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DEVELOPMENT TECHNOLOGY OF FUNCTIONAL SOFT ICE CREAM USING BEET PECTIN CONCENTRATE AND PROBIOTIC

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Technology of soft ice cream has been developed using beet pectin concentrate (BPC) as a functional component. As an additional component of the probiotic action, the probiotic Bifidobacterium, Lactobacillus were introduced in an amount of 0.1 %. The regularities of the influence of BPC on the density and viscosity of prescription mixtures, whipping and resistance to melting of soft ice cream have been established.

With the introduction of more than 10.0 % of BPC, milk proteins coagulated, the texture of the prescription mixture was characterized by heterogeneity, a slight detachment of the aqueous phase was observed; soft ice cream had a slightly flaky texture.

The quality indicators of soft ice cream with different fat content (plombir –14.0 %, creamy – 11.6 %) with the addition of pectin concentrate and probiotic Bifidobacterium + Lactobacillus were studied. Soft ice cream is characterized by high nutritional value (the mass fraction of protein is 2.6–3.2 %, milk fat – 11.0 14.0 %, sucrose – 11.2 11.7 %), contains water-soluble vitamins and pectin (0.5–1.0 %), which is a natural enterosorbent.

The development of technology for the soft use of BPC allows expanding the range of food products enriched with functional ingredients. The introduction of probiotic improves the physiological functionality of the product, in particular, improves the functioning of the gastrointestinal tract

Keywords: functional soft ice cream, beet pectin concentrate, probiotic, heavy metals

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1. Introduction

The general deterioration of the ecological situation in the world has led to a decrease in the immunity of the population. Nutritionists from around the world argue that the growth of chronic human diseases is directly related to the deterioration of the environmental situation and the changed chemical composition of food products. It is possible to preserve and improve human health through the regular consumption of products that help strengthen the body's defenses.

One of the effective ways to provide the population with vital nutrients is the introduction of functional foods into diets. According to [1], functional food ingredients include physiologically active, valuable and safe for health ingredients with known physical and chemical characteristics, for which properties useful for maintaining and improving health have been identified and scientifically substantiated, a daily physiological need has been established: soluble and insoluble dietary fiber (pectins, fiber, etc.), vitamins (vitamin E, folic acid, etc.), minerals (calcium, magnesium, iron, selenium, etc.), fats and substances associated with fats (polyunsaturated fatty acids, plant sterols, conjugated isomers of linoleic acid, structured lipids, sphingolipids, etc.), polysaccharides, secondary plant compounds (flavonoids/polyphenols, carotenoids, lycopene, etc.), probiotics, prebiotics and synbiotics. Due to their regular use, the risk of occurrence and prevention of chronic diseases is reduced.

An important component of the human diet is dairy products, including ice cream. Variable nutritional value (a source of complete proteins, milk fat, a wide range of vitamins and minerals), high taste indicators make this product popular among all segments of the population.

Modern trends in the development of the food industry have contributed to the development of a network of enterprises (milk bar, ice cream bar, ice cream parlor, food-truck, food-court, etc.) that offer soft ice cream. The ability to implement the concept of eat&go, milk&snack, to observe the process of its preparation, independently select syrups, fruits, etc. contribute to the growing popularity of soft ice cream among adults and children. In this regard, the development of functional soft ice cream by using physiologically functional ingredients in its composition is extremely important.

Due to the increasing contamination of food products with salts of heavy metals [2], it is promising to develop such food products that contain functional ingredients that can bind and remove these compounds from the human body [3]. Pectins have high absorbent properties, which makes them a promising additive for functional food products [4].

It should be noted that commercially available ice cream, including soft ice cream, usually does not contain all of the vital nutrients. In this regard, it is of interest to improve the nutritional value of ice cream by using functionally physiological ingredients – pectins (in the composition of beet pectin concentrate (BPC)) and probiotic microorganisms.

The use of BPC in soft ice cream as a source of low-esterified pectin [5], which is able to absorb and remove from the human body ions of toxic metals and microorganisms that normalize the activity of normal microflora [6], is relevant.

2. Analysis of literature data and statement of the problem

The modern market for ice cream is highly competitive. This is due not only to the presence of a large number of manufacturers, a variety of assortment and different pricing policies, but also to changed consumer preferences. The preferences of modern consumers differ significantly from those of 10 years ago. Nowadays the main trend of consumer demand goes on products that meet the requirements of a healthy lifestyle. It is important to develop innovative technologies for the production of ice cream, the main types of which will be in the field of functional products. Those are reducing the calorie content by eliminating fat or sugar from ice cream along with the usage of various functional ingredients like seeds, spices, algae, etc. that are beneficial for human health; the creation of ice cream with a high protein content, fat-burning components, vitamins to meet the needs of athletes, and the development of ice cream with a complete replacement of animal raw materials with vegetable raw materials, for people intolerant of gluten or lactose, and giving ice cream pre- or probiotic properties, etc.

Thus, in [7], a mixture of soy protein hydrolysate with xanthan gum was used to produce low-calorie ice cream. The effects of freezing time on whip, melting properties, thermal stability and organoleptic ice cream performance were studied. It has been established that a mixture of soy protein hydrolyzate with gum stabilizes the microstructure during freezing, increasing the resistance to melting and improving the organoleptic properties of ice cream. The disadvantage of this technology, however, is the high probability of soy protein allergenicity.

In [8], walnut milk was used to produce ice cream, which significantly affected the physical and chemical properties of the ice cream and increased its fat due to the high fat content in the walnut. The use of walnut milk improved the rheological properties and whipping of the ice cream. The disadvantage of this technology is the increased cost of the finished product.

The work [9] reports on the production of ice cream with the addition of probiotics Saccharomyces boulardii and Lactobacillus rhamnosus as a carrier. Inoculation of S. boulardii and L. rhamnosus as separate cultures resulted in the formation of various flavor compounds in ice cream products. The highest overall sensory acceptance score was obtained for ice cream products produced with probiotic inoculation after the ripening stage.

The role of the effect of exopolysaccharide (EPS) secreted by EPS+ strains of Streptococcus thermophilus on the physicochemical, rheological, microstructural and organoleptic properties of ice cream was studied [10] in order to develop a fermented functional product without stabilizers. Rheological analysis of ice cream produced by EPS+ strains revealed its highly viscous and pseudoplastic behavior of a non-Newtonian fluid. This demonstrates the potential of using S. thermophilus EPS as a thickener and gelling agent to improve the rheological properties of ice cream.

One of the promising areas for the development of functional ice cream is the use of pectin in the form of pectin raw materials and/or functional ingredients. To date, a lot of experience has been gained in the use of pectin in the production of jelly, marmalade, pastel, dairy products [11]. They are used as a gelding, stabilizing or thickening agent in the production of jams, yogurt drinks, fruit, milk drinks and ice cream.

One of the most important properties of pectins, which refer to soluble food fibers, is their physiological functional activity. Pectins are natural enterosorbents, able to bind and remove toxic metals, harmful substances accumulating in the body: excess cholesterol, bilirubin, bile acids, etc. The ability of pectins to reduce the accumulation of radionuclides in the body and to decompress heavy metals has been confirmed. Such properties are due to the presence of free carboxyl groups (–COOH), which are capable of forming stable low-dissociation compounds, chelates, with metal ions. The ability of pectins to absorb metal cations is related to the degree of their esterification, polymerization, and the composition of the glycosyl residue [4].

Biodegradability, biocompatibility, universal chemical and physical properties of pectin enable them to be used as a polymer matrix for food films [6]. Pectin can be an alternative to conventional chelators by binding heavy metals such as lead, cadmium, mercury and removing them from the human body [12, 13].

Algae products can be used as a source of pectins in ice cream technology. Thus, the authors [14] have added Nannochloropsis oculata, Porphyridium cruentum and Diacronema Vlkianum microalgae at various concentrations (0.1 %, 0.2 % and 0.3 %). Influence of microalgae on color, thawing resistance, organoleptic, rheological and functional properties of ice cream has been investigated. It is concluded that microalgae can be used in ice cream to improve color and functional properties. The rational concentration of microalgae correlates with the organoleptic characteristics of the desert.

Products derived from algae have also been used as gel-forming additives. Studies [15] provide comparative data on the use of κ-carrageenan and ι-carrageenan (at concentrations of 0.025–0.150 g/100 g) in cream desserts, and study their organoleptic and rheological properties. During storage of the samples, a slight decrease in pH was observed. The samples were characterized as homogeneous, no separation of the aqueous phase and accumulation of foreign taste were found. The proposed concentration of carrageenans to obtain products with desired properties lies in the range of 0.050–0.125 g/100 g.

The work [16] explored the possibility of using ice cream as a prospective carrier and means of delivery of biologically active compounds and useful microorganisms. Prospective directions of production of acidophilic ice cream with various prebiotics, food fibers, substitution of refined sugar with honey and unrefined sugar, with addition of whey proteins, fruit puree, cereal additives and other components are considered. Methods for obtaining ice cream with L. Acidophilus, Bifidobacterium and other starter cultures are described, the expediency of their use in the production of ice cream is substantiated.

Based on the stated objectives, the research related to the use of frozen milk desserts in the technology of pectineus raw materials [14, 15] and probiotic bacteria [12, 16] deserves special attention. Pectins are known to have prebiotic properties, that is, they are a medium for the growth of probiotic crops. The synergy between pectin and probiotic microorganisms is confirmed in the work [17–19] where citrus pectin with low methoxylated groups was used as encapsulating material for delivery of probiotics. The authors of [20] proved the positive anti-tumor co-use effect of apple pectin and Bifidobacterium longum culture condensate. The joint use of pectins and probiotic microorganisms is also technologically convenient. These microorganisms do not liquefy pectin jelly, that is, they do not worsen their technological properties as part of finished products [21].

The possibility of joint use of pectin-containing raw materials (pumpkin puree) and probiotics Bifidobacterium, Lactobacillus was studied in the work [22] using the example of frozen milk-whey desserts. It was noted not only the acquisition of functional properties by the product, but also their positive effect on the process of milk fermentation and on the quality of the finished product. This confirms the compatibility of pectins and probiotics with milk-containing products from a technological point of view.

The main part of the above-mentioned works is devoted to enriching dairy products of lactic acid bacteria or studying the interaction of probiotic strains with pectins. Here is widespread experience in the food industry with the use of lactic acid bacteria, mainly for the enrichment of beverages such as yogurt and cheese products. There is experience in the ice cream industry using probiotics and prebiotics separately. Since good mutual influence of probiotics and prebiotics on processes occurring in the intestinal tract has been proven many times, let's consider it expedient to use them together in ice cream technology.

Justifying the relevance of the study, one should focus on the feasibility of using domestic pectin-containing raw materials in the context of resource-saving technologies. Thus, in the process of processing beets accumulate pulp, which is processed into a pectin concentrate. Pectins isolated from sugar beet are promising additives for the food industry due to their good emulsifying properties [23], including in dairy production due to stability of pectin bond with milk protein [24]. The above works are aimed at optimizing the parameters of the technological process, organoleptic properties of ice cream, replacing the dairy base with vegetable components. The proposed ice cream technology using beet pectin concentrate will make it possible to create a functional product. Its consumption will contribute to the removal of heavy metals from the human body. The prospect of using beet pectin concentrate from raw materials of regional origin also makes the technology affordable and inexpensive.

Studies [25] show the positive impact of highly esterified pectin on the stability of emulsion and the whipping of milk desserts.

At the same time, it was found that there are no systemic studies aimed at developing soft-ice cream technology for functional purposes by sharing pectins and micro-organisms. The technology and the main technological parameters for its production have not been developed, and there is a lack of data on the nutritional value of new products. There is no information on the effect of low esterified pectin on the quality of soft ice cream.

The above demonstrates the expedient of developing soft ice cream technology using BPC and micro-organisms. The introduction of new technology will make it possible to bring products with new consumer properties to the market, expand the range and improve the provision of functional dairy products to the population of the country.

3. The aim and objectives of the study

The aim of the study is to develop a technology for functional soft ice cream using BPC and probiotics. This will expand the range of dairy products enriched with functional ingredients. To achieve the goal, the following tasks were set:

– to study the effect of BPC and probiotics on the density and viscosity of prescription mixtures, overrun and melting resistance of soft ice cream;

– to develop the recipe composition of soft ice cream using BPC and probiotics and technological scheme of process;

– to study the organoleptic and physico-chemical parameters, the nutritional value of soft ice cream with the addition of BPC and probiotics *Bifidobacterium+Lactobacillus*.

4. Materials and research methods

The objects of the study:

– mixtures for the production of ice cream without and with the use of BPC in the amount of 2.5–12.5 %;

– mixtures for the production of ice cream without and with the use of BPC in the amount of 2.5–12.5 % and probiotic *Bifidobacterium+Lactobacillus* (0.1 %);

– soft ice cream obtained by freezing the above-mentioned prescription mixtures.

When conducting research, samples of soft ice cream with a fat content of 14.0 % and 11.6 % were selected as controls (Table 1). With a variety of existing recipes, the samples taken as control ones are representatives of ice cream ice cream and cream. This will allow the results of the research to be extended to a wide range of ice creams produced in the restaurant industry. The technological process of ice cream production was carried out according to the classical technology, which provides for the preparation of a prescription mixture, pasteurization, homogenization, cooling and freezing.

Table 1

Composition of control samples of soft ice cream

Name of components	Content of components in control samples with fat content, %	
	14.0	11.6
Cream (35 %)	36.0	29.0
Skimmed milk powder	5.0	8.2
Raw cow's milk (3.2 %)	42.0	46.2
Sugar	11.7	11.3
Stabilization system	0.4	0.4
Vanillin	0.1	0.1
Drinking water	5.1	5.1
Total	100.0	100.0

When preparing soft ice cream with BPC and microorganisms, the latter were added to the recipe mixture, precooled to 37 °C. This temperature is optimal for the vital activity of microorganisms, which was confirmed in [9].

BPC was obtained from sugar beet varieties "Avantage". The technological process of BPC production is described and published [26]. BPC is a homogeneous light gray viscous liquid. The content of pectins in the concentrate is 10.0±0.2 %, the degree of esterification of pectins is 34.7±0.5 %, the complexing ability is 270±5 mg Pb^{2+}/g.

Starter culture microMilk PRP2 (10 u, microMILK s.r.l., Italy) and Bifilakt-B (1 u, Experimental Biofactory, RF) were taken as probiotics for food enrichment. The cultures were revived (activated) in accordance with the recommendations on milk whey LLP "Plant of the Kazakh Academy of Nutrition "Amiran" (Republic of Kazakhstan).

When conducting experimental robots, the following research methods were used. The mass fraction of solids was determined according to State standard 3626; the mass fraction of protein, according to State standard 34454; the mass fraction of fat, according to State standard 5867; the mass fraction of sucrose, according to State standard 3628; acidity, according to State standard 3624.

The pectin content was determined according to State standard 29059–91. The method is based on alkaline titration of pectin substances before and after hydrolysis. The titration results are proportional to the amount of free and esterified carboxyl groups and, when multiplied by the appropriate coefficients, give the content of polyuronides in the pectin substances of the product.

Quantitative determination of the mass fraction of water-soluble vitamins of group B was carried out by capillary electrophoresis on the Kapel–105M device (Lumex). The method of determination is based on the migration and separation of free forms of analyzed water-soluble vitamins under the action of an electric field with registration at a wavelength of 200 nm of their electrophoretic mobility. Determination of vitamins B_1, B_2, B_3, B_5 (nicotinic acid), B_6 and ascorbic acid was carried out by capillary zone electrophoresis. Extraction of vitamins was carried out with an aqueous solution of sodium tetraborate in the presence of sulfite ions. The mixture was centrifuged (5000–6000 rpm for 5 minutes) and filtered through a membrane filter. Vitamins were detected by their own absorption at 200 nm and 267 nm using programmable wavelength switching. Separation conditions: borate buffer pH=8.9; capillary L_{eff}/L_{total}=65/75 cm/cm, capillary diameter=50 μm; voltage +25 kV; temperature +30 °C [27].

Ice cream whipping was determined by measuring the mass of a fixed volume of mixture entering the freezer and the same volume of air-saturated soft ice cream leaving the freezer. Weighing was carried out on class II scales with an accuracy of 0.01 g.

Whipping of ice cream (B, %) was calculated by the formula:

$$B = \frac{m_2 - m_3}{m_3 - m_2} \times 100,$$

where m_2 – the mass of the glass filled with the mixture, g; m_3 – the mass of a glass filled with ice cream, g; m_1 – the mass of the glass, g; 100 – the conversion factor to percent.

The determination of the melting resistance of ice cream was carried out in the following way [28]. A sample of soft ice cream at a temperature of minus (4–6) °C was taken with a probe in the form of a hollow cylinder 35 mm in diameter and 50 mm high, placed in a cup, in the bottom of which there are holes for draining the thawed mixture. The resistance of ice cream to melting was characterized by the amount of melted ice cream (in ml), which accumulates when ice cream is kept for 15 minutes in a thermostat at a temperature of 25.0±1.0 °C.

The viscosity was determined on the Rotational viscometer Star Plus (Fungilab, Spain), the principle of operation of which is based on measuring the moment of resistance force created by the test product at various speeds of rotation of the inner cylinder and the measuring device. The rotation speed, depending on the viscosity of the system, varied in the range of 0.3–200 rpm. The moment of rotational resistance force was determined by the twisting of the drive spring, which is measured by the angle of rotation sensor. The measurement of indicators was controlled from an internal controller compatible with a computer using a special software package.

The organoleptic quality of soft ice cream was evaluated according to State standard 31986 [29] according to such indicators as appearance, texture, color, odor and taste. The temperature of soft ice cream in the organoleptic evaluation was minus 3.5±0.5 °C.

All experiments were carried out in triplicate. The results were expressed as mean ± standard deviation. Processing of experimental data, calculation of the numerical characteristics of the sample, construction of tables and graphs, calculations were carried out using the Microsoft Excel (Microsoft, USA) software packages [30].

5. Study of the influence of BPC and probiotic on the quality indicators of soft ice cream

5. 1. Influence of BPC and probiotic on the density and viscosity of prescription mixtures, whipping and ice cream melting resistance

The plombir and creamy ice cream (fat content 14.0 % and 11.6 %) were taken as controls samples during the research. This will make it possible to extend the results of the research to a wide range of ice cream produced in food establishments. The technological process of ice cream production was carried out according to the classical technology, which provides for the preparation of a prescription mixture, pasteurization, homogenization, cooling and freezing.

At the first stage of research, the effect of BPC in the concentration range of 2.5–12.5 % (dosage step – 2.5 %) on the physicochemical and organoleptic properties of mixtures and soft ice cream after freezing was studied (Fig. 1). When choosing the range of BPC concentrations, the functional-technological and functional-physiological properties of the pectins included in the BPC were taken into account. From the point of view of functional and technological properties, the introduction of BPC (consequently, pectins) should ensure the formation of a homogeneous creamy consistency, high melting resistance. From the point of view of the functional and physiological properties of pectins, it was taken into account that, being natural enterosorbents, they will remove heavy metals and harmful substances from the body that accumulate in the body.

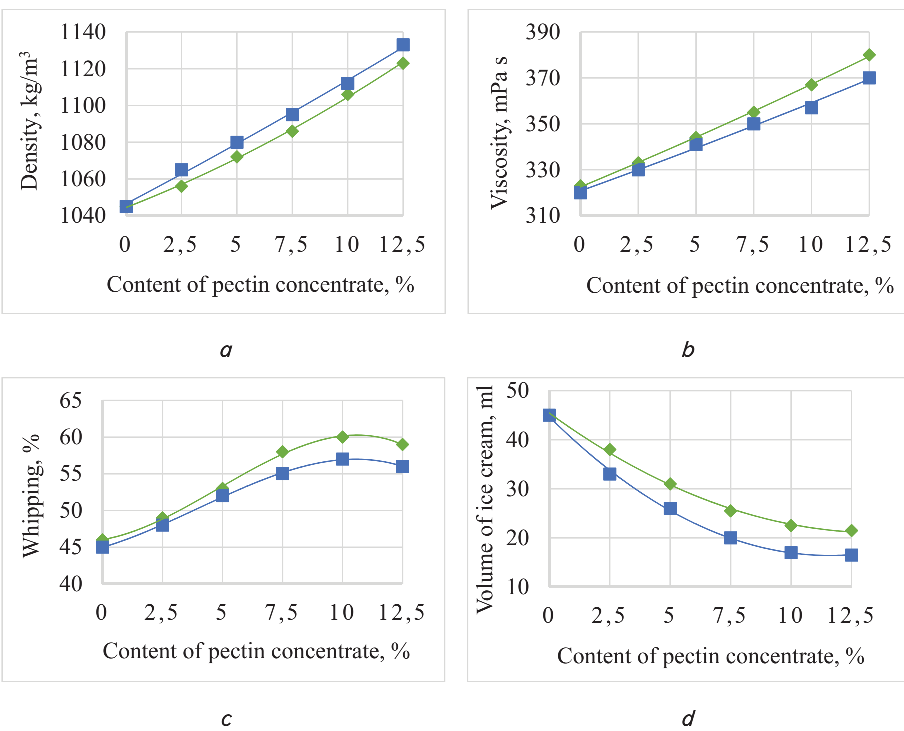

Fig. 1. Influence of BPC on the physicochemical properties of soft ice cream with different fat content: *a* — on density; *b* — on viscosity; *c* — on whipping; *d* — on melting resistance (volume of melted ice cream): 1 — 14.0 % fat; 2 — 11.6 % fat

Adding to mixtures BPC in the amount of 2.5–12.5 %, the density increases from 1050 kg/m^3 to 1140 kg/m^3, viscosity – from 320 mPa s up to 380 mPa s (Fig. 1, *a*, *b*). Conclusions about the rational range of BPC content are made on the basis of a comprehensive assessment of its effect on the physicochemical and organoleptic parameters of systems. Changes in the overrun of ice cream and its resistance to melting (Fig. 1, *c*, *d*) in relation to the consistency and taste were the priority. It has been established that in the range of BPC content of 2.5–10.0 %, an increase in ice cream overrun is observed. The maximum overrun of ice cream is achieved with a concentrate content of 10.0 %. A further increase in the concentrate leads to a slight decrease in overrun from 56–60 % to 52–55 %, probably as a result of an increase in viscosity. In this case, the resistance to melting monotonically increases.

Important in determining the rational content of BPC are the organoleptic indicators of the developed products. During the organoleptic evaluation of the samples, it was found that in terms of such indicators as appearance, color, taste and aroma, the samples practically do not differ from each other. All samples had a clean, creamy taste and aroma without foreigners, as well as a uniform color – white with a slightly creamy tint. It has been found that the content of BPC (C_{BPC}) affects the consistency of soft ice cream. In the concentration range $2.5 \leq C_{BPC} > 5.0$ %, soft ice cream has a homogeneous, loose texture without noticeable ice crystals, lumps of fat and stabilizer, light snowiness. There is a vague relief pattern on the surface of the ice cream when leaving the freezer, the ice cream melts quickly. In the concentration range $5.0 \leq C_{BPC} \geq 10.0$ %, ice cream has a uniform, moderately dense creamy texture, with a relief pattern on the surface. Ice cream is free of snow and ice crystals.

A further increase in the BPC content ($10.0 < C_{BPC} \geq 12.5$ %) leads to a deterioration in consistency. The consistency of ice cream is felt as too dense, oily, which is not acceptable. Thus, based on the results of physicochemical and organoleptic studies of prescription mixtures and finished ice cream, a rational BPC content of 5.0–10.0 % was chosen.

Due to the need to maximize the enrichment of ice cream with pectin, further studies were carried out on samples with the maximum possible content of BPC – 10.0 %.

In accordance with the purpose of the research – the development of technology for soft ice cream for functional purposes – the possibility of introducing microorganisms Bifidobacterium [31] and Lactobacillus [32] into the composition of ice cream was studied. The ratio of microorganisms (1:1) is based on the results of the studies described in [33].

The influence of the duration of thermostating of the prescription mixture with a fat content of 14.0 % and 11.6 % on the change in its acidity was studied (Table 2). The content of microorganisms in the prescription mixtures varied in the range of 0.01–1.0 %, the thermostating temperature was

37 °C, the duration of the thermostating of the prescription mixture after the introduction of *Bifidombacterinum+Lactobacillus* microorganisms was 30–120 minutes.

Table 2

Change in the acidity of the prescription mixture of soft ice cream depending on the content of microorganisms and the duration of thermostating (measurement accuracy: n=3, P≥0.95, σ=3...5 %)

Ratio and concentration of microorganisms	Acidity (°T) of prescription mixtures of soft ice cream, subjected to thermostating at a temperature of 37 °C, min											
	Control sample						10.0 % BPC					
	fat content 14.0 %			fat content 11.6 %			fat content 14.0 %			fat content 11.6 %		
	30	60	120	30	60	120	30	60	120	30	60	120
Bifidobacterinum+Lactobacillus (1:1) – 0.01 %	20.0	24.0	42.0	26.0	30.0	46.0	22.0	27.0	43.0	23.0	28.0	45.0
Bifidobacterinum+Lactobacillus (1:1) – 0.1 %	37.0	47.0	66.0	41.0	55.0	73.0	39.0	50.0	69.0	40.0	53.0	70.0
Bifidobacterinum+Lactobacillus (1:1) – 1.0 %	47.0	67.0	93.0	48.0	75.0	98.0	47.0	70.0	95.0	48.0	72.0	96.0

It was found that both in the control sample (without BPC) and in samples with BPC content of 10.0 %, with an increase in the duration of thermostating and the concentration of microorganisms, an increase in acidity is observed – by 1.8–2.1 times. It should be noted that the increase in acidity is also affected by the concentration of microorganisms. With an increase in their concentration from 0.01 % to 1.0 %, ceteris paribus, acidity increases. The acidity growth rates in all studied samples are close. In samples of prescription mixtures with BPC, the increase in acidity is slightly lower.

Increasing the duration of thermostating for more than 30 min. accompanied by a further increase in acidity, the formation of local clots, which is unacceptable in the production of ice cream. Taking into account the obtained results, further studies of the joint effect of BPC and microorganisms on the quality indicators of products were carried out at the above indicated parameters (the content of microorganisms is 0.1 %, the duration of thermostating is 30 minutes, the thermostating temperature is 37 °C).

The effect of *Bifidobacterium+Lactobacillus* microorganisms applied at a concentration of 0.1 % on the physicochemical parameters of prescription mixtures and soft ice cream with the addition of 10 % pectin concentrate was studied (Table 3).

Table 3

Influence of probiotic *Bifidobacterium+Lactobacillus* on the density, viscosity, whipping and melting resistance of soft ice cream

Name of indicator	Ice cream samples					
	fat content 14.0 %			fat content 11.6 %		
	Control sample	10.0 % BPC	10.0 % BPC+0.1 % probiotic	Control sample	10.0 % BPC	10.0 % BPC+0.1 % probiotic
Density, kg/m^3	1,050±10	1,133±10	1,133±10	1,052±10	1,137±10	1,137±10
Viscosity, mPa·s	320±5	367±4	370±5	320±6	357±5	364±5
Whipping, %	55±2	60±2	58±2	55±2	57±2	55±2
Melting resistance, ml	43±1	20±1	19±1	45±1	23±1	22±1

It has been established (Table 3) that with the introduction of *Bifidobacterium+Lactobacillus* microorganisms, the physicochemical parameters of the prescription mixture and soft ice cream practically do not change. So, the density of prescription mixtures has not changed. There is a slight increase in the viscosity of the recipe mixture for all ice cream samples, regardless of fat content. Overrun and melting resistance of soft ice cream are slightly (by 1.5–2.0 %) lower in comparison with samples that contain only 10.0 % BPC in their composition.

The obtained research results form the basis of the technology and formulation of soft ice cream using BPC and microorganisms.

5. 2. Formulation of soft ice cream using BPC and probiotic and technological scheme of process

The technological process for the production of soft ice cream using BPC and microorganisms is based on the classical technology, which provides for the preparation of a prescription mixture, pasteurization, homogenization, cooling and freezing. Experimental data on the effect of BPC and probiotic *Bifidobacterium+Lactobacillus* on the quality indicators of soft ice cream are implemented in its production technology (Fig. 2) and recipe composition (Table 4). The technological scheme for the production of functional soft ice cream using BPC and probiotic provides for:

– preparation of raw materials, preparation of a prescription mixture;

– pasteurization, homogenization and cooling of the recipe mixture;

– introduction of probiotic, thermostatting of the prescription mixture;

– cooling, maturation and freezing of the recipe mixture.

To prepare the mixture, cream, raw cow's milk, skimmed milk powder are loaded into the pasteurizer-cooler, the mixture is heated to a temperature of 40–45 °C with constant stirring. Then granulated sugar and pectin concentrate are added, heating is continued with constant stirring, the mixture is filtered and subjected to pasteurization at a temperature of 83–87 °C for 3–5 minutes. The introduction of BPC at this stage allows to distribute it throughout the mixture, remove impurities, provides the required microbiological parameters after pasteurization.

After filtering and pasteurization, the recipe mixture is homogenized to break up the fat globules to reduce their settling during storage and churning (enlargement) during the freezing of the mixtures. Homogenization is carried out at a temperature close to the pasteurization temperature without allowing the mixture to cool. The high temperature of pasteurization is explained by the fact that ice cream mixtures contain an increased amount of solids, which, by increasing the viscosity of the mixture, have a protective effect on probiotic.

After pasteurization, the mixture is cooled to a temperature of 37 °C, a starter consisting of probiotic *Bifidobacterium+Lac-*

tobacillus in an amount of 0.1 % is introduced, thermostated for 30 minutes. The introduction of microorganisms is carried out at a temperature optimal for their cultivation 37 °C. The expediency of cooling the mixture to a given temperature is also described in [9]; the authors point out that with decreasing temperature there is a deterioration in their viability. Then the mixture is cooled to a temperature of 2–6 °C, kept for 4–5 hours at a temperature of 2–6 °C to mature the mixture.

Table 4

Composition of soft ice cream using BPC and probiotic

Name of components	Content of components, %, in samples of ice cream with fat content			
	14.0	11.6	14.0	11.6
	No. 1	No. 2	No. 3	No. 4
Cream (35 %)	36.0	29.0	36.0	29.0
Skimmed milk powder	5.0	8.2	5.0	8.2
Raw cow's milk (3.2 %)	37.0	41.2	37.0	41.2
Sugar	11.7	11.3	11.6	11.2
BPC/pectin	10.0/1.0	10.0/1.0	10.0/1.0	10.0/1.0
Probiotic *Bifidobacterium+Lactobacillus*	–	–	0.1	0.1
Stabilization system	0.2	0.2	0.2	0.2
Vanillin	0.1	0.1	0.1	0.1
Total	100	100	100	100

Further, from the pasteurizer-cooler, the mixture is pumped into the freezer and subjected to freezing. During freezing, the recipe mixture is saturated with air (whipped) and partially frozen; air is distributed in the product in the form of tiny bubbles, the mixture is cooled to cryoscopic temperature (depending on the composition of the mixture from minus 2.3 °C to minus 4.5 °C). The temperature of the ice cream at the exit from the freezer was not higher than minus 3.5 °C. The whipping of ice cream is determined by the composition of the mixture, including the reasonable concentration of pectin.

5. 3. Physical and chemical parameters, organoleptic indicators and nutritional value of soft ice cream with the addition of BPC and probiotic *Bifidobacterium+Lactobacillus*

The main physicochemical, nutritional (Tables 5, 6) and organoleptic (Table 7) indicators of soft ice cream with different fat content – 14.0 % (Table 5) and 11.6 % (Table 6) with addition of BPC and probiotics were studied. It has been established that in ice cream samples with fat content 14.0 % the mass fraction of solids ranges from 39.0±0.5 % to 42.0±0.5 %, protein and milk fat content are 3.0±0.1 % and 13.8±0.3 %, accordingly. The ice cream samples with fat content 11.6 % have the mass fraction of solids 38.5±0.5 %, protein 2.9±0.1 %, milk fat content 11.4±0.3 %. It has been established that an increase in the amount of BPC in the composition of ice cream leads to a decrease in the titratable acidity index.

It has been established that with an increase in the amount of BPC, a slight change in active and titratable acidity is observed. Titratable and active acidity of ice cream samples varies from 20.0±0.3 °T to 39.0±0.3 °T and from 6.2±0.1 to 6.9±0.1, respectively, depending on the amount of added BPC. With the combined use of BPC and microorganisms, a significant increase in titratable acidity by 1.7–2.0 times is observed.

In all samples the amount of water-soluble vitamins was observed at approximately the same level: thiamine chloride from 0.017±0.001 to 0.023±0.001 mg/100 g, riboflavin from 0.025±0.001 to 0.036±0.001 mg/100 g, pyridoxine from 0.138±0.001 to 0.163±0.001 mg/100 g, pantothenic acid from 0.051±0.001 to 0.068±0.001 mg/100 g, nicotinic acid from 0.525±0.001 to 0.672±0.001 mg/100 g. Ascorbic acid was more than others, respectively between 1.180±0.001 and 1.549±0.001 mg/100 g.

It was established (Table 6) that the content of vitamins in the control sample and samples 2, 4 is almost the same. In sample 4, an increase in the content of B vitamins, ascorbic acid, pantothenic and nicotinic acids by 1.1–1.2 times is observed.

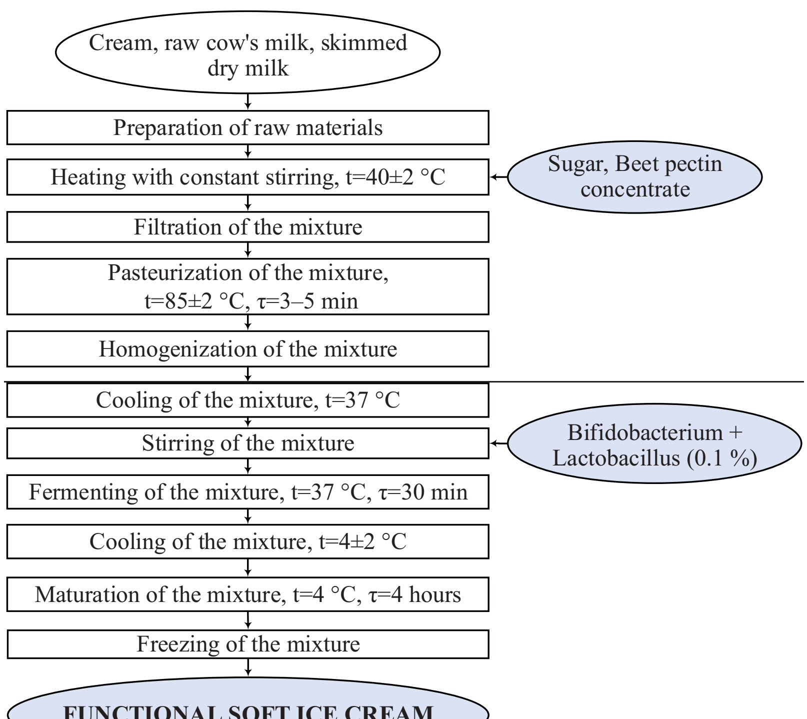

Fig. 2. Technological scheme for the production of functional soft ice cream using BPC and probiotic

Table 5

Nutritional value and physicochemical parameters of soft ice cream (fat content 14.0 %) using BPC and probiotic

Name of indicator	Content in ice cream samples*		
	Control sample (fat content 14.0 %)	No. 1	No. 3
Mass fraction of solids, %	39.6±0.5	42.0±0.5	39.0±0.5
Mass fraction of protein, %	3.1±0.1	3.0±0.1	3.0±0.1
Mass fraction of milk fat, %	14.0±0.3	13.8±0.3	13.8±0.3
Mass fraction of sucrose, %	11.6±0.2	11.7±0.2	11.6±0.2
Acidity, °T	23.0±0.3	20.0±0.3	39.0±0.3
pH	6.8±0.1	6.9±0.1	6.2±0.1
Pectin substances, %	–	1.00±0.01	0.98±0.01
Thiamine chloride (vitamin B_1), mg/100 g	0.021±0.001	0.023±0.001	0.017±0.001
Riboflavin (vitamin B_2), mg/100 g	0.025±0.001	0.025±0.001	0.035±0.001
Pyridoxine (vitamin B_6), mg/100 g	0.138±0.001	0.143±0.001	0.163±0.001
Ascorbic acid, mg/100 g	1.180±0.001	1.181±0.001	1.549±0.001
Pantothenic acid (vitamin B_5), mg/100 g	0.051±0.001	0.054±0.001	0.067±0.001
Nicotinic acid (vitamin B_3), mg/100 g	0.525±0.001	0.527±0.001	0.672±0.001

*Note: *The composition of the control sample is presented in Table 1, samples No. 1, 3 – in Table 4*

Table 6

Nutritional value and physico-chemical parameters of soft ice cream (fat content 11.6 %) using BPC and probiotic

Name of indicator	Content in ice cream samples		
	Control sample (fat content 11.6 %)	No. 2	No. 4
Mass fraction of solids, %	36.5±0.5	38.0±0.5	38.0±0.5
Mass fraction of protein, %	3.1±0.1	2.9±0.1	2.9±0.1
Mass fraction of milk fat, %	11.6±0.3	11.4±0.3	11.4±0.3
Mass fraction of sucrose, %	11.3±0.2	11.3±0.2	11.2±0.2
Acidity, °T	26.0±0.3	24.0±0.3	40.0±0.3
pH	6.8±0.1	6.9±0.1	6.2±0.1
Pectin substances, %	–	1.00±0.01	0.99±0.01
Thiamine chloride (vitamin B_1), mg/100 g	0.017±0.001	0.0230.001±	0.0170.001±
Riboflavin (vitamin B_2), mg/100 g	0.035±0.001	0.0250.001±	0.036±0.001
Pyridoxine (vitamin B_6), mg/100 g	0.163±0.001	0.1440.001±	0.162±0.001
Ascorbic acid, mg/100 g	1.549±0.001	1.1810.001±	1.549±0.001
Pantothenic acid (vitamin B_5), mg/100 g	0.067±0.001	0.0530.001±	0.068±0.001
Nicotinic acid (vitamin B_3), mg/100 g	0.672±0.001	0.5280.001±	0.672±0.001

*Note: *The composition of the control sample is presented in Table* 1, samples *No. 2, 4 – in Table 4*

Table 7

Organoleptic characteristics of soft ice cream using BPC and probiotics

Name of indicator	Product Feature
Appearance and texture	Homogeneous dense mass with a relief pattern on the surface, the consistency of ice cream is homogeneous, creamy, without organoleptically perceptible ice crystals, fat and stabilizer. Ice cream does not have a snowy, flaky and sandy texture
Color	White with a slightly creamy tint, homogeneous throughout the mass
Smell and taste	Clean, creamy-vanilla, without foreign tastes and odors

The results of studying the organoleptic characteristics of ice cream using BPC and probiotics (Table 7) showed that they fully comply with the current requirements: all samples had a uniform, moderately dense texture; after leaving the freezer, the relief surface remained on the ice cream, no ice crystals, sandy or snowy consistency were found in any of the samples, the ice cream was characterized by a clear pronounced creamy vanilla smell and taste.

6. Discussion influence of BPC and probiotic on the quality of soft ice cream

It has been established that BPC affects the physico-chemical parameters of ice cream prescription mixtures. There is a change in the density of prescription mixtures (Fig. 1, *a*), which is associated with their chemical composition: with the introduction of BPC, the density increases. For all studied samples, a lower density is characteristic for mixtures with a fat content of 14.0 %. As a result of the solvation of pectin molecules, a decrease in the mobility of water molecules, an increase in the viscosity of the mixture (Fig. 1, *b*) and, as a result, an increase in ice cream overrun (Fig. 1, *c*) are observed. When using pectin concentrate in the system, the amount of bound water increases, and the cryoscopic temperature decreases [34, 35]. This provides high resistance to ice cream melting (Fig. 1, *d*).

The increase in the viscosity of prescription mixtures is explained by the fact that with an increase in the content of BPC, the content of pectin substances increases up to 1.00±0.01 % (Tables 5, 6). Being highly hydrophilic compounds, pectins bind water to form viscous systems. This allows pectin to be used as a multifunctional ingredient.

It was experimentally established that the introduction of microorganisms into the prescription mixture significantly not effects on its physicochemical parameters (Table 2), except for acidity. In the interrelation of indicators "thermostating duration – acidity", the most rational is the use of microorganisms at a concentration of 0.1 %. After 30 minutes of fermentation, the acidity reaches 39–40 °T for prescription ice cream mixtures with a fat content of 11.6 % and 14.0 %.

In prescription mixtures with BPC, the acidity values are somewhat lower. This is probably explained by the fact that the introduction of BPC leads to an increase in the viscosity of mixtures and, as a consequence, a decrease in the rate of enzymatic processes.

The introduction of microorganisms into prescription mixtures with subsequent fermentation leads to a decrease in overrun and resistance to ice cream melting (Table 3). This is due to the fact that an increase in acidity leads to a deterioration in the solubility of proteins and the realization of their functional and technological properties.

BPC and microorganisms affect the physicochemical parameters and the nutritional value of ice cream (Tables 5, 6). Thus, the mass fractions of solids, protein, milk fat and sucrose are determined by the prescription composition of ice cream; the acidity and pH of ice cream samples with BPC are almost the same. Ice cream samples with BPC and microorganisms are characterized by higher acidity values. This is due to the accumulation of organic acids during the fermentation of mixtures.

The nutritional value of experimental samples in terms of such indicators as the mass fraction of protein, milk fat, sucrose is comparable with control samples. A distinctive feature of the new products is the presence of pectin substances up to 1.00±0.01 %, depending on the prescription composition. Control samples of soft ice cream do not contain pectin.

As for the vitamin composition of new products, the content of B vitamins and ascorbic acid in ice cream samples with BPC (Tables 5, 6) has similar indicators – their changes are within the measurement error. In ice cream samples with BPC and microorganisms, a slight increase in the content of B vitamins and ascorbic acid was noted. According to [33], this is due to an increase in the availability of vitamins as a result of the metabolic activity of microorganisms.

A distinctive feature of the obtained results in comparison with existing studies [36] is that, within the framework of the developed technology, pectin substances simultaneously perform a technological role (it is possible to reduce the content of the stabilization system) and a functional physiological role. In this regard, the use of BPC containing low esterified pectin makes it possible to identify the developed ice cream as a functional dairy product.

It is important that the raw material base for its production is available in the country. The production of our own pectin concentrate will ensure import substitution through the use of the country's internal resources. However, the implementation of this direction has some limitations. It is necessary that BPC be characterized by a stable composition and properties. It is required to establish large-scale production of concentrate, provide a logistics system for the movement of resources (raw materials, related materials, finished products – concentrates), conduct research and develop technologies for food products (confectionery, sauces, jams, fruit and dairy fillings, drinks) with its use. In this case, the unique ability of pectins to bind and remove heavy metals will be fully realized.

The development of this study involves:

– conducting research on the influence of technological factors – ingredients (sugar, pH systems, dietary fiber) and heat treatment (temperature, duration) on the characteristics of pectin concentrate;

– development of technology for new types of ice cream (in particular, fruit sorbets) using BPC;

– development of technology for functional hardened ice cream using pectin concentrate and probiotic *Bifidobacterium+Lactobacillus*;

– development of technology for a wide range of confectionery products, fillings, sauces, desserts, where pectin substances will not only act as thickeners, structure formers and stabilizers, but also positively affect human health and performance.

The full-scale implementation of this research requires additional BPC experimental studies and technological developments in production conditions. In the future, studies will be carried out on the effect of BPC on the cryoscopic temperatures of prescription mixtures and the amount of frozen water, the dispersion of the fat and air phases of ice cream, depending on technological factors.

7. Conclusions

1. Taking into account the qualitative and quantitative results of the research, it has been established that an increase in BPC leads to an increase in the density (from 1070 kg/m^3 to 1140 kg/m^3) and viscosity (from 320 mPa·s to 380 mPa·s) of prescription mixtures. This in turn affects the overrun and melt resistance of the ice cream. The maximum value of ice cream overrun (56–60 %) is achieved when using a concentrate in the amount of 10.0 %. The melting resistance of ice cream in the studied range of concentrate content droningly increases.

2. Technological scheme for the production of soft ice cream using pectin concentrate and probiotic has been developed. The rational content of BPC – 10.0 %, probiotic – 0.1 % from the mass of raw materials, and the parameters of the technological process were determined. It has been shown that it is expedient to carry out the process of fermentation of the recipe mixture at a temperature of 36–38 °C for 30 minutes.

3. The quality indicators of soft ice cream of various fat content (ice cream –14.0 %, cream – 11.6 %) with the addition of BPC and probiotic *Bifidobacterium+Lactobacillus* were studied. Soft ice cream is characterized by high nutritional value (mass fraction of protein 2.6–3.2 %, milk fat 11.0–13.9 %, sucrose 11.2–11.7 %, contains water-soluble vitamins and physiologically significant content of pectin (0.95–0.98 %), which is a natural enterosorbent. The obtained research results indicate the significant potential of pectin concentrate as a prescription component in the composition of functional dairy products.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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