Influence of sweeteners on rheological and qualitative indicators of ice cream

Oksana Bass[1], Galyna Polischuk[1] , Olena Goncharuk[2]

1 – National University of Food Technologies, Kyiv, Ukraine.
2 – Institute of Surface Chemistry of National Academy of Sciences of Ukraine, Kyiv

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Corresponding author:

Oksana Bass
E-mail:
Kleona@meta.ua

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Abstract

Introduction. The research was conducted to determine the influence of sweeteners on the rheological and qualitative characteristics of ice cream.

Materials and methods. Mixtures of cream-based ice cream and aromatic ice cream with sugar, a mixture of molasses (glucose-fructose syrup and molasses caramel), erythritol and sorbitol, as well as their compositions were investigated . Rheological characteristics were studied by rotational viscometry.

Results and discussions. The viscosity of creamy and aromatic ice cream increased in the case of a complete replacement of sugar by syrup starch. The ability to restore the structure of such systems during measurements in the mode of gradual decrease of the rate of displacement increased and ranged from 110.3% to 112.4%, which corresponds to reopectic behavior. However, the effective viscosity of ice-cream with polyols decreased compared to control, and the restoration of the structure of these systems was only 46.8 and 55.9%. In the case of combining a mixture of molasses with erythritol or sorbitol in equal ratios in cream-based ice cream, an increase in the effective viscosity for the degree of regeneration of the structure was recorded 81.9 and 87.0%, respectively.

A certain correlation was found between the effective viscosity and the physical and chemical parameters of ice cream. Thus, in the range of recommended values of effective viscosity of mixtures of ice cream of different chemical composition, the loss rate was not less than 60% of the periodic production method. It should be noted a slight decrease in the loss of ice cream in the case of the use of stomach molybdenum, which can be compensated by its combination with polyols.

The highest defilement was found in samples of ice cream with erythritol and sorbitol, and the lowest – in the case of a mixture of molasses . The combination of erythritol with a mixture of molasses was the highest technological effect.

The resistance to melting of cream ice cream with polyols declined to 44.1 min. with erythritol, and 45.2 min with sorbitol and raised for ice cream with a mixture of molasses up to 54.1 min. (control – 48.2%). For aromatic ice cream a similar pattern has been obtained.

Conclusions. The use of polyols and patch compositions makes it possible to adjust the degree of sweetness of the finished product and to formulate the specified physical and chemical characteristics of the mixtures and ice cream.

Introduction

The processes of formation and stabilization of the structure of ice cream are significantly influenced by the physical and chemical characteristics of the mixtures subject to further thermo mechanical treatment. The content of fat, sugar, dry skim milk and the stabilizer of the structure determine the technological properties of the mixtures and the quality indices of the finished product. Within certain species of ice cream groups there are certain requirements for the range of the content of each of these components, in particular, to the mass fraction of sugar. It is the presence of fat, sugar, dry skim milk and the stabilizer of the structure determines the technological properties of the mixtures and determines the quality indices of the finished product.

Within certain species of ice cream groups there are certain requirements for the range of the content of each of these components, in particular, to the mass fraction of sugar. Thus, its content in milk-based ice cream is usually not less than 14–15.5%, and in ice-cream aromatic and fruit-berry – about 25–28%. Thus, sugar serves not only as an intensive sweetener, but also adds dry matter to the composition of the product, which accounts for a percentage of their total content of about 35% for sealants, about 50% for dairy ice cream and up to 80–85% for aromatic and fruit and berry ice cream. Therefore, the purpose of the study is a comparative analysis of the technological efficiency of sweeteners of different origin for use in the composition of ice cream and aromatic sugar free [1, 2].

Literature review

It is important for consumers demanding organoleptic parameters and composition of ice to reduce its sweetness and glycemic index. Therefore, partial or complete replacement of sugar by other sweeteners for the preservation of the characteristic of the product of organoleptic and physical indicators of quality is an urgent task in the field of ice cream production. Sorbitol, xylitol, maltitol, erythritol, isomalt and other polyols are a good alternative to sugar, characterized by a moderate degree of sweetness, effectively affect the cryoscopic temperature of the product, are stable and soluble in water, are well digested, give the foodstuff a cooling effect [3].

Thus, according to the results of organoleptic evaluation of ice cream with polyols, a rather pleasant moderate sweetness of such a product without sugar (Maltisweet) was noted, compared with the excessive sweetness of the traditional composition of ice cream [4]. At the same time, consumption of polyols per day more than 20 g often leads to gastrointestinal disorders, diarrhea, bloating and other complications. Therefore, according to Codex Alimentarius, a product containing polyols should be marked accordingly with respect to the possible mitigating effect [5].

According to the recommendations of the American Dietetic Association, the consumption of sorbitol in quantities greater than 50 g, mannitol – in excess of 20 g, and isomalt – more than 40 g per day is considered superfluous. At the same time, there are no restrictions for laktitol, maltotol and erythritol. Of course, the daily requirement of polyols depends on age, weight, and the state of human health. Older people suffering from diabetes suffer from constipation, so restrictions on the use of polyols are individual and different for each person [6].

More known in the composition of ice cream as a sweetener molasses starch. It is obtained by sequential cleavage of macromolecules of starch by enzymatic hydrolysis to the desired carbohydrate composition and dextrose equivalent. Functional characteristics of molasses and syrups vary depending on the dextrose equivalent, which is directly related to the degree of hydrolysis of starch in the production process.

According to the results of previous studies, the authors found the expediency of using in the composition of ice cream a composite mixture of high-soluble molasses of the brand HFCS-42 (glucose-fructose syrup) and molasses of low degree of sucrose HFCS-30 (carbohydrate molasses) for the ratio of 30:70. Such mixture provides a proper degree of sweetness (0.7 units) and at the same time essentially structure mixtures of ice cream in the presence of higher sugars in the low-soluble molasses. The effective viscosity of mixtures of creamy ice cream with the specified composition of patches reached 1085.45 mPa·s, and mixtures of aromatic ice cream – 291.6 mPa·s, which are the recommended values for these types of ice cream [7].

Rheological characteristics of mixtures of ice cream of various composition, as well as the influence of individual components and technological regimes on the viscosity of mixtures were the subject of study since the 20-ies of the last century. Rheological characteristics of mixtures of ice cream of various composition, as well as the influence of individual components and technological regimes on the viscosity of mixtures were the subject of study since the 20-ies of the last century. So, F.F. Sherwood, H.L. Smallfield, G.D. Turnbow and K.W. Nielson describes the influence of technologically important parameters (temperature and duration of pasteurization, maturation of mixtures, pressure and temperature of homogenization, chemical composition of mixtures, etc.) on the rheological characteristics of mixtures for the production of classical ice cream on a milk basis [8, 9]. But, given the progressive changes in ice cream technology for almost 100 years, the results of these studies can only be used as general information. The use of stabilizers and stabilization systems, sweeteners, the improvement of classical technologies and technical innovations require further study of all factors affecting the quality indicators as mixtures for the production of ice cream and finished product.

So, already in our time, Arbuckle, W. S. found that the viscosity of the mixture is a function of the composition (mainly of fats, stabilizers and sugar), the conditions of treatment (mainly pasteurization, homogenization and maturation) and the temperature of the mixture. He also believed that the effective viscosity of the mixture consists of a structural component that dissipates during the mixing process and a plastic component fluctuating in the range from 50 to 300 mPa·s. This effective viscosity at rest or at low shear rates is partly due to various phenomena (aggregation of fat globules, free water content, etc.) that increase viscosity with a decrease in the rate of displacement, including due to thixotropic properties of mixtures [10]

Moser R. etc. studied the influence of polyols and guar gum on the rheological characteristics of their aqueous solutions. The behavior of these mixtures was estimated by measuring the shear under the action of constant and oscillatory stresses, as well as after the freeze / thawing cycle of the prototype samples. An increase in the relative viscosity of guaric solutions in the case of addition of polyols and increase of their concentration is established. The exception is the system of mixtures for the ratio between 40 g/100 g of sorbitol and 1 g/100 g of guar gum, in which the viscosity decreases. Studies of systems after their freezing / defrosting showed no change in visco-elastic properties of solutions [11].

In China (Tianjin University) it has been found that for a specific molar concentration of polyol, the density and viscosity of such solutions decrease as the temperature rises. In the case of heating the solutions, the thermal energy of the molecules and the distance between them increases, and, accordingly, the density and viscosity decrease. At the same time, the density and viscosity of the mixtures, respectively, increase with increasing concentration of solutions. As the temperature rises, the viscosity of the solutions of polyhydric alcohols decreases nonlinearly, whereas the density decreases linearly. By gradually increasing the number of carbon atoms in polyols (erythritol, xylitol, mannitol, and maltitol), their molecular weight increases accordingly, which leads to an increase in the viscosity of solutions at a specific molar concentration and temperature [12].

Siefarth etc. have proved that the addition of sucrose, polyols and fillers contributes to enhancing the perception of the aroma of aqueous solutions of relatively pure water. The relationship between taste and viscosity was not found in solutions with low viscosity [13].

The authors have previously studied the rheological characteristics of cream and aromatic ice cream with complete and partial replacement of sugar on starch molasses. It is proved that the degree of saccharification of molasses significantly affects the structural and mechanical properties of mixtures. The content of higher sugars in the low-degree of saccharification, in contrast to glucose-fructose syrup, containing the vast majority of monosubstances, contributes to a better structuring of mixtures in terms of effective viscosity. Excessive viscosity of mixtures with molasses caramel requires its combination with high-soluble molasses at a ratio of 30:70, which ensures the effective structuring of mixtures and gives the moderate sweetness of ice cream to cream and aroma, compared with control samples [14].

Consequently, it is evident that it is expedient to replace the sugar in the ice cream component with the technological-functional ingredients – polyols and starch molasses. At the same time, there is no comparative assessment of their impact on the quality of mixtures and ice cream both individually and in composition.

In the article a comparative analysis of the influence of polyols (sorbitol and erythritol) and a mixture of starch packs of different degrees of sucrose (glucose-fructose syrup and caramel molasses) on the physical parameters of cream and aromatic ice cream and mixtures for their production are given.

Materials and methods

For control of samples of creamy ice cream, a typical prescription with a mass fraction of fat was chosen – 10%, dried skim milk residue – 10%, sugar – 14% and stabilization system (Cremodan SE 709, Danisco) – 0,5%.

For the study of ice cream on the basis of sugar syrups for control sample, an aromatic mixture with a mass fraction of sugar of 28% and gelatin in the amount of 0,5% of the total mass of the mixture was chosen as the control sample.

In experimental samples, sugar was completely replaced by a mixture of glucose-fructose syrup (HFCS-42) and carotene molasses (HFCS-30) for a ratio of 30:70 and polyols of erythritol and sorbitol, based on dry matter.

Ice cream mixtures were prepared according to the classical technological scheme: they were pasteurized at 85±2 ºC for 2–3 minutes, cooled to a temperature of 4±2 ºC and, at the same temperature, matured for 12 hours. The content of sweeteners in mixtures of ice cream is shown in Table 1.

The defilement of soft ice-cream (S, %) was determined by the weight method and calculated by the formula [15]:

$$S = \frac{m_m - m}{m} \cdot 100\%$$

where m_m – the mass of a mixture of ice cream of a certain volume, g; m – weight of ice cream of the same volume, g.

Table 1

Mixes of ice cream with various sweeteners

Sample number	Mixtures type and sweetener content
1	Control 1 (ice cream) (sugar=14 %)
2	Ice cream (starchy syrups=14 %)
3	Ice cream (erytritol=14%)
4	Ice cream (erytritol=7 % + starchy syrups=7%)
5	Ice cream (sorbitol=14 %)
6	Ice cream (sorbitol=7% + starchy syrups=7%)
7	Control 2 (aromatic ice cream) (Sugar=28 %)
8	Aromatic ice cream (erytritol =28 %)
9	Aromatic ice cream (sorbitol=28 %)
10	Aromatic ice cream (starchy syrups=28%)

The viscosity characteristics of ice cream mixtures were determined on the rotating viscosimeter "REOTEST 2.1" with the cylinder cylinder measuring system by removing the curvatures of the kinetics of deformation (flow) at a temperature of 20 ºC. Measuring cylinder (rotor) S1 was selected in such a way that the gradient layer was distributed over the entire thickness of the product layer located in the annular gap of the viscometer gauge. The measurement of the shear stress was carried out in twelve values of the shear rate γ in the range from 3 to 1312.2 s^{-1} with successive incremental rates of shear rate, endurance at the highest speed and subsequent successive gradual reduction of velocities [14].

Resistance to melting was determined by the modified method by L. D. Buldenko. Ice cream samples in the form of cylinders with a diameter of 35 mm and a height of 50 mm were pre-maintained at -25 ºC for 24 hours. After that, they were warmed at a temperature of 20 º C [16] on stainless steel grates with apertures of 2.5 mm in size. Samples were placed with a measuring cylinder. The time of occurrence of the first drop "float" and the time of leakage of 10 cm^3 "float" were fixed.

The size of the air bubbles was determined by microscopy for an increase of x = 150. A sample of ice cream was applied to the calibrated chamber Goryaev's grid, covered with a cover glass from above, and a bubble size was calculated in four to seven fields of view. The average diameter of the bubbles was calculated by the diameter of the particles in an amount not less than 400 in the five-seven fields of view [16].

Organoleptic evaluation of ice cream samples was carried out qualitatively and quantitatively (on a 10-point scale) [15].

Results and discussions

Replacing sugar with polyols and molasses due to increasing the viscosity of unpermoited water in hardened ice cream can prevent recrystallization of water and lactose due to violation of temperature regimes of storage and the emergence of consistency defects – sandy and coarse-crystalline structure. Therefore, the dynamics of changes in the effective viscosity of mixtures for the production of ice cream of different chemical composition with successive incremental increase and subsequent decrease of the shear rate γ in the range from 3 to 1312.2 s^{-1} was investigated.

The rheological characteristics of the samples under study are given in Table 2

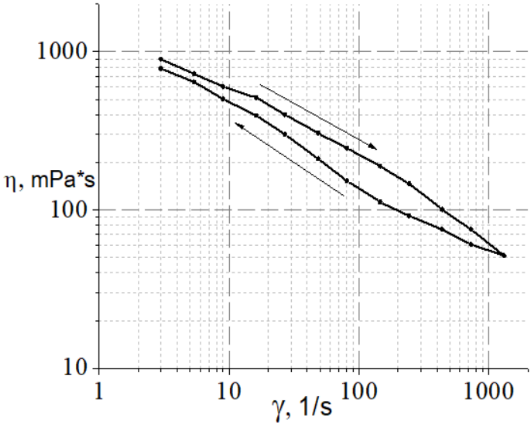
Table 2

Rheological characteristics of the studied systems

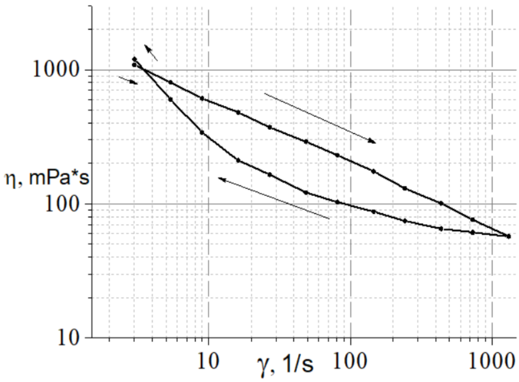
Sample number	η_1 (γ=3), mPa·s	η_2 (γ=1312,2), mPa·s	η_3 (γ=3), mPa·s	τ (γ=1312,2), s
Mixtures of ice cream				
1	896,9	51,35	782,1	336
2	1085,45	57,24	1197,2	370
3	815,4	34,93	381,5	351
4	982,65	39,20	804,31	354
5	616,8	39,88	344,5	404
6	864,41	38,81	752,32	392
Mixtures of aromatic ice cream				
7	252,3	6,2	193,5	152
8	198,52	3,48	83,6	163
9	177,32	5,91	83,74	185
10	291,6	7,8	327,9	185

The nature of the destruction of the structure of the studied food systems in the process of measuring the effective viscosity, for example, of mixtures of cream and aromatic with complete replacement of sugar on the syrup of starch and on polyols is shown on Figure 1, Figure 1.1, Figure 2.1 and on Figure 2 .

Sample No. 1



Sample No.2



Sample No.3

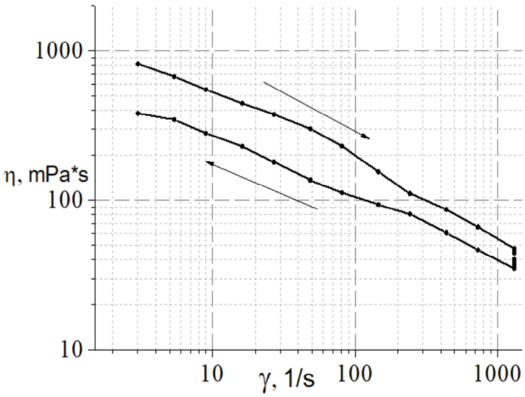
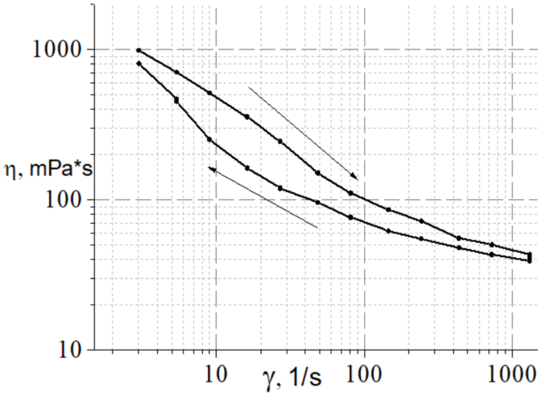
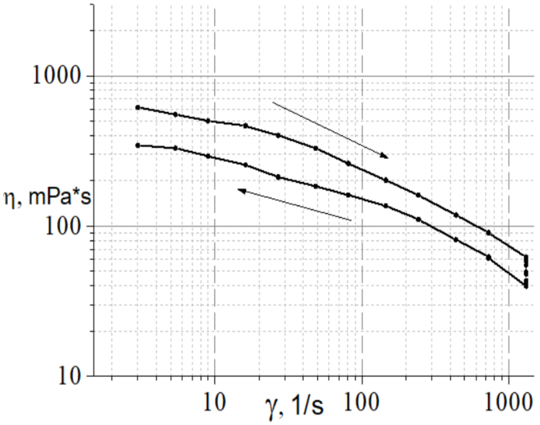


Figure 1. Dynamics of the change of effective viscosity of mixtures for the production of cream ice cream with various sweeteners

Sample No.4



Sample No.5



Sample No.6

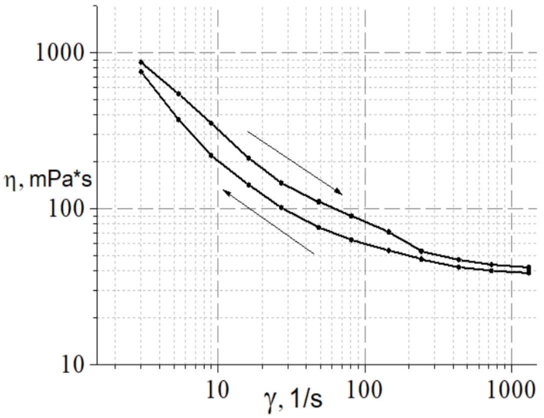
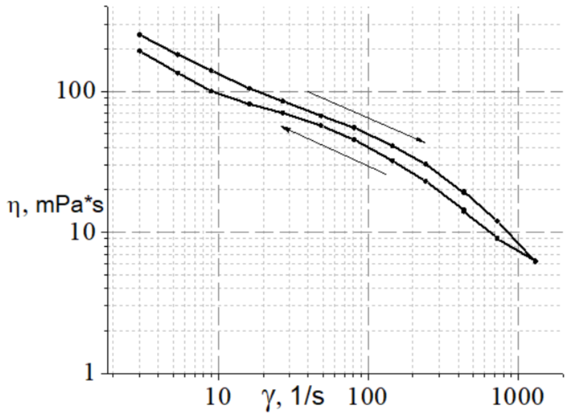
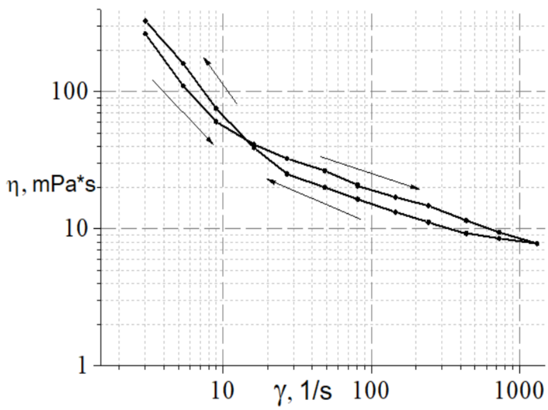


Figure 1.1. Dynamics of the change of effective viscosity of mixtures for the production of cream ice cream with various sweeteners

Sample No. 7



Sample No. 8



Sample No. 9

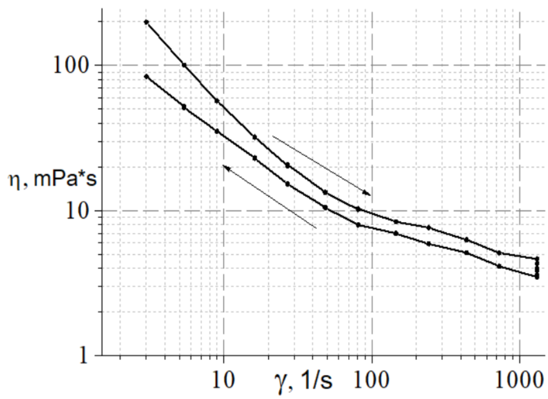


Figure 2. Dynamics of the change of effective viscosity of mixtures for the production of aromatic ice cream with various sweeteners

Sample No. 10

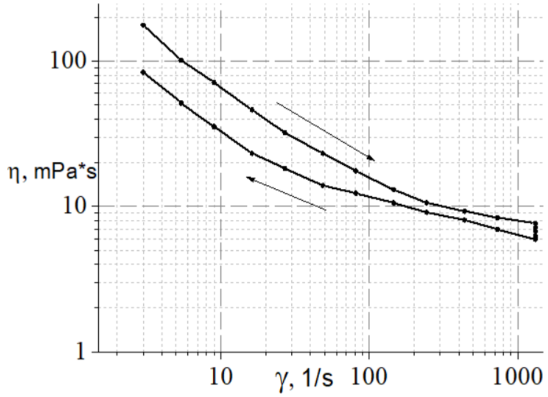


Figure 2.1. Dynamics of the change of effective viscosity of mixtures for the production of aromatic ice cream with various sweeteners

According to the results of the study, thixotropic properties revealed samples of control cream and aromatic mixtures and mixtures with molasses and polyols. For these samples, in the process of rheological research, the gradual destruction of the structure and the corresponding reduction of the effective viscosity (η_3) in comparison with the initial values (η) with the subsequent partial restoration of the structure is characteristic. The complete replacement of the traditional sweetener with polyols, in turn, contributes to reducing the viscosity of the mixture and the ability to restore its structure. Thus, for ice cream, the cream's ability to restore the structure of the control sample is 87.2%, and for creamy ice cream with a complete replacement of sugar for erythritol and sorbitol – only 46.8 and 55.9% respectively.

At the same time, the food systems containing a mixture of strains, can not only almost completely restore the structure but also reveal weak reopectic properties. The latter are manifested in increasing the effective viscosity in the shear rate reduction mode (η_3) by 10.3% for creamy ice cream and 12.4% for aromatic ice cream for complete replacement of sugar compared to the initial values (η).

In the case of the simultaneous use of a mixture of polyethylene tubes (samples number 4 and number 6), the process of structuring becomes more pronounced. Thus, the initial viscosity of the mixtures is 982.65 mPa·s for ice cream with molasses and erythritol and 864.41 mPa·s for ice cream with molasses and sorbitol in equal proportions. The reproducibility of the structure of these samples is quite high and reaches 81.9 and 87.0%, respectively. That is, the structure of mixtures with complexes of sugar substitutes of different origin allows to partially or completely restore the structure of the formed portions of soft ice-cream before quenching, which significantly increases the quality of its quality [5].

For mixtures of ice cream of classical species (milk ice cream, creamy ice cream, sundae) at a temperature of 20 ºC and a shear rate $\gamma = 3\ s^{-1}$, the relative viscosity of the mixtures should be about 200, 600 and 1200 mPa·s with respectively. For mixtures, the aromatic effective viscosity is much lower and can reach only 250 mPa·s [1]. The viscosity of all the specimens examined was within the recommended values, except for cream and aromatic mixtures with starch molars whose viscosity exceeded the norm. But the latter can be used effectively to regulate the structural characteristics of ice cream eskimo, which should be more dense and form-resistant.

Physical parameters of ice cream made from samples of mixtures (see Table 1) are shown in the table. 3

Table 3

Physical indicators of ice cream with various sweeteners
(P≥ 0.95; n = 3)

Indicator	Sample number									
	1	2	3	4	5	6	7	8	9	10
Overrun, %	77,2 ±2,0	76,0 ±2,3	82,1 ±1,9	79,0 ±1,3	80,1 ±1,9	79,5 ±1,8	73,5 ±1,8	78,3 ±1,1	77,5 ±0,9	72,1 ±1,9
Resistance to melting, s	48,2 ±1,4	54,1 ±0,7	44,1 ±1,0	46,3 ±1,1	45,2 ±0,9	46,4 ±0,9	28,0 ±0,6	22,3 ±0,5	23,4 ±0,7	29,0 ±0,6
Average diameter of the bubbles, μm	45,7 ±1,0	50,2 ±1,1	22,1 ±0,6	32,8 ±0,7	25,2 ±0,6	34,2 ±0,6	51,1 ±0,7	27,8 ±0,9	28,1 ±0,8	30,2 ±0,9
The temperature of the soft ice cream,ºC	-3,5 ±0,1	-4,0 ±0,1	-7,5 ±0,2	-5,5 ±0,2	-6,0 ±0,2	-4,2 ±0,1	-5,0 ±0,2	-7,5 ±0,2	-7,1 ±0,2	-6,5 ±0,1

The highest deficiency was found in control samples with sugar (No. 1, No. 7) and samples with polyols (No. 3–6 and No. 8–9). At the same time, ice cream with erythritol and sorbitol at high bruise shows an unsatisfactory resistance to dying.

In turn, a certain decrease in the losses was recorded for samples No. 2 and No. 10 with a mixture of starch packs while improving the uniformity of the ice cream. As a result of the comparative analysis of the distribution of air bubbles by size in soft ice-cream, an increase in the dispersion of the air phase in specimens with polyols was found. This effect is probably due to a decrease in the viscosity of the mixtures, which leads to their more efficient chopping and distribution of the air phase. According to studies by Adapa and al. the more viscous system contributes to less foam formation, but the higher stability of the structure [17], which explains the detected effect.

It should also be noted that the cooling of mixtures with polyols in the process of freezing should be noted. However, the surface of ice cream on the exit from the freezer was shiny and watery due to low resistance to dessert. Ice cream with molasses is more structured, with a dry surface due to the presence of higher sugars in the molasses PC (up to 70% of the total dry matter content). All samples of ice cream on the exit from the freezer had a temperature not exceeding the recommended -3.5 ºC [16].

Regarding organoleptic characteristics, the lack of sweetness and low ability to make ice cream with a complete replacement of sugar on erythritol and sorbitol, moderate sweetness and high structural capacity for samples with starch molasses should be noted. Therefore, the highest scores were obtained from cream ice cream no. 4 and no. 6 and a sample of aromatic ice cream №10. Balance assessment of organoleptic parameters of the studied ice cream samples is shown in Figure 3.

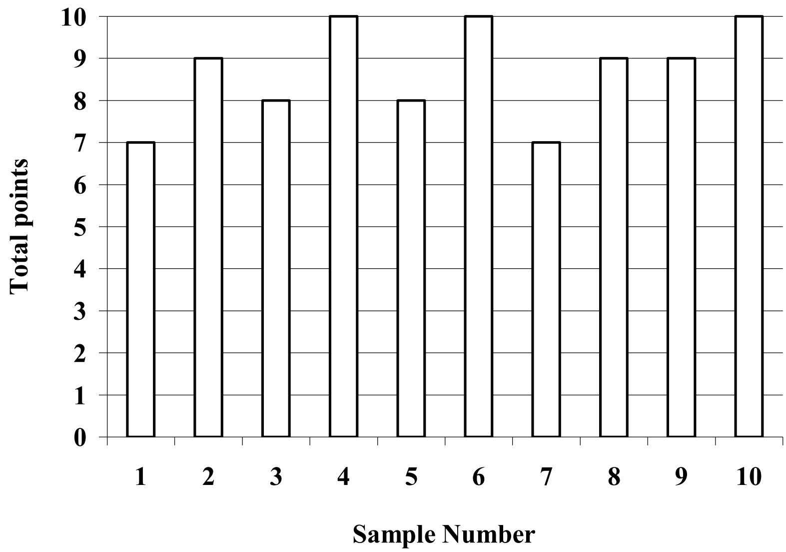


Figure 3. Organoleptic evaluation of ice cream samples on a 10-point scale

According to Figure 3, the use of polyols and patch compositions makes it possible to adjust the degree of sweetness of the finished product and to form the physical characteristics of mixtures and ice cream close to those for classical sugars.

Consequently, polyols as sugar substitutes are better used to produce ice-cream soft or packaged in rigid consumer containers before quenching. A mixture of straw is universal and can be used for different types of ice cream. But lower whip and good structuring are ideal for ice cream Eskimo.

Replacing sugar with a mixture of polyethylene tubes to a sufficient degree ensures its structuring. Using exclusively polyols does not provide ice cream with the required degree of sweetness and reduces dandruff resistance. Therefore, for the formation of a structure characteristic for a soft ice-cream, it is advisable to use a mixture of low-and high-soluble patches together with polyols.

Conclusions

1. Replacing sugar on the composition of starch hoods HFCS-42 and HFCS-30 for a ratio of 30:70 significantly increases the effective viscosity of mixtures for the production of cream and aromatic ice cream. Replacing sugar with polyols leads to the reverse effect. At the same time, the replacement of sugar on a complex of sweeteners of various origins (polyols + molasses) provides an effective viscosity of mixtures in the recommended range of values.
2. Replacement of sugar into sorbitol and erythritol leads to a decrease in the sweetness of the ice cream, an increase in its loss and worsens resistance to dying. Replacing sugar with a mixture of straw also reduces the sweetness, but reduces stiffness and improves resistance to dandruff.

3. The expediency of the complex use of polyols and a mixture of strawberries in creamy and aromatic ice cream has been proved, which makes it possible to achieve the maximum technological effect.

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