Journal homepage: http://fens.usv.ro/index.php/FENS
Journal of Faculty of Food Engineering,
Ştefan cel Mare University of Suceava, Romania
Volume XXI, Issue 2 - 2022, pag. 116 - 128

FOOD AND ENVIRONMENT SAFETY

FUNCTIONAL AND TECHNOLOGICAL PROPERTIES OF OAT BETA-GLUCAN IN ACIDOPHILIC-WHEY ICE CREAM

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Received 13th May 2022, accepted 25th July 2022

Abstract: *The purpose of the work is to study the functional and technological properties of oat beta-glucan both individually and as part of acidophilic-whey ice cream. The research methods, that were used, are well known and have relevant references in the work.*
At the first stage of the experiment, the functional and technological properties of oat beta-glucan from two manufacturers were studied: «AMULYN» (China) and «DANSON» (China). According to the results of sensory evaluation, beta-glucan «DANSON» received 8.75 points, and «AMULYN» - 10 points. It was found that the water holding capacity of beta-glucan «AMULYN» is 15.45 % higher than with beta-glucan «DANSON», and fat binding capacity is higher by 8.61 %, which is probably due to the different degree of purification of these additives. Therefore, a more effective beta-glucan «AMULAN» was chosen for further use in acidophilic-whey low-fat ice cream.
At the second stage of scientific work the influence of oat beta-glucan «AMULYN» on the quality of acidophilic-whey low-fat ice cream was studied. It was found that beta-glucan in the amount of 0.75 % increases the indicator of overrun more than twice compared to the control sample without beta-glucan. Beta-glucan in a certain amount also significantly improves the organoleptic characteristics of ice cream, increases resistance to melting and ensures uniform distribution of the air phase throughout the volume of the product, as evidenced by microstructural analysis of its samples.
A significant effect of beta-glucan on the dynamic viscosity coefficient of ice cream mixes has been established. The detected effect allows to reduce the ripening process of ice cream mixtures with beta-glucan in the amount of 0.75 % by 2 hours, provided that the recommended viscosity of these systems is achieved.
Thus, the expediency of using oat beta-glucan as an effective functional and technological ingredient in acidophilic-whey ice cream is scientifically substantiated.

Keywords: *β-glucan, fermented ice cream, whey, viscosity, overrun, microstructure.*

1. Introduction

In modern human life and activity, it is important to increase the biological value of functional foods, which play a key role in improving overall health and preventing a number of diseases. Fermented milk products contain all the nutrients of milk, and in the presence of natural probiotic cultures help strengthen the body's resistance [1,2].

Recently, scientists are paying more attention to studying the properties and possibilities of using the acidophilic bacillus *Lactobacillus acidophilus,* in particular in the technology of fermented dairy products such as beverages, including on the base of buttermilk, whey and fermented milk ice cream [3-5].

DOI: https://doi.org/10.4316/fens.2022.012

Fermented ice cream is a product made from whey and/or starter on a pure cultures of lactic acid bacteria with or without the addition of aromatic substances [6]. Its production at domestic enterprises in Ukraine is extremely limited, and its most popular type is yogurt ice cream.
At the same time, even according to the interstate GOST 32929-2014 "Fermented ice cream" [7], adopted for use in the post-soviet countries, including Ukraine, fermented ice cream is intended to be made on the basis of not only yogurt and curd, but also kefir, acidophilin, airan, rhazhenka, sour clotted milk, cultured cream, cultured baked milk and kumys, which is not taken into account by domestic producers. In addition, the schemes of fermented ice cream production described in the Standard Technological Instruction [8] are very complex.
Ice cream made by this technology has low resistance to melting, overrun and "empty" taste, which emphasizes the need to improve the technology and composition of fermented ice cream, in particular acidophilic-whey.
In order to avoid the above defects in the ice cream producers add technological ingredients that act as a thickener and moisture-binding agent, structure the mixture at the stage of ripening and allow to obtain ice cream with high resistance to melting, overrun and original taste [9-11].
Due to their high molecular weight, beta-glucans are better thickeners than other polysaccharides, such as starch, inulin, dextrin, xylan, pectin preparations, fiber [12,13]. The use of beta-glucans can reduce the use of stabilizing substances in the prescription composition of ice cream, which is consistent with the concept of healthy eating [14-16], as well as give low-fat ice cream creamy taste, as this additive mimics fat in low-fat and non-fat products.
Nevertheless, the number of published research results on the use of beta-glucan in the production of ice cream, in particular low-fat dairy, is limited [17]. The effect of polysaccharide content and structure, including highly purified beta-glucan preparations, on the functional properties of low-fat ice cream has never been thoroughly studied.
The aim of the research was to study the functional and technological properties of oat beta-glucan both individually and as part of acidophilic-whey ice cream.
To achieve this goal, the following tasks were set:
1. To study the functional and technological properties of oat beta-glucan from different manufacturers and choose the most appropriate for further use in formulation of acidophilic-whey ice cream.
2. Investigate the effect of oat beta-glucan on the resistance to melting, overrun and dispersion of the air phase in acidophilic-whey ice cream.
3. Identify the features of structuring mixtures of low-fat ice cream with beta-glucan.

2. Matherials and methods

Raw materials for research

Dry demineralized whey with a degree of demineralization of 90 % (TM "Dairy Alliance", Ukraine), with a mass fraction of moisture 3.0 %, protein - 10 %, fat - 1.0 %, lactose - 80 % was selected for research.
A single-strain probiotic culture of *L. Acidophilus* (TM "Danisko", Denmark) was used as a starter, that intended in the production of dairy products and cheeses.

To study the technological parameters of beta-glucans in order to compare and select the best for further use in the composition of acidophilic-whey ice cream were selected oat beta-glucan from two manufacturers: «AMULYN» (China), «DANSON» (China).

The recipe composition of the studied samples of ice cream is due to the following requirements:

- dry matter content should be from 23.79 to 24.09 %, which is typical for the chemical composition of acidophilic-whey ice cream with low fat content;
- mass fraction of fat - 2.0 %, which corresponds to its content in low-fat ice cream;
- mass fraction of dry non-fat residue - 6.79 %, which ensures the completeness of the milk taste in ice cream with low fat content;
- mass fraction of sugar - 17.0 %, which provides the traditional degree of sweetness and maintains the dry matter content in ice cream not less than 23.5 %;
- mass fraction of the stabilizator - from 0.1 to 0.3 %, which corresponds to its recommended content for this type of ice cream in accordance with the manufacturer's recommendations;
- mass fraction of oat beta-glucan - from 0.25 to 1.0 %, which corresponds to the research of other scientists [18-20].

Preparation of samples

The following samples were made:

1. Control - without beta-glucan, mass fraction of stabilizer (guar gum) - 0.4 %.
2. Sample 1 - parts of beta-glucan - 0.25 %, mass fraction of stabilizer (guar gum) - 0.3 %.
3. Sample 2 - parts of beta-glucan - 0.5 %, mass fraction of stabilizer (guar gum) - 0.2 %.
4. Sample 3 - parts of beta-glucan - 0.75 %, mass fraction of stabilizer (guar gum) - 0.1 %.
5. Sample 4 - parts of beta-glucan - 1.0 %, without stabilizer.

Preparation of samples was carried out as follows.

Starter activation. Weighed with an open fire scalpel lyophilized starter on the basis of *Lactobacillus acidophilus* at the rate of 0.5 g per 1 liter of mixture. The weighed starter was added to the pre-calculated amount of milk that was pasteurized at a temperature of 84…88 °C for 3…5 min and cooled to a fermentation temperature of 38…42 °C. The duration of fermentation was 6…8 hours before reaching the acidity of not more than 5.0 pH.

Preparation of the mixture. Dry components (demineralized dry whey, sugar, stabilizer, beta-glucan) were weighed according to recipes on laboratory scales to the nearest 0.01 g. The components were mixed and distilled water was added. After this mixture was pasteurized at the temperature of 84…88 °C for 3...5 min and cooled to 38…42 °C. Pre-activated starter was added. The fermented mixture was subjected to ripening for 6…8 years until the acidity is not higher than 5.0 pH.

The fermented mixture was cooled to a temperature of 2…6 °C, kept for at least 2 hours and freezed in a freezer for making ice cream "Frosty ICM-15A" with a power of 50 rpm for 45 minutes.

Storage. Ice cream samples were cooled and stored in a freezer "Caravell" A / S (Denmark) at a temperature of minus 21…23 ° C in the continuation of the study. Samples of the same chemical composition were made at least 3 times.

Research methods

Organoleptic evaluation of beta-glucan. The product was mixed and determined the color, structure, consistency, the presence of dense lumps that do not fall apart when lightly tapped and foreign particles. When mixing, it was necessary to pay attention to the presence or absence of product compaction and signs of caking.

To determine the color of beta-glucan (particle size up to 1 mm), it was placed in a clean dry container at a layer height of at least 2 mm and evaluated in high light conditions. Odor, taste and aroma were analyzed immediately after consistency assessment.

The evaluation was carried out on a scale of six people. The maximum value of the score for each of the indicators was 5 points. Based on the results, a histogram was constructed.

The general complex indicator of organoleptic evaluation [21] of dry ingredients (beta-glucan) can be represented as a set of the following characteristics: appearance (K_1), color (K_2), taste (K_4), odor (K_4).

The overall complex indicator of organoleptic evaluation was determined by the equation:

$$K = K_1 \times M_1 + K_2 \times M_2 + K_3 \times M_3 + K_4 \times M_4$$

where K is the overall complex indicator;
M_1, M_2, M_3, M_4 are importance factors of each of the groups of indicators K_1, K_2, K_3, K_4.

Fat binding capacity (FBC) of beta-glucan was determined by centrifugation method [22].

After receiving the results, the values of the FBC, %, were calculated according to the formula:

$$FBC = \frac{(c-b)}{(b-a)} \times 100\%,$$

where a is a weight of test tube with test material and bound oil, g;
b is the weight of the test tube with the test material, g;
c is a sample of experimental material, g

Water holding capacity (WHC) of beta-glucan was determined by centrifugation method [22].

WHC, %, was calculated by the formula:

$$WHC = \frac{m_2 - m_1}{m} \times 100,$$

where m is the mass of the sample, g;
m_1 is the mass of the test tube with the dry sample, g;
m_2 is mass of test tube with wet sample, g.

Studies of fat binding capacity and water holding capacity were conducted on the basis of Milk and Dairy Technology Department of the National University of Food Technologies using a laboratory centrifuge «Orbit» (CLU-1) at a speed of 1370 rpm.

To determine the coefficient of dynamic viscosity [23], a Hepler viscometer with a set of 6 glass and metal beads of different diameters was used.

The calculation of the coefficient of dynamic viscosity of the mixture μ (MPa·s) was performed by the formula:

$$\mu = k \times (\rho_1 - \rho_2) \times t,$$

where k is the constant of the ball, MPa*cm^3/g;
ρ_1 and ρ_2 are respectively, the density of the materials of the ball and the mixture, g/cm^3;
t is the duration of the ball between the ring marks, s.

Resistance to melting was determined by a modified method [24], according to which the time of appearance of the first drop of "melt" and the time of leakage from the sample of ice cream 10 cm^3 "melt" were recorded.

The size of air bubbles was determined by the method of VNIHI (All-Russian Research Institute of Refrigeration Industry) [25], according to which an ice cream sample was applied to the calibrated grid of Goryaev's chamber, covered with a cover glass and immediately microscopied at 160 times magnification.

Overrun (S), %, of ice cream was determined by weight method [26].

Organoleptic evaluation of ice cream was performed by tasting by a commission of

10 people with an assessment of compliance with the requirements of DSTU 4733: 2007 (State Standard of Ukraine) [27], as well as a 10-point scale, according to which the maximum number of points for taste and smell is 6, for consistency is 3, for color and appearance is 1.

Statistical processing after laboratory experiment was performed using Microsoft Excel. Graphical representation of the numerical data of the experiment was performed using the program Mathcad 15. To ensure the accuracy of the experimental results, experiments were performed three to five times under the same conditions.

3. Results and discussion

Investigation of functional and technological properties of oat beta-glucan

At the first stage of the research, a comparative analysis of oat beta-glucan indicators of two manufacturers, whose products are presented on the ukrainian market of food additives, was conducted. Beta-glucan «DANSON» (China) and «AMULYN» (China) were selected for the study. Organoleptic evaluation of these additives is given below (Table 1).

Table 1.

Organoleptic evaluation of beta-glucan

Indicator	Sample 1 (DANSON)	Sample 2 (AMULYN)
Appearance and color	The surface is homogeneous, smooth and clean. The color is white with a cream tinge, uniform throughout the mass.	The surface is homogeneous, smooth and clean. The color is cream, uniform throughout the mass.
Taste, smell and aroma	No foreign odors, but there is a taste of oatmeal.	Clean, without foreign tastes and odors.
Structure and consistency	Homogeneous, without mechanical inclusions, with single lumps.	Homogeneous, without lumps and mechanical inclusions.

Based on the results of organoleptic evaluation of beta-glucan from two manufacturers, a histogram was constructed, which is presented in Figure 1.

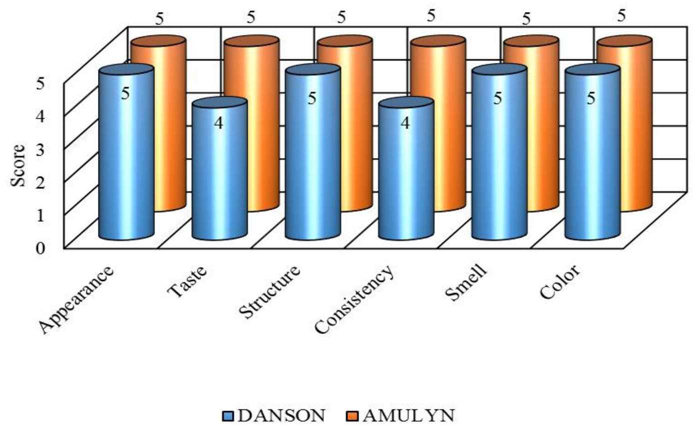


Fig.1 - Histogram of organoleptic evaluation of beta-glucan

Based on the results of organoleptic evaluation, the overall complex indicator of organoleptic evaluation of beta-glucan of two manufacturers was calculated. The results are shown below (Table 2).

Table 2.

Overall complex indicator of organoleptic evaluation of beta-glucan

Indicator	Coefficient of importance	Sample №	
		1 (DANSON)	2 (AMULYN)
Appearance	1,0	4	5
Smell	0,25	1,25	1,25
Taste	0,25	1	1,25
Color	0,5	2,5	2,5
Overall complex indicator (K)	2,0	8,75	10

According to the results of the calculation of the overall complex indicator of beta-glucan (sample № 1) received 8.75 points, and sample № 2 - 10 points. The difference in estimates may indicate a higher degree of purification of beta-glucan «AMULYN» (no oatmeal taste), as well as possible non-compliance with the technological process of production beta-glucan «DANSON» (the presence of single lumps).

The next step was to investigate the FBC and WHC of beta-glucan in order to determine the most effective additive for its further use in the composition of acidophilic-whey ice cream. The results obtained are shown below (Table 3)

Table 3.

The results of the study of fat binding capacity and water holding capacity of beta-glucan, %

Indicator	Sample №	
	1 (DANSON)	2 (AMULYN)
WHC	76.4±1,8	88.2±2,1
FBC	32.04±0,8	34.8±0,7

(P ≥ 95 %, n = 3)

In accordance with those specified in table 3 data, it is noticeable that the WHC for sample № 2 is higher than in sample № 1, by 15.45 %, and FBC - by 8.61 %. The higher WHC and FBC of «AMULYN» beta-glucan compared to «DANSON» beta-glucan is probably due to the higher degree of purification of the first additive according to the manufacturer's specification, which requires further study. The obtained data are correlated with the indicators of other researchers who studied oat beta-glucan both individually and as part of food products [28,29].

According to the results of the study of functional and technological properties of beta-glucan of two manufacturers, beta-glucan «AMULYN» was chosen as more technologically effective for further use in the composition of acidophilic-whey ice cream.

Investigation of the effect of oat beta-glucan on the quality of acidophilic-whey ice cream

To conduct the study, experimental samples of ice cream were made and their physicochemical and organoleptic characteristics were studied.

Indicators of overrun and resistance to melting of ice cream are shown in Figure 2.

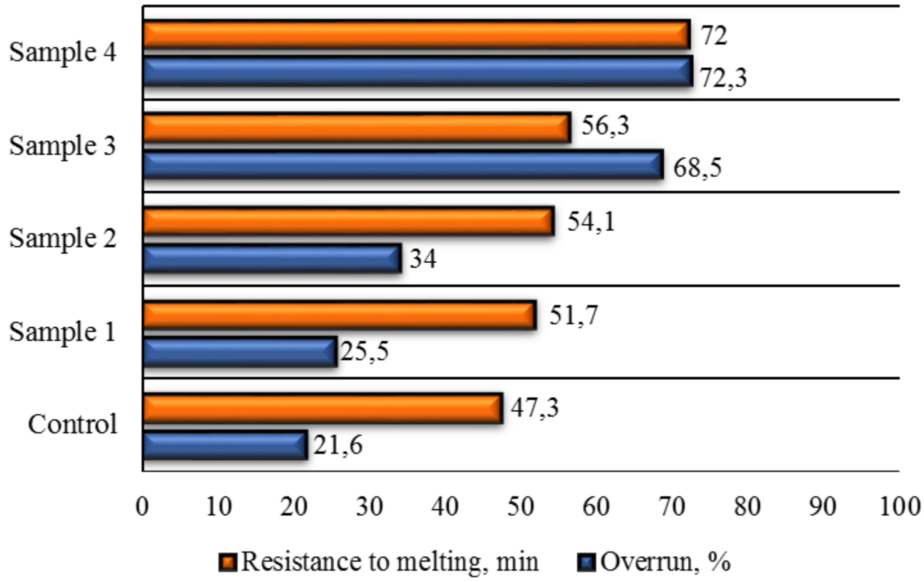


Fig. 2 - Overrun and resistance to melting of ice cream with beta-glucan and without (control)

The overrun of the control sample is 21.6 %, the addition of beta-glucan in the amount of 0.25 % (sample № 1) leads to an increase in overrun by 18.1 %, and a dose of 0.5 % of beta-glucan (sample № 2) - at 57.7 %.

With a beta-glucan content of 0.75 % (sample № 3), the overrun increases by 217.6 %. However, a further increase in the dose of beta-glucan to 1.0 % (sample 4) has a negligible effect on the overrun of the ice cream and leads to a compaction of the mass, which impairs the organoleptic characteristics of the product.

It should be noted that the mass fraction of stabilizer (guar gum) in the composition of ice cream is gradually reduced from 0.4 % for control to 0.1 % for sample № 3, and in sample № 4 it is absent. At the same time, the revealed properties of beta-glucan allow to significantly reduce the use of stabilizing substances in ice cream and achieve a high technological effect.

Resistance to melting during the accumulation time of 10 cm^3 of "melt" also increases steadily from 47.3 min (control) to 72.1 min (sample № 4). This confirms the technological possibility with the help of beta-glucan to purposefully influence the indicators of overrun and resistance to melting of ice cream.

The next step was to study the microstructure of ice cream samples for a more detailed study and explanation of the effect of oat beta-glucan on overrun and resistance to melting. The microstructure of the samples is shown in Figure 3.

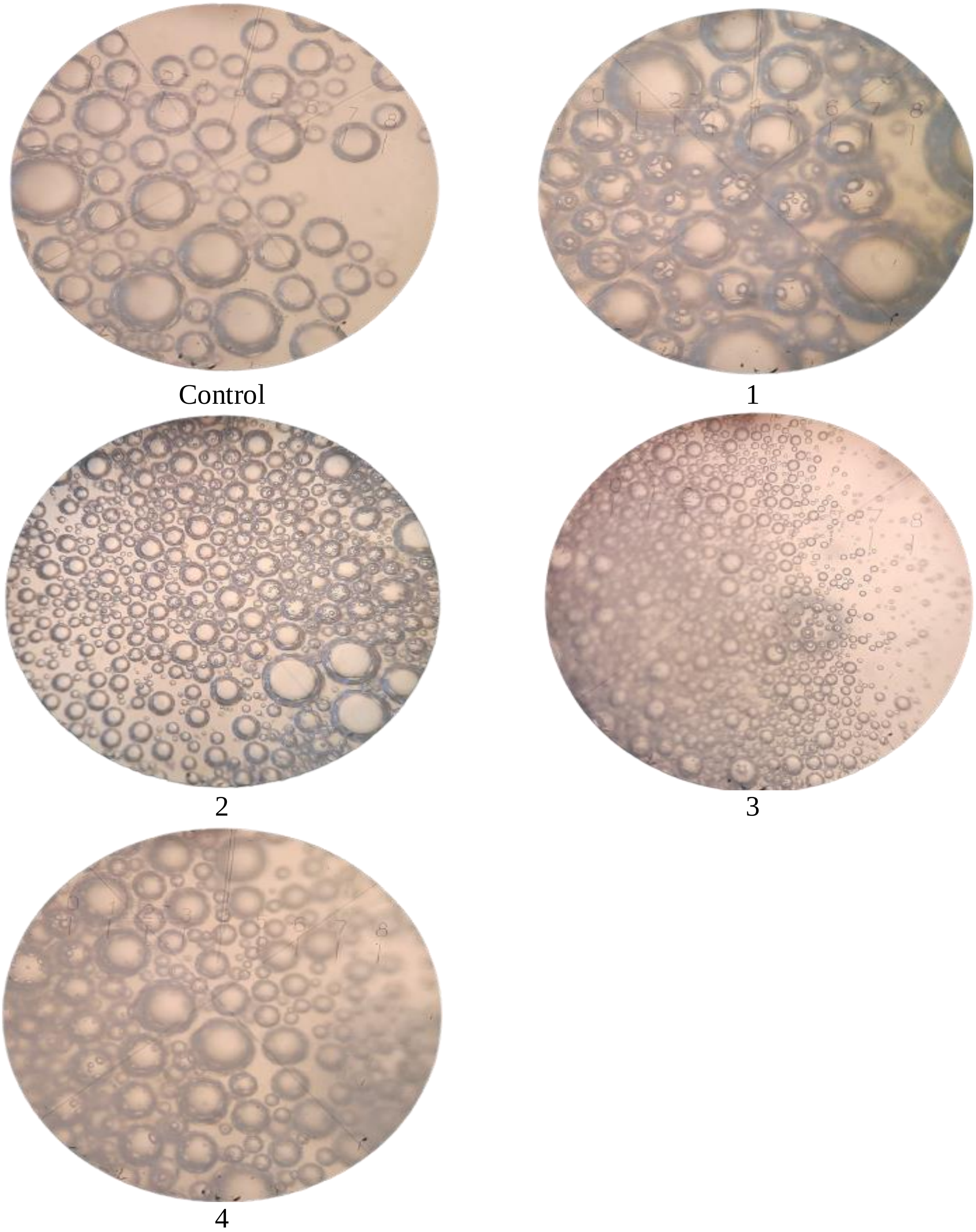


Fig. 3 - Microstructure of ice cream

As can be seen in Fig. 3, the content of beta-glucan at the level of 0.75 % provides the most uniform distribution of the air phase inside the ice cream, which has a positive effect on its consistency. The phenomenon of "cluster formation" from air bubbles due to their aggregation was also observed, which can be explained by the specific interaction between beta-glucan macromolecules in aqueous medium [30], which should be further studied.

The addition of beta-glucan in the amount of 0.25…0.5 % does not ensure uniform distribution of the air phase in full, sometimes large air bubbles are observed. At the same time, increasing the dosage to 1.0 % leads to an excessive increase in the viscosity of the ice cream mixture and, as a result, complicates its saturation with air during freezing. As can be seen in Fig. 3 (sample № 4), in some places there are gaps at the junction of air bubbles, which further adversely affects the consistency of the product.

In order to study the taste properties of experimental samples of acidophilic whey ice cream with beta-glucan and without it, an organoleptic evaluation was performed. The results of organoleptic evaluation of ice cream are shown in Table 4.

Table 4.

Organoleptic evaluation of acidophilic whey ice cream with beta-glucan and without (control)

Indicator	Sample №				
	Control	**1**	**2**	**3**	**4**
Color	Light yellow,		Yellow,		Saturated yellow,
	uniform throughout the mass				
Taste and smell	Too sweet taste with a slight sourness, with noticeable ice crystals		Sweet taste with a slight sourness	Moderately sweet taste with a slight sourness	Moderately sweet taste with a slight sourness and extraneous aftertaste
	without foreign odors				
Consistence	Homogeneous mass with ice crystals, that melts quickly	Homogeneous mass with single ice crystals that melt quickly	Homogeneous, whipped mass	Homogeneous, creamy mass	Too dense mass

Quantitative assessment of organoleptic characteristics of ice cream was expressed on a 10-point scale and is presented in Figure 4.

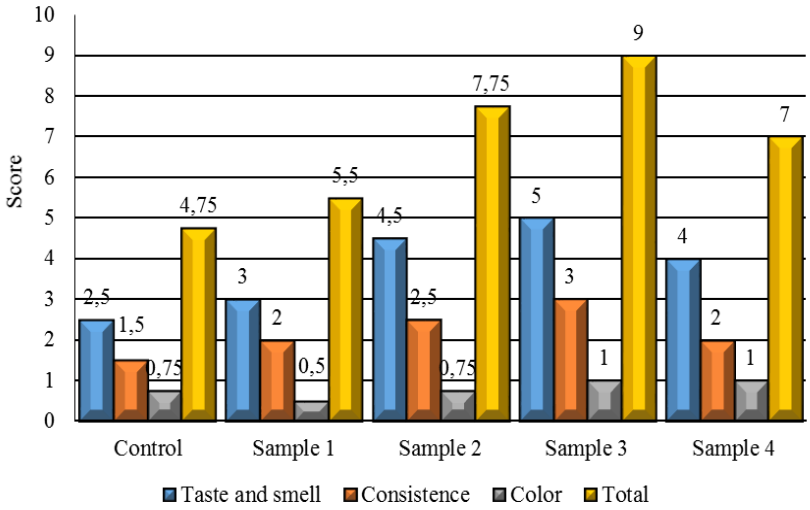


Fig. 4 - Organoleptic evaluation of ice cream on a scale

From the above data of organoleptic evaluation, it can be concluded that the dose of beta-glucan at 0.75 % provides the optimal combination of physicochemical and organoleptic parameters of acidophilic-whey ice cream, which allows to obtain a product with excellent consumer properties.

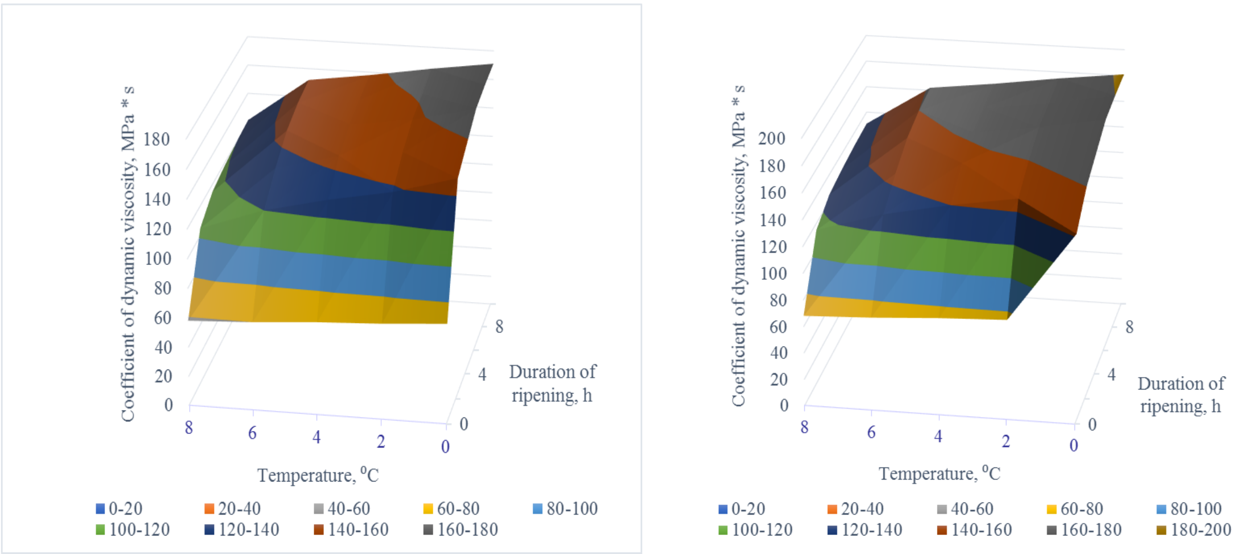
Investigation of the features of structuring mixtures of low-fat ice cream with beta-glucan

At the last stage of scientific research, the effect of oat beta-glucan on the structuring of ice cream mixes was studied. The control mixture and the mixture with the addition of beta-glucan in the amount of 0.75 %, which was selected as the most technologically feasible according to the results of the previous stage of the experiment.

Since the recommended values of the dynamic viscosity coefficient of milk ice cream mixtures are not less than 140 MPa*s [23], this minimum allowable value was chosen as a criterion of efficiency when studying the process of structuring mixtures with beta-glucan.

To establish rational modes of maturation of mixtures of the developed type of ice cream, the values of effective viscosity were measured at variable parameters: at temperatures in the range of 0…8 ºC in steps of 2 ºC; the duration of ripening was varied in the range from 0 to 10 hours in steps of 2 hours.

The dependence of the dynamic viscosity of the control and test ice cream mixes on the temperature and duration of ripening is illustrated in Figure 5.



a b

Fig. 5 - Dynamic viscosity of ice cream mixes under variable ripening modes: a - control mix, b - mix of new type of ice cream (P ≥ 95%, n = 3).

According to fig. 5, rational modes of ripening of acidophilic-whey ice cream mixtures were established.

Thus, the achievement of the minimum required value of the dynamic viscosity at 0 ºC for control was observed after 2 h, and the mixture of acidophilic-whey ice cream with oat beta-glucan was already structured without aging, immediately after cooling. In the case of compliance with the recommended temperature from 2 to 6 ºC, the duration of exposure to the control mixture of ice cream should be at least 4 hours, and for the mixture of a new type of ice cream - at least 2 hours.

It is proved that it is possible to reduce the duration of ripening of ice cream of the developed composition by 2 hours, compared to the control sample of the classic composition, which will be taken into account in the technological scheme of its production.

For both samples, the ripening temperature of 8 ºC does not allow to reach the recommended value of the dynamic viscosity of ice cream mixes.

4. Conclusion

For use in acidophilic whey low-fat ice cream, technologically effective oat beta-glucan of the trademark «AMULAN» was chosen.

Beta-glucan «AMULYN» in the amount of 0.75 % increases the overrun of ice cream more than twice compared to the control sample without beta-glucan, as well as improves organoleptic performance, increases resistance to melting and ensures uniform distribution of the air phase in the finished product.

Beta-glucan in the amount of 0.75 % significantly affects the coefficient of dynamic viscosity of ice cream mixes, which allows to reduce by 2 hours the ripening of such mixes with beta-glucan.

The prospect of further research is to determine the foaming properties of oat beta-glucan in order to explain the effect of "cluster formation" in the air phase of ice cream, which was detected during microscopy.

5. Acknowledgments

The work was performed at the National University of Food Technologies within the state research «Implementation of resource-saving methods of modification of functional and technological characteristics of whey in the technology of food products» (state registration number: № 0120U100868) and «Scientific substantiation of resource-efficient food technologies, enriched with polyfunctional ingredients» (state registration number: № 0120U102556).

6. References

[1]. A. SOLOMON, Development of technology for fermented sour milk desserts enriched with bifidobacteria and biologically active substances, 15 (102), *Colloquium-journal*, (2021), 61-64. https://doi.org/10.24412/2520-6990-2021-15102-62-64.

[2]. M. GARCÍA-BURGOS, J. MORENO-FERNÁNDEZ, M. J. ALFÉREZ, J. DÍAZ-CASTRO, I. LÓPEZ-ALIAGA, New perspectives in fermented dairy products and their health relevance. 72, *Journal of Functional Foods*, (2020), 104059. https://doi.org/10.1016/j.jff.2020.104059.

[3]. J. R. WILBURN, E. P. RYAN, Fermented foods in health promotion and disease prevention: An overview. *Fermented foods in health and disease prevention*, (2017), 3-19. https://doi.org/10.1016/B978-0-12-802309-9.00001-7.

[4]. M. I. TORINO, G. FONT DE VALDEZ, F. MOZZI, Biopolymers from lactic acid bacteria. Novel applications in foods and beverages. 6, *Frontiers in microbiology*, (2015), 834. https://doi.org/10.3389/fmicb.2015.00834.

[5]. A. BASCHALI, E. TSAKALIDOU, A. KYRIACOU, N. KARAVASILOGLOU, A. L. MATALAS, Traditional low-alcoholic and non-alcoholic fermented beverages consumed in European countries: A neglected food group. 30 (1), *Nutrition Research Reviews, (2017),* 1-24. https://doi.org/10.1017/S0954422416000202.

[6]. R.H. Davidson, S.E. Duncan, C.R. Hackney, W.N. Eigel, J.W. Boling, Probiotic culture survival and implications in fermented frozen yogurt characteristics. 83 (4), *Journal of dairy science*, (2000), 666–673. https://doi.org/10.3168/jds.S0022-0302(00)74927-7.

[7]. GOST 32929-2014 (Mezhgosudarstvennyj standart) «Morozhenoe kislomolochnoe. Tehnicheskie uslovija» [Fermented ice cream. Specifications] (in Russian).

[8]. Tipova tehnologichna instrukcija z virobnictva moroziva molochnogo, vershkovogo, plombiru; plodovo-jagidnogo, aromatichnogo, shherbetu, l'odu; moroziva z kombinovanim skladom sirovini [Typical technological instructions for the production of ice cream: milk, cream, plombir, fruit and berry, aromatic, sherbet, ice, with a combined composition of raw materials]: TTI 31748658-1-2007 do DSTU 4733:2007, 4734:2007, 4735:2007. Kiïv: Asociacija ukraïns'kih virobnikiv «Ukraïns'ke morozivo ta zamorozheni produkti». 2007. 100 s (in Ukrainian).

[9]. J. CHENG, Y. MA, X. LI, T. YAN, J. CUI, (2015). Effects of milk protein-polysaccharide interactions on the stability of ice cream mix model systems. 45, *Food Hydrocolloids*, (2015), 327-336. https://doi.org/10.1016/j.foodhyd.2014.11.027.

[10]. R. K. GORAYA, M. SINGLA, U. BAJWA, A. KAUR, S. PATHANIA, Impact of sodium alginate gelling and ingredient amalgamating order on ingredient interactions and structural stability of ice cream. 147, *LWT*, (2021), 111558. https://doi.org/10.1016/j.lwt.2021.111558.

[11]. R.B. MENESES, M.S. SILVA, M.L.G. MONTEIRO, M.H.M. ROCHA-LEÃO, C.A. CONTE-JUNIOR, Effect of dairy by-products as milk replacers on quality attributes of ice cream. 103 (11), *Journal of Dairy Science*, (2020), 10022-10035. https://doi.org/10.3168/jds.2020-18330.

[12]. A. AHMAD, F.M. ANJUM, T. ZAHOOR, H. NAWAZ, Z. AHMED, Extraction and characterization of β-d-glucan from oat for industrial utilization. 46 (3), *International journal of biological macromolecules*, (2010), 304–309. https://doi.org/10.1016/j.ijbiomac.2010.01.002.

[13]. D. EL KHOURY, C. CUDA, B. L. LUHOVYY, G. H. ANDERSON, Beta glucan: health benefits in obesity and metabolic syndrome. *Journal of nutrition and metabolism*, (2012), 851362. https://doi.org/10.1155/2012/851362.

[14]. Z. BURKUS, F. TEMELLI, (2000). Stabilization of emulsions and foams using barley β-glucan. 33, *Food Research International*, (2000), 27–33. https://doi.org/10.1016/S0963-9969(00)00020-X.

[15]. A. M. H. ABDEL-HALEEM, R. A. AWAD, Some quality attributes of low-fat ice cream substituted with hulless barley fl our and barley β-glucan. 52 (10), *Journal Food Science & Technology*, (2015), 6425–6434. https://doi.org/10.1007/s13197-015-1755-x.

[16]. M. ALJEWICZ, E. TONSKA, J. JUSKIEWICZ, G. CICHOSZ, The influence of product acidity and β-glucans isolated from various sources in the mineral composition and the mechanical and microstructural properties of the femur in growing Wistar rats. 44, *Journal of Functional Foods*, (2018), 191–200. https://doi.org/10.1016/j.jff.2018.02.035.

[17]. V. SAPIGA, G. POLISCHUK, M. BUNIOWSKA, I. SHEVCHENKO, T. OSMAK, Enzymatic destruction of protopectin in vegetable raw materials to increase its structuring ability in ice cream. 10 (4), *Ukrainian Food Journal*, (2021), 691–702. https://doi.org/10.24263/2304-974X-2021-10-4-5.

[18]. M. SHOUKAT, A. SORRENTINO, (2021), Cereal β-glucan: a promising prebiotic polysaccharide and its impact on the gut health. 56 (5), *International Journal of Food Science & Technology*, 2088-2097. https://doi.org/10.1111/ijfs.14971.

[19]. M. ALJEWICZ, A. FLORCZUK, A. DĄBROWSKA, Influence of β-Glucan Structures and Contents on the Functional Properties of Low-Fat Ice Cream During Storage. 70 (3), *Polish Journal of Food and Nutrition Sciences*, (2020), 233-240. https://doi.org/10.31883/pjfns/120915.

[20]. F. SHIBANI, S. ASADOLLAHI, M. ESHAGHI, The effect of beta-glucan as a fat substitute on the sensory and physico-chemical properties of low-fat ice cream. 1 (1), *Journal of Food Safety and Processing*, (2021), 71-84.

[21]. O.V. KOCHUBEJ-LITVINENKO, A.V. TIMCHUK, T.G. OSMAK, Tehnologiї konservuvannja ta zberigannja molochnih produktiv: laboratornij praktikum dlja zdobuvachiv osvitn'ogo stupenja «Bakalavr» special'nosti 181 «Harchovi tehnologiї» osvitn'oprofesijnoї programi «Harchovi tehnologiї ta inzhenerija» dennoї formi navch. [Technologies of preservation and storage of dairy products: laboratory workshop for applicants for the degree of "Bachelor" specialty 181 "Food Technology" of educational and professional program "Food Technology and Engineering" of full-time education], K.: NUHT, (2020), 93 s (in Ukrainian).

[22]. M. KLIMENKO, I. KIShEN"KO, O. GREK, Viznachennja vodo- ta zhiroutrimuval'noї zdatnosti harchovoї sirovini [Determination of water holding and fat binding capacity of food raw materials]. 3, Tavrijs'kij visnik, Herson, (1998), S. 176-177 (in Ukrainian).

[23]. T. P. ARSEN"EVA, Spravochnik tehnologa molochnogo proizvodstva. T.4. Morozhenoe [Handbook of dairy production technologist. V. 4. Ice cream], SPb: GIORD, (2003), 184s (in Russian).

[24]. G.E. POLISHUK, Formuvannja skladnih dispersnih sistem moroziva molochnogo z natural'nimi komponentami: dis. … doktora tehn. nauk: 05.18.04 «Tehnologija m`jasnih, molochnih produktiv ta produktiv z gidrobiontiv [Formation of complex dispersed systems of milk ice cream with natural components: dis. … Doctor of technical sciences: 05.18.04 «Technology of meat, dairy products and products from hydrobionts]. K., (2013), 248 s (in Ukrainian).

[25]. G. N. KRUS", A. M. ShALIGINA, Z. V. VOLOKITINA, Metody issledovanija moloka i

molochnyh produktov [Methods of research of milk and dairy products]. M.: Kolos, (2002), 368 s (in Russian).
[26]. G. POLISCHUK, O. KOCHUBEI-LYTVYNENKO, T. OSMAK, U. KUZMYK, O. BASS, A. MYKHALEVYCH, V. SAPIGA, Scientific explanation of composition of acidophilic-whey ice cream, enriched with protein. 20 (1), *Food and Environment Safety*, 2021, 13-20.
[27]. V. SAPIGA, G. POLISCHUK, T. OSMAK (FEDCHENKO), A. MYKHALEVYCH, M. MASLIKOV, Scientific explanation of the composition and technological modes of manufacture of dairy ice cream with vegetable puree. 7 (1), *Ukrainian Journal of Food Science*, (2019), P. 83-91. https://doi.org/10.24263/2310- 1008-2019-7-1-10.
[28]. S. Berggren, Water holding capacity and viscosity of ingredients from oats: the effect of b-glucan and starch content, particle size, pH and temperature (Dissertation), (2018), Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:lnu:diva-70544.
[29]. S. KARP, J. WYRWISZ, M. A. KUREK, The impact of different levels of oat β-glucan and water on gluten-free cake rheology and physicochemical characterisation. 57 (10), *Journal of food science and technology*, (2020), 3628–3638. https://doi.org/10.1007/s13197-020-04395-5.
[30]. A. M. H. ABDEL-HALEEM, R.A. AWAD, Some quality attributes of low-fat ice cream substituted with hulless barley fl our and barley β-glucan. 52 (10), *Journal Food Science & Technology*, (2015), 6425–6434. https://doi.org/10.1007/s13197-015-1755-x.