

Investigation of viscous characteristics of ice cream mixtures with starch syrup

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Abstract

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Introduction. Starch syrup is widely used as a sweetener for the production of ice cream, but its structuring ability is not sufficiently studied and requires additional research. Revealing patterns of structuring mixtures with the syrup of different degrees of saccharification allows to reduce the need for structural stabilizers and to achieve a technological effect in the process of ice cream production at the expense of only natural ingredients.

Materials and methods. Rheological characteristics of mixtures of ice cream and aromatic ice cream with glucose-fructose syrup (HFCS-96), glucose syrup (HFCS-42) and carotene syrup (HFCS-30) have been investigated by using a rotary viscometer.

Results and discussions. With complete replacement of sugar for starch syrup HFCS-30 and HFCS-42, the initial effective viscosity of ice cream mixtures increases by 22,1% and 2,5% respectively, compared to the control sample with sugar. As compared to the control sample with sugar. At the same time, complete replacement of sugar on the syrup HFCS-96 contributes to a decrease in the initial effective viscosity of the ice cream mixture by 15,3%. Initial effective viscosity of aromatic ice cream mixtures at full replacement of sugar by HFCS-30 and HFCS-42 increased by 27,1% and 14,8% respectively, and decreased by 11,6% at full replacement of sugar for HFCS-96 syrup.

Starch syrups HFCS-42 and HFCS-96 provide mixtures of thixotropic properties. Instead, systems with syrup HFCS-30 can not only completely restore the structure, but also show weak repective properties. Due to this, in the mode of inverse reduction of the shear rate, the effective viscosity of the mixtures of ice cream of cream and aromatic, in case of complete replacement of sugar, increases by 12,7% and 18,8%, respectively, compared with the initial values. In mixtures containing a mixture of HFCS-96 and HFCS-30 patches at a ratio of 30:70, the effective viscosity increases in reverse slip rate by 9,5% and 12,5% for ice cream and aromatic ice cream, respectively, compared to Initial values.

Conclusions. The structuring ability of starch syrup decreases with increasing its degree of saccharification. The revealed pattern of the effect of starch syrup with different dextrose equivalent on viscosity characteristics of mixtures of different chemical compositions makes it possible to purposefully form indicators of ice cream quality.

Introduction

The viscosity characteristics of ice cream mixtures change during the technological process under the influence of certain types of thermal and mechanical processing (mixing, pasteurization, homogenization, cooling, maturation, freezing) [1-6]. Thus, scientists at the University of Manchester (UK) have confirmed that the viscosity of ice cream mixtures is volatile and depends, first of all, on the temperature of the samples under study and the rate of shear [2]. Scientists at the Department of Food Science, Faculty of Agriculture, University of Udine (Udine, Italy) have proved the dependence of the viscosity characteristics of ice cream mixtures on the process of homogenization [3].

Existing recommendations on the regulation of structural and mechanical properties of ice cream mixtures chiefly take into account only the effective viscosity of the virtually undamaged structure of mixtures. Thus, for mixtures of ice cream of classical species (milk, cream, plombir) at a temperature of 20 °C at a shear rate $\dot{\gamma} = 3$ this figure should be about 200, 600 and 1200 mPa·s respectively. For the aromatic mixtures, effective viscosity is much lower and can reach 250 mPa·s [5].

In the process of ice cream production, in the period between two technological operations, "freezing" and "quenching", when the structure of a complex food system varies from liquid (mixture) to a practically solid (hardened ice cream), it is equally important that the ability of ice cream mixes to collapse significantly under the action of the external shearing forces of the blades of the stirrer in the frieze and to quickly and effectively restore the structure in a static state after the formation of portions before the quenching process. The structure of the mixture must be partially or completely restored in the formed portion of the finished product, which significantly improves its quality [2, 5]. Proper viscosity of the mixtures and the ability to restore it contributes to the formation of a solid structure of ice crystals and the formation of a hard ice cream consistency [1, 2, 4, 5, 18]. Instead, scientists almost do not pay attention to the ability of mixtures to restructure the structure, in spite of the fact that in ice cream technology this particular characteristic is one of the most important.

Initial relative viscosity of the finished mixtures and its change in the production of ice cream, primarily, are determined by the physical and chemical characteristics of the formulation components [4]. Hydrocolloids and surfactants (stabilizers, emulsifiers and stabilization systems) are essential in the structuring of mixtures for the production of ice cream [5]. Equally important is the content of the fatty component, with the increase in the viscosity of the mixtures also rises [1-7], as well as its chemical composition and degree of conscientiousness. In the course of the latest developments, so-called "low-fat" milk fat substitutes such as starch, starch-lipid compositions, serum protein isolates (WPI), maltodextrins, etc. are becoming increasingly popular. [6-9], whose influence on the organoleptic and structural-mechanical properties of ice cream is still not sufficiently studied.

Sugar and sugar-containing components, in particular starch syrup, also influence the process of forming the rheological characteristics of the mixtures and the finished product [4, 9-14]. The content of reducing agents in the starch syrup is designated as dextrose equivalent (DE): low conversion DE 28-38, intermediate DE 49-58, and high conversion DE 59-96. Ice cream makers usually use liquid or dry corn syrups from DE 28-42 [4, 14]. With a decrease in DE, the sweetness of the molasses decreases, and the structuring ability increases [5, 10, 15], which should be taken into account when used as part of food systems. At the same time, there is no information on the possibility of complete

replacement of sugar by starch syrup and its influence on the viscosity characteristics of mixtures for the production of ice cream.

Consequently, taking into account the above, the study of the effect of starch syrup of different degrees of saccharification on the viscosity characteristics of dessert mixtures is a promising scientific direction in ice cream technology.

In view of the above, the purpose of scientific research is to determine the patterns of the influence of starch syrup of varying degrees of saccharification on the effective viscosity of mixtures for the production of ice cream.

Materials and methods

Materials

For the comparison of the rheological characteristics of milk-based mixtures for control, the typical formula of ice cream is selected: with a mass fraction of fat – 10%, dry skim milk residue – 10%, sugar – 14%, stabilizing system Cremodan SE 709 – 0,5%. For the study of ice cream on the basis of sugar syrups, a flavor mixture with a mass fraction of sugar of 28% and a classical stabilizer (gelatin) in the amount of 0,5% of the total mass of the mixture was selected as the Control sample.

As a sweetener and a structuring component, molybdenum-fructose syrup (HFCS-96), glucose syrup (HFCS-42), carotene molasses (HFCS-30) and glucose-fructose syrup were used as a syrup of starch dry.

The following designations were adopted.

Mixtures of ice cream:

- Control 1 (14% of sugar);
- Sample No. 1 (7% sugar + 7% HFCS-42);
- Sample No. 2 (14% HFCS-42);
- Sample No. 3 (7% sugar + 7% HFCS-96);
- Sample No. 4 (14% HFCS-96);
- Sample No. 5 (7% sugar + 7% HFCS-30);
- Sample No.6 (14% HFCS-30);
- Sample No. 7 (4.2% HFCS-96 + 9.8% HFCS-30);

Mixtures of aromatic ice cream:

- Control 2 (28% of sugar);
- Sample No. 8 (14% sugar + 14% HFCS-42);
- Sample No. 9 (28% HFCS-42);
- Sample No. 10 (14% sugar + 14% HFCS-96);
- Sample No. 11 (28% HFCS-96);
- Sample No. 12 (14% sugar + 14% HFCS-30);
- Sample No. 13 (28% HFCS-30);
- Sample No. 14 (8.4% HFCS-96 + 19.6% HFCS-30).

Preparation of mixture for ice cream samples with starch syrups

Mixture for ice cream production was prepared according to the classical technological scheme and typical recipes (pasteurization at a temperature of 85 ± 2 °C for 2-3 minutes, cooling to 4 ± 2 °C, maturity for 12 hours).

In the samples under study, 50 and 100% of the sugar replacement was performed on starch syrup with different DE and composition (HFCS-96:HFCS-30 = 30:70), the feasibility of which was confirmed by the authors earlier [11].

Research of rheological characteristics of ice cream mixtures

The viscosity characteristics of the ice cream mixtures were determined by removing the curves of the kinetics of deformation (flow), using a rotary viscometer with a measuring system, cylinder-cylinder. Measurements were performed at a temperature of 20 °C. The 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 shear stress was carried out in twelve values of shear rate $\dot{\gamma}$ in the range from 3 to 1312,2 s⁻¹ in series with a gradual increase in shear rates at the highest speed for reverse gradual reduction of velocities [12].

Results and discussions

The dynamics of changes in the effective viscosity of ice cream mixtures of different types for the gradient of the shear rate $\dot{\gamma}$ in the range from 3 to 1312,2 s⁻¹ in the direct and reverse is determined (Table 2).

Table 2

Rheological characteristics of the studied systems

Sample name	η_1 ($\dot{\gamma}=3$), mПа·с	η_2 ($\dot{\gamma}=1312,2$), mПа·с	η_3 ($\dot{\gamma}=3$), mПа·с	τ ($\dot{\gamma}=1312,2$), с
Mixtures of ice cream				
Control 1	896,92	51,35	782,11	336
Sample No. 1	907,64	51,72	808,42	318
Sample No. 2	919,12	51,55	829,53	304
Sample No. 3	793,56	48,12	674,46	267
Sample No. 4	759,91	47,51	628,93	200
Sample No. 5	967,63	60,63	1050,19	425
Sample No. 6	1095,34	64,50	1234,31	440
Sample No. 7	1001,71	57,24	1097,26	370
Mixtures of aromatic ice cream				
Control 2	252,30	6,21	204,54	152
Sample No. 8	269,82	6,66	208,96	141
Sample No. 9	288,61	6,91	217,57	139
Sample No. 10	206,43	5,73	182,32	99
Sample No. 11	191,55	4,84	160,45	83
Зразок No. 12	299,11	7,92	342,03	181
Sample No. 13	323,67	9,42	384,51	197
Sample No. 14	291,61	7,81	327,95	185

The nature of the structure destruction of the studied food systems in the process of measuring the effective viscosity is shown in Figure 1 and 2 on the example of a mixture of ice cream and aromatic cream with a complete replacement of sugar on the starch syrup.

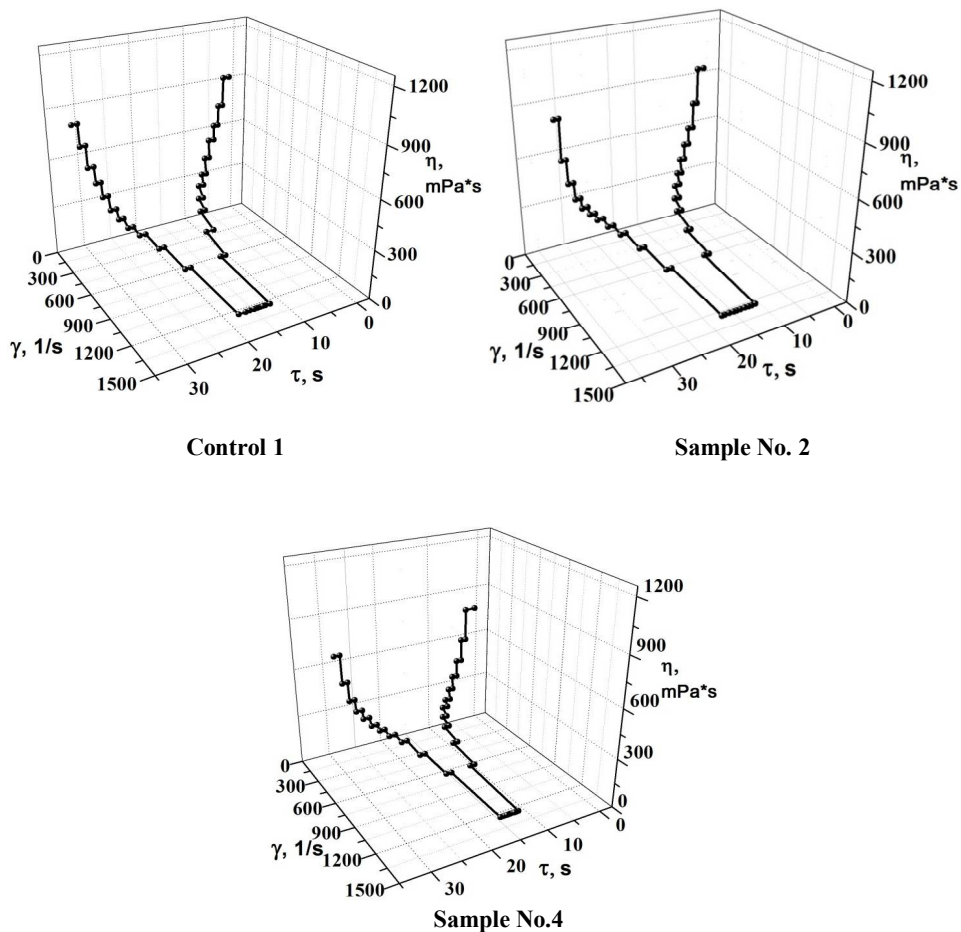


Figure 1. Dynamics of changes in the viscosity characteristics of ice cream cream (Control 1) and samples with 100% sugar substitution on HFCS-42 (sample No.2) and 100% sugar substitution

According to the results of the study, it is evident that samples of mixtures of control and mixtures with HFCS-42 and HFCS-96 have thixotropic properties. In the process of rheological research the gradual destruction of the initial structure and the corresponding reduction of the effective viscosity (η_3) by 10,8% and 17,2% respectively for ice cream cream and 11,9% and 16,23% for aromatic ice cream per 100%-substitutes of sugar compared to their initial values (η_1) are characteristic for them. At the same time, food systems containing HFCS-30, are able not only to almost completely restore the structure, but also to show weak reopectic properties. The latter are manifested in increasing the effective viscosity in reverse shear rate (η_3) by 12,7% for ice cream and 18,8% for aromatic ice cream at full sugar replacement compared to the initial values (η_1). For comparison, in control samples of ice cream and aromatic ice cream with sugar, effective viscosity decreases by 12,1% and 18,7% respectively.

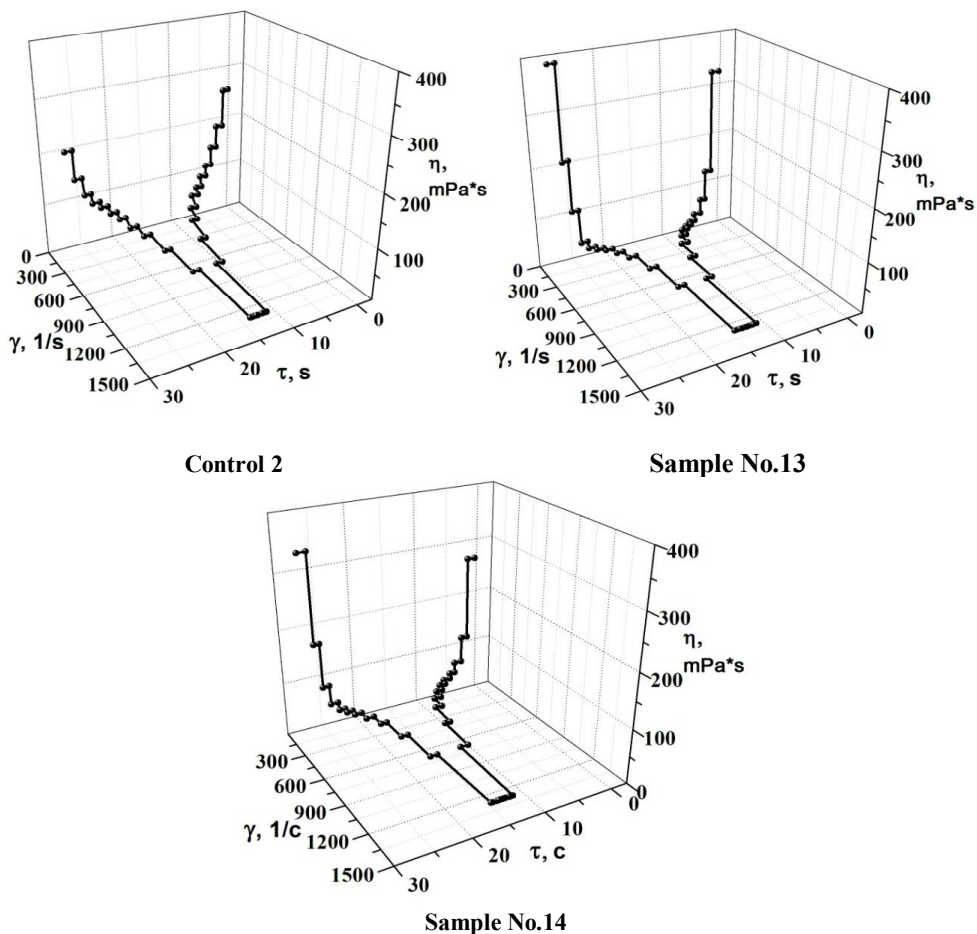


Figure 2. Dynamic of change of viscosity characteristics of aromatic ice cream (Control 2) and samples with 100% sugar substitution on HFCS-30 (Sample No.13) and 100% sugar substitution for a mixture of HFCS-96: HFCS-30 = 30:70 (Sample No.14)

It should also be noted, that in the event of an increase in the degree of saccharification and an increase in the content of mono-sugars in the syrups/molasses, the time for which the systems under study are transferred to a state of equilibrium (τ) is reduced.

The use of HFCS-30 at the expense of increased content of polysaccharides not only structures the mixture, but also improves the ability to restore the structure of the formed portions of soft ice cream before quenching. At the same time, the effective viscosity of such mixtures is too high, which can lead to a decrease in the loss of the finished product and the formation of an overly dense structure and coarse consistency of the product [1, 2, 4, 5, 18]. Therefore, the complete replacement of sugar by HFCS-30, taking into account its significant effect on the rheological properties of the mixture for ice cream of various species, is not appropriate.

The partial and complete replacement of the traditional sweetener by HFCS-96, in turn, contributes to reducing the viscosity of the mixture and the ability to restore its structure, compared with the control sample. Considering the chemical composition of HFCS-96, the effect is due to the predominant content of monosaccharides in its composition [13]. That is, the surplus or lack of polysaccharides does not ensure the proper formation and stabilization of the structure of ice cream.

The food system, which has an overwhelming number of HFCS-30 polysaccharides, compared to HFCS-96 samples, does not provide sufficient structuring, while the use of HFCS-96 alone will provide ice cream with excessive sweetness and low resistance to dandruff [15, 16]. Therefore, in order to create a structure characteristic for a soft ice-cream, to balance the taste and consistency of the finished product, it is expedient to use a mixture of starch syrup with a low and high DE for a ratio that ensures the formation of the given physicochemical and organoleptic parameters of ice cream mixtures of different species, in comparison with control samples.

For mixtures with HFCS-96 + HFCS-30 syrup composition for 100% sugar replacement, an increase in effective viscosity is observed in reverse slope reduction (η_3) by 9,5% for ice cream and 12,5% for aromatic ice cream compared to the initial values (η_1). It should be noted that the use of the specified starch syrup composition also fully provides the degree of sweetness typical of the classic ice cream. While the replacement of sugar by HFCS-42 slightly affects the rheological parameters of mixtures, but significantly reduces the sense of sweetness.

Similar studies were carried out by the Atatürk University Department of Food Sciences by Cihat Ozdemir, using mixtures for the production of 5% fat dairy ice cream and a mass fraction of the sweetening component of 18%. As sweeteners in the samples studied, HFCS maltodextrin, HFCS low-soluble molasses, HFCS mixture of medium sugary sugar with a 1:1 ratio, HFCS low-sugar molasses mixture ratio of 1:1 were used in the samples studied. The results of the study showed an increase in the effective viscosity of HFCS low-octane samples and HFCS with an average degree of saccharification of 17,6% and 2,2%, respectively, for complete replacement of sugar [15]. According to the results of our study, the effective viscosity of ice cream mixtures with HFCS-30 and HFCS-42 increases by 22,1% and 2,5%, respectively in the case of complete replacement of sugar. Replacing sugar with molasses HFCS-96 contributes to lowering the initial effective viscosity of the cream mixture by 15,3%. Initial effective viscosity of aromatic ice cream mixtures at full replacement of sugar by HFCS-30 and HFCS-42 increased by 27,1% and 14,8% respectively, and decreased by 11,6% with full replacement of sugar for HFCS-96 starch syrup.

These results confirm the general tendency of the influence of the degree of saccharification of syrup on the structural and mechanical properties of the mixtures, but are more versatile due to the nature of the change in the viscosity characteristics of systems of different chemical compositions in the process of mechanical treatment.

The low viscosity of the mixture for aromatic ice cream, as compared with milk-based ice cream, is due to the use of gelatin as a stabilizer. Its macromolecules are not able to form a sufficiently dense framework, compared with the current stabilization system in the ice cream.

The revealed ability of mixtures with starch syrup and polysaccharides in its composition to restore the destroyed structure has practical significance, especially in the case of production of ice cream on the stream extrusion lines, which will improve the efficiency of the process of forming and dosage of ice cream portions.

In further researches it is planned to study the indexes of quality of ice cream with starch syrup taking into account the results of research of structural and mechanical properties of mixtures for its preparation.

Conclusions

1. Starch syrup in mixtures for ice cream, depending on the degree of saccharification, significantly affects their structural and mechanical characteristics. The content of higher sugars in the HFCS-30 syrup, unlike HFCS-96, contains the majority of monolysaccharides, contributes to the better structuring of mixtures, which directly affects the increase of their effective viscosity.
2. HFCS-96 and HFCS-42 mixtures are thixotropic, and mixtures with HFCS-30 have low reoplectic properties, which allows to predict the dynamics of change in effective viscosity in the technological process of ice cream production.
3. It is expedient to use an HFCS-30 + HFCS-96 composite mixture at a ratio of 30:70 to produce ice cream with high whipping, proper melting resistance and a sufficient degree of sweetness.

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