Modification of the carbohydrate component of ice cream and frozen desserts using glucose-galactose syrup

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Abstract. Functional and technological properties of glucose-galactose syrup as a substitute for sucrose in the technology of functional ice cream and milk desserts are studied. A comparative analysis of the effect of sucrose, fructose, galactose, and glucose-galactose syrup on formation of the sensory profile of sweeteners is performed. Patterns of the impact of concentration and temperature on the degree of sweetness of glucose and galactose syrup are revealed. The optimal ratio of glucose-galactose syrup and sucrose (50/50) in ice cream and frozen milk desserts is determined.

1. Introduction
Food technology enriched with functional components is currently particularly relevant due to a fast pace of modern life and increased demand for products that have a positive effect on the human body, restore its biological parameters and improve general well-being. The list of such products is constantly expanding, including products manufactured from raw materials of plant origin combined with raw materials of animal origin. Emphasis is placed on dairy products, as they are in high demand among the population, and the milk base allows development of a wide range of formulations of such products as yoghurts, puddings, ice cream and other dairy desserts. Enrichment with functional components can be performed through the use of both special additives and plant materials, including natural nutrients, such as vitamins, antioxidants, micro- and macronutrients, etc.

However, the increasing tendency to process dairy raw materials into individual ingredients, including protein, observed in recent years dictates the need to use a carbohydrate component of milk, which is modified into dairy or whey permeates. Increased volumes of permeates are not used efficiently. Modification of the carbohydrate part to glucose and galactose monosaccharides, as an example, is considered to be promising. Nevertheless, specific features of the resulting glucose-galactose syrup require a special technological approach to its use [1, 2].

Given both trends, the development of ice cream production technology with glucose-galactose syrup as a sucrose substitute and vegetable raw materials (berry and vegetable) is promising in manufacturing functional, and therapeutic and prevention-oriented products.
2. Materials and methods
The analysis of literature and patent sources confirms that glucose-galactose syrup can be used as raw material for production of ice cream and frozen desserts. The disadvantage of glucose-galactose syrup, its slightly bitter taste, prevents its widespread use in traditional dairy products, it is better to combine it with vegetable raw materials to improve its sensory parameters [3].

In development of new technologies for milk dessert production, the use of plant components improves current technological processes, and the finished product exhibits functional properties due to its enrichment with natural nutrients that are part of plant materials, such as vitamins, macro- and micronutrients, antioxidants.

3. Results and discussion
At the first stage, the technological properties of glucose-galactose syrup, as a sucrose substitute, were investigated.

The main requirement for sugar substitutes is the quality of sweetness, which should not differ from the sweetness parameter of sucrose. Sugar substitute should have a clean, pleasant sweet taste, manifested instantaneously and not lasting for too long; it must be thermally and chemically stable, without color and flavor [4, 5].

To compare the relative sweetness of glucose-galactose syrup, traditional sweeteners such as sucrose, fructose and glucose were used (figures 1, 2). The sweetness of 60% sucrose solution was taken for 100%.

A comparative analysis of the sweetness of 5, 10 and 20% sucrose solutions shows that the sweetness increases linearly when temperature grows up. In 30, 40, 50, and 60% sucrose solutions, when temperature increases, sweetness nonlinearly grows. When temperature increases, sweetness of 5% fructose solution decreases (figure 1).

![Figure 1. Effect of temperature on the sweetness of sweeteners with the weight of dry solids of 5%.](image1)

![Figure 2. Effect of temperature on the sweetness of sweeteners with the weight of dry solids of 10%.](image2)

At increased temperature, sweetness of 10 and 20% fructose solutions increases and exceeds the sweetness parameter of sucrose solution (figure 2).

Sweetness of 30 and 40% fructose solutions is also observed to decrease at increased temperature, and at 50 °C, sweetness of the solution grows.

The perception of sweetness of 50 and 60% fructose solutions at increased temperature grows, and at temperatures above 60 °C, it becomes less distinct. When solution is heated, sweetness of fructose decreases 3-fold; therefore, the amount of fructose added must be more than that of sucrose.
At increased temperature, in 5, 20, 50, and 60% solutions, the glucose sweetness of solutions at temperatures of 50 °C and above remain stable. Among the test solutions, glucose shows the lowest degree of relative sweetness, since its sweetness index is 0.7 relative to sucrose.

Sweetness of 10, 30, and 40% glucose solutions at increased temperature grows slowly. Upon reaching 40 °C and subsequent increase in temperature, sweetness remains constant.

Sweetness of 5 and 10% glucose-galactose syrup solutions at increased temperature grows in close succession.

Sweetness of 20% solution of glucose-galactose syrup at temperatures from 10 to 50 °C is found to slightly increase, and a significant increase can be observed at temperature above 50 °C.

Sweetness of 30% solution of glucose-galactose syrup at increased temperature and at 80 °C is found to be similar to that of sucrose solution.

In 40% solution of glucose-galactose syrup, the sweetness increases nonlinearly when temperature grows.

An increase in temperature causes a nonlinear increase in the sweetness of 50 and 60% solutions of glucose-galactose syrup, which is higher than that of the sucrose solution.

The data obtained show that the increased temperature and concentration lead to an increase in the sweetness of glucose-galactose syrup, and at high temperature the sweetness parameter increases sharply.

These data are consistent with the generally accepted mechanism for the emergence of sweet taste, which implies interaction between the flavoring substance and the receptor. The interaction causes formation of a hydrogen bond between certain parts of the sweet substance and the active centers of the receptor [6, 7]. As a result, a chain reaction responsible for the final chemical dynamic effect starts. An increase in temperature, on the one hand, increases the rate of bond formation. Therefore, the perception of the sweetness of sugars improves at insignificantly increased temperature, which is consistent with the data obtained for all studied sugars, with the exception of fructose. This is probably due to the fact that the increased temperature shifts the equilibrium of the transition of the cyclic and linear forms of sugar towards the latter. Since the cyclic form of sugar is sweeter, the relative sweetness of the solution decreases.

A quantitative descriptive (profile) test was used to compare sensory properties of glucose-galactose syrup (figure 3) with regard to 6 descriptors:

- intensity of sweetness (A);
- enveloping aftertaste (B);
- bitter aftertaste (C);
- time of the onset of maximum sweetness (sec) (D);
- the degree of conformity to the taste of sugar (E);
- time of extinction of sweetness (sec) (F).

Analysis of the sensory profile showed that glucose-galactose syrup has a more intense and long-lasting sweetness than sucrose due to the presence of monosaccharides (glucose and galactose), which are sweeter than lactose, which is consistent with the literature data. Glucose-galactose syrup has a pronounced enveloping aftertaste. The onset of maximum sweetness is similar to that of sucrose. However, solutions of glucose-galactose syrup have a slightly bitter taste due to the presence of mineral substances, residual amounts of short peptides and amino acids [8].
The color of glucose-galactose syrup solutions was determined in accordance with GOST 14871-76. Solutions of sucrose, glucose and fructose remained transparent at concentrations of 5 to 40%, and slight turbidity appeared at concentrations of 50 and 60%. Solutions of glucose-galactose syrup at all concentrations exhibited a characteristic greenish-yellow color due to the presence of riboflavin.

A widespread use of glucose-galactose syrup in the formulations of traditional dairy desserts and ice cream is limited due to a more intensive color of the syrup compared to traditional sugar substitutes, and requires a special selection of raw materials and ingredients to mask its undesirable technological properties.

Similar to sucrose, glucose-galactose syrup is the main filler that imparts sweetness to products and affects their structure. It can be assumed that a change in the sucrose/glucose-galactose syrup ratio in a frozen dessert can affect the physico-chemical and sensory properties of the finished product [9, 10].

To determine the optimal sucrose/glucose-galactose syrup ratio in ice cream mixtures, a two-factor experiment was carried out. The effect of the glucose-galactose syrup dose – $X_2$ (GGS, %) and the stabilizer dose – $X_1$ (S, %) was taken into account when planning the experiment. The indicators of sensory evaluation (OL) and overrun (S, %) of the mixture for ice cream were used as an output parameter (figures 4, 5).

Based on the analysis of surfaces and sections, the following optimal parameters were selected: the dose of stabilizer (6.0–8.0)% and the dose of replacing sucrose with glucose-galactose syrup (50%).
4. Conclusion

Thus, the study of technological properties of glucose-galactose syrup as a sucrose substitute in ice cream and milk desserts shows that the increased concentration and temperature of glucose-galactose syrup increases its sweetness.

The optimal ratio of glucose-galactose syrup and sucrose in ice cream and frozen dairy desserts has been determined. The dose of glucose-galactose syrup is 50%, which is optimal for partial replacement of sucrose.

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