations: tempering of the mix to 80...82 °C for the activation of protein-carbohydrate complex formation; whipping at 25...30 °C; addition of the acidic pH regulator at the final stage of whipping to provide optimum conditions for interaction between the protein and pectin; cooling of finished products to the temperature of consumption.

Based on the experimental data and in accordance with the innovative strategy, the production process parameters of the PCM were determined, the prescription of three types of the PCM was developed and their chemical composition was investigated (Table 1).

According to Table 1, the developed PCM have lower protein content compared to the control (low-fat curd cheese) due to the presence of up to 20 % of the vegetable component that enriches them with carbohydrates. The PCM contain 10.2...10.5 times more carbohydrates and 1.6...3.4 times fatter than the control.

Table 1

Characteristics of the chemical composition of mixes, (α≤0.05)

Indicator	Mass fraction, %			
	Control	Protein-carbohydrate mix		
		Dogberry	Sloe	Dogberry-sloe
Dry matter	30.00	29.54	30.62	30.15
Proteins	16.22	10.05	10.20	10.12
Fats	0.54	0.89	1.82	1.26
Carbohydrates	1.62	16.57	17.01	16.91
Ash	1.08	1.84	1.22	1.65
Energy value, kcal	76.14	114.49	125.22	119.46

18 amino acids (AA), including all essential, were identified and quantified in the mixes. The cumulative percentage of essential AA of the total amount of AA is 45.59 % for the dogberry PCM, 43.25 % for the sloe PCM and 44.53 % for the dogberry-sloe PCM, which is by 0.38...2.79 % higher than in the control.

It was found that the PCM protein contains no limiting amino acids, has a good balance by the "tryptophan" and "threonine" indexes. The score of the control-limiting methionine in the PCM is 129...134 %. The study of the proteolysis degree of proteins of mixes by enzymes indicates that the PCM proteins are characterized by a high degree of proteolysis by pepsin and trypsin due to the carbohydrate component.

The content of most minerals and vitamins in the developed mixes is much higher than in the control. The ratio Ca:P:Mg for the PCM is 1:(1.16...1.18):(0.61...0.63), which is close to the formula of balanced nutrition. It was found that microbiological indicators of the PCM and the content of toxic elements meet the regulatory requirements.

Based on the study of changes in the microbiological parameters over time, the storage conditions and shelf life of the PCM: temperature – 4±2 °C; duration – no more than 72 hours were justified.

The study of the dynamics of the functional-technological and structural-mechanical properties of the PCM when stored at 4±2 °C within 72 hours showed an increase of effective viscosity by 45...50 %, which reduces the FC by 7.1...8.1 % and foam stability (FS) – by 3.9...4.7 %. Also, the protein-carbohydrate complex formation strengthens the structure during storage, with the increase in the initial shear stress R_0 by 8.3 % and shear stress in the creep area R_1 – by 30.7 %. It was found that the PCM are capable of thixotropic recovery during storage, so the hysteresis loop area after 72 hours of storage decreases by 11.2 %.

Given the above, it can be concluded that due to the functional and technological properties, the PCM can be used in technologies of whipped dessert products. We consider the PCM use in technologies of frozen dessert products (dzhelato, sorbets, etc.) as promising. To take account of modern approaches to creating foods, the goal of developing the low-sugar frozen dessert technology was set, with the fructose, which, as you know, has a higher sweetness and does not overload the pancreas due to the low glycaemic index as the sweetening component.

The PCM under study structurally resembles curd cheese, so it can be the basis for producing whipped and aerated desserts. However, the frozen dessert technology requires the addition of a liquid component, such as cream, vegetable or fruit puree. The basic requirement for the selection of raw materials for puree is a sufficient amount of pectin, which, when whipped with the PCM can form a stable foam-like structure of the frozen dessert. From this perspective, it is reasonable to add puree on the basis of pumpkin and sea buckthorn, produced by the new technology using enzymes [22], which provides a puree with a high pectin content. Besides pectin, the puree is a valuable source of carotenoids and fiber.

Based on the studies, the formulation of the developed frozen dessert on the PCM basis with the fructose content of 4.5 %, stabilization system "Kremodan SE406" – 0.2...0.3 % and pumpkin-sea-buckthorn puree – 30...32 % can be considered the most reasonable.

The known formulation of soft ice cream was used as the control [23]. Table 2 indicates that the developed dairy-vegetable frozen dessert has a higher whipping capacity (by 12.9 %) and foam stability (by 20.1 %); the fat phase dispersion degree is less by 14.5 %, due to lower fat in the experimental sample (by 3.8 times).

Table 2

Functional and technological indicators of dairy-vegetable mixture for the frozen dessert

Indicators	Control	Dairy-vegetable mixture for frozen dessert
Whipping capacity, %	62±1.5	70±1.8
Stable foaming capacity, %	67±1.5	81±2.0
Fat phase dispersion degree, mcm	110±2.8	96±2.3

The studies confirm the feasibility of the PCM use in technologies of frozen dessert products both in terms of effectiveness and nutritional value. The developed technology is low-waste, resource-saving and simple. Domestic origin of the basic raw ingredients of the developed technology is also an advantage. The resource of SM is inexhaustible due to the nature of the whole milk processing, and the resource of the dogberry, sloe, sea-buckthorn, and pumpkin harvest is hardly used today.

6. Discussion of results of study of the PCM use in the technology of disperse products

The paper presents the use of skim milk proteins and pectins of infrequent berries (dogberries and sloes).

The high-quality whipped system based on the protein-carbohydrate clot and berry puree after the activation of functional compounds in their joint whipping, due to the presence of surface-active sodium caseinate and stabilizing properties of pectin was obtained. The stability of this system can be significantly increased by the complex formation at certain pH between proteins and soluble pectin due to calcium ions. As a result of the controlled interaction of these substances, calcium pectate and protein-carbohydrate complexes are formed, which ultimately improves viscosity and causes gelation. The PCM can be used in the FDP technologies in case of performing a number of operations: tempering of the mix to 80...82 °C for the activation of protein-carbohydrate complex formation; whipping at 25...30 °C; addition of the acidic pH regulator at the final stage of whipping to provide optimum conditions for interaction between the protein and pectin; cooling of finished products to the temperature of consumption.

Based on the experimental data and in accordance with the innovative strategy, the production process parameters of the PCM were determined, the prescription of three types of the PCM was developed and their chemical composition was investigated.

On the basis of the studies, the formulation of the frozen dessert based on the PCM with the low content of highly glycemic sugars due to vegetable and berry puree and fructose was developed. The subject of future research is to determine the glycemic index.

7. Conclusions

1. The stable whipped disperse system based on the protein-carbohydrate clot and berry puree after the activation of functional compounds in their joint whipping, due to the presence of surface-active sodium caseinate and stabilizing properties of pectin was obtained.

2. It was proved that the maximum precipitation of SM proteins occurs with the introduction of 2.5...3.5 % berry puree at a coagulation temperature of 90...94 °C and coagulation duration of 10...15 min.

3. It was found that the maximum effective viscosity of the clots (ε=1.8 s^{-1}) increases due to the pectin and the stabilizing effect of protein-carbohydrate complexes by 2.62 and 2.66 times compared to the control for the clots with the dogberry and sloe puree.

Along with the viscosity increase, the strength growth is observed in the samples. Thus, the initial shear stress in the investigated clots is by 2.53...2.63 times higher than in the control sample.

4. It was found that the viscosity (ε=1.8 s^{-1}) of compositions of the PCC with dogberry and sloe puree with the addition of up to 15 % of sugar increases by 18.39 % and 20.27 % respectively. A further increase in the sugar content leads to syneresis with a visible fluid release and reduction of the structural and mechanical properties of the compositions.

5. Based on the experimental data and in accordance with the innovative strategy, the production process parameters of the PCM were determined, the prescription of three types of the PCM was developed and their chemical composition was investigated. The developed PCM contain by 10.2...10.5 times more carbohydrates and by 1.6...3.4 times more fat compared to the control (low-fat curd cheese). It was also found that the PCM protein contains no limiting amino acids and is balanced for the "tryptophan" and "threonine" indexes.

Thus, the developed PCM are appropriate to be used as a basis for frozen desserts. The prospect of further research is to develop a range of frozen desserts based on PCM and fruit and vegetable and berry puree with reduced sugar.

References

1. Kilara, A. Frozen dairy products [Text] / A. Kilara, R. Chandan // Milk and Dairy Products in Human Nutrition, Wiley-Blackwell Publishers. – 2013. – P. 435–457. doi: 10.1002/9781118534168.ch20

2. Polumbryk, M. O. Harchovi produkty z nyz'kym glikemichnym indeksom u dijetoterapii' hvoryh na ozhyrinnja [Text] / M. O. Polumbryk // Praktykujushhemu endokrynologu. – 2008. – Vol. 5, Issue 17. – P. 15–19.
3. Evdokimov, I. A. Mediko-tehnologicheskie aspekty ispol'zovanija zamenitelej sahara v molochnyh produktah [Text] / I. A. Evdokimov // Sev.-Kavk. gos. tehn. un-ta. Serija «Prodovol'stvie». – 2006. – Vol. 2. – P. 85–88.
4. Alizadeh, M. Impact of using stevia on physicochemical, sensory, rheology and glycemic index of soft ice cream [Text] / M. Alizadeh, M. Azizi-Lalabadi, S. Kheirouri // Food and Nutrition Sciences. – 2014. – Vol. 5, Issue 4. – P. 390–396. doi: 10.4236/fns.2014.54047
5. Soukoulis, C. Enrichment of ice cream with dietary fiber: effects on rheological properties, ice crystallization and glass transition phenomena [Text] / C. Soukoulis, D. Lebesi, C. Tzia // Food Chemistry. – 2009. – Vol. 115, Issue 2. – P. 665–671. doi: 10.1016/j.foodchem.2008.12.070
6. Low carbohidrate, high protein, fiber enriched gelato formulation and method of manufacture: Pat. WO 2011069224 A1, MPK A 23 G 9/32 [Text] / Carella L., Salvaggio P., Salvaggio E., Salvaggio V. – № PCT/CA 2009/001782; stated 07.12.2009; published 16.06.2011. – 7 p.
7. Production of enriched products: Pat. WO 2013/036726 A1, MPK C 07 D 311/00 [Text] / Raskin L., Gradiose R. – № US 2012/054096; stated 07.09.2012; published 03.12.2013. – 5 p.
8. Akbari, M. The effect of inulin on the physicochemical properties and sensory attributes of low-fat ice cream [Text] / M. Akbari, M. H. Eskandari, M. Niakosari, A. Bedeltavana // International Dairy Journal. – 2016. – Vol. 57. – P. 52–55. doi: 10.1016/j.idairyj.2016.02.040
9. Slashheva, A. V. Rozrobka tehnologii' funkcional'nogo napivfabrykatu z laktulozoju dlja m'jakogo morozyva ta solodkyh strav [Text] / A. V. Slashheva // Naukovyj zhurnal «Visnyk DonNUET». Serija: Tehnichni nauky. – 2008. – Vol. 1, Issue 37. – P. 53–57.
10. Frozen dessert mixes using protein products: Pat. WO 2014008580 A1, MPK A 23 G 9/42 [Text] / Medina S., Segall K. I. – the applicant and patent holder Burcon Nutrascience (Mb) Corp . – № PCT/CA 2013/000626; stated 08.07.2013; published 16.01.2014. – 6 p.
11. Morozyvo, zbagachene sojeju i chornyceju: Pat. UA 104954 C2, MPK A23 G 9/04 (2006.01), MPK A23 G 9/42 (2006.01) [Text] / Grek O. V., Os'mak T. G., Turkova T. M., Turkova G. M. – zajavnyk ta patentovlasnyk Nacional'nyj universytet harchovyh tehnologij (Ukrai'na). – № a201213583; zajavl. 27.11.2012; opubl. 25.03.2014, Bjul. № 6. – 3 p.
12. Skorchenko, T. A. Syr kyslomolochnyj – komponent diabetychnyh vydiv morozyva [Text] / T. A. Skorchenko, T. G. Fedchenko // Molochnoe delo. – 2006. – Vol. 2. – P. 48–49.
13. McGhee, C. E. Evaluation of total fatty acid profiles of two types of low-fat goat milk ice creams [Text] / C. E. McGhee, B. P. Gupta, Y. W. Park // Open Journal of Animal Sciences. – 2015. – Vol. 5, Issue 1. – P. 21–29. doi: 10.4236/ojas.2015.51003
14. Daw, E. Fat destabilization and melt-down of ice creams with increased protein content [Text] / E. Daw, R.W. Hartel // International Dairy Journal. – 2015. – Vol. 43. – P. 33–41. doi: 10.1016/j.idairyj.2014.12.001
15. Morozyvo «Sonjachne»: Pat. UA 87387 U, MPK A23 G 9/32 (2006.01) [Text] / Pavlova V. A., Gonchar L. A., Holodova O. Ju. – № a201308932; zajavl. 04.07.2013; opubl. 10.02.2014, Bjul. № 3. – 5 p.
16. Morozyvo «Mauleja»: Pat. UA 96136 C2, MPK A23 G 9/42 (2006.01) [Text] / Ditrih I. V., Molokanova L. V., Jarysh Ju. V. – zajavnyk ta patentovlasnyk Donec'kyj nacional'nyj universytet ekonomiky i torgivli imeni Myhajla Tugan-Baranovs'kogo (Ukrai'na). – № a200805670; zajavl. 30.04.2008; opubl. 10.10.2011, Bjul. № 19. – 3 p.
17. Morozyvo «Brazyl'jero»: Pat. UA 87825 U, MPK A23 G 9/42 (2006.01), MPK A23 L 1/221 (2006.01) [Text] / Raksha-Sljusareva O. A., Gluhov O. Z., Cymbal G. O., Kustova O. K. et. al. – zajavnyk ta patentovlasnyk Raksha-Sljusareva O.A. – № a201308811; zajavl. 15.07.2013; opubl. 25.02.2014, Bjul. № 4. – 3 p.
18. Pat. 86292 «Sklad morozyva «Karambola» [Text] / Jemec' A. M., Matjushekno R. V. – zajavnyk i patentovlasnyk Nacional'nyj universytet harchovyh tehnologij. №260443342; zajav. 11.05.13; opubl. 25.12.13, Bjul. № 6.
19. Morozyvo «Ozdorovche»: Pat. UA 108693 C2, MPK A23 G 9/32 (2006.01) [Text] / Bazhaj-Zhezherun S. A. – zajavnyk ta patentovlasnyk Nacional'nyj universytet harchovyh tehnologij (Ukrai'na). – № a201312600; zajavl. 28.10.2013; opubl. 25.05.2015, Bjul. № 10. – 2 p.
20. Os'mak, T. G. Rozroblennja tehnologii' morozyva z cukrozaminnykamy [Text]: avtoref. ... dys kand. teh. nauk / T. G. Os'mak. – Nacional'nyj universytet harchovyh tehnologij, 2012. – 18 p.
21. Nykyforov, R. P. Obg'runtuvannja ta doslidzhennja umov otrymannja bilkovo-vuglevodnogo napivfabrykatu na osnovi bilkiv znezhyrenogo moloka ta dykoroslyh jagid dlja zbytyh desertnyh strav [Text] / R. P. Nykyforov // Visnyk DonNUET. Serija: Tehnichni nauky. – 2009. – Vol. 1 (41). – P. 244–249.
22. Gnicevych, V. A. Obg'runtuvannja mozhlyvosti vykorystannja fermentnyh preparativ u tehnologijah roslynnyh napivfabrykativ z pidvyshhenym vmistom pektynovyh rechovy [Text] / V. A. Gnicevych, A. V. Slashheva, M. V. Ivashhenko // Visnyk DonNUET. Serija: Tehnichni nauky. – 2014. – Vol. 1 (58). – P. 37–45.
23. Pat. 2204261 Rossija, MPK A 23 G 9/04. Sposob prigotovlenija morozhenogo mjagkogo [Text] / Zhukova L. P., Kanunnikova N. E. – № 200119687/13; zajavl. 24.07.2000; opubl. 20.05.2003; Bjul. № 6. – 5 p.