

LACTOSE-FREE ICE CREAM TECHNOLOGY BASED ON SECONDARY DAIRY RAW MATERIALS

<https://doi.org/10.15673/fst.v17i1.2564>

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Cite as Vancouver style citation

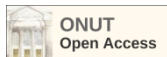
Trubnikova A., Chabanova O., Sharakhmatova T., Bondar S., Nedobiichuk T. Lactose-free ice cream technology based on secondary dairy raw materials. Food science and technology. 2023;17(1):87-93.
<https://doi.org/10.15673/fst.v17i1.2564>

Цитування згідно ДСТУ 8302:2015

Trubnikova A., Chabanova O., Sharakhmatova T., Bondar S., Nedobiichuk T. Lactose-free ice cream technology based on secondary dairy raw materials // Food science and technology. 2023. Vol. 17, Issue 1. P. 87-93
<https://doi.org/10.15673/fst.v17i1.2564>

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Introduction. Formulation of the problem

Ice cream is the most favorite dairy dessert among the population of Ukraine and the world. The growing popularity of ice cream has given birth to many varieties. Today, more than 1,000 types of domestic ice cream are known, which differ in physico-chemical and organoleptic indicators, production methods, recipe composition, surface design, and packaging.

The main trends in the development of the ice cream industry in the world are as follows: an increase in the volume of production of low-calorie ice cream with a low fat content or without fat, as well as without

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Abstract. Expanding the assortment of lactose-free dairy products, namely, ice cream for people who cannot tolerate lactose is a promising direction of research. The purpose of the work is to develop the technology of milk lactose-free synbiotic yogurt ice cream based on buttermilk protein-lipid concentrate, obtained by ultrafiltration/diafiltration, with the addition of natural flavoring and food additives, and the study of its quality indicators. A protein-lipid concentrate of buttermilk with a low lactose content was obtained by ultrafiltration/diafiltration, and its quality indicators were determined. The concentrate has a high protein content (16.01%) and a low lactose content (1.28%). Protein-lipid concentrate fermented with synbiotic sourdough is the main component included in the formulation of lactose-free synbiotic yogurt ice cream. The main physico-chemical parameters of the obtained fermented protein-lipid concentrate were determined, which ensures a rational content of the main components of the chemical composition in the finished lactose-free ice cream (it does not contain lactose, the protein content is 8.46%) and a high content of useful microflora (bifido- and lactobacilli). A mixture for lactose-free synbiotic yogurt ice cream was obtained according to a scientifically based recipe. A sample of lactose-free ice cream was made from the mixture using traditional technology, and organoleptic, physico-chemical and microbiological quality indicators were investigated. A comparison of the quality indicators of the studied sample with the control, which was taken as classic yogurt ice cream, was carried out. The mass fraction of lactose in samples of lactose-free ice cream is 0,011%. The developed lactose-free synbiotic yogurt ice cream has high probiotic activity (contains lacto- (3.0×10^8 CFU/g) and bifidobacteria (3.5×10^9 CFU/g)).

Keywords: secondary raw materials, recipe design, technology, lactose-free ice cream, quality indicators.

sugar; stimulation of demand for ice cream due to new textures; the appearance of numerous seasonal, festive series of ice cream and ice cream intended for different age groups; the appearance of various types of ice cream for special purposes, in particular lactose-free, etc. [1,2].

Milk-based ice cream contains milk raw materials that contain lactose, so not all consumers can consume such ice cream. There is a group of the population that is unable to absorb lactose, to ensure its full nutrition, lactose-free dairy products, in particular ice cream, are necessary.

There are some lactose-free ice creams available on the world market, made from hydrolyzed lactose milk or from alternative milk sources, which have low nutritional and organoleptic properties and are expensive compared to traditional dairy raw materials. In Ukraine, the lactose-free ice cream market is in its infancy, the assortment includes several types of lactose-free ice cream, which is not enough to meet the needs of the lactose-intolerant population. In addition, today, both in the whole world and in Ukraine, there is a steady trend of protein deficiency in nutrition, and the problem of complete collection and rational use of valuable secondary dairy raw materials is acute. Secondary dairy raw materials include buttermilk, which is formed during the production of butter. Buttermilk is a potential natural source of complete protein and has high nutritional and biological value. Buttermilk resources in the country are significant, but it is used mainly for the normalization of dairy products and drying. The use of buttermilk in the production of ice cream will ensure a more complete use of the components of milk, will allow the development of resource-saving technologies and the use of non-traditional raw materials. But buttermilk, as a dairy raw material, contains a significant amount of lactose, which must be removed. The removal of lactose from buttermilk can be solved through the use of appropriate enzymes and by of the molecular-sieve phenomena. The latter are implemented through the introduction of membrane technologies of concentration and separation. Membrane methods include, in particular, ultrafiltration and diafiltration. Ultrafiltration is used to isolate and concentrate proteins. Diafiltration is a common and effective method of cleaning various high-molecular compounds from unwanted low-molecular substances. Membrane methods are energy-saving and have a number of advantages over enzymatic methods [3]. The use of protein buttermilk concentrate obtained by ultrafiltration/diafiltration of buttermilk as the main ingredient in the production of lactose-free ice cream, will improve the functional properties of the finished product.

Therefore, removing lactose from milk raw materials, increasing the biological value of ice cream and giving it functional properties due to the concentration of proteins, the introduction of sourdough microflora, prebiotics and other ingredients will allow to expand the product range, the circle of consumers (in particular, the lactose-intolerant population) and increase the demand for ice cream, which brings not only pleasure, but also benefit.

Considering the above, there is an urgent need to develop a technology for lactose-free ice cream with a high content of complete protein (the source of which is buttermilk protein concentrate obtained by ultrafiltration/diafiltration of buttermilk), sourdough microflora, prebiotics and other ingredients, which will ensure high organoleptic and nutritional value and high

probiotic activity of ice cream, will be economical and will make it possible to solve the problem of energy and resource conservation when it is introduced into production.

Analysis of recent research and publications

Today, it is necessary to constantly improve the assortment of ice cream and pay special attention to the quality of ice cream, because there are many ice cream manufacturers on the market. Therefore, this problem is relevant today. Specialists in the field of ice cream see a perspective in the transition to ice cream, which is enriched with useful functional additives. Ice cream as a functional product should ensure the health of the population [1,2]. And the global trend of ice cream consumption shows growth in the direction of health benefits. But diseases such as lactose intolerance do not allow patients to consume ice cream made by traditional technology [3-7]. And such patients in Ukraine number from 15 to 35% of the adult population, depending on the region. Therefore, it is necessary to remove lactose from dairy raw materials.

A detailed description of the existing methods of removing lactose from dairy products, their advantages and disadvantages, is given in [3]. Among known methods of lactose removal, enzyme, membrane, and their combination are widely used. The choice of method of lactose removal depends on many factors. The main ones are the requirements for the composition of the product and the general costs of the process. Membrane processing favorably differs from others. In this case, reagents are not added to the product.

Cleaning is carried out at a low temperature, which contributes to the preservation of biologically valuable components. Membrane methods for lactose removal include diafiltration as the main process. Diafiltration is a variant of the baromembrane process of separation of dissolved high-molecular and low-molecular components, in which the concentrate is diluted with a solvent. Water is used as a solvent. The concentration of compounds in the product decreases. Further ultrafiltration of the diluted solution leads to the separation of high- and low-molecular substances. Mineral substances with a solvent pass through the membrane. This method of processing is used to purify protein concentrates from lactose and minerals [3].

There are many schemes for removing lactose from dairy raw materials by membrane or combined method. Thus, the combined method (membrane+enzymatic) involves obtaining of the diafiltration concentrate with a lactose content of 1.3–1.5% at the diafiltration stage. When a certain concentration of lactose remains in the milk, the enzyme lactase is added to the milk. Since the concentration of lactose is reduced at the stage of membrane processing due to the combination of membrane processes, hydrolysis does not lead to the accumulation of a high glucose content, as is

investigated in exclusively enzymatic processing of milk. In addition, lactose-free milk has 35% less carbohydrates, which reduces the caloric content of milk by about 20% [3].

Production of ice cream with lactic acid bacteria is one of the ways to reduce the lactose content.

There is an increasing number of clinical studies, the results of which prove that probiotics can help alleviate lactose intolerance [8-10]. Although the specific mechanism is not clear, it is generally believed that changes in the composition of the microbial flora by probiotics and enhancement of immune function are the basis of their effects [11]. *Lactobacillus* (including *Lactobacillus acidophilus*, *Lactobacillus rhamnosus*, *Lactobacillus casei*, etc.), *Bifidobacterium* and *Saccharomyces* and other probiotics are often used in the production of fermented milk products.

It is considered appropriate to use combined probiotics, the symbiotic strains of which have a wide range of physiological effects. Such probiotics provide an opportunity to prevent or reduce the risk of developing multifactorial diseases, since probiotic properties are strain-specific. Combined probiotics have a more pronounced effect than probiotics containing a monoculture of probiotic bacteria. Lactic acid cultures have a fairly high β -galactosidase activity compared to other microorganisms, *thermophilic streptococcus*, *Bulgarian bacillus* and *acidophilic bacillus* have the highest activity to ferment lactose [12,13].

To obtain lactose-free ice cream, where the main recipe component of the mixture is protein concentrate buttermilk, such an ice cream mixture must be fermented. For the fermentation of ice cream mixture, it is advisable to choose [14]: *Lactobacillus bulgaricus*, *Streptococcus thermophilus* and probiotics – *Bifidobacterium animalis* and *Lactobacillus acidophilus* as sourdough cultures. In the author's work, sourdough cultures containing the specified lactic acid microorganisms were analyzed – dry bacterial starters for direct application of the company "Hr. Hansen" (Denmark): FD DVS YF-L903, which includes mixed cultures of *Streptococcus thermophilus* + *Lactobacillus delbrueckii ssp. bulgaricus* (yogurt starter), in combination with starter FD DVS La-5, which contains monocultures of *Lactobacillus acidophilus* and starter FD DVS Bb-12, which contains monocultures of *Bifidobacterium animalis*.

Prebiotics are also functionally beneficial for gut health. However, compared to probiotics, there are there is little research on the improvement of lactose intolerance using only prebiotics [15]. Presumably, the selective utilization of prebiotics by epy host microorganisms increased the survival of probiotics in the gastrointestinal tract. This is why a lot of research has focused on the combination of probiotics and prebiotics. Commonly used prebiotics include galactooligosaccharides, fructooligosaccharides (FOS), inulin, and the like.

For example, Pereira et al. [16] used *Lactobacillus acidophilus*, *Bifidobacterium lactis* and inulin to produce fermented milk with lactose content below 0.1%, and this product had high organoleptic indicators and probiotic activity. The focus of these articles was on ensuring the viability of probiotics in products (not less than 10^6 CFU/g) to improve lactose digestion and absorption.

Therefore, the use of a combination of probiotics and prebiotics during the fermentation of the mixture for lactose-free ice cream will allow to reducing the lactose content and obtaining a product with high pre- and probiotic activity.

There are technologies for obtaining low-lactose frozen desserts and soft ice cream using β -galactosidase enzyme preparations, where it is proposed to hydrolyze lactose up to 50% [17].

The authors of the work [18] investigated the production of frozen lactose-free yogurt by enzymatic hydrolysis of lactose and its effect on the characteristics of the final product. The study showed that lactose-free frozen yogurt can be successfully used to produce new lactose-free frozen desserts, particularly ice cream. Hydrolysis of lactose improves the texture and viscosity of the product, as well as improves its taste.

A lot of attention in Europe and Asia is paid to yogurt ice cream [19,20]. There are three ways of obtaining yogurt ice cream [19,21]. According to the first method, yogurt ice cream is obtained by mixing 30% yogurt with 70% traditional ice cream (adding large amounts of yogurt (more than 30%) to ice cream is not recommended due to sensory and melting problems); according to the second method – the initial mixture of components is fermented with yogurt cultures before freezing; the third method involves adding yogurt cultures to the finished ice cream. However, ice cream obtained by the third method cannot be called yogurt.

El-Nagar and others [22] developed a low-fat yogurt ice cream technology by including 5% inulin in the formulation. Otero et al. [23] reported the addition of 4% inoculum of *L. acidophilus* and *Bifidobacteria bifidum* at a ratio of 1:1 during the production of yogurt ice cream, which was sufficient to achieve levels greater than 10^5 cells per gram. Various flavors of yogurt ice cream, including chocolate, orange, blackberry, raspberry, black mulberry, and strawberry, were studied by the authors in [24].

Lactose-free ice cream is produced either by adding lactose-free milk to the ice cream mix or by adding lactase enzyme after pasteurization and incubation during the ripening period before freezing [2,25]. The authors proved that the hydrolysis of lactose increases the apparent viscosity of the ice cream mixture, lowers the freezing point, increases sweetness, which allows to reducing the addition of sugar by 25%, reduce the "sandy" and improving the organoleptic properties of the ice cream.

Studies [26,27] established the expediency of using ultrafiltration to concentrate the protein-lipid fraction of buttermilk and its diafiltration with NF permeate to remove lactose under the condition of proper selection of NF membranes that provide high selectivity for lactose; developed a technology for continuous production of lactose-free protein-lipid concentrate of buttermilk and an installation for its implementation, which contains circuits interconnected by technological pipelines: ultrafiltration, diafiltration, nanofiltration; Scientifically based formulations and technology of low-lactose synbiotic yogurt ice cream have been developed ice cream based on lactose-free buttermilk concentrate with enhanced functional properties.

Production of ice cream with increased protein content and correspondingly reduced lactose content is given in [28]. The protein content in the mixtures varied from 3.74% (in the control) to 7.08%. The level of milk protein affected the size of the ice crystals. With increased protein content, the size of ice crystals decreased. It has been proven that it is possible to produce ice cream with increased protein content. The key roles of proteins in ice cream: emulsification, aeration, structural stability (as the protein content in the ice cream recipe increases, the ice crystals in the resulting product will be smaller in size; the formation of ice crystals significantly affects the final quality of the product, for example, how it melts and how it is felt in the mouth; proteins not only reduce the size of ice particles, but also contribute to the development of a more stable structure).

The authors in studies [29,30] offer ice cream manufacturers an alternative source of skimmed milk powder, namely milk protein concentrates, especially in mixtures with reduced lactose or fat, where a higher content of skimmed milk powder is required to compensate for other losses in total solids content.

Therefore, the development of scientifically based technology of lactose-free ice cream based on protein-lipid concentrate from buttermilk, obtained by membrane methods, is an actual and promising direction in food science, besides, it makes it possible to solve the problem of energy- and resource conservation.

The purpose of the work is to develop the technology of milk lactose-free synbiotic yogurt ice cream based on buttermilk protein-lipid concentrate, obtained by ultrafiltration/diafiltration, with the addition of natural flavoring and food substances, and the study of its quality indicators.

To achieve the goal, the following tasks were solved:

- obtaining by ultrafiltration/diafiltration the protein-lipid concentrate of buttermilk with a low lactose content and determining its chemical composition;
- obtaining a mixture of the lactose-free synbiotic milk yogurt ice cream according to the developed recipe and making ice cream samples;

- development of a technological scheme for the production of lactose-free synbiotic milk yogurt ice cream;

- study of the quality indicators of the received sample of lactose-free synbiotic milk yogurt ice cream and its comparison with classic milk yogurt ice cream and the requirements of DSTU 4733:2007.

Research materials and methods

The object of the research is milk lactose-free synbiotic yogurt ice cream with the addition of natural flavoring and food substances.

The research was conducted in the conditions of the laboratory of the Odessa National University of Technology.

The main ingredient of the ice cream recipe is a functional basis obtained in laboratory conditions: a liquid protein-lipid concentrate of buttermilk with a low lactose content (BLCB) (obtained by diafiltration (DV=3) of an ultrafiltration concentrate with a concentration factor of FC=5).

The additional ingredients of the ice cream recipe were chosen: stabilization system "Ultra tex" ISE1-0023 (Private enterprise "Textra-Vita", Ukraine), which has the following composition: modified starch E 1442, whey protein concentrate, modified starch E 1450, mono- and diglycerides fatty acids E 471, guar gum E 412, locust bean gum E 410; dry bacterial starters FD DVS YF-L903 (*Streptococcus thermophilus*, *Lactobacillus delbrueckii ssp. bulgaricus*), FD DVS La-5 (*Lactobacillus acidophilus*), FD DVS Bb-12 (*Bifidobacterium animalis*) ("Hr. Hansen", Denmark); inulin preparation of the trade mark "Frutafit IQ" (Netherlands); lactulose preparation ("Fresenius Kabi Company", Italy); citric acid of the trade mark "Mriya" ("Ukroptbakalia", Ukraine), according to DSTU GOST 908:2006; ginger powder of the trade mark "Eko" ("Ekotechnika", Ukraine), according to DSTU ISO 1003:2005; crystalline granulated sugar of the "Khutorok" trade mark (Ukraine), in accordance with DSTU 4623:2006.

The following research methods were used during the experiments: titrated and active acidity – according to DSTU 8550:2015; organoleptic indicators – according to DSTU ISO 22935-2-2011; mass fraction of dry substances – according to DSTU 8552:2015; mass fraction of protein – Kjeldahl method – according to DSTU 8063:2015; mass fraction of fat – gravimetric method according to DSTU ISO 7208-2002, DSTU ISO 7328:2005; mass fraction of lactose – enzymatic method – according to DSTU ISO 11285:2004/ IDF 175:2012; mass fraction of sucrose – by the iodometric method – according to DSTU 7381:2013; determination of the whippedness of ice cream – according to DSTU 4733:2007, determination of the resistance of ice cream to melting – determined by the accumulation time of 10 cm³ of liquid (melt) flowing from a sample of ice cream in the form of a cylinder with a diameter of 30 mm and a height of 50 mm when heated at a

temperature of $20 \pm 1^\circ\text{C}$, values of no less than 41 min were taken as a satisfactory indicator of resistance to melting; microbiological indicators: the number of bacteria of the group of *Escherichia coli* – according to DSTU IDF 73 A; the most likely number of lactic acid microorganisms – according to DSTU 7999:2015; the number of bifidobacteria – according to DSTU 7355:2013; the number of mold fungi and yeast – according to DSTU 8447:2015.

Statistical processing of the obtained results was carried out in the Microsoft Office Excel, 2010.

Results of the research and their discussion

Literature research made it possible to draw up a scheme (Fig. 1), which explains the principles that formed the basis of the creation of lactose-free synbiotic yogurt ice cream.

Prebiotics (lactulose), water-soluble dietary fibers (inulin), which is also a prebiotic, and probiotics (synbiotic sourdough starter) were added to enrich the ice cream with healthy ingredients. to change the components of the ice cream, a protein-lipid concentrate of buttermilk with a low lactose content was added; to change the taste and aroma of ice cream, ginger and citric acid were added.

For the production of lactose-free ice cream, research was divided into four stages. The first stage is obtaining a protein-lipid concentrate of buttermilk with a low lactose content; the second stage – adding leavens (combination of starters FD DVS YF-L903 + FD DVS La-5 + Bb-12) and fermentation of the protein-lipid concentrate of buttermilk with a low lactose content; the third stage is obtaining experimental samples of the mixture for lactose-free synbiotic yogurt ice cream; the fourth stage is the study of quality indicators of the received ice cream sample and its comparison with classic yogurt ice cream.

The protein-lipid concentrate of buttermilk with a low lactose content (BLCB), which served as the main recipe component of lactose-free ice cream, was obtained according to the technological scheme shown in Fig. 2 [14,16,17].

The scheme consists of processes for obtaining buttermilk concentrate by combining membrane methods of ultrafiltration and diafiltration.

For ultrafiltration (UF) and diafiltration (DF), VPU-15 hollow fiber membranes were used as part of the AR-2 module of the UPL-0.6 ultrafiltration unit. The molecular weight of membrane separation (cut-off) is 15 kDa. The selectivity of VPU-15 membranes for lactose was 4%, for protein – 99.6–99.7%. The membrane material is polyamide.

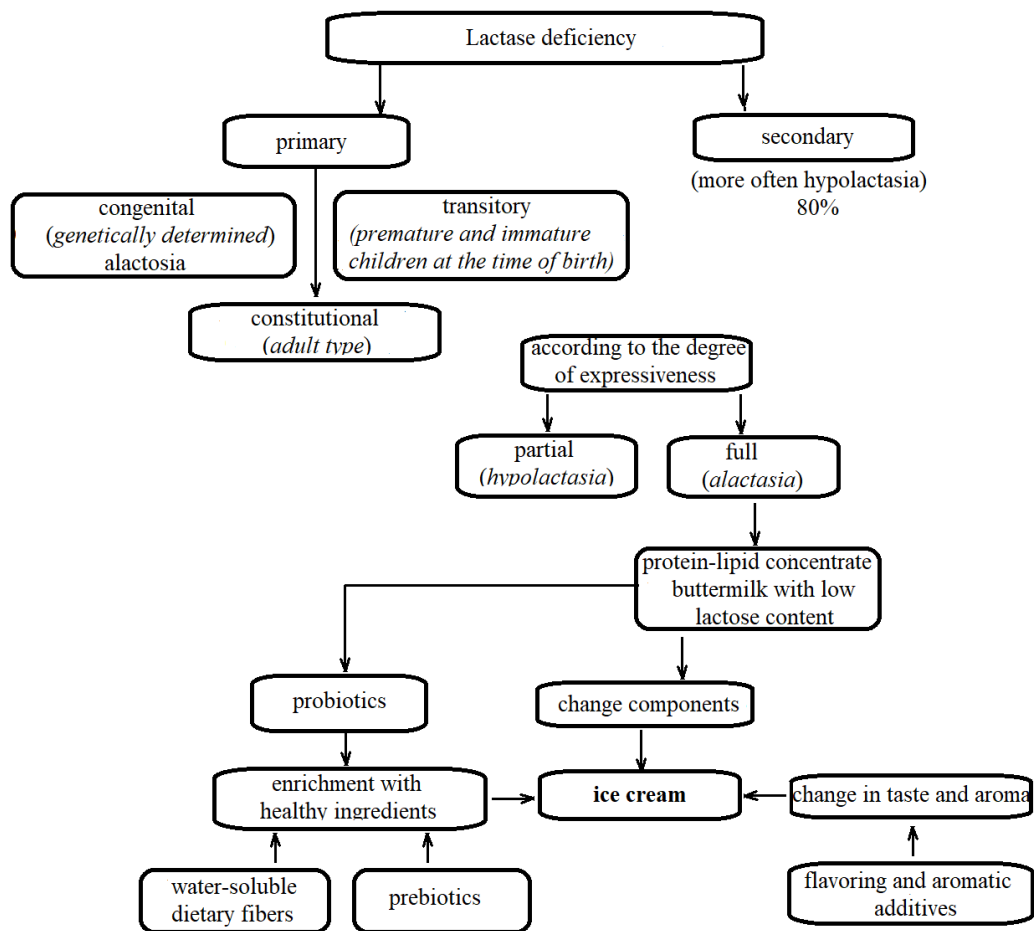


Fig. 1. Principles of creating lactose-free synbiotic milk ice cream

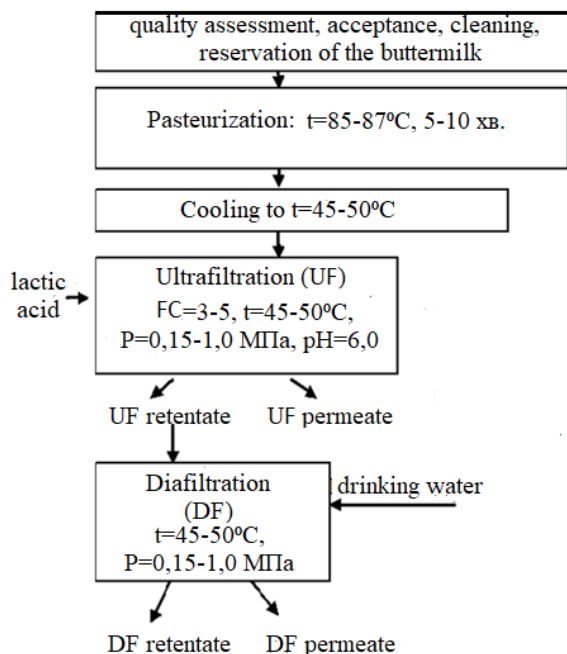


Fig. 2. Technological scheme for the production of liquid protein-lipid concentrate buttermilk with a low lactose content

The buttermilk obtained during periodic whipping of cream at LLC «Hormolzavod» was pasteurized for 5–10 minutes at a temperature of 85–87°C, cooled to 45–50°C and subjected to ultrafiltration at a pressure of 0.15–1.0 MPa with a concentration factor FC=5. The buttermilk concentration factor is limited by the membrane properties. When FC is more than 5, productivity drops, which is explained by of a gel and concentration polarization on the membrane surface. In the process of ultrafiltration, the buttermilk was acidified with lactic acid to a pH of 6.0 units. The technique used (acidification of buttermilk during ultrafiltration) made it possible to obtain a protein-lipid concentrate (UF retentate) with improved functional properties (emulsifying capacity – 47%; emulsion stability – 87%, foaming capacity – 250%, foam stability – 100%) and prevent the appearance of bitterness in it.

The UF concentrate obtained by ultrafiltration (FC=5) of buttermilk (at pH=6.0) was subjected to further diafiltration treatment with drinking water (for the purpose of purification from low molecular weight compounds) until the specified lactose content was reached (1.25–1.30%), while indicators of active acidity reached values of pH = 6.54 units.

The chemical composition of the obtained protein-lipid concentrate of buttermilk with low lactose content (DF retentate) is given in the table. 1.

The resulting liquid buttermilk proteins concentrate had a high composition of nutrients (proteins, fats) compared to buttermilk-raw material, namely: proteins – 16.01%, lipids – 2.36%, and a low content of low molecular weight substances: lactose – 1.28%, ash – 0.39% (see Table 1). The low content of

lactose and ash is due to their washing out by drinking water from the protein-lipid concentrate during diafiltration. The resulting concentrate had the desired lactose content (see Table 1). Concentrate it is the main component of lactose-free ice cream.

Table 1 – Chemical composition of the protein-lipid concentrate of buttermilk with low lactose content

Parameter	Buttermilk-raw material	BLCB (DF retentate), obtained by diafiltration (DV=3) of UF buttermilk concentrate
Mass fraction of dry substances, %, in particular:	9.0±0.01	20.06±0.01
mass fraction of proteins, %	3.2±0.05	16.01±0.05
mass fraction of lactose, %	4.50 ± 0.01	1.28±0.05
mass fraction of fat, %	0.48±0.01	2.36±0.01
mass fraction of ash, %	0.80±0.09	0.39±0.09

The selection was justified [26,27] and the concentrations of recipe components for the production of ice cream were selected, the mass fractions of which were: inulin – 2%; lactulose – 1%; ginger – 0.3%; citric acid – 0.15%; stabilizer – 0.2%. Two types of prebiotics – inulin and lactulose – were chosen due to their combined effect on the growth of lactic acid microorganisms and bifidobacteria. The combined use of both inulin and lactulose increases the growth of beneficial microflora to a greater extent than their separate use.

The residual amount of lactose in the protein-lipid concentrate of buttermilk (mass fraction of lactose 1.28±0.05%) was reduced by its fermentation as follows: dry components (inulin+lactulose+stabilization system) were added to BLCB according to the recipe, the resulting mixture was pasteurized, cooled to a temperature of 37–40°C and fermented with a combination of DVS starters: FD DVS YF-L903 (*Streptococcus thermophilus*, *Lactobacillus delbrueckii ssp. bulgaricus*), FD DVS La-5 (*Lactobacillus acidophilus*) and FD DVS Bb-12 (*Bifidobacterium animalis*). Fermentation took place at this temperature for 4–5 hours until pH 4.6.

Mass fraction of lactose was determined in the obtained fermented protein-lipid concentrate of buttermilk. Mass fraction of lactose It was 0.011±0.06%. The resulting concentrate is lactose-free.

The calculated recipe for lactose-free milk ice cream is given in the table. 2.

According to the recipe, a mixture of lactose-free synbiotic yogurt ice cream was prepared, in which the mass fraction of lactose was determined. Ice cream was produced according to traditional technology.

Table 2 – Lactose-free ice cream recipe (in kg per 1000 kg without taking into account losses)

Raw material	Weight, kg per 1000 kg of ice cream
Liquid BLCB (DF retentate), obtained by diafiltration (DV=3) of UF buttermilk concentrate at FC=5	528.5
Inulin powder (dry matter =95,8%)	20.0
Lactulose powder (dry matter=99,2%)	10.0
Sugar	155.0
Stabilization system	2.0
Ginger powder	3.0
Citric acid is crystalline	1.5
Leaven FD DVS YF-L903, conditional units of activity	50.0
Leaven FD DVS La-5 + FD DVS Bb-12, conditional units of activity	25.0
Drinking water	280.0
Sum	1000.0

Based on the research results, a technological scheme for the production of lactose-free ice cream

was developed, which consists of two blocks: a block of processes for obtaining a liquid protein-lipid concentrate of buttermilk with a low lactose content (Fig. 2) and a block of processes for obtaining yogurt ice cream (Fig. 3).

Inulin – 2.0%, lactulose – 1.0%, stabilization system "Ultra tex" ИСЕ1-0023 – 0.2% were added to the protein-lipid concentrate of buttermilk (DF retentate) (Fig. 2); the mixture was kept for 20–40 minutes; the mixture was a filtered; the mixture was pasteurized for 50–60 seconds at 85–87°C, homogenized at this temperature and pressure of 12.5–15.0 MPa; the mixture was cooled to 37–40°C and a combination of DVS starters (*Lactobacillus delbrueckii ssp. bulgaricus*, *Streptococcus thermophilus*, *Lactobacillus acidophilus* and *Bifidobacterium animalis*) was a introduced; was fermented for 4–5 hours to pH 4.6; the fermented mixture was at cooled to 4–6°C and ginger – 0.30%, citric acid – 0.15% and prepared sugar syrup was added; the mixture was a stirred; was freezed at t=-(2–3)°C; ice cream was prepackaged; ice cream was hardened at -(20–30)°C for 30–40 minutes; ice cream was packed and stored at -(26–28)°C for 6 months.

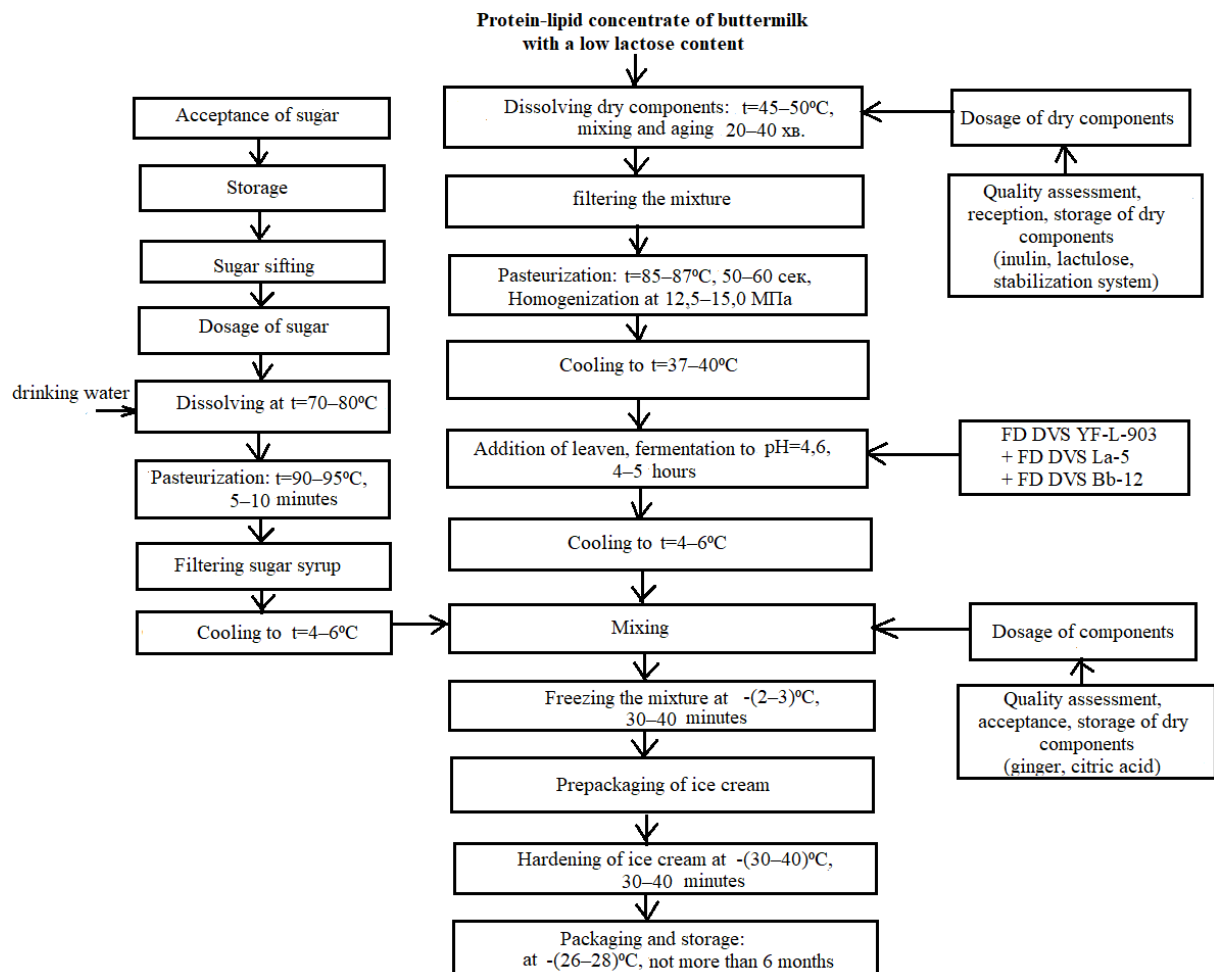


Fig. 3. Technological scheme of production of lactose-free synbiotic yogurt ice cream

The test sample of ice cream was characterized by a harmonious, noticeable gingery, soft sweet-sour taste, a "creamy" aftertaste, a light cream color with sprinkles of ginger, uniform throughout the mass. The structure and consistency of the experimental sample of lactose-free synbiotic yogurt ice cream is homogeneous, creamy throughout the mass of the ice cream, without noticeable ice crystals, sugar, lumps of fat and stabilizer, with sufficient density and whipping.

In the table 3 shows the physico-chemical and microbiological indicators of lactose-free synbiotic yogurt ice cream (experimental sample) and the control, which was taken as a classic milk yogurt ice cream.

Table 3 – Physico-chemical and microbiological indicators of ice cream

Parameter	Experimenta l sample	Control	DSTU 4733:2007
Physico-chemical parameters:			
Acidity, °T	58	60	60
Mass fraction of fat, %, %	1.24 ± 0.1	3.51 ± 0.1	0.5–7.5
Mass fraction of sucrose, %	15.5±0.05	15.5±0.05	14.5–15.5
Mass fraction of lactose, %	0.011±0.06	5.67± 0.06	–
Mass fraction of proteins, %	8.46 ± 0.05	3.74 ± 0.05	–
Whippedness, %	89	72	–
Resistance to melting, minutes	48	42	–
Microbiological parameters:			
The most likely number of lactic acid microorganisms, CFU/cm ³	(3.0±0.9)·10 ⁸	1.0·10 ⁷	–
Number of bifidobacteria, CFU/cm ³	(3.5±0.2)·10 ⁹	–	–
Mold fungi, CFU/cm ³	Not found	Not found	500
Yeast, CFU/cm ³	Not found	Not found	100
Escherichia coli bacteria in 0.1 cm ³ of the product	Not found	Not found	Not allowed

According to organoleptic, physico-chemical and microbiological indicators (Table 3), a sample of ice cream for lactose intolerant people fully meets the requirements of DSTU 4733:2007 "Milk, cream, filling ice cream. General technical conditions".

The mass fraction of lactose in a sample of lactose-free ice cream is 0.011%, in classic ice cream – 5.67% of lactose. In addition, the mass fraction of protein in a sample of lactose-free synbiotic yogurt ice cream is 8.46%, which is more compared to classic ice cream (3.74%). The high number of lacto- and

bifidobacteria in the studied sample of lactose-free ice cream indicates a high probiotic effect.

The obtained experimental data (Table 3) indicate an increase in whipping and melting resistance of the experimental sample of ice cream, in contrast to the classic milk yogurt ice cream, taken as a control. The increase in whipping is due to the higher amount of proteins in the ice cream mix. The increase in melting resistance is associated with the formation of viscous films around air bubbles and the adhesion of the particles of the mixture components. During the melting of ice cream, the ice melts and at the same time the foam structure is destroyed. Even after the complete melting of the ice, the experimental sample retained the volume of the dispersed air phase until the gradual destruction of air bubbles stabilized by viscous films.

The absence of bacteria the group of Escherichia coli, mold fungi and yeast indicates the correct selection of all modes of the main technological processes.

Approbation of research results

The proposed technology for obtaining a protein-lipid concentrate of buttermilk can be implemented at any enterprise where an ultrafiltration membrane unit is available, for example at Ternopil Milk Factory. Combining ultrafiltration with diafiltration, unlike other methods of concentration, allows to reduce energy costs by at least 15-20 times due to the absence of a liquid phase transition, to simplify equipment and to combine two important processes at the same time – removal of lactose and concentration of the most important components of raw materials (proteins and fats). The proposed technology of lactose-free synbiotic yogurt ice cream can be implemented in any ice cream factory and use the existing equipment.

Conclusion

1. A protein-lipid concentrate of buttermilk with a low lactose content was obtained by ultrafiltration/diafiltration and its chemical composition was determined. Membrane treatment of buttermilk concentrate by the diafiltration method is an effective technique for lactose removal. Prepared drinking water was used as a buffer during diafiltration. The obtained concentrate can be used as the main recipe component in the production of ice cream. Chemical composition of the concentrate: mass fraction of proteins – 16.01%, mass fraction of lipids – 2.36%, mass fraction of lactose – 1.28%, ash content – 0.39%.

2. A sample of the mixture for lactose-free ice cream was obtained according to the developed recipe and the ice cream was made. The mass fraction of lactose in ice cream was 0.011%.

3. A technological scheme for the production of lactose-free synbiotic milk yogurt ice cream was developed. The technological process for the production of lactose-free ice cream consists of two

blocks: a block of processes for obtaining a liquid protein-lipid concentrate of buttermilk with a low lactose content and a block of processes for obtaining yogurt ice cream.

4. Quality indicators of the received ice cream sample were studied, namely: organoleptic, physicochemical, functional technological and microbiological. Ice cream has a high organoleptic and nutritional value. The mass fraction of lactose in a sample of lactose-free ice cream is 0.011%. The mass share of protein is 8.46%, which is much more than in classic yogurt ice cream. The high number of lacto- and bifidobacteria in the test sample of lactose-free ice

cream indicates high probiotic activity (it contains lacto- ($3.0 \cdot 10^8$ CFU/g) and bifidobacteria ($3.5 \cdot 10^9$ CFU/g). According to organoleptic, physicochemical and by microbiological indicators, a sample of lactose-free ice cream fully meets the requirements DSTU 4733:2007 "Milk, cream, filling ice cream. General technical conditions". Lactose-free ice cream is qualitatively different from classic ice cream in terms of ice crystal size, whipping and melting resistance. The sizes of ice crystals are much smaller than their sizes in classic yogurt ice cream, whipping and melting resistance, on the contrary, have higher indicators.

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ТЕХНОЛОГІЯ БЕЗЛАКТОЗНОГО МОРОЗИВА НА ОСНОВІ ВТОРИННОЇ МОЛОЧНОЇ СИРОВИНИ

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Анотація. Розширення асортименту безлактозних молочних продуктів, а саме морозива для людей, які не переносять лактозу, є перспективним напрямком досліджень. Мета роботи – розробка технології морозива молочного безлактозного синбіотичного йогуртового на основі білково-ліпідного концентрату маслянки, отриманого ультрафільтрацією/діафільтрацією, з додаванням натуральних смакових та харчових добавок та дослідження показників його якості. Ультрафільтрацією/діафільтрацією отримано білково-ліпідний концентрат маслянки з низьким вмістом лактози, визначено його показники якості. Концентрат має високий вміст білків (16,01%) та низький вміст лактози (1,28%). Білково-ліпідний концентрат, сквашений синбіотичною закваскою, – основний компонент, що входить до рецептури безлактозного синбіотичного йогуртового морозива. Визначені основні фізико-хімічні показники отриманого сквашеного білково-ліпідного концентрату, що забезпечує раціональний вміст у готовому безлактозному морозиві основних компонентів хімічного складу (не містить лактозу, вміст білків – 8,46%) та високий вміст корисної мікрофлори (біфідо- та лактобактерій). За науково-обгрунтованою рецептурою отримано суміш для безлактозного синбіотичного йогуртового морозива. Із суміші виготовлено зразок безлактозного морозива за традиційною технологією та досліджено органолептичні, фізико-хімічні, мікробіологічні та функціонально-технологічні показники якості. Проведено порівняння показників якості дослідженого зразку з контролем, за який взято класичне йогуртове морозиво. Масова частка лактози в зразках безлактозного морозива 0,011%. Розроблене безлактозне синбіотичне йогуртове морозиво має високу пробіотичну активність (містить лакто- ($3,0 \times 10^8$ КУО/г) і біфідобактерії ($3,5 \times 10^9$ КУО/г)).

Ключові слова: вторинна сировина, проєктування рецептури, технологія, безлактозне морозиво, показники якості.