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Review article

Functional ice cream with a "clean label"

Wojciech Motyl[1,2,*] Piotr Dziugan[2], Ilona Motyl[2], Aleksandra Jóźwiak[2], Szymon Nowak [2,3]

[1] Kilargo Ltd., 90-105, Lodz, Poland
[2] Institute of Fermentation Technology and Microbiology, Lodz University of Technology, 90-924, Lodz, Poland
[3] National Sugar Company "Polski Cukier" S.A., Production Facility Dobrzelin Sugar Factory, Dobrzelin 99-319, Poland

*w.motyl@op.pl

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Abstract: *High market competitiveness as well as increased interest in health-related products forces producers to create new products and innovative production technologies that would encourage a potential customer to buy. The idea of "clean label" enjoys growing popularity due to the strong interest in healthy, unprocessed products and simple ingredients. Currently, products of this type are not yet very popular in the assortment of ice cream available on the Polish market. Ice cream enriched with selected nutrients are in accordance with prevailing dietary trends. An interesting proposal to increase the health value of ice cream may be the introduction of vitamins, mineral preparations and dietary fiber into their composition. The pro-health activity of dietary fiber is related to their beneficial effects on human intestinal microflora. From technological point of view, ice cream with the addition of fiber preparation was characterized by a significantly longer melting time than ice cream without fiber. Another way to enrich the ice cream is the addition of probiotics. Consumption of probiotic-containing ice cream can have a positive effect on human health mainly through immune system. In order to achieve the desired health effect as a result of consumption of probiotic ice cream, it is necessary to ensure therapeutic minimum related to ensuring the minimum number of viable cells of probiotic bacteria necessary to guarantee the beneficial effects of probiotic microflora on the human body (e.g. milk fermented beverages, the therapeutic minimum is 10^6-10^7 CFU/g).*

Keywords: *functional foods; probiotics; lactic acid bacteria.*

Introduction

Nothing enjoys and refreshes like ice cream, which is the basic type of frozen desserts produced industrially all over the world. Ice cream is a very popular form of dessert, which has an increase in demand. It is estimated that the annual consumption of ice cream is 2 L per person in 2016 [1].

Ice cream is a combination of fat droplets, air molecules and ice crystals connected in a continuous water phase, forming a colloidal system in a frozen state. The dispersed phase consists of polysaccharides, lactose, proteins and minerals that are part of the ice cream [2]. Ice cream is a product obtained by freezing a pasteurized and chilled liquid mixture made of milk with a stabilizer, further containing flavourings. The technology of producing, storing and consuming ice cream requires the application of precisely defined technological parameters at all stages of production. The use of high-quality raw materials with properly selected prescription composition and proper control of technological parameters, enables obtaining final products with the desired characteristic qualitative features. High quality of ice cream depends also on the proper storage and transport conditions.

According to definition in the Polish Standard (PN-A-86431) [3], ice cream is a product obtained from fat and protein emulsion, with the addition of other raw materials and substances and simultaneously, ice cream is described as a product obtained from mixture of water, sugar and other raw materials and substances, pasteurized, frozen, intended for direct consumption or storage. The main criterion for dividing the ice cream into five groups is the amount and type of fat used. Ice-cream varieties are distinguished [3] depending on the flavour and flavour additives used. The basic composition of ice cream is most often: 9-12% milk solids, non-fat milk, sweetening substances in the amount of 12-16%, and 0.3-0.5% stabilizing and emulsifying substances. Ice cream with low fat content (about 3%) is also produced, as well as ice cream without fat and protein called fruit and water ice cream. The type and amount of ingredients found in ice cream affects the high energy value.

According to Euroglaces Code For Edible Ices Version 2013 [4] (European Ice cream association) the definition of ice cream follows: Ice cream – food products with a solid texture obtained as a result of freezing. Stored, transported and sold to consumers in a frozen state. Water ice cream – contains mainly water and sugars [4]. Ice cream – usually composed of water and / or milk, fats, proteins and sugars. Milk ice cream- is a term reserved for a product containing at least 2.5% milk fat, at least 6% milk solids non-fat (MSNF) without added fat or protein other than dairy. Dairy ice cream – a product containing at least 5% milk fat, without the addition of fat or protein of non-dairy origin. Fruit ice cream – containing mainly water and sugars and moreover at least 15% fruit. Sorbets – fruit ice cream that does not contain added fat or milk and which contains a minimum of 25% fruit. However, the fruit content may be reduced to 15% and up to 7% respectively. Fruit for which the content may be less than 25% of the fruit:

a) the minimum fruit content reduced to 15% for:

- citrus fruits: lemon, orange, mandarin, grapefruit, etc.

- other sour fruits: fruit juice or fruit blend whose acidity, expressed as citric acid, is at least 2.5%
- exotic or fruit with a strong aroma and/ or dense consistency like pineapple, banana, corossol, cherimoya, guanabana, guava, kiwi, lychee, mango, passion fruit

b) the minimum content reduced to 7% for:

- nuts and nut products.

The requirements for ice cream can vary between the European Union and the definition of Austrian ice cream according to Österreichisches Lebensmittelbuch IV Edition, chapter, B 2, Ice cream [5]. Fruit ice cream: fruit additive is at least 20%, unless the fruit is strongly aromatic or sour – then lower. Ice cream based on dairy products: Oberseiscreme - cream ice cream: contain at least 15% milk fat, while fruit – 12% milk fat. Milch-Eiscreme or Milch Creme Eis – milk ice cream or milk cream ice cream: contain at least 8% milk fat. Volmilcheis – whole-milk ice cream: contain at least 60% whole milk (3.5%) or at least 2.1% milk fat in the product; when fruity - at least 50% of whole milk, or at least 1.7% of milk fat [5].

Industrial production of food ice cream

In the first step, properly selected ingredients are mixed together. Next, pasteurization is applied, which removes the pathogenic microflora, additionally supporting the solubility of the ingredients [6]. In the production of ice cream, two types of pasteurization are used: batch pasteurisation (>69°C, 30 minutes) or continuous pasteurisation (>80°C, 15-25 seconds) [6]. In order to create the emulsion, homogenization is carried out, consisting of pressing the mixture under the pressure of 15.5-18.9 MPa through a small hole. The ripening process aims to hydrate proteins and stabilizers, as well to crystallize fat molecules. During this stage, the mixture should have the temperature kept as low as possible at which it is not yet frozen (below 4°C). The duration of maturation should be at least 4 hours. [6]. The next step is freezing. This process takes place in freezers, where the water crystallizes, as well as the aeration of the mixture, which affects its structure and ultimately the sensory feelings of the consumer. After forming, the packaging is packed, which should guarantee the preservation of product quality (insulation from foreign odours, resistance to temperature changes, etc.), and then stored under appropriate conditions [7].

High-quality ice cream so-called "homemade", "traditional" sold as "natural" products are produced in small quantities by craft ice-cream factories. Thanks to a thorough market analysis of ice products and nutritional trends, it was possible to identify the following problems:

- there is a shortage of ice cream produced on an industrial scale, which would have a high nutritional value,
- no ice cream produced on an industrial scale, which would consist largely of vegetables or fruit,

- no ice cream with a simple composition which are not hand-made ice-cream,
- no ice cream with functional additives including prebiotics.

Consumers more and more often when choosing ice cream, pay attention to the flavours that producers have in their offer and the innovativeness of the solutions used. What counts is the use of new production technologies, the quality of ingredients, and their impact on health. Naturalness is becoming an increasingly desirable attribute. It is associated with:

• food safety,
• lower / zero degree of processing,
• simple ingredients,
• high product quality.

Consumer research indicates that naturalness is associated with food safety, with the lack of additional substances with "E" numbers, lack of preservatives, artificial flavors, shoulder dyes and less food processing, e.g. "home", "traditional" products sold as "natural" products they are produced in small quantities by craft production plants.

High market competitiveness as well as increased interest in health-related products forces producers to create new products and innovative production technologies that would encourage a potential customer to buy. Due to that fact, ice cream as a dairy dessert stored at a low temperature, characterized by the ability to stabilize the ingredients, can be a carrier for health-promoting substances, e.g. nutraceuticals [8].

The idea of "clean label" enjoys growing popularity due to the strong interest in healthy, unprocessed products and simple ingredients. Currently, products of this type are not yet very popular in the assortment of ice cream available on the Polish market. It results from many factors, mainly from technological problems, which are connected with an attempt to return to natural ingredients:

• problems with proper emulsification,
• stabilization,
• maintaining the right consistency,
• obtaining natural equivalents for standard additives with symbols E.

However, despite visible market trends and changes in consumers' nutritional trends, none of the ice cream producers offer ice cream rich in natural ingredients and nutritional values, which would be available in stores of various retail chains. That means that right now, no company is offering ice cream produced on an industrial scale, which due to its nutritional values could be compared to products offered by small ice cream parlours.

Currently, products of this type are not yet very popular in the assortment of ice cream available on the Polish market. Especially ice cream produced on an industrial scale based on this trend. It results from many factors, mainly from technological problems that entails an attempt to return to natural ingredients:

problems with proper emulsification, stabilization, maintaining proper consistency, obtaining natural equivalents for standard additives with symbols E.

Replacement of currently used stabilizing systems seems to be particularly difficult. The standard stabilizing systems for milk-based ice cream include mono- and di-glycerides of fatty acids (which act as an emulsifier) and locust bean gum and guar gum (hydrocolloids that act as stabilizers/ thickeners). All three of these ingredients are supplementary substances with their "E" numbers.

Mono- and di-glycerides of fatty acids are synthetic fats made from glycerol and natural fatty acids, mainly of vegetable origin, but also from animal fats. Depending on the fatty acid composition, their activity may be different. Generally, as emulsifiers, they have a hydrophobic and hydrophilic group, thanks to which they reduce the surface tension and enable the formation of emulsions – a relatively stable mixture of two intrinsically immiscible phases. In the case of ice cream, it is an oil-in-water emulsion. The use of emulsifiers during homogenization allows reducing the size of molecules and reducing surface tension, allows to obtain smaller globules of fat and increases fat dispersion, increases the release of protein molecules during maturation, increases the crystallization of fat during maturation, facilitates the introduction of air and its stability, controls agglomeration of fat, improves the ice creaminess, reduces the growth of ice crystals and reduces the risk of ice cream shrinkage.

Lowering the content of the emulsifier means that it is impossible to obtain a high aeration of the ice cream – less air is able to be pressed, the mixture must have a higher fat content, a lower freezing temperature is needed to create the ice cream structure – and as a result, the ice cream obtained has a harder structure.

Within emulsifiers that can be used in ice applications as an alternative to mono- and di-glycerides, we can use phospholipids or proteins. Egg yolks can be used for this. Certainly, they are not so efficient and stable, so their use would have to be preceded by many laboratory tests to select the right dosage and other process parameters.

Locust bean gum E410 is a natural polysaccharide obtained from the seeds of the locusts, also known as the carob tree. Used mainly in the food industry as a food additive for thickening and stabilizing products.

Guar gum – an organic chemical compound from the group of galactomannans, i.e. polysaccharides whose main chain is formed from mannose units with side monogalactosyl branches. It is a food additive, listed as E412, thickening and stabilizing products.

Both these components are hydrocolloids, which are responsible for water binding and gelation. In the ice mix, we usually have about 60% water content, so hydrocolloids are a very important ingredient that gives the structure to ice cream. Other hydrocolloids used in the production of ice cream are xanthan gum E415, carrageenan E407, Alginate E401, Pectin E440, carboxymethylcellulose E466. Hydrocolloids in ice cream, bind water, increase viscosity, reduce syneresis, improve the introduction of air, improve the distribution of air bubbles, form a network, thanks to which the ice crystals do not combine with each other, i.e. they do not grow. Similar properties have whey proteins, milk proteins, egg albumin, but here the most frequent gelation is caused by a change in pH or heating.

Ice cream enriched with selected nutrients in accordance with prevailing dietary trends

An interesting proposal to increase the health value of ice cream may be the introduction of vitamins, mineral preparations and dietary fiber into their composition. In recent years, Poland has been experiencing a systematic decrease in fiber intake, and now a statistical Pole consumes 5-10 g per day too little [9, 10].

A) Fiber

Long-lasting fiber deficiencies in the diet may lead to disturbances in the digestive system, lower immunity, as well as an increase in the incidence of diet-related diseases, including diabetes and/ or obesity [10].

In the production of ice cream, soluble fiber preparations may have the greatest use. Of the preparations available on the market, classified as soluble fiber, inulin is the most popular. However, polydextrose and refractory maltodextrin are less widespread. The pro-health activity of these fiber preparations is related to their beneficial effects on human intestinal microflora. Undigested in the digestive tract, they constitute a substrate for a useful bacterial microflora [11, 12].

In addition to health-promoting properties, these fiber preparations also have many valuable technological properties. This allows them to be used in the production of food also as an additive shaping rheological and sensory properties. For example, inulin is used in the food industry as a substitute for sugar and/ or fat, a thickening and filling substance as well as stabilizing foams and emulsions [13]. Polydextrose is used as a stabilizer, filler and thickening agent and as a sugar substitute in low-calorie products and in diabetic products. In turn, maltodextrin is resistant in food products mainly as a filling and stabilizing substance, it regulates hygroscopicity, increases viscosity and prevents the crystallization of sucrose [14]. Thanks to their properties, these fiber preparations have already found application in various food products, mainly in the dairy, confectionery and non-alcoholic beverage industries. However, there are no broader studies on the impact of their application on the quality of ice cream.

The quality of ice cream depends, among other things, on the density and viscosity of the ice cream mix before freezing. These features affect the so-called smoothness of the consistency, possible to obtain aeration degrees and hardness of ice cream [15]. Increasing the density of an ice cream mix by using water-binding fiber preparations may be disadvantageous [16]. Excessive density of the mixture may prevent proper aeration of the ice, and thus increase their hardness. Increasing the viscosity of the ice-cream mixture containing inulin preparations as a component is indicated by studies [17, 18]. The fluffiness, i.e. the degree of aeration of the ice cream mix, is one of the most important differentiators considered when assessing the quality of ice cream. The components of the ice cream mix have the greatest influence on this parameter, especially the content and proportion of protein relative to fat. The addition of inulin and polydextrose reduces the degree of ice aeration [19]. The addition of resistant maltodextrin did not significantly reduce the iciness of the ice cream, compared to the control variant, although the viscosity of the ice cream mixture with its addition was significantly higher and comparable to the viscosity of the inulin containing mix. Jasińska et al. [20], analysing the possibility of partial replacement of sucrose with polydextrose in ice cream, stated that higher doses of this type of fiber caused a decrease in the degree of ice aeration. The authors showed that the aeration of ice cream with the addition of polydextrose was hampered by the increasing density of the ice cream mix and the thickening properties of this preparation. Less puffiness of the ice cream resulted in longer melting time [19]. The addition of mineral, protein or fiber components may affect the freezing process of the ice cream mass and, consequently, the rheological properties of the product [21]. They pointed out that the increase in ice cream hardness could be related to the change in the freezing point resulting from the increase in the concentration of soluble substances in the ice cream mix.

Ice cream with the addition of each fiber preparation was characterized by a significantly longer melting time than ice cream without fiber. As results from the research [21, 22]. Lengthening the melting time of ice cream with the addition of inulin results in the ability of this saccharide to bind water molecules, which prevents them from moving freely in the product. Analysis of the colour components of ice cream made with the addition of various cellulose preparations, e.g. inulin and resistant maltodextrin did not affect the colour of the ice cream [19, 23]. The consequence of increasing the health value of food products by introducing health-promoting additives into their composition may be a deterioration of their sensory quality. The type and level of vitamin and mineral or fiber additives should be chosen so that it does not affect changes in organoleptic sensations during consumption, i.e. the sandiness, malleability and melt flow in the mouth, as well as during ice cream storage.

B) Probiotics

Another way to enrich the ice cream is the addition of probiotics. According to the FAO/ WHO [24] definition, probiotics are living microorganisms (bacteria or yeast) that, after ingestion or topical use, at a sufficiently high number thereof, show one or more proven health benefits for the host organism [24].

Due to the higher pH value than other dairy products, ice cream can be a better environment for storing probiotic bacteria. Another advantage of ice cream is the popularity of the product and sensory attractiveness for the consumer, which may facilitate the delivery of probiotics in this form [25].

Probiotics facilitate digestion, stimulate the immune system, exert anti-carcinogenic effects, prevent heart disease, reduce the level of so-called bad cholesterol in the blood, prevent allergic reactions and facilitate the treatment of bacterial food poisoning [26,27]. Consumption of probiotic-containing ice cream can have a positive effect on human health through [28]:

- limiting the development of caries,
- beneficial effects on the immune system and microflora of the digestive system,
- inhibition of the development of pathogenic microorganisms.

Milk fermented beverages belong to food products containing in their composition probiotic bacterial strains that have a beneficial effect on human health, therefore they are included in the so-called functional food.

Despite the patented technology for production of powdered ice-cream in Poland over 20 years ago, probiotic ice cream still has the hallmark of a niche market in our country. In view of the huge variety of ice cream and sorbets and other frozen desserts, the availability of ice cream with probiotics is very limited, and available ice cream and desserts based on yogurt, due to the lack of a statement about the type and level of live bacteria, cannot always be called probiotic ice cream [29]. From a technological point of view, the production of probiotic ice cream is not complicated and consists of combining an ice cream mix with ready-made (bio) yoghurt, (bio) kefir or other probiotic milk drink [29]. As in the case of yoghurt ice cream, the technology envisages the production of probiotic ice cream using two methods: direct or indirect. The classic indirect method combines separately produced natural yoghurt [mixed] and so-called yoghurt, syrup base (syrup obtained by dissolving sucrose and other sweeteners in a small amount of water, pasteurized and cooled to approx. 15°C, and then introduced into the yogurt container), and after mixing both semi-finished products (during production of soft ice cream syrup ratio for yoghurt should be 3.5:6.5, and when producing hard ice cream – tempered – 1:4), the whole is frozen in a freezer, packed and then hardened. In the direct method, the production process in the initial phase proceeds as a typical production of mixed yogurt, and in the next phase as the production of ice cream. All ingredients of the ice cream mix are mixed and dissolved in milk, followed by homogenization, heat treatment, probiotic cultures and incubation. The obtained clot is mixed and freezed in the beater, packaged and hardened in the hardening tunnel [26]. The indirect method is more widespread because the combining of all the components of an ice cream mix and introducing clean probiotic cultures to them in the direct method, is more difficult to control the lactic fermentation process. It is much easier to control the lactic fermentation process if biomass in the form of (bio) yogurt or another fermented milk drink is produced on a separate processing line. The product thus prepared is mixed with the already mature ice-cream mixture immediately before freezing. Probiotics can be added directly in front of the mill, but to ensure a homogeneous product, it is better to add them to the ice cream mix and mix thoroughly before the whole is directed to the freezer [30]. Instead of ready biomass with probiotics, in an indirect method during the production of confectionery ice cream, DVS can be added to the ice cream mix, but this requires the earlier introduction of the vaccine into a small amount of pasteurized milk, cooled to about 37-40°C [31]. Regardless of the probiotic ice cream production method used, the most important technological problem is to ensure an adequate level of living cells of probiotic bacteria in the product ready for the end of its durability, as well as a guarantee of the lack of negative impact of probiotics on the organoleptic properties of ice cream. The available studies on the influence of different strains of probiotic bacteria on the flavour characteristics, colour and texture of probiotic ice cream indicate that probiotics do not affect the deterioration of organoleptic and sensory properties during long-term frozen storage [32, 33].

When it comes to ensuring an adequate level of live probiotic bacteria in ice cream, this problem is a bit more complex and is the result of many factors. In order to achieve the desired health effect as a result of consumption of probiotic ice cream, it is necessary to ensure therapeutic minimum related to ensuring the minimum number of viable cells of probiotic bacteria necessary to guarantee the beneficial effects of probiotic microflora on the human body. In milk fermented beverages, the therapeutic minimum is 10^6-10^7 CFU/g [26] and similar levels of viable cells should have probiotic ice cream. It is this level of live probiotic bacteria, supported by the results of microbiological research, that entitles us to use the term "probiotic ice cream".

For probiotic ice cream to carry pro-health benefits, it should contain the right number of live microorganisms. Currently, I assume that this dose should be in the range of 10^6-10^9 CFU/g of the product [29, 34].

Determinants of the survival of probiotic bacteria

The survival of probiotic bacteria is influenced by many factors that are related to the type of components used, probiotic strains, the acidity of the finished product, the oxygen content in the air bubbles and storage conditions of the ice cream after curing:

Acidity. A condition for ensuring high survival of probiotic bacteria in ice cream is the relatively high pH in the range 5.5-6.5, which in the case of acidic environment of yoghurt and fermented milk beverages (pH 4.4-4.8) is the basic factor undermining the bacteria survivability. For the low pH are particularly sensitive *Bifidobacteria* strains, while *Lactobacillus* strains are slightly more stable in the acidic environment [35]. Decreasing the acidity of probiotic ice cream can be achieved by adding liquid milk or milk powder, which are the basic component of an ice cream mix. *In vitro* laboratory studies have shown that the addition of calcium carbonate and sodium citrate to neutralize lactic acid during the production of probiotic biomass may increase the survival of some probiotic bacteria in an acidic environment [36]. However, this method was not used in conditions with the use of probiotic biomass, therefore it is difficult to assess this kind of activity as practically useful.

Oxygen shock. Due to fact that the lactic acid bacteria are anaerobs or microaerophils, oxygen contained in air bubbles formed during the freezing of the ice-cream mixture in freezer, is an important factor impeding the survival of probiotic bacteria in ice. On contact with water, oxygen is partially reduced to form peroxide (O2-) and hydroxyl ion (OH-), which damages the proteins, lipids and nucleic acids leading to cell death of bacteria. Granato et al. and Farez et al. [31, 37] have shown that the degree of aeration of the cream of the probiotic affects the survival of *L.acidophilus*. After producing ice cream, in which the aeration amounted to 45, 60 and 90% after 60 days of frozen storage in all three samples, the levels of viable cells of *L.acidophilus* was high and exceeded 10^6 CFU/ g. However, in the case of aeration of 90% reduction in the number of viable cells as compared to baseline it was highest (2 logarithmic cycles), suggesting that the lower level of aeration provides a higher level of survival of the bacteria.

In order to reduce the negative impact of oxygen on probiotic bacteria, various solutions are proposed, including [35, 37]:

- addition of antioxidants (ascorbic acid),
- use of active (oxygen absorbing) packaging,
- microencapsulation,
- use of plastic packaging with different polarization,
- use of an oxygen barrier,
- aeration of the ice with nitrogen,
- use of enzymes (glucose oxidase),
- introduction of probiotic strains that tolerate the presence of reactive oxygen species.

Zhao and Li [36] suggested that chemicals such as sodium ascorbate or D-ascorbate added to a product containing *Bifidobacterium bifidum* (4g/kg of product) can effectively react with reactive oxygen species and weaken their harmful effects in relation to the above-mentioned bacteria.

Type of sweetener. It is believed that the survival of probiotic bacteria may also be determined by the type of sweetener used. The addition of aspartame is considered a factor reducing the survival of probiotic bacteria in ice cream [38], but not all confirm this. Başyiğit et al. [39] showed that the addition of sucrose and aspartame to ice cream containing probiotics in the form of *Lactobacillus* bacteria did not affect to reduce the survivability of the analysed bacterial strains (*L.acidophilus* AB5-18, *L.agilis* AA17-73 and AC18-88, *L.rhamnosus* AB20-100 and *L.acidophilus* AK4-14). During the 6-month storage of freezing ice cream with the addition of probiotics, no significant reduction of live bacteria was found.

Thermal shock. Another factor that determines the number of bacteria in probiotic ice cream is freezing, hardening and freezing storage, which due to thermal shock, probiotic bacteria die. The first phase of freezing (in the beater), during which more than half of the water is frozen [40], must be carried out quickly enough (at most a dozen or so seconds) so that the size of the emerging ice crystals slightly exceed the size of the bacteria. If freezing is carried out slowly, and the size of the ice crystals exceeds 20 μm, the cells of the probiotic bacteria will be damaged by the crystals of frozen water formed and the survival of the bacteria will be significantly reduced.

While in the freezer the bacteria are additionally exposed to mechanical damage due to friction and shear forces resulting from the quickly rotating scraper. This action further reduces the number of viable cells of probiotic bacteria, which is why some technological solutions predict the use of probiotics subjected to the microencapsulation process [35, 41].

Between the milling cutter and the quenching tunnel is another point determining the survival of probiotic bacteria. If, after exiting the cutter, the temperature of the ice cream rises by 1-2°C, it will be in accordance with the freezing curve, which will result in a few percent reduction in the amount of frozen water, which in practice means that this part of not frozen water will increase on already existing ice crystals during hardening. As a result, large ice crystals will begin to destroy the cells of probiotic bacteria. That is why it is so important that there is no significant increase in the temperature of the soft ice cream after the cutter. Similarly, temperature fluctuations during freezing, transport and distribution must be prevented.

Microencapsulation of probiotics. One of the newer ways of increasing the survival of probiotic bacteria in ice cream can be the addition of microencapsulated probiotic cultures during ice cream production. Microencapsulation consists of coating an unstable bioactive agent (e.g. probiotic) with a protective substance but allowing the release of a bioactive agent.

In practice, various methods of microencapsulation of probiotic bacteria have been used for many years with the use of coating materials such as starch, milk proteins, chitosan, cellulose acetate phthalate, carrageenan, alginates, etc. [41, 42] investigated the effect of microencapsulation of *Lactobacillus casei* and *Bifidibacterium lactis* bacteria on their survival in probiotic ice cream. Bacterial cells were microencapsulated using indigestible starch. After the introduction of microencapsulated probiotics to the ice, a significant improvement in the survivability of bacteria was noted during long-term storage of freezing probiotic ice cream. Microcapsules with probiotics are a protective layer for probiotics against harmful environmental factors, such as e.g. low pH, hydrogen peroxide, bacteriocins, temperature shocks, and even protect probiotics from phages [42].

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