Development of ice cream technology enriched with an encapsulated form of vitamin C

S V Tsyrendorzhieva, S D Zhamsaranova, E V Syngeyeva, N D Ipatova, I V Khamaganova and I I Badmaeva

1Eastern Siberian Technological University of Technology and Management, ul. Klyuchevskaia, 40V-1, Ulan-Ude, 670013, Republic of Buryatia (Russia)

E-mail: ts-svetlana1971@mail.ru

Abstract. In this study, an ice cream technology using an encapsulated form of vitamin C was developed. When conducting an organoleptic evaluation, the developed ice cream showed higher creaminess, a pleasant sour-milk taste and smell, and the absence of organoleptically perceptible ice crystals compared to soft ice cream of traditional composition. Additionally, in soft ice cream containing an encapsulated food ingredient, higher resistance to melting was noted: the mass fraction of melt after 2 hours was 11% lower than in the control sample. The research results show that in the developed ice cream there is an improvement in structural, mechanical, and organoleptic properties. The mass fraction of vitamin C in the developed ice cream was set at no more than 46.8 mg%. The study justifies the ingredient composition and the appropriateness of using encapsulated vitamin C in soft ice cream, expanding the assortment and range of sweet foods with functional nutrition, and indicating improved consumer characteristics of the finished product through its functional properties.

1. Introduction
Ice cream is a sweet, whipped, and frozen dairy product that people have been familiar with since childhood. It occupies a strong place in the list of desserts popular among people of different age groups. In addition, ice cream is an affordable delicacy, and as a result, the volume of ice cream consumption has little to do with the income level of consumers. The ice cream market is thus quite stable since all consumers of ice cream already consume it in the volume in which they want to, with no price restriction. It should be noted that in 2019 the market for ice cream and frozen desserts grew by 10% [1].

Most types of ice cream presented on the modern domestic market are difficult to attribute as nutritional products due to their high-calorie content, the content of synthetic sweeteners, colorants, flavorings, and stabilizers.

Considering the growing consumer demand for natural products without any additives, the enrichment of ice cream with berries, fruit, and grains, all of which are natural sources of vitamins, prebiotic oligosaccharides, dietary fiber, minerals, and antioxidants as part of its production process, could be considered a promising direction to pursue.

Currently, scientists around the world are paying great attention to the enrichment of food products, including dairy products, with vitamins, micro, and macro elements. Biologically active additives are
creating new and promising technologies, introducing modern nanotechnologies into the food industry, and contributing to the emergence of a new class of food products – “nanoproducts” [2-4].

One of the main components used for food fortification is vitamin C, which is responsible for the implementation of the main biochemical and physiological processes in the body as an antioxidant, reducing agent, and coenzyme of individual metabolic processes [5].

According to the Federal State Statistics Service, the raised significant deficiency of ascorbic acid in the diet of Russians leads to weakened immunity and other disorders of the body [6]. The daily intake of ascorbic acid is 80 mg/day [7]. Based on the Russian Academy of Medical Sciences, 80% of the child population has a deficiency of vitamin C, the main reasons for which are its instability, essentiality, and poor digestibility [8]. Due to the low stability of the vitamin, it is necessary to increase the safety of vitamin C, in particular, enclosing it in a protective shell to prevent its loss during technological processes and assimilation in the body. For better absorption, scientists recommend consuming vitamin C with carotenoids, flavonoids, and vitamin E, which helps increase the antioxidant effect of ascorbic acid [5].

Encapsulation is a promising and new method of preserving the qualitative and quantitative characteristics of vitamins [9]. The main methods and technologies for the encapsulation of vitamins are emulsions, solid lipid nanoparticles, surface-active systems, and polymer-lipid encapsulation. The latter includes liposome encapsulation, which is currently of great interest due to its ability to extend shelf life and improve the bioavailability of vitamins [10]. Recently, it has been found that liposomes, which are spherical particles, ranging in size from a nanometer to a micrometer, consisting of one or more bilayer membranes, are a very suitable system for delivering a wide range of substances to body cells [11].

Phospholipid molecules serve as the basis for the formation of liposomes because a substance enclosed in the aqueous part of the vesicular particle is protected from the effects of enzymes, which increases the effectiveness of the drug and improves digestibility [12]. In this case, nanostructures mainly act as a carrier of bioactive food substances in encapsulated form and can be directly incorporated into a food product to obtain nutritional benefits. Phospholipid-based carrier systems are among the most promising encapsulation technologies used in the rapidly growing field of nanotechnology [13].

Encapsulated food ingredients are directly used in various products, such as functional foods, drinks, semi-manufactured goods, bakery, and confectionery products, as well as dairy products [14].

The aim of this study was to develop an ice cream technology enriched with a liposomal form of vitamin C.

2. Materials and methods

The experimental study used cream-based soft ice cream samples (mass fraction of fat - 33%) with the inclusion of the liposomal form of ascorbic acid. Granulated soya lecithin (TU 9146-008-5887368-2005) containing 97% phospholipids (“Protein” LLC, St. Petersburg, Russia) was used to obtain the liposomes. Ethyl alcohol of the 1st grade (GOSTR 51652-2000) was used as a solvent. As a part of the encapsulated substance, food ascorbic acid (CJSC “Vekton,”China) was used. The preparation of liposomal substances using micronutrient (vitamin C) was carried out according to the technology proposed by F.R. Shazzo, which involved mixing two previously prepared phases: soya lecithin dissolved in alcohol and a solution of vitamin C in a buffer [14]. After a three freezing-thawing cycle of the liposomal substance, liposomes were formed through membrane filters with a pore diameter of 100 nm on an Avestin Liposo-Fast-basic mini-extruder (Canada) [12].

To determine the characteristics of the research objects and technological processes, generally accepted, standard methods were used. The mass fraction of the moisture and solids was determined by drying, according to GOST 3626. The mass fraction of fat was determined by the acid method, according to GOST 5867. The titratable acidity was determined titrimetrically, according to GOST 3624-92. Determination of the overrun and resistance of the ice cream to thawing was carried out according to GOSTR 31457-2012. Vitamin C content was determined in accordance with GOST
and organoleptic indicators of soft ice cream were evaluated in accordance with GOSTR ISO 22935-2-2011. Statistical processing of the results was performed using the STATISTICA 6.0 program.

3. Results and discussion

Soft ice cream belongs to the category of products that have a low content of vitamin C (0.4–0.6 mg%). In this regard, the choice of this component as an object to improve the composition of ice cream not only met the criteria for it being a healthy food product but also ensured that the structure and consistency of ice cream varieties with a higher mass fraction of vitamin C was improved. This product can be the basis for creating new formulations of healthier, functional products demanded by the population.

When developing the composition of the ice cream, it was important to maintain the mass fraction of vitamin C in the product in an amount that satisfied the recommended daily intake (i.e., from 15 to 45 mg% for children). Taking into account the fact that the encapsulated food ingredient had a sour taste, it was important not to exceed the limit of sufficient acidity in the developed ice cream, which should not exceed 25% [15]. With this fact, and also our aim to create a product with a creamy product structure consistency without an organoleptically perceptible acidic taste, it was proposed to introduce a liposome form of vitamin C in a quantity of 25 ml per 100 g of product. The mass fraction of vitamin C in the developed ice cream was set at no more than 46.8 ± 5.2 mg%, which allowed us to meet the recommended daily intake for children’s consumption.

However, it was extremely challenging to create a creamy consistency and structure in the ice cream developed at the given dose. It was therefore decided to increase the solids content in ice cream to 32% [14] instead of 28% in traditional varieties of ice cream, with at least 0.5% of thickener (agar-agar).

During the organoleptic evaluation, the developed ice cream showed a higher creaminess, a pleasant sour-milk taste, and smell, as well as the absence of organoleptically noticeable ice crystals, lumps of fat, protein particles and a stabilizer compared to soft ice cream of traditional composition. The physicochemical characteristics of the developed ice cream are given in Table 1.

| Indicator                               | Value                        |
|-----------------------------------------|------------------------------|
| control                                 | experiment (100 mg / 100 ml) |
| Moisture content,%                      | 65±1,2                       | 68±1,18                       |
| Mass fraction of solids,%               | 35±0,8                       | 32±0,85                       |
| Mass fraction of fat,%                  | 10±0,2                       | 11,5±0,3                      |
| Mass fraction of vitamin C, mg /%       | 9,87±3,1                     | 46,8±5,2                      |
| Overrun, %                              | 75±4,1                       | 85±2,4                        |
| Titratable acidity, °T                   | 22±0,6                       | 25±0,55                       |
| Resistance to thawing, min              | 18±3,4                       | 22±3,9                        |

It was found that the introduction of an encapsulated food ingredient led to an increase in the ability of the mixture to saturate with air. The formation of a stable emulsion structure of the developed ice cream, in our opinion, can be explained by the synergistic effect of emulsifying and stabilizing components of the system. In this case, the proteins of milk and the liposomal form of ascorbic acid are emulsifiers, forming an adsorption layer on the surface of the oil phase, and pectin thickeners stabilize it. As a result, the strength of the interfacial adsorption layer and the stability of the emulsions increased. The gravitational stability of the developed ice cream was slightly higher compared to that of the control sample. In addition, the developed ice cream showed higher resistance to melting - the mass fraction of melt after 2 hours was 11% lower than in the control sample.
Thus, our research results allowed us to conclude that the developed ice cream was characterised by a high content of vitamin C and had improved structural, mechanical, and organoleptic properties.

4. Conclusion
As a result of scientific and technological research, we substantiated the ingredient composition and the appropriateness of using an encapsulated food ingredient in soft ice cream that extends the assortment line of sweet functional foods. The results of the experimental study indicated that the change increased consumer characteristics of the soft ice cream and its functional properties. The vitamin C content in 100 g of developed ice cream was 46.8 ±5.2 mg%, which corresponds to the recommended daily intake for children and also indicates the possibility of creating other functional products with a high content of vitamin C.

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