Effect of natural ingredients on the structural-mechanical and physicochemical properties of ice cream mixes

Victoria Sapiga[1], Galina Polishchuk[1], Marta Tomczyńska-Mleko[2], Stanisław Mleko[2], Konrad Terpiłowski[3], Salvador Pérez-Huertas[4]

1 - National University of Food Technologies, Kyiv, Ukraine
2 - University of Life Sciences in Lublin, Lublin, Poland
3 - Maria Curie Skłodowska University, Lublin, Poland
4 – University of Granada, Granada, Spain

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Corresponding author:

Victoria Sapiga
E-mail: vika.sapiga1904@ukr.net

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Abstract

Introduction. The purpose of the work was to study the functional and technological properties of natural ingredients in low-calorie ice cream as potential structure stabilizers and fat substitutes.

Materials and methods. Ice cream mixes with β-glucans from oats and yeast, with fermented and non-fermented pectin-containing beet purée were studied. The viscosity of the mixes was measured on an ultrasonic viscometer Unipan type 505, viscoelastic properties on a Kinexus lab+ device, surface tension on a KSV Sigma 700 tensiometer, water activity on an AWMD-10 device.

Results and discussion. According to the results of the research, it was established that oat β-glucan shows greater technological activity in the composition of ice cream mixes with a low fat content (2%), compared to β-glucan from yeast, including the combination with soluble pectin of vegetable purée. Fermented beet purée, which contains at least 1.0% soluble pectin, has the greatest impact on the structural and mechanical characteristics of low-fat ice cream mixes in all its combinations with other structuring ingredients. Ice cream mixes with oat β-glucan and vegetable purée at lower frequencies of measurement of viscoelastic properties show high elasticity, but after exceeding a certain frequency value, the structure is destroyed and the mixes show greater viscosity than elasticity, which will allow more intense saturation of the mixes with air under freezing. A correlation between viscosity, water activity and surface tension of low-fat ice cream mixes was revealed, which is explained by intermolecular interaction between macromolecules of hydrocolloids and active binding of free water by a complex of low- and high-molecular compounds. An alternative substitute for the Vianoks C45 stabilization system (mono- and diglycerides of fatty acids + polysaccharides) in the amount of 0.5% in low-fat ice cream is a complex of natural ingredients - oat β-glucan and fermented beetroot purée in amounts of 0.5 and 15%, respectively.

Conclusions. β-glucan from oat and fermented vegetable puree reveal synergism between β-glucan macromolecules and vegetable pectin to form complex three-dimensional structures in low-fat ice cream mixes that significantly improve the viscoelastic characteristics, surface tension, and water activity of the obtained ice cream mixes.

Introduction

In modern nutrition, there is an increased consumer demand for low-calorie products. Meanwhile, ice cream of classic types is a product with a high fat content (10–16%). Therefore, there is a high demand on production of new types of low-fat or non-fat ice cream (McGhee et al., 2015; Wang et al., 2022, Yilsay et al., 2006). An ice cream is treated as a low-fat product when it contains below 5% of fat (Azari-Anpar et al., 2017).

In the process of modifying ice cream recipes, the main task is to obtain a product with a characteristic creamy consistency and high resistance to melting, which is ensured by maintaining a certain balance between the content of free and bound water, the specified values of the cryoscopic temperature and other physicochemical parameters (Raheem et al., 2021).

The ice cream structure is polydisperse and can be identified as a three-component foam consisting of a network of fat globules and ice crystals dispersed in a highly viscous aqueous phase. A three-dimensional network of partially aggregated fat globules is formed during the freezing of ice cream mixes. Such a network of fat globules surrounds the air bubbles, stabilizes the air phase, and thus improves the resistance to melting of the ice cream (Granger et al., 2005). During the production process of low-fat ice cream, the network of fat globules can be either disrupted or completely absent, which negatively affects the texture of the product (Silva Junior et al., 2011). Therefore, fat in ice cream performs important technological functions, in particular, it ensures the formation of a creamy consistency, stabilizes the foam structure, increases the resistance to melting, and counteracts the excessive growth of ice crystals (Zhang et al., 2018). Instead, the absence of fat or its low content is the reason for the appearance of a coarse crystalline structure, low overrun, low resistance to melting, and "empty" taste (Akalın et al., 2008; Jardines et al., 2020).

This problem prompts scientists to search for new natural ingredients and compositional systems capable of compensating for the lack of fat in ice cream.

Current state of the problem

According to many authors, the energy value of food products can be reduced by partially replacing fat with polysaccharides that effectively mimic its presence (Javidi et al., 2016). The main function of these compounds is the formation of sensory properties characteristic of full-fat ice cream. Polysaccharides, including guar gum (Javidi et al., 2018), maltodextrin and polydextrose (Güzeler et al., 2011), fructooligosaccharides (Akalın et al., 2008), dietary fibers from cereals and citrus fruits (Soukoulis et al., 2010), starch (Sharma et al., 2017) and β-glucans (Abdel-Haleem and Awad, 2015) are most widely used in ice cream as fat substitutes. Among the polysaccharides listed above, β-glucans are not only capable of simulating the presence of fat, but also exhibit high foaming and stabilizing ability. β-glucans also have positive effects on human health, reducing the risk of diet-dependent diseases such as hyperinsulinemia, hyperlipidemia, weakened immunity (Kanagasabapathy et al., 2013), and osteoporosis (Aljewicz et al., 2018).

β-glucans are natural and non-starch polysaccharides (Nishantha et al., 2018) found in algae, yeast, some bacteria, cereals (wheat, oats, barley), seaweed, and fungi (Du et al., 2019; Ege et al., 2021; Şimşekli et al., 2015). The structure and physicochemical properties of β-glucans, in particular water solubility and structuring ability, depend on the source of origin (Lattimer et al., 2010). Thus, the structure of (1-3) β-glucan isolated from *Euglena gracilis*, a single-celled microalgae, is linear. A linear structure is also characteristic of (1-3) β-glucan and (1-4) β-glucan isolated from barley. (1-6) β-glucan and (1-3) β-glucan isolated from mushroom *Schizophyllum commune* have both linear and branched structures (Seo et al., 2019). It is known that β-glucans with a high molecular weight are more effective biologically compared to β-glucans with a low molecular weight. However, Lei et al. (2015), found that β-glucans obtained from yeast with a low molecular weight are better immunostimulators and antioxidants compared to β-glucans with a high molecular weight. It is also known that β-glucans with a short chain have greater mobility and the ability to form low-energy bonds with active groups of other macromolecules with subsequent possible rearrangement of the formed associates, which is widely used to obtain pseudoplastic food systems (Mishra, 2020). Therefore, it is obvious that β-glucans of various origins have a positive effect on the physicochemical and sensory properties of structured food products. However, there is no comparative analysis of the functional and technological properties of β-glucans of different origins in food systems with the same chemical composition.

β-glucans have not yet been widely used in food technologies (Khanjani et al., 2022), which is due to insufficient awareness of scientists and manufacturers about their functional and technological properties. Instead, Rezaei et al. (2019) proved the expediency of using β-glucan in the amount of 1-2% in the composition of frozen soy yogurt, the viscosity and overrun of which increased while reducing the resistance to melting. To improve the dimensional stability of the ice cream, it is recommended to prolong the exposure of the mix at low positive temperatures before freezing.

Aljewicz et al. (2020) investigated the effect of highly purified (1-3)(1-4) and (1-3) β-glucans in amounts of 0.5 and 1.0% on the physicochemical characteristics of low-fat ice cream. A significant influence of the structure of β-glucans on the consistency and viscosity index, fluidity, cohesiveness and hardness of ice cream was established. The use of (1–3)(1–4) β-glucan led to a significant decrease, and (1–3) β-glucan to an increase in the hardness of ice cream, although both types of β-glucans effectively mimic milk fat content. Abdel-Haleem and Awad (2015) proved the possibility of replacing 0.4% of carboxymethyl cellulose in low-fat ice cream with the same amount of barley β-glucan, which significantly increased the air content in the product with slight thickening of the mix.

The given research results proved that β-glucans are effective multifunctional ingredients in ice cream, in particular, they structure, increase overrun, affect resistance to melting , and imitate the fat content in the product. However, the authors did not investigate the physical characteristics of the aqueous phase of ice cream with β-glucans. There are also no data on the possibility of complex application of polysaccharides of different types and origins.

Currently, ice cream with pectin-containing raw materials (vegetables, berries, fruits and their processing products) is particularly popular as a multifunctional ingredient (Alfaro-Viquez et al., 2018). Pectin substances of plant raw materials (Cornelia et al., 2019; Koxholt et al., 2001) show foaming, emulsifying and structuring ability. High stabilization of the structure of ice cream is usually achieved by increasing the content of soluble pectin in pectin-containing raw materials (Bezusov et al., 2008) by thermoacidic or enzymatic hydrolysis of protopectin contained in puréed fruits and vegetables (Matsko, 2016; Sukhenko et al., 2012). The stabilizing ability of pectins depends on their molecular weight, structure and content in food systems and physicochemical properties of these systems (Fraeye et al., 2009; 2010).

A number of scientists have proven the possibility of replacing pectin with β-glucan in yogurts (Rinaldi et al., 2015; Sahan et al., 2008), milk gels (Sharafbafi, 2012) and low-fat ice cream (Brennan et al., 2002; Schmidt, 2022). However, the structuring ability of β-glucans in the presence of pectin, particularly in low-fat ice cream, has not been studied. Also, the effectiveness of the functional and technological properties of β-glucans of various origins, in particular their influence on water activity and surface tension in the aqueous phase of low-fat ice cream mixes, has not been analyzed. The above confirms the relevance of conducting this research.

The purpose of the research is to study the functional and technological properties of natural ingredients in low-calorie ice cream as potential structure stabilizers and fat substitutes.

The objectives of the study:

- to conduct a comparative analysis of the structuring ability of β-glucans of different origins in milk ice cream mixes;
- to investigate the effect of β-glucans on water activity and surface tension of low-fat ice cream;
- to identify the most effective option of using natural structuring ingredients for obtaining ice cream with low fat content, including pectin-containing vegetable filler.

Materials and methods

Preparation of experimental samples of mixes for the production of ice cream

Milk and milk-vegetable mixes were obtained by sequential mixing of the recipe ingredients at a temperature of 40-45 ºC, with their subsequent pasteurization at a temperature of 85±2 ºC for 2–3 minutes. After that, the mixes were homogenized at a speed of 15 000 rpm using an Unidrive X1000 laboratory homogenizer (Ingenieurbüro CAT M. Zipperer), cooled to a temperature of 4±2 ºC, vegetable purées were added (if necessary), mixed for 1–2 min and stored for 12 hours.

Vegetable purée was obtained by grinding blanched pieces of beet using a laboratory homogenizer with cutting knives at a speed of 15 000 rpm for 3 min to obtain a purée with a particle size of no more than 1-2 mm. The vegetable purée was divided into two parts. One part was left unchanged, and the other was fermented with Pectolad brand pectinase (Enzym, Ukraine) with a pectolytic activity of at least 30 units/g. The enzymolysis conditions were as follows: mass fraction of pectinase, 0.1%; temperature, 40 ºC; duration, 2 hours; active acidity, 4.0 units of pH. The active acidity of vegetable purées was adjusted with the help of citric acid. After the end of enzymolysis, the enzyme was inactivated by the vegetable purée heating to a temperature of 90 ºC without holding. The mass fraction of soluble pectin in fermented purée was at least 1.06% (Sapiga et al., 2021).

Chemical composition of mixes for the production of ice cream:

- mass fraction of total solids, 27.5%;
- mass fraction of fat, 2.0%;
- mass fraction of milk solids non-fat, 10.0%;
- mass fraction of Vianoks C45 stabilization system (composition: mono- and diglycerides of fatty acids (E471), guar gum (E412), locust bean gum (E410), carrageenan (E407), 0.5%;
- mass fraction of sugar, 15.0%;
- mass fraction of β-glucan from oats 70%, (AMULYN, China), 0.5%;
- mass fraction of β-glucan from yeast (*Saccharomyces cerevisiae*) 70%, (GOLDCELL, Brazil), 0.5%;
- mass fraction of table beet purée (non-fermented and fermented), 15.0%.

The mass fraction of β-glucan of 0.5% in the composition of ice cream mixes was chosen in accordance with the recommendations of Aljewicz et al. (2020).

A total of 8 mix samples were prepared:

- **control (C)**: mix of classic composition with Vianoks C45 stabilization system;
- **sample 1**: mix with β-glucan from oats;
- **sample 2**: mix with β-glucan from yeast;
- **sample 3**: mix with Vianoks C45 stabilization system and unfermented vegetable purée;
- **sample 4**: mix with Vianoks C45 stabilization system and fermented vegetable purée;
- **sample 5**: mix with β-glucan from oats and unfermented vegetable purée;
- **sample 6**: a mix with β-glucan from oats and fermented vegetable purée;
- **sample 7**: mix with β-glucan from yeast and unfermented vegetable purée;
- **sample 8**: mix with β-glucan from yeast and fermented vegetable purée.

Research methods

The viscosity of the studied mixtures (mPa×s×g×cm^{-3}) was measured using an ultrasonic viscometer Unipan type 505 (UNIPAN, Warsaw, Poland). Before each measurement, the level of the ultrasonic signal was checked. The measuring probe of the magnetostrictive vibrator was completely placed in the mix. The induced ultrasonic waves were damped by the test material, and the results were displayed as the product of viscosity and density in units of mPa × s × g × cm^{-3}. The viscosity was measured for 10 min at 20 °C (Tomczyńska-Mleko et al., 2014).

The viscoelastic behavior of the test samples was measured using plate geometry on a Kinexus lab+ device (Malvern, UK). Two serrated plates with a diameter of 40 mm (PU40X SW1382 SS and PLS40X S2222 SS, plate–plate configuration) were used to minimize the slippage of the mixes, and the gap between them was 2 mm. Tests were performed in the range of 0.1–10.0 Hz at a strain of 0.01%, and changes in the storage (G') and loss (G'') moduli, as well as the phase angle (d) were recorded. For comparative analysis of rheological differences between samples, the specified parameters were recorded at a frequency of 1 Hz. The research was carried out at a temperature of 25 ºC. The measurement results were registered on a computer in the Kinexus Malvern – rSpace program (Nastaj et al., 2020).

Surface tension was measured using a tensiometer KSV Sigma 700 (KSV Instruments, Ltd., Finland) eqipped with a platinum de Nooy ring. The dynamic surface tension was calculated using the Sigma 700 Force software complex. Before each analysis, the de Nooy ring was cleaned with distilled water and dried under a flame (Flook et al., 2022).

Water activity (aw) was measured using an AWMD-10 water activity meter (NAGY, Gäufelden, Germany) with an accuracy of ±0.001 aw unit. Before measurement, the device was calibrated according to a special humidity standard (95% HR). Measurements were made at a temperature of 20 ºC (Małecki et al., 2020).

Charts were drawn using Microsoft Excel 2016, data processing was carried out in Statistics 10.

Results and discussion

At the first stage, the structural and mechanical characteristics of ice cream mixes were investigated.

The viscosity of ice cream mixes is shown in Figure 1.

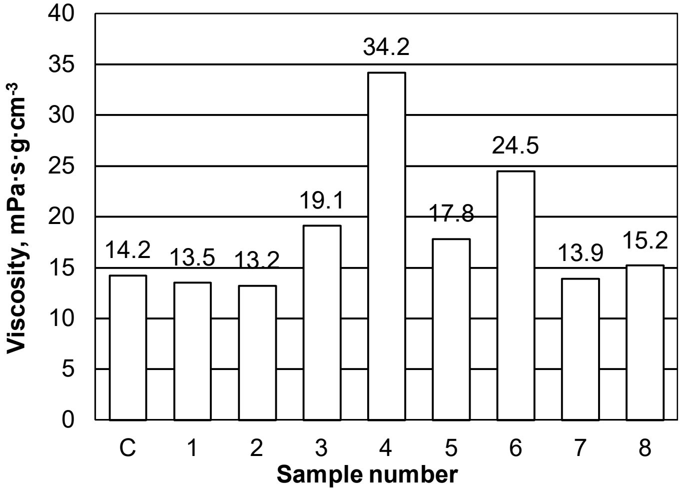

Figure 1. Viscosity of ice cream mixes with structuring ingredients.
Samples:

(C) control – mix of classic composition with Vianoks C45 stabilization system;
1 – mix with β-glucan from oats;
2 – mix with β-glucan from yeast;
3 – mix with Vianoks C45 stabilization system and unfermented vegetable purée;
4 – mix with Vianoks C45 stabilization system and fermented vegetable purée;
5 – mix with β-glucan from oats and unfermented vegetable purée;
6 – mix with β-glucan from oats and fermented vegetable purée;
7 – mix with β-glucan from yeast and unfermented vegetable purée;
8 – mix with β-glucan from yeast and fermented vegetable purée.

The viscosity of the control sample (C) was taken as a reference for conducting a comparative analysis of the effectiveness of the structuring ability of β-glucans from oat and yeast, both individually and in combination with pectin-containing vegetable purées. It was established that the structuring ability of β-glucans is quite high, but somewhat lower, compared to the stabilization system. β-glucan from oat in all combinations structures was more effective than β-glucan from yeast. This applies both to mixes with β-glucans and in the case of their combination with vegetable purées, which is explained by the different molecular structure and physicochemical properties of these polysaccharides. Thus, the chemical structure of β-glucan from oat is an unbranched polysaccharide formed from glucopyranose residues connected by β-(1-4) bonds and isolated β-(1-3) bonds. Oat β-glucan has a very high solubility in water (Synytsya et al., 2014). The chemical structure of β-glucan from the yeast *Saccharomyces cerevisiae* is represented by a complex of linear β-(1-3) chains with residual straight chains connected to them by long branches connected through β-(1-6) bonds (Aboushanab et al., 2019; Suzuki, et al., 2021). Therefore, it can be assumed that the high solubility and mobility of linear macromolecules of oat β-glucan in an aqueous environment with the formation of numerous low-energy bonds provide more effective structuring of ice cream mixes compared to β-glucan from yeast.

In the presence of vegetable purées in all samples, the viscosity significantly increases, which is explained by the probable interaction between macromolecules of β-glucans and pectin with the formation of complex three-dimensional structures. It should be noted that the greatest manifestation of such interaction was in case of combination of the Vianoks C45 stabilization system with pectin-containing purées. A greater manifestation of this effect is characteristic of fermented purée with an increased content of soluble pectin, which is quite understandable. The same pattern is observed for samples with vegetable purées that contain β-glucans.

Figure 2 and 3 show viscoelastic behavior of the test samples. The control sample with the stabilizing structuring system Vianoks C45 (mono- and diglycerides of fatty acids, guar gum, locust bean gum and carrageenan) is a weak gel (Figure 2, 3). The complex viscosity of the sample decreases with an increase in the frequency, and then increases (U-shaped), which is associated with a decrease in the tangent of the phase angle with an increase in frequency. The share of elastic properties in relation to viscous properties is increasing (Tomczyńska-Mleko et al., 2016). Probably the presence of several compounds with long molecular chains causes increased friction between them and corresponding contacts at higher frequencies. At very low frequency, the dispersion behaves as a predominantly viscous material (phase angle tangent greater than 1). However, when the frequency increases, the material increases its elastic properties (the tangent of the phase angle decreases) due to the interaction between macromolecules and their entanglement (Zhang, 2010). Shah et al. (2020) found that complex viscosity decreased with increasing frequency, but at higher frequency, complex viscosity increased. At a lower frequency, the dispersion behaves as a pseudo-plastic material, but at a higher frequency, a rheopectic behavior is observed.

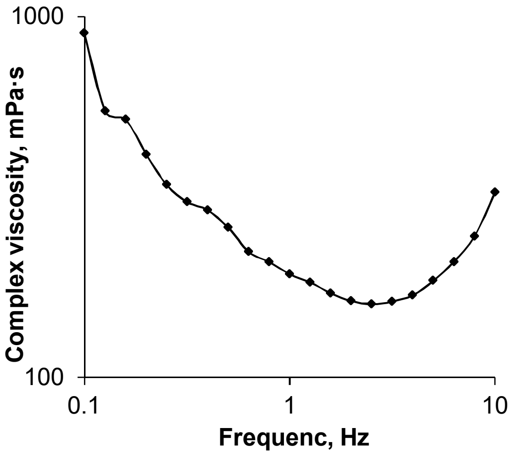

Figure 2. Complex viscosity of the control sample at variable frequency

For sample No1 with oat β-glucan, a characteristic intersection of the G' and G" graphs is observed (Figure 4), which indicates even greater entanglement of the chains. Agbenorhevi et al. (2011) found that the mechanical spectra of the investigated oat β-glucan isolates were typical of solutions of entangled biopolymers. Atomic force microscopy images showed the formation of β-glucan aggregates connected by individual polymer chains, heterogeneously scattered throughout the dispersion. Sample No 2 with yeast β-glucan behaved similarly.

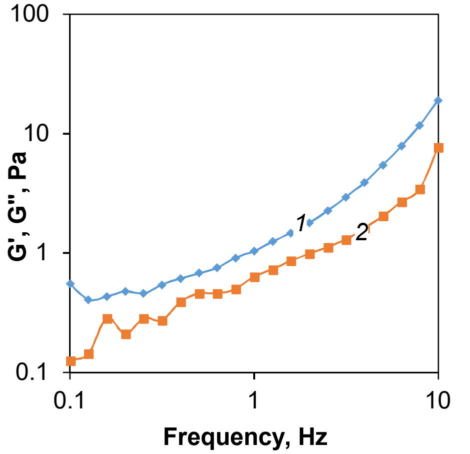

Figure 3. Ratio of the shear modulus (elastic component) to the shear modulus (viscous component) of the control sample at variable frequency

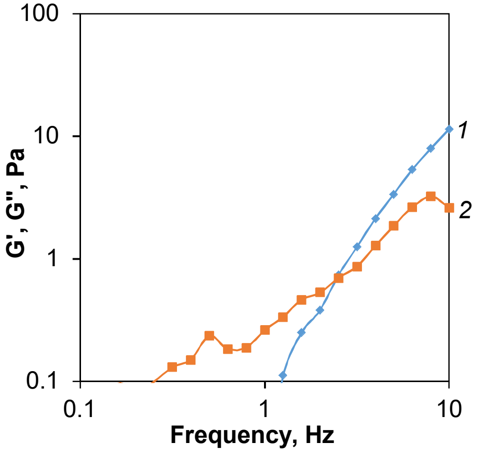

Figure 4. Ratio of shear modulus (elastic component) to shear modulus (viscous component) of sample No 1 at variable frequency

1 – Shear modulus (elastic component), Pa;
2 – Shear modulus (viscous component), Pa

Samples No3 and No4 are elastic materials, the viscosity of which decreases with frequency (Figure 5 and 6). The viscosity of this dispersion exceeds the viscosity of previous preparations, which is probably due to the addition of beet puree.

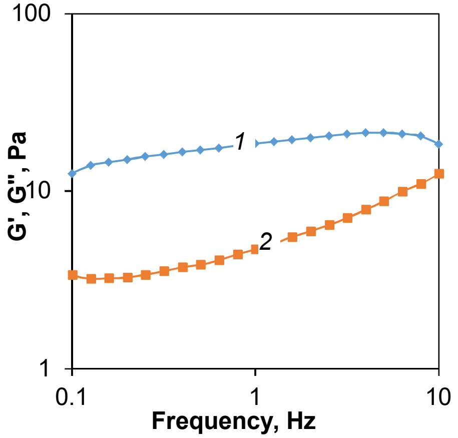

Figure 5. Ratio of the shear modulus (elastic component) to the shear modulus (viscous component) of sample No 3 at variable frequency

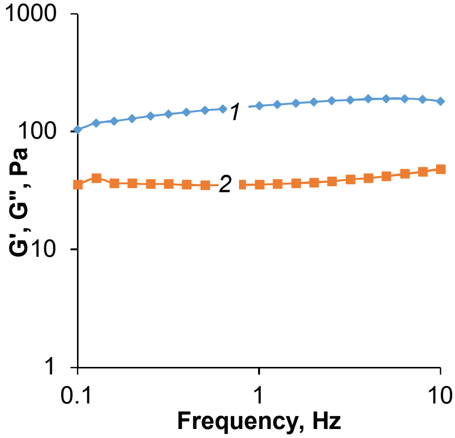

Figure 6. Ratio of the shear modulus (elastic component) to the shear modulus (viscous component) of sample No 4 at variable frequency

1 – Shear modulus (elastic component), Pa;
2 – Shear modulus (viscous component), Pa

Sample No 5 shows very interesting rheological properties (Figure 7). At lower frequencies, the sample is elastic. After exceeding a certain value of the frequency, the structure collapses, and the value of the shear modulus (elastic component) suddenly drops. The module values overlap, and the sample is more viscous than elastic. This is confirmed by the increasing values of the tangent of the phase angle. The detected effect is positive from a technological point of view, because during freezing of ice cream mixes, they are saturated with air, followed by a uniform redistribution of air bubbles throughout the entire volume of the product. This process is effective under the condition of reducing the degree of structuring of mixtures during intensive mechanical processing. Similar behavior is demonstrated by sample No 6.

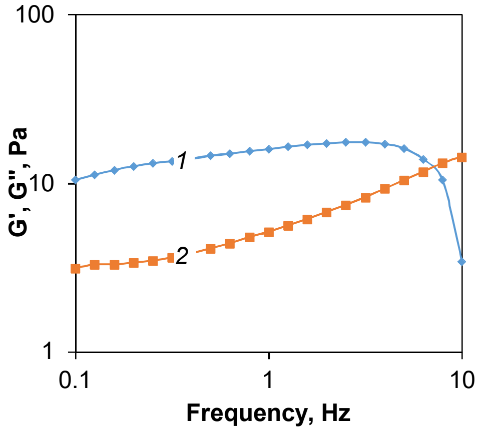

Figure 7. The ratio of the shear modulus (elastic component) to the shear modulus (viscous component) of sample No 5 at variable frequency:
1 – Shear modulus (elastic component), Pa;
2 – Shear modulus (viscous component), Pa

In use of different β-glucan from yeast with fermented and unfermented vegetable purée (samples No 7 and No 8), the structure of the samples did not deteriorate as a whole with increasing frequency.

The diagram in Figure 8 represents the correlation between storage modulus values reported at 10 Hz and ultrasonic viscosity. There is a strong linear correlation between these rheological properties (R^2 = 0.82). In previous studies, Tomczyńska-Mleko et al. (2022) found a linear correlation between complex modulus and ultrasonic viscosity (R^2 = 0.91), complex modulus and hardness (R^2 = 0.89), and ultrasonic viscosity and hardness (R^2 = 0.82). The highest correlation was found between the complex modulus and ultrasonic viscosity. The highest value of a correlation between complex modulus and ultrasonic viscosity was probably caused by the fact, that both methods used small strain measurements (Tomczyńska-Mleko et al., 2022).

At the next stage, to study the influence of structuring ingredients of different origin on the state of the aqueous phase of ice cream mixes, the water activity and surface tension of the control and experimental samples were determined (Table 1).

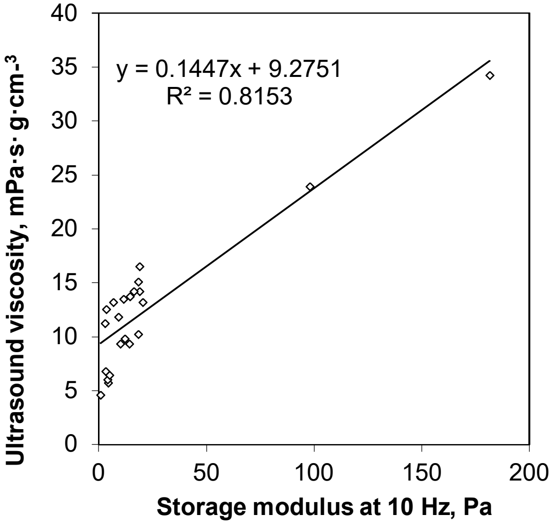

Figure 8. Correlation between ultrasonic viscosity and viscoelastic modulus at 10 Hz

Table 1
Water activity and surface tension of ice cream mixes with different structuring ingredients (P≥0.95; n=3)

Sample numbers of mixtures with structuring ingredients	Water activity, aw	Surface tension, mN/m
Control (Vianoks C45)	0.04±0.041	44.088±1.990
No1 (oat β-glucan)	0.947±0.042	46.621±1.444
No 2 (yeast β-glucan)	0.959±0.040	49.696±1.551
No 3 (Vianoks C45+non-fermented vegetable puree)	0.923±0.041	43.293±1.118
No 4 (Vianoks C45+fermented vegetable puree)	0.855±0.044	41.428±1.122
No 5 (oat β-glucan + non-fermented vegetable puree)	0.933±0.043	45.893±1.118
No 6 (oat β-glucan + fermented vegetable puree)	0.893±0.043	43.827±0.903
No 7 (yeast β-glucan + unfermented vegetable puree)	0.948±0.040	46.428±0.990
No 8 (yeast β-glucan + fermented vegetable puree)	0.940±0.043	43.928±1.505

According to the data given in Table 1, the correlation between the values of water activity and surface tension is traced. The lowest water activity and surface tension are observed for sample No 4 (combination of hydrocolloids and surface-active compounds of the Vianoks C45 stabilization system and soluble pectin in fermented vegetable purée). Among the samples that contain only natural structuring ingredients the closest to the control is sample No 6, in which the "β-glucan oat + fermented beetroot purée" complex exerts the most significant influence on the aqueous phase. This sample is an alternative substitute for the control sample, which contains mono- and diglycerides of fatty acids and high-value polysaccharides as part of the Vianoks C45 stabilization system. It should also be noted that the fermented vegetable purée itself has a rather significant effect on the specified physical characteristics of ice cream mixes in all its combinations with other structuring ingredients.

This is explained by the content in fermented vegetable purée of at least 1.0% of soluble pectin (Sapiga et al., 2021), which ensures its additional presence in mixtures in the amount of at least 0.15%.

It should also be noted that the structuring ability of the mix samples correlates to some extent with water activity, in particular, the maximally structured samples No 4 and No 6 showed the lowest water activity (0.855 and 0.893, respectively). The same effect was observed by Mazurkiewicz and Tomasik (2001) in solutions of sugar, salt, and glycerin, which allows controlling the activity of water in solutions with the required viscosity and vice versa.

Since viscosity and surface tension are determined by intermolecular bonds, we expected a positive correlation between these physical characteristics and found it in all samples. However, using the example of aqueous solutions of agar polysaccharides and starch-containing flour, Wei et al. (2014) found that with an increase in the viscosity of aqueous solutions, the surface tension was either the same as water or slightly lower. The authors explained this effect by assuming that internal friction, caused by the interaction between macromolecules of polysaccharides with numerous polar groups, affects viscosity more than surface tension. In our case, all samples were multicomponent mixes containing low-molecular water-soluble compounds (sucrose, lactose, salts) and high-molecular compounds (milk proteins, polysaccharides), and the control sample and samples No 3 and No 4 were emulsifiers (mono-, diglycerides of fatty acids), therefore the surface tension of the mixes was significantly different from that of water and correlated with the viscosity and activity of water.

Thus, based on the set of research results, it can be stated that the most promising for use in the composition of low-fat ice cream with natural ingredients is oat β-glucan in combination with fermented beetroot purée in the specified quantities of 0.5% and 15%, respectively.

Conclusions

1. Fermented beet purée containing at least 1.0% soluble pectin has the greatest impact on the structural and mechanical characteristics of low-fat ice cream mixes in all its combinations with other structuring ingredients. In turn, oat β-glucan shows greater technological activity compared to β-glucan from yeast, including when combined with soluble pectin of vegetable purée. Mixes of ice cream with oat β-glucan and vegetable purée at lower frequencies of measuring viscoelastic properties show elasticity, but after exceeding a certain frequency value, the structure is destroyed and the mixes show greater viscosity than elasticity.
2. The correlation between viscosity, water activity and surface tension of low-fat ice cream mixes was revealed, which is explained by the presence of a complex of low-molecular (sucrose, lactose, salts) and high-molecular compounds (proteins, polysaccharides) in multicomponent mixtures.
3. An alternative substitute for the Vianoks C45 stabilization system (mono- and diglycerides of fatty acids + polysaccharide complex) in the amount of 0.5% is a complex of natural ingredients - oat β-glucan and fermented beet pulp in amounts of 0.5 and 15%, respectively.
4. The perspective of further research is to optimize the ratio between structuring natural ingredients (oat β-glucan and fermented vegetable purée) to achieve appropriate values of ice cream quality indicators (overrun, resistance to melting, distribution of dispersed particles), including during storage.

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