Scifood
vol. 19, 2025, p. 128-144
https://doi.org/10.5219/scifood.11
ISSN: 2989-4034 online
https://scifood.eu

Received: 14.1.2025
Revised: 11.2.2025
Accepted: 12.2.2025
Published: 26.2.2025

Optimisation of the composition of мelon-based sorbets using simplex-centroid processing system

Bibipatyma Yerenova, Yuliya Pronina, Nikolay Penov, Rada Dinkova-Hadzhiyski, Nataliia Kondratiuk, Aigul Almaganbetova

ABSTRACT

Technology and formulation of various compositions of melon-based sorbets, enriched with additives of plant origin: fruits (apples, pears, plums, lemons), and vegetables (beetroot, red cabbage, sorrel leaves), were developed. Regression equations on the influence of formulation composition of three variants of melon-based sorbets on their sensory evaluation with high determination accuracy were derived. The coefficient of determination varies from 92.71% to 97.2%, which allows us to determine the zone where indicators have their maximum values. Using the simplex–centroid processing system the composition of melon-based sorbets was optimized, and their maximum sensory evaluation was determined with an optimal composition ratio: Zhelsiz Tunde – 50.6% of melon, 3% of beetroot, 6% of lemon and 25% of pears; Kokoray Shalgyn – 48.8% of melon, 3% of sorrel, 8% of lemon and 25% of apples; Kystyn Syzy – 46.8% of melon, 7% of red cabbage, 8% of lemon and 23% of plums. The developed compositions of melon-based sorbets were subjected to organoleptic evaluation using a scoring system from 1 to 10 points, and the reflecting surfaces were presented. The results confirm that using melon as the main raw material and enriching it with additives of plant origin allows for the preparation of functional, low-calorie dietary frozen desserts.

Keywords: melon, technology, optimization, simplex-centroid system, sensory evaluation

INTRODUCTION

Nowadays, frozen desserts are one of the most in-demand and popular food products. Nonetheless, the desserts present on the market do not contain important functional ingredients. Often, they have high energy value due to sugar and fat; synthetic colors and flavoring agents also dominate, which entails metabolic disorders, obesity, diabetes mellitus, and other concomitant diseases **[1]**.

Functional sorbets based on fruit, berry, and vegetable raw materials are particularly interested in expanding the product line of frozen desserts. Frozen fruit, berry, and vegetable desserts have high nutrition and biological value; they are rich in vitamins, minerals, and quickly digested carbohydrates **[1]**.

For instance, the study conducted by Putradamni et al. employed the D-optimal method to optimize the process. The resulting optimal blended frozen dessert formula comprised 60.146% beetroot juice, 37.354% pineapple juice, and 2% honey, achieving a desirability score of 0.644. This research contributes to developing a wider variety of low-calorie, low-sodium products enriched with vitamin C **[2]**.

The cucurbits, the melon in particular, are rich sources of many vital nutrients for the human body, namely vitamins, carbohydrates, and minerals. Due to the high sugar content, good flavor properties, and easy digestibility, melon fruits have a special place in the food ration. Melon contains many pectin substances, which is not significant for dietetic nutrition. The unique combination of healthy qualities that melons possess allows for use for the production of natural, high-quality, nutritious, and low-calorie sorbets, and the use of fruit-and-berry and vegetable raw materials as enriching additives contributes to the nutritional and biological value and long-term storage **[3]**.

The study **[4]** evaluates the effects of modifying a sorbet recipe by incorporating different percentages of *Zizyphus jujube* powder. *Stevia rebaudiana* was employed as a sugar substitute. A control sample and five variations were developed for comparison. Peaches of the "Laskava" variety, a native Bulgarian cultivar, were used as the primary ingredient. The sensory evaluation identified the most preferred variation, with assessors rating its appearance (n = 6), aroma (n = 5), flavor (n = 5), mouthfeel (n = 7), and aftertaste (n = 5). Complementary physicochemical analysis showed soluble solids content ranging from 17.50% to 33.03%, ash content from 0.36% to 5.21%, and moisture content from 63.77% to 80.21%. The analyzed sorbet matrices also exhibited overrun values between 8.11% and 12.32%. These findings provide valuable insights for developing dietary sorbets with enhanced nutritional and sensory properties.

Malgor et al. **[5]** developed and detailed characterized an amaranth-lemon Corbett. Their study revealed that amaranth proteins are an effective foaming ingredient, making them suitable for potential functional foods with antithrombotic activity.

Przybylski Wiesław et al. **[6]** also explored the effect of inulin on the sensory quality and specific physicochemical parameters of carrot and strawberry sorbets. The resulting sorbets exhibited acceptable sensory quality and favorable physicochemical properties. The study recommends adding 2% inulin to carrot sorbet and 4% to strawberry sorbet. These amounts are sufficient to impart prebiotic properties to the product while minimally affecting the sensory characteristics of the sorbets.

Agnieszka Palka et al. **[7]** examined the effect of inulin on the sensory characteristics and health benefits of avocado, kiwi, honeydew melon, cantaloupe, and mango sorbets. Three variations of sorbets were prepared: two with inulin (2% and 5% wt%) and one without, using fresh fruit combined with water, sucrose, and lemon juice. Among the tested fruits, kiwi sorbet exhibited the highest antioxidant potential. These findings highlight the potential for developing innovative dietary frozen desserts enriched with health benefits.

In the authors' research **[8]**, X-ray micro-computed tomography and image processing techniques were employed to analyze fresh frozen sorbets at the outlet of a batch freezer. Sorbets composed of water and sucrose were visualized, and their microstructure was quantified at a resolution of 9 µm. Ice crystals accounted for approximately 50% of the weight of the product, with a mean size of about 60 µm, while air bubbles constituted approximately 6% of the volume. The research establishes a scientific foundation for developing new formulations and technologies, including dietary and low-calorie sorbets with enhanced properties.

Despite the extensive contribution of scientists to the development of frozen fruit-and-berry desserts, nonetheless, the question of providing consumers with high-quality, low-calorie frozen desserts that have a functional purpose remains open **[9]**, **[10]**, **[11]** Therefore, the development of natural low-calorie frozen desserts - sorbets having the functional purpose, produced out of traditional and less-common raw materials with high nutritional and biological value is relevant.

Scientific Hypothesis

This study hypothesizes that combining various plant-based additives (such as beetroot, lemon, apples, cabbage, and plums) helps increase sorbets' nutrient and biologically active substance content, making them functional products.

Objectives

This study aims to develop a technology for producing melon-based sorbets with an optimal component ratio and enhanced nutritional and biological value.

To achieve this goal, the following objectives must be addressed:

- Develop a production technology for melon-based sorbets incorporating fruit and vegetable additives.
- Optimize the component composition of the sorbets.
- Determine the physicochemical properties of the optimized sorbet formulations that contribute to their nutritional and biological value.

MATERIAL AND METHODS

Samples

Samples description: During experimental research conducted at the University of Food Technologies in Plovdiv, Bulgaria, the technology and formulation for melon-based sorbet compositions incorporating fruit pieces – "Zhelsiz Tunde," "Kokoray Shalgyn," and "Kystyn Syzy" – were developed.

Samples collection: Each sample, weighing 2 kg, was prepared and temporarily stored at a temperature of -18°C for subsequent organoleptic and physicochemical analyses.

Samples preparation: 1.5 kg of each sample was divided into 50 g portions for organoleptic analysis, while the remaining 500 g of each sample was allocated to determine physicochemical parameters.

The process flow diagram of the production of the melon-based sorbets with fruit pieces is shown in Figure 1.

Technological Process for Melon-Based Sorbet Production

The production process follows these steps:

Preparation of Ingredients

Auxiliary materials such as granulated sugar, sugar/glucose-fructose syrup, dry apple pectin, and vanillin are prepared. The melon, fruit, and vegetable base is also ready.

Sorting and Inspection

Melons, fruits, and vegetables are sorted and inspected on tables or conveyor belts to ensure quality. Defective products, foreign impurities, and unsatisfactory sorrel leaves are removed, and roots are trimmed. Lemons are inspected for quality; underripe, overripe, or damaged fruits are discarded. Roller conveyors are recommended for fruit inspection to streamline rejection.

Washing and Rinsing

Water meeting drinking water standards is used.

Seed fruits: Washed in drum or fan washers at a water pressure not exceeding 50 kPa.

Stone fruits: Washed in elevator, fan, or shaking machines.

Lemons: Washed in fan or shower machines at a similar pressure, with subsequent vibration to remove water droplets.

Melons and red cabbage: Washed under a shower at ≤50 kPa pressure.

Sorrel leaves are washed under a 200–300 kPa shower on metal grids (3–4 kg portions, 5–6 minutes). Excess moisture is removed by shaking. They must presoak in cold water for 30–60 minutes if they are heavily soiled.

Beetroot: It should be treated with a 2.5–3% caustic soda solution at 80–90 °C for 3 minutes, followed by abrasive-free washing or mechanical cleaning.

Secondary Inspection

Post-wash inspection removes branches and ridges from seed fruits, defective cabbage leaves, and lemon peel.

Peeling and Seed Removal

Melons and lemons are peeled, and the seeds are removed. Citrus peel can be used for essential oil extraction. Apples and pears are halved, and tender skins may remain intact. Plums and peaches are halved, with stones removed. Red cabbage: Remove the core and clean the upper leaves.

Cutting

Melons: Cut into 20 × 50 mm slices or 30 × 30 mm cubes for blanching. Frozen melon is recommended for operational efficiency.

Apples, pears, plums, and peaches: Cut into 4 × 4 mm cubes before blanching.

Red cabbage: Shredded into particles ≤20 mm in size.

Blanching

Melons: Blanched in 35% sugar syrup at 85 °C for 5 minutes.

Sorrel leaves: Blanched at 85 °C for 3 minutes.

Apples and pears: Blanched in 50% sugar syrup at 90 °C for 8 minutes.

Plums and peaches: Blanched at 85 °C for 5 minutes, maintaining their shape. The syrup should be 10–15% of the fruit weight.

Red cabbage: Blanched with hot steam at 140–150 °C for 5 minutes.

Beetroot: Blanched at 120 °C for 20–40 minutes.

Crushing, Pressing, and Filtering

Peeled lemons are crushed in a fruit crusher, and juice is extracted using continuous or hydraulic presses. Juice is filtered through filter cardboard.

Freezing and Defrosting

Melons are pre-frozen at −25 to −35 °C, stored at −18 to −28 °C for up to 12 months, and thawed as needed at 20–25 °C for 30–40 minutes.

Pureeing

Blanched fruits and vegetables are pureed using sieves with 1.5–2.0 mm holes, ensuring the removal of mineral impurities. The product is then passed through 0.5–0.8 mm sieves in final finishing to eliminate coarse particles.

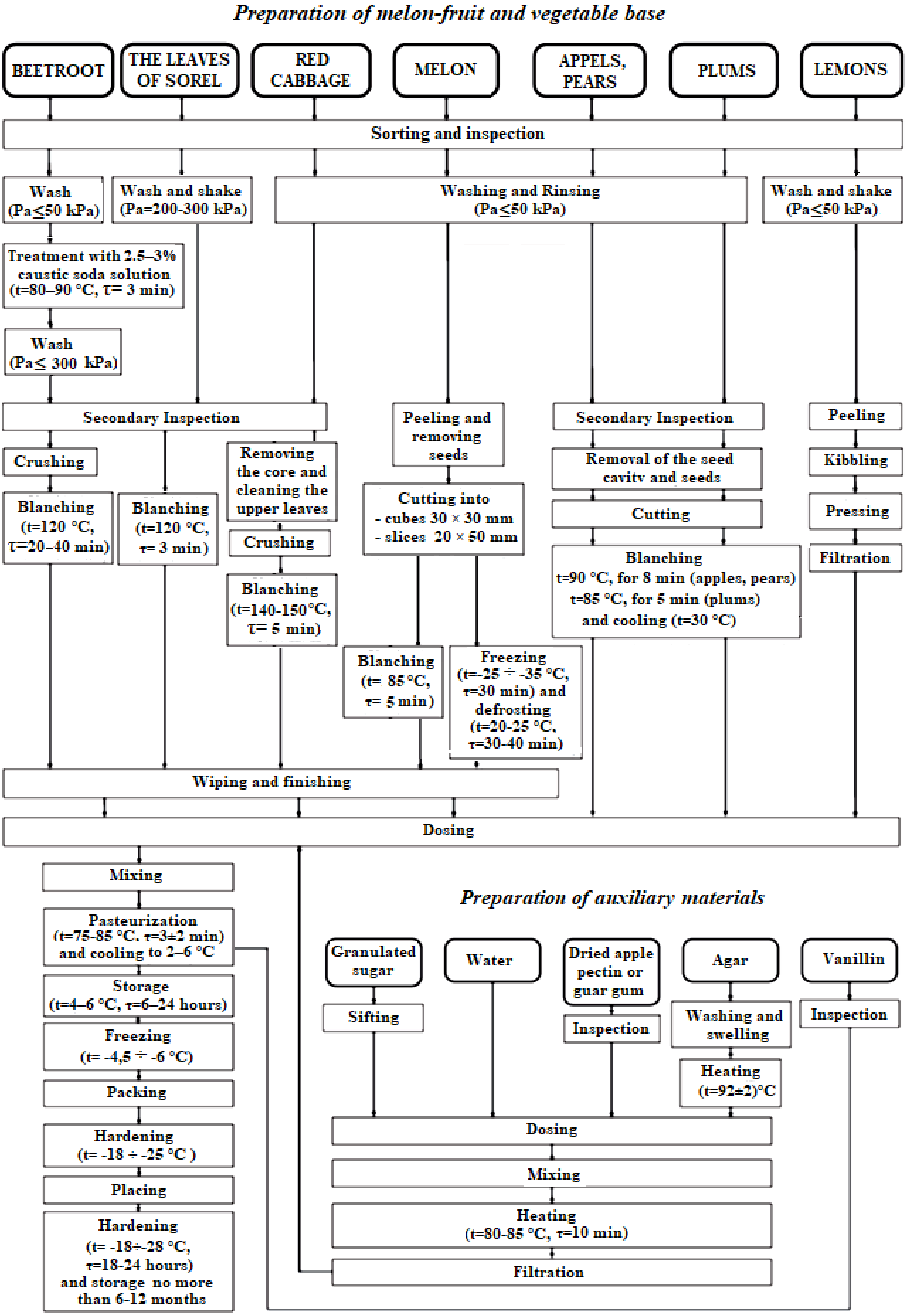


Figure 1 Process flow diagram of the production of the melon-based sorbets with fruit pieces.

Dosing and Mixing

Melon-fruit-vegetable puree, lemon juice, and auxiliary materials are measured according to the recipe and mixed into a homogeneous mass in stainless steel tanks.

Pasteurization and Cooling

The mixture is pasteurized at 75–85 °C for 3±2 minutes and cooled to 2–6 °C. Vanillin is added during cooling. Acidity is adjusted to ≤70 °T for summer sorbets and 55–60 °T for autumn and winter varieties.

Storage

The mixture is stored at 4–6 °C for 6–24 hours, stirring occasionally to prevent settling.

Freezing and Packaging

The mixture is whipped (≥40%) and frozen, reaching −4.5 to −6 °C, forming evenly distributed air bubbles (≤60 μm). After freezing, the sorbet is packaged in 70 g to 2 kg portions. τ=÷

Hardening and Storage

Packaged sorbet is immediately hardened at −25 °C (acceptable: −18 °C) to ensure structure and storage stability. Final storage occurs at −18 to −28 °C with relative humidity of 85–90%. Manufacturer storage should not exceed 6 months, while total shelf life in retail is 12 months at ≤−18 °C.

Number of samples analysed: Three samples of melon-based sorbet were analyzed: "Zhelsiz Tunde," "Kokoray Shalgyn," and "Kystyn Syzy."

Chemicals

The following reagents were used for analytical purposes: DPPH [2,2-diphenyl-1-picrylhydrazyl] and Trolox [(+/−)-6-hydroxy-2,5,7,8-tetramethyl-chromane-2-carboxylic acid] (Sigma-Aldrich, Steinheim, Germany); TPC [2,4,6-tripyridyl-s-triazine] and gallic acid monohydrate (Fluka, Buches, Switzerland); Folin-Ciocalteu Reagent (Merck, Darmstadt, Germany). All other reagents and solvents had the analytical class.

Animals, Plants and Biological Materials

The subject of this research is melon-based sorbets enriched with additives of plant origin: fruits (apples (mālum), pears (Prúnus pérsica), plums (Prúnus doméstica), lemons (Cítrus límon)), vegetables (beetroot (Beta vulgaris L.), red cabbage (Brassica oleracea var. Capitata f. Rubra)), sorrel leaves (Rumex acetosa)).

Instruments

Pocket refractometer ATAGO Pal-α (Japan), Solventextractorser 148 - VELP Scientifica Srl (Italy), Kjeldahl analyzer IDK-129 - VELP Scientifica Srl (Italy), the capillary electrophoresis system "Kapel-105" Lumex (Russia), the high-performance liquid chromatograph Agilent Technologies 1200 Series (США), the electric atomization spectrometer "QUANTUM-Z.ETA-T" - Kortek LLC, (Russia), the meter Tsvet Yauza 01-AA with an amperometric detector - Brand: Chemical Automation (Russia).

Laboratory Methods

The dry solids mass fraction was studied using the Pocket refractometer ATAGO Pal-α.

The weight fraction of fats was determined according to GOST 8756.21-89 **[12]** using the meter Solventextractorser 148. The method is based on extracting fats with a chloroform and ethyl alcohol mixture in a filtering separating funnel and determining their weight in the obtained extract after removing the solvent.

The weight fraction of the proteins was determined using the Kjeldahl analyzer IDK-129.

The soluble dry substances are determined according to GOST ISO 2173-2013 **[13]**.

The weight fraction of carbohydrates is determined using permanganometric method.

The pectic substances were determined by titration according to GOST 29059-91 **[14]**, **[15]**.

The water-soluble vitamins were determined using the capillary electrophoresis system Kapel-105.

The method for determining β-carotin is based on the extraction of carotenoids from a sample or sediment previously obtained by treating the sample with solutions Carrez I and Carrez II, on the subsequent purification of the isolated preparation with petroleum-ether, and on the spectrophotometric determination of the weight concentration or weight fraction of carotenoids. The proportions of detached carotenoids (from the total carotenoid content) are determined by spectrophotometric measurement in fractions obtained during the chromatographic fractionation of the extract.

Vitamin E was determined in the extract obtained from the analyzed sample, followed by the separation of tocopherols using normal-phase high-performance liquid chromatography on the Agilent Technologies 1200 Series high-performance liquid chromatography. The mineral content was determined by the method of atomic absorption spectroscopy (ASS) on the electric atomization spectrometer QUANTUM-Z.ETA-T with the software by GOST R 53152-2008 **[16]**.

The antioxidant activity was determined on the meter Tsvet Yauza 01-AA with an amperometric detector.

The antioxidant activity was evaluated according to the Brand-Williams et al. **[17]** (radical-scavenging activity (DPPH test)), Benzie and Strain **[18]** (ferric-reducing power (FRAP test)) methods.

The organic acids were studied using the methodology M 04-47-2007, based on measuring the weight concentration of organic acids and their salts using the capillary electrophoresis Kapel 105.
The acidity in degrees Turner is determined according to GOST ISO 750-2013 **[19]**.

Description of the Experiment

Study flow: In the initial stage of the experiment, raw materials were selected to enrich the melon-based sorbe. The production modes and parameters were determined following the technology used to produce melon-based sorbet. Subsequently, organoleptic analysis was conducted using simplex centroid methodology to identify optimal samples. The selected organoleptically optimal samples were then analyzed for their nutritional and biological value. The results of these experiments were used to test the research hypothesis.

Quality Assurance

Number of repeated analyses: All analyses were performed in triplicate.

Number of experiment replication: Each experiment was conducted three times. Nine experiments were conducted to optimize the formulation.

Reference materials: -

Calibration: All instruments were calibrated before the experiments following standard methods and the technical specifications outlined in the equipment's datasheet.

Laboratory accreditation: Physicochemical analyses were conducted in the accredited "Food Safety" laboratory of Almaty Technological University. The laboratory is accredited within the accreditation system of the Republic of Kazakhstan, in compliance with the requirements of GOST ISO/IEC 17025-2019, “General Requirements for the Competence of Testing and Calibration Laboratories” (Accreditation Certificate No. KZ.T.02.E 1158).

Data Access

Tasting protocols for organoleptic analyses and test protocols for determining physicochemical parameters are available and can be provided upon request.

Statistical Analysis

Statistical analysis was carried out using SAS software (SAS Institute Inc.) by the method of one-way analysis of variance (ANOVA) according to the Student's test with the probability of accepting the null hypothesis ($p < 0.05$). Different melon-based sorbet compositions were developed and subjected to organoleptic evaluation using the scoring system. When the organoleptic analysis, the sensory panel used a rating from 1 to 10 points with 0.5 steps, corresponding to the quality of the product when examining each indicator: appearance, taste and flavor, color, texture, and harmoniousness. Each indicator has a weight assignment: appearance – 0.2; taste and flavor – 0.35; color – 0.2; texture and harmoniousness – 0.25. The ten-point rating system assigned the final assessment of the quality of the finished product based on the calculation of the total number of points received: 9.0 ÷ 10.00 points – the finished product is excellent; 8.00 ÷ 8.99 points – the finished product is good; 7 ÷ 7.99 points – the finished product needs the follow-on revision; less than 7 points – the finished product needs the significant correcting.

During the experiments, a simplex-centroid formulation optimization system was used. This system is suitable for studying and modeling multicomponent mixtures’ properties (Y). The total amount of the mixture is assumed to equal one (or 100%), Xi is part of the i-th component in the mix, and q is the number of components. The components meet the following conditions **[20]**:

$$0 \leq X_i \leq 1 \qquad (i = 1, 2, \ldots, q)$$

(1)

The Schefe simplex lattices are used to derive the adequate mathematical model of the studied indicators. To describe the properties of mixtures, the polynomial of the third incomplete degree:

(2)

Where: ßi, ßij and ßijk – coefficients of the equation, and Xi – components of the mixture.

Based on mathematical models, reflecting surfaces in a triangular coordinate system were presented. The values of separate factors are plotted along the edges of the equilateral triangle on a uniform scale from 0 to 1 (Figure 2) **[20]**, **[21]**.

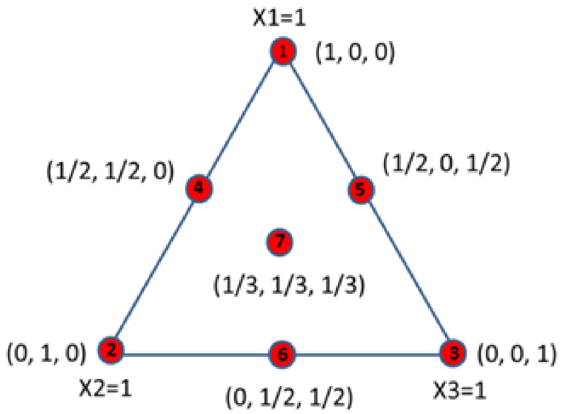


Figure 2 Simplex-centroid system of the optimization of formulation.

RESULTS AND DISCUSSION

Optimization of variants of the melon-based sorbets formulation. Special attention is given to organoleptic parameters such as color, aroma, taste, texture, and overall acceptability when optimizing a formulation. Scientific studies commonly evaluate these essential parameters during formulation development **[22]**. Taste and aroma are given particular emphasis, as sweetness is a potent stimulus among the sensory factors, and the preference for sweetness is widely recognized as an innate human trait **[23]**. This principle applies to many products, especially fruit and vegetable preserves. For example, sorbets must have an appealing and attractive color and be made from fresh, high-quality fruits or vegetables. Consumers often pay a premium for products that resemble fresh or minimally processed items **[7]**. The quality of industrial sorbets can be improved by providing fresh, good-quality fruits for production and reducing the addition of water to the mixtures in favor of the fruit and vegetables **[24]**.
Different formulations and quantities of raw products and materials used are shown in Table 1.

Table 1 Formulation and quantities of raw products and materials for producing melon-based sorbets, kg per 1000 kg.

Name	Formulation per parts, %	Wastes and losses, %	Rates of use, kg
Melon-based sorbet Zhelsiz Tunde			
Melon	50.6	19.0	602.14
Beetroot	3-7	20.0	36.0
Lemon	4-8	12.0	67.2
Pear	23-28	15.0	287.5
Granulated sugar	10-14	2.0	142.8
Dry apple pectin	0.8-1.2	0.5	12.06
Vanillin	0.1-0.2	0.5	2.01
Melon-based sorbet Kokoray Shalgyn			
Melon	48.8	19.0	580.72
Sorrel	2-7	10.0	33.0
Lemon	6-11	12.0	89.6
Apples	23-28	10.0	275.0
Granulated sugar	10-14	2.0	142.8
Dry apple pectin	0.8-1.2	0.5	10.05
Vanillin	0.1-0.2	0.5	2.01
Melon-based sorbet Kystyn Syzy			
Melon	46.8	19.0	556.92
Red cabbage	5-14	20.0	84.0
Lemon	6-15	12.0	89.6
Plum	18-23	10.0	253.0
Granulated sugar	10-14	2.0	142.8
Dry apple pectin	0.8-1.2	0.5	10.05
Vanillin	0.1-0.2	0.5	2.01

A simplex-centroid system of the experiment's performance was used to optimize the formulation, presented in Table 2 and Figure 2. Previously, the authors studied combinations of different berry juices (bilberry, strawberry, and raspberry) to develop blended berry juices with high antioxidant activity using a simplex centroid design. In addition to enhancing antioxidant capacity, incorporating berry juice blends improved the sensory qualities of mixed melon-based juices, such as flavor and color. These studies provided a foundation for enriching frozen melon-based desserts while optimizing their formulation **[25]**.
A formulation of 3% beetroot, 6% lemon, and 25% pears (Experiment 6) achieved the best-tasting score (10).

Table 2 Simplex-centroid system of the experiment on the optimization of the melon-based sorbets formulation

Melon-based sorbet Zhelsiz Tunde				
N	**Beetroot**	**Lemon**	**Pears**	**Tasting evaluation**
1	7	4	23	8
2	3	8	23	7
3	3	4	27	6
4	5	6	23	6
5	5	4	25	8.5
6	3	6	25	10
7	4.33	5.33	24.33	9
8	7	4	23	8.5
9	3	8	23	7.5
Melon-based sorbet Kokoray Shalgyn				
N	Sorrel	Lemon	Apples	**Tasting evaluation**
1	7	6	23	7
2	2	11	23	8
3	2	6	28	7.5
4	4.5	8.5	23	8.5
5	4.5	6	25.5	9.5
6	2	8.5	25.5	9.5
7	3.66	7.66	24.66	10
8	7	6	23	6
9	2	11	23	7.5
Melon-based sorbet Kystyn Syzy				
N	**Red cabbage**	**Lemon**	**Peach**	**Tasting evaluation**
1	14	6	18	7.5
2	5	15	18	6.5
3	5	6	27	8.5
4	9.5	10.5	18	7.5
5	9.5	6	22.5	10
6	5	10.5	22.5	10
7	8	9	21	8.5
8	14	6	18	6.5
9	5	15	18	7.5

Proportions with higher beetroot (7% as in Experiments 1 and 8) yielded moderately high scores (8–8.5). Lower beetroot (3–5%) and varied pear content (23–25%) achieved a broader range of scores. Increased proportions of lemon and pears with lower beetroot levels enhance sensory appeal. It is crucial to optimize for balance in acidity (from lemon) and sweetness (from pears). The top scores (10) were achieved in Experiment 7 with 3.67% sorrel, 7.67% lemon, and 24.67% apples.

Lower sorrel percentages paired with moderate apple and lemon levels generally performed well.

The highest sorrel content (7%, as in Experiments 1 and 8) resulted in lower scores (6–7). Excessive sourness from high sorrel content may detract from flavor balance.

Balanced proportions of sorrel and lemon, complemented by a consistent amount of apples, are key to optimal sensory performance. The highest score (10) was achieved with 9.5% red cabbage, 6% lemon, and 22.5% peach (Experiment 5 and 6).

Excessive red cabbage content (14%, as in Experiments 1 and 8) reduced the tasting scores.

Variations around moderate levels of red cabbage (8–9.5%), paired with peach and lemon, achieved consistently better scores. A balance of natural sweetness (peach) and acidity (lemon) enhances the flavors when complemented by a moderate red cabbage content for color and texture enhancement. Ingredients like lemon juice contribute acidity, while fruits such as pears, apples, and peaches provide sweetness. A balanced ratio significantly enhances consumer acceptability.

The results of the experiments conducted on formulation optimization are shown in Figure 3.

The content of melon, granulated sugar, dry apple pectin, and vanillin was set at a constant value, while the remaining ingredients varied within certain limits.

Figure 3 shows that red regions represent the optimal and highest indicators for organoleptic parameters—combining taste, aroma, and texture—while blue areas indicate low taste preference scores.

The diagram shows a nonlinear TE distribution in the sorbet Chelsiz Tunde. The most favorable results are achieved in areas with a balanced content of Lemon and Pears, whereas Beetroot contributes minimally. A high proportion of Beetroot results in a significant decline in organoleptic parameters.

In the sorbet Kokoray Shalgyn, the diagram exhibits a relatively smooth variation in the TE index, with a clearly defined central zone of high intensity. The Apple component exerts a dominant influence on achieving high values, while the impact of Sorrel remains limited.

For the sorbet Kystyn Syzy, the TE distribution, as illustrated in the diagram, reveals a pronounced gradient with significant asymmetry towards Peach. This component has the most decisive influence on the target value compared to the other ingredients. This underscores the importance of precise concentration of Peach relative to Red Cabbage and Lemon in the sorbet composition.

After the processing of the experimental data, regression equations on the influence of the composition of the three formulation variants on their sensory evaluation (equations 3-5) were derived. The obtained dependencies describe the target functions with high accuracy. The coefficient of determination varies between 92.71% and 97.2%. This allows us to determine the zone where those combinations of indicators have their maximum.

Melon-based sorbet Zhelsiz Tunde

TE =8.23282* Beetroot + 7.23282* Lemon + 5.96564* Pears - 6.38153* Beetroot* Lemon + 6.15282* Beetroot * Pears + 14.1528* Lemon * Pears, $R2 = 97.2$ % (3)

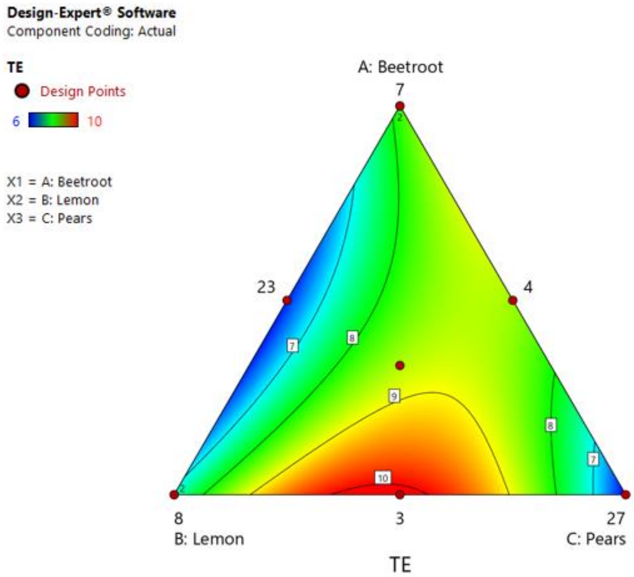
Melon-based sorbet Kokoray Shalgyn

TE = 6.5*Sorrel + 7.75* Lemon + 7.5* Apples + 5.5*Sorrel* Lemon + 10.0*Sorrel* Apples + 7.5* Lemon * Apples + 5.24705*Sorrel* Lemon* Apples, $R2 = 95.54$ % (4)

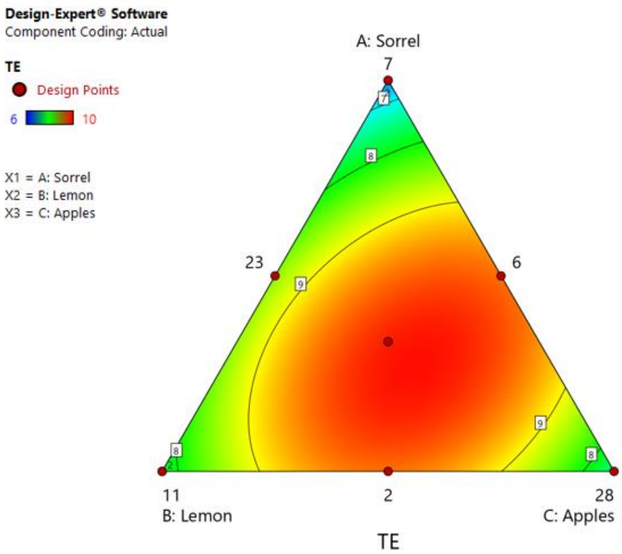
Melon-based sorbet Kystyn Syzy

TE = 7.0*Red cabbage + 7.0* Lemon + 8.5*Peach + 2.0*Red cabbage* Lemon + 9.0*Red cabbage*Peach + 9.0* Lemon *Peach - 33.0*Red cabbage* Lemon *Peach, $R2 = 92.71$ % (5)

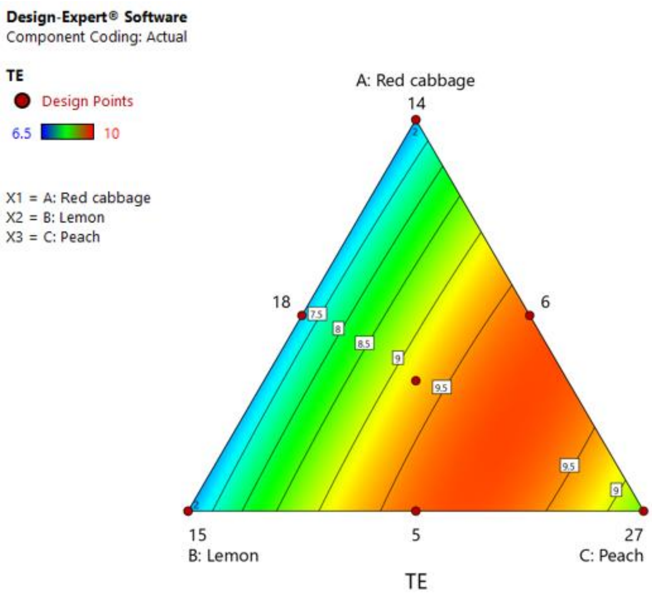
The maximum sensory evaluation of melon-based sorbets is reached under the following composition ratio: Zhelsiz Tunde - the content of red beetroot is 3%, lemon is 6%, and pears is 25%; Kokoray Shalgyn - the content of sorrel is 3%, lemon is 8% and apples is 25%; Kystyn Syzy - the content of red cabbage is 7%, lemon is 8% and plum is 23%. Including red beet in sorbet, Zhelsiz Tunde imparts functional properties to the finished product, as red beetroot (Beta vulgaris L.) is a rich source of betalains, polyphenols, and nitrates **[26]**. Recent in vivo and in vitro studies have also highlighted the potent immunomodulatory effects of betalains, which are demonstrated through molecular interactions with pro-inflammatory and/or cytoprotective signaling pathways. This leads to the modulation of downstream target proteins and enzymes that regulate inflammatory processes and cellular antioxidant status **[27]**. The functional properties of melon-based sorbet are further enhanced by including pear, which contains various nutritional components, phenolic phytochemicals, and soluble dietary fiber. Numerous animal, epidemiological, and clinical studies have shown that a diet rich in soluble dietary fiber can modulate gut microbiota **[28]**, protecting against obesity by reducing body weight, waist circumference, and visceral fat **[29]**. Soluble nutritional fiber from pears represents a valuable intervention target for treating high-fat diet (HFD)-induced obesity and related metabolic disorders, ultimately contributing to public health improvements through such products **[30]**.



Zhelsiz Tunde



Kokoray Shalgyn



Kystyn Syzy

Figure 3 Reflecting surface of sensory evaluation of the melon-based sorbets.

The inclusion of sorrel in the composition of the "Kokoray Shalgyn" sorbet imparts a refreshing and pleasant greenish hue while adding apple cubes creates intriguing pale yellow accents. Sorrel is known for its potential health benefits, including positive effects on diabetes, hypertension, and various other illnesses, primarily due to its antioxidant, antibacterial, and anti-inflammatory properties, attributed mainly to its anthocyanins **[31]**. Apples rich in bioactive compounds, vitamins, minerals, and dietary fiber offer many health advantages. Regular consumption of apples has been shown to reduce the risk of atherosclerosis, coronary artery disease, heart attacks, and diabetes while providing anti-asthmatic and anti-allergic benefits **[32]**.

Adding red cabbage and plum to the "Kystyn Syzy" sorbet recipe gives it a delicate lilac hue with deeper purple highlights. Red cabbage is a nutrient-rich ingredient, offering amino acids, organic acids, and a significant amount of dietary fiber. Moreover, recent studies have demonstrated that red cabbage contains various bioactive compounds, including polyphenols and anthocyanins, potent antioxidants with effective free radical-scavenging properties **[33]**. Plums, whether fresh or dried, are highly beneficial for promoting overall health by helping to prevent inflammation, hypertension, thrombotic risks, and certain types of cancer **[34]**.

Determination of the nutritional and biological value of melon-based sorbets. After the optimization and formulation and working out the production technology of melon-based sorbets with fruit pieces in the accredited laboratory Food Safety of Almaty Technological University, the nutritional and biological values of three chosen variants were determined (Table 3).

Table 3 The nutritional and biological value of melon-based sorbets with fruit pieces.

Indicators name, un. of meas.	**Melon-based sorbets**		
	Zhelsiz Tunde	**Kokoray Shalgyn**	**Kystyn Syzy**
Dry solids mass fraction, %	9.28	8.81	6.14
Fats mass fraction, %	0.060	0.062	0.066
Proteins mass fraction, %	0.71	0.74	0.73
Mass fraction of solids soluble in water, %	1.3408	1.3406	1.3431
Carbohydrate mass fraction, %	9.43	9.42	10.0
incl., saccharose, g/100g	4.5	4.25	6.0
Pectic substances mass fraction, %	1.91	1.50	1.16
Vitamin B_1, mg/100g	0.03	0.08	0.04
Vitamin B_2, mg/100g	0.03	0.05	0.03
Vitamin B_3, mg/100g	0.06	0.1	0.17
Vitamin B_5, mg/100g	0.14	0.13	0.18
Vitamin B_6, mg/100g	0.04	0.05	0.07
Vitamin B_9, mg/100g	4.6	4.15	5.2
Vitamin C, mg/100g	14.2	17.5	19.5
Vitamin E, mg/100g:	0.15	0.21	0.2
β - carotin, mg/kg	3.13	2.95	2.97
Potassium, mg/100g	133.75	152.05	140.3
Calcium, mg/100g	21.10	16.40	21.24
Sodium, mg/100g	25.95	24.80	26.75
Magnesium, mg/100g	13.2	14.65	12.25
Ferrrum, mg/100g	1.20	1.15	1.05
Total antioxidant activity, mg/100g	25.67	30.58	34.56
Antioxidant activity:			
- DPPH, µmolTE/100g	133.00	90.67	126.92
- FRAP, µmolTE/100g	143.50	98.17	138.92
Ethane diacid, mg/kg	30.48	31.14	28.81
Dihydroxysuccinic acid, mg/kg	361.95	124.56	54.24
Hydroxysuccinic acid, mg/kg	130.00	250	260.00
Citric acid, mg/kg	400.00	1212.86	1017.00
Amber acid, mg/kg	68.58	196.68	76.28
Lactic acid, mg/kg	152.40	124.56	94.92
Acetic acid, mg/kg	123.83	295.02	169.50
Phosphate ion, mg/kg	127.64	88.51	103.40
Acidity, °T	14.50	13.40	17.60

As seen from Table 3, the dry solids mass fraction is represented at most in the samples of sorbet Zhelsiz Tunde (9.28%) and Kokoray Shalgyn (8.81%). All samples' fat and protein mass fractions have approximately the same levels and averages 0.0626% and 0.72%, respectively. During the refractometric analysis, it was found that the mass fraction of water-soluble solids in the melon-based sorbets is on average 1.3502%, as the highest content of the mass fraction of water-soluble solids was found in the sample of the sorbet Kystyn Syzy (1.3431%) and the lowest in the sorbet Kokoray Shalgyn (1.3406%).

In all sorbets, the mass fraction of carbohydrates is approximately at the same level and varies from 9.42% to 10.00%. With this, the level of saccharose in the presented samples of the sorbets ranges from 4.25 g/100g to 6.00 g/100g.

The mass fraction of pectin substances follows a similar pattern: the sorbet "Zhelsiz Tunde" exhibits the highest levels (1.91%), while the sorbet "Kystyn Syzy" shows the lowest (1.16%). Pectin is an essential dietary fiber commonly found in the human diet and is widely used as an additive for various purposes. In recent years, its hydrolysis for producing pectic oligosaccharides has been extensively studied, highlighting its potential as a functional ingredient, mainly due to its prebiotic effects **[35]**.

The research revealed that vitamin B_9 is the most abundant sorbets among B-group vitamins, ranging from 4.15 mg/100g in the sorbet variety Kokoray Shalgyn to 5.2 mg/100g in Kystyn Syzy. Vitamins B_5 and B_3 rank next in abundance, with the highest concentrations found in Kystyn Syzy (0.18 mg/100g and 0.17 mg/100g, respectively), followed by Kokoray Shalgyn (0.13 mg/100g and 0.1 mg/100g) and Zhelsiz Tunde (0.14 mg/100g and 0.06 mg/100g).

Nicotinic acid is most concentrated in Kystyn Syzy (0.17 mg/100g), 1.7 times lower in Kokoray Shalgyn and 2.83 times lower in Zhelsiz Tunde. Riboflavin, pyridoxine, and thiamine chloride are the least abundant B-group vitamins across all sorbet samples, with an average concentration of 0.046 mg/100g.

Recent research has demonstrated that nicotinamide and nicotinic acid, combined with gamma-aminobutyric acid, may exert neuroprotective effects. These effects include reducing levels of pro-apoptotic regulators and enhancing the expression of angiogenic and cytoskeletal proteins impaired by hyperglycemia in rat brains **[36]**. This study supports the conclusion that consuming foods rich in B vitamins may help prevent complications associated with diabetes and protect nervous tissue from damage caused by hyperglycemia.

Vitamin C is observed most of all in the sorbet Kystyn Syzy (19.5 mg/100g); it's inferior by 10.25% in the sorbet Kokoray Shalgyn and by 27.17% in the sorbet Zhelsiz Tunde. The authors **[37]** of the study investigating the effects of vitamin C requirements in individuals with type 2 diabetes mellitus and obesity concluded that people with type 2 diabetes likely require higher vitamin C intake than those without the condition. This increased need is attributed not only to weight-based volumetric dilution but also to the additional metabolic dysregulation associated with the disease, which is evident even at the prediabetes stage. Consequently, consuming dietary frozen desserts could serve as a partial source of vitamin C for the body.

Vitamin E is approximately at the same level in the samples of sorbets Kokoray Shalgyn and Kystyn Syzy - per 0.21 and 0.2 mg/100g, respectively, the sorbet Zhelsiz Tunde is inferior by 0,06 mg/100g to the sorbet Kokoray Shalgyn. The results of the authors' research **[38]** suggest the potential benefits of vitamin E-rich diets in promoting cardiovascular health and reducing mortality. The vitamins mitigate or eliminate any adverse action of many medicaments on the human organism **[39]**.

In the sorbet Zhelsiz Tunde, β-carotene is present in the amount of 3.13 mg/kg, which is 0.16 mg/kg and 0.18 mg/kg higher than in the sorbets Kystyn Syzy and Kokoray Shalgyn, respectively. Carotenoids are antioxidants that help detoxify free radicals in cells, thereby preventing oxidative damage and reducing the risk of related diseases **[40]**. According to the analyses, the sorbet Zhelsiz Tunde nearly meets the daily carotenoid requirement. Consuming such desserts provides an enjoyable and accessible way to intake beneficial nutrients.

Among other mineral substances, potassium is contained most of all in the sorbet composition; its content is higher in the sample of the sorbet Kokoray Shalgyn (152.05 mg/100g) and least in the sorbet Zhelsiz Tunde (133.75 mg/100g). The sodium and calcium content are highest in the sorbet Kystyn Syzy 26,75,41 mg/100g and 21.24 mg/100g, respectively. In the sorbet Zhelsiz Tunde, calcium is contained in 21.1 mg/100g, 22.27% more than in the Kokoray Shalgyn. Calcium plays a vital role in numerous physiological processes. Disruptions in calcium balance can lead to impaired growth, osteoporosis, nephrolithiasis, tissue calcification, and cardiovascular diseases **[41]**. Disorders involving calcium and magnesium are often challenging to diagnose due to their nonspecific initial symptoms. Nevertheless, correcting these electrolyte imbalances is crucial to preventing serious cardiovascular and neurological complications **[42]**. Frozen desserts can be a supplementary source of essential minerals, contributing to maintaining the body's vital functions.

The sorbet Zhelsiz Tunde contains 25.95 mg/100g of sodium, 1.15 mg/100g higher than in the sorbet Kokoray Shalgyn.

The sorbet Kokoray Shalgyn contains the highest amount of magnesium (14.65 mg/100g), the sorbet Zhelsiz Tunde contains 13.2 mg/100g, and the sorbet Kystyn Syzy has 12.25 mg/100g.

The sorbet Zhelsiz Tunde leads in iron content, with 1.08 mg/100g, surpassing Kokoray Shalgyn and Kystyn Syzy by 0.17 mg/100g and 0.22 mg/100g, respectively. Iron is an essential nutrient and a key component of ferroproteins and enzymes that perform critical biochemical functions. Although iron is one of the most abundant elements on Earth, its naturally occurring forms are often insoluble and exhibit low bioavailability in many diets. Humans typically conserve iron efficiently, losing less than 0.1% of their total body iron daily – an amount replenished through dietary absorption **[43]**. Notably, vitamin C in the developed frozen desserts enhances iron absorption, making these products a valuable source of both nutrients.

The sorbet Kystyn Syzy has the highest total antioxidant activity (34.56 mg/100g), which is 11.5% more than the sorbet Kokoray shotgun and 25.72% more than the sorbet Zhelsiz Tunde. Antioxidant and anti-inflammatory properties aid the body in eliminating uric acid and reducing the risk of diabetes **[44]**. Therefore, consuming antioxidant-rich foods is crucial for maintaining health and preventing related conditions.

The analysis of the determination of the antioxidant activity by radical-scavenging activity (DPPH-test) showed that the sorbet Zhelsiz Tunde demonstrated the best results (133.00 µmolTE/100g). The results of the sorbet Kystyn Syzy are inferior only by 4.57%. The sorbet Kokoray Shalgyn is in the following position with a decrease in content by 31,82% compared to Zhelsiz Tunde.

When studying the antioxidant activity by ferric-reducing power (FRAP-test), the sorbet Zhelsiz Tunde also showed the best results (143.50 µmolTE/100g). The sorbets Kystyn Syzy and Kokoray Shalgyn were inferior by 3.2% and 31.6%, respectively.

In all the samples of sorbets, the citric acid, among the organic acids, is contained most of all; with this, the leader is the sorbet Kokoray Shalgyn (1212.86 mg/kg), the sorbet Kystyn Syzy is inferior by 16%, the sorbet Zhelsiz Tunde is inferior by 84.3%. Along with this, the highest concentration of acetic acid is also observed in the sorbet Kokoray Shalgyn (295.02 mg/kg), and the lowest one is in the sorbet Zhelsiz Tunde – 123.83 mg/kg. In addition to contributing to taste, organic acids significantly enhance the overall flavor profile, preserve nutritional value, and support human health. For example, organic acids such as acetic acid, lactic acid, and butanoic acid have been shown to alleviate symptoms associated with obesity and diabetes **[45]**. Furthermore, citric and malic acids exhibit protective effects on the myocardium and have shown benefits in addressing ischemic lesions **[46]**. These findings highlight the potential health benefits of consuming frozen desserts enriched with such components.

In terms of the dihydroxy succinic acid, its content is most of all in the sorbet Zhelsiz Tunde (361.95 mg/kg), sorbets Kokoray Shalgyn (124.56 mg/kg) and Kystyn Syzy (54.24 mg/kg) come next.

The malic acid is mostly found in the sorbet Kystyn Syzy (260 mg/kg); it is 1,04 times less in the sorbet Kokoray Shalgyn and 2 times less in the sorbet Kystyn Syzy.

The lactic acid and phosphate ions are approximately at the same level, and their content in the sorbet samples is 123.96 mg/kg and 106.52 mg/kg, respectively, on average.

In all sorbet samples, among other organic acids, the amber acid and the ethane diacid are found least. On average, their content is 113.85 mg/kg and 30.14 mg/kg, respectively; with this, most of all of the amber acid is contained in the sorbet Kokoray Shalgyn (196.68 mg/kg).

The acidity of sorbets Kokoray Shalgyn, Zhelsiz Tunde, and Kystyn Syzy varies between 13.40 and 17.60°T.

CONCLUSION

According to the research results, regression equations were derived to describe the influence of the composition of three formulation variants on their sensory evaluation, achieving very high determination accuracy. The coefficient of determination ranged from 92.71% to 97.2%. The composition of melon-based sorbets was optimized using the simplex-centroid processing system, and the maximum sensory evaluation was achieved with the following optimal composition ratios:"Zhelsiz Tunde": 50.6% melon, 3% beetroot, 6% lemon, and 25% pears. "Kokoray Shalgyn": 48.8% melon, 3% sorrel, 8% lemon, and 25% apples. "Kystyn Syzy": 46.8% melon, 7% red cabbage, 8% lemon, and 23% plums. It was determined that melon-based sorbets enriched with plant-derived additives – "Zhelsiz Tunde," "Kokoray Shalgyn," and "Kystyn Syzy" – possess high nutritional and biological value. They can be recommended as functional frozen desserts for individuals engaged in predominantly physical or mental work, elderly people, and those with specific health conditions, including digestive and cardiovascular diseases or varying degrees of obesity. These findings highlight the potential of melon-based sorbets as health-conscious, functional frozen desserts.

REFERENCES

1. Yerenova, B., & Pronina, Yu. (2018). Influence of the low-temperature storage mode on qualitative indicators of melon sorbe. Scientific Works of University of Food Technologies, (Vol. 65, Issue 1, p. 18-23). https://uft-plovdiv.bg/site_files/file/scienwork/scienworks_2018/docs/1-2.pdf
2. Putradamni, A. M., & Pramitasari, R. (2024). Formula optimization, physicochemical characterization, and sensory evaluation of beetroot-based blended frozen dessert. In Food Chemistry Advances (Vol. 4, p. 100672). Elsevier BV. https://doi.org/10.1016/j.focha.2024.100672
3. Yerenova, B. Y., & Pronina, Yu. G. (2020). Progressive technology of functional melon-based products of long-term storage (monograph). Almaty: V.T.O Creative & Marketing Laboratory LLP. https://library.atu.edu.kz/files/63515/
4. Petkova, T., Doykina, P., Alexieva, I., Mihaylova, D., & Popova, A. (2022). Characterization of Fruit Sorbet Matrices with Added Value from Zizyphus jujuba and Stevia rebaudiana. In Foods (Vol. 11, Issue 18, p. 2748). MDPI AG. https://doi.org/10.3390/foods11182748
5. Malgor, M., Sabbione, A. C., & Scilingo, A. (2020). Amaranth Lemon Sorbet, Elaboration of a Potential Functional Food. In Plant Foods for Human Nutrition (Vol. 75, Issue 3, pp. 404–412). Springer Science and Business Media LLC. https://doi.org/10.1007/s11130-020-00818-y
6. Przybylski, W., Sionek, B., Jaworska, D., Spychalska, A., & Rupińska, M. (2020). Wpływ dodatku inuliny na jakość sorbetów owocowych i warzywnych. In Zywnosc Nauka Technologia Jakosc/Food Science Technology Quality (Vol. 124, Issue 3, pp. 66–76). Polskie Towarzystwo Technologow Zywnosci Wydawnictwo Naukowe PTTZ. https://doi.org/10.15193/zntj/2020/124/348
7. Palka, A., & Skotnicka, M. (2022). The Health-Promoting and Sensory Properties of Tropical Fruit Sorbets with Inulin. In Molecules (Vol. 27, Issue 13, p. 4239). MDPI AG. https://doi.org/10.3390/molecules27134239
8. Masselot, V., Bosc, V., & Benkhelifa, H. (2021). Analyzing the microstructure of a fresh sorbet with X-ray micro-computed tomography: Sampling, acquisition, and image processing. In Journal of Food Engineering (Vol. 292, p. 110347). Elsevier BV. https://doi.org/10.1016/j.jfoodeng.2020.110347
9. Konstantas, A., Stamford, L., & Azapagic, A. (2020). A framework for evaluating life cycle eco-efficiency and an application in the confectionary and frozen-desserts sectors. In Sustainable Production and Consumption (Vol. 21, pp. 192–203). Elsevier BV. https://doi.org/10.1016/j.spc.2019.12.006
10. Lee, L. Y., Chin, N. L., Christensen, E. S., Lim, C. H., Yusof, Y. A., & Talib, R. A. (2018). Applications and effects of monoglycerides on frozen dessert stability. In LWT (Vol. 97, pp. 508–515). Elsevier BV. https://doi.org/10.1016/j.lwt.2018.07.020
11. Landikhovskaya, A. V., & Tvorogova, A. A. (2021). Ice cream and frozen desserts nutrient compositions: current trends of researches. In Food systems (Vol. 4, Issue 2, pp. 74–81). The Gorbatov's All-Russian Meat Research Institute. https://doi.org/10.21323/2618-9771-2021-4-2-74-81
12. GOST 8756.21-89. (1989). Fruit and vegetable products. Methods for determination of fat content.
13. GOST ISO 2173-2013. (2013). Products of processing fruits and vegetables. Refractometric method of determination of solids.
14. GOST 29059-91. (1991). Products of fruit and vegetables processing. Titration method for pectin substances.
15. B. Medvedkov, E., E. Yerenova, B., G. Pronina, Yu., D. Penov, M., D. Bilozerceva, O., & V. Kondratiuk, N. (2022). Extraction and characterization of pectins from melon peels: experimental review. In Journal of Chemistry and Technologies (Vol. 29, Issue 4, pp. 650–659). Oles Honchar Dnipropetrovsk National University. https://doi.org/10.15421/jchemtech.v29i4.252250
16. GOST R 53152-2008. (2008). Food products. Determination of PAHs by HPLC method.
17. Brand-Williams, W., Cuvelier, M. E., & Berset, C. (1995). Use of a free radical method to evaluate antioxidant activity. In LWT - Food Science and Technology (Vol. 28, Issue 1, pp. 25–30). Elsevier BV. https://doi.org/10.1016/s0023-6438(95)80008-5
18. Benzie, I. F. F., & Strain, J. J. (1996). The Ferric Reducing Ability of Plasma (FRAP) as a Measure of "Antioxidant Power": The FRAP Assay. In Analytical Biochemistry (Vol. 239, Issue 1, pp. 70–76). Elsevier BV. https://doi.org/10.1006/abio.1996.0292
19. GOST ISO 750-2013. (2013). Fruit and vegetable products. Determination of titratable acidity.
20. Cornell, J. A. (2002). Experiments with Mixtures. In Wiley Series in Probability and Statistics. Wiley. https://doi.org/10.1002/9781118204221
21. Jensen, W. A. (2017). Response Surface Methodology: Process and Product Optimization Using Designed Experiments 4th edition. In Journal of Quality Technology (Vol. 49, Issue 2, pp. 186–188). Informa UK Limited. https://doi.org/10.1080/00224065.2017.11917988

22. Akalın, H., Kınık, Ö., & Şatır, G. (2024). Manufacturing plant-based non-dairy and probiotic frozen desserts and their impact on physicochemical, sensory and functional aspects. In Journal of Food Science and Technology (Vol. 61, Issue 10, pp. 1874–1883). Springer Science and Business Media LLC. https://doi.org/10.1007/s13197-024-05964-8
23. Iatridi, V., Hayes, J. E., & Yeomans, M. R. (2019). Reconsidering the classification of sweet taste liker phenotypes: A methodological review. In Food Quality and Preference (Vol. 72, pp. 56–76). Elsevier BV. https://doi.org/10.1016/j.foodqual.2018.09.001
24. Palka, A., & Wilczyńska, A. (2023). Storage Quality Changes in Craft and Industrial Blueberry, Strawberry, Raspberry and Passion Fruit-Mango Sorbets. In Foods (Vol. 12, Issue 14, p. 2733). MDPI AG. https://doi.org/10.3390/foods12142733
25. Yerenova, B., Pronina, Y., Penov, N., Mihalev, K., Kalcheva-Karadzhova, K., Dinkova, R., & Shikov, V. (2019). Optimization of the Mixed Melon-berry Juice Composition, Using Simplex Centroid Experimental Design. "Prof. Marin Drinov" Publishing House of Bulgarian Academy of Sciences. https://doi.org/10.7546/crabs.2019.12.16
26. Wang, Y., Do, T., Marshall, L. J., & Boesch, C. (2023). Effect of two-week red beetroot juice consumption on modulation of gut microbiota in healthy human volunteers – A pilot study. In Food Chemistry (Vol. 406, p. 134989). Elsevier BV. https://doi.org/10.1016/j.foodchem.2022.134989
27. Fernando, G. S. N., Sergeeva, N. N., Frutos, M. J., Marshall, L. J., & Boesch, C. (2022). Novel approach for purification of major betalains using flash chromatography and comparison of radical scavenging and antioxidant activities. In Food Chemistry (Vol. 385, p. 132632). Elsevier BV. https://doi.org/10.1016/j.foodchem.2022.132632
28. Tran, T. T. T., Cousin, F. J., Lynch, D. B., Menon, R., Brulc, J., Brown, J. R.-M., O'Herlihy, E., Butto, L. F., Power, K., Jeffery, I. B., O'Connor, E. M., & O'Toole, P. W. (2019). Prebiotic supplementation in frail older people affects specific gut microbiota taxa but not global diversity. In Microbiome (Vol. 7, Issue 1). Springer Science and Business Media LLC. https://doi.org/10.1186/s40168-019-0654-1
29. You, Y., Song, H., Yan, C., Ai, C., Tong, Y., Zhu, B., & Song, S. (2022). Dietary fibers obtained from Caulerpa lentillifera prevent high-fat diet-induced obesity in mice by regulating the gut microbiota and metabolite profiles. In Food & Function (Vol. 13, Issue 21, pp. 11262–11272). Royal Society of Chemistry (RSC). https://doi.org/10.1039/d2fo01632j
30. Zhao, J., Ji, Y., Tian, G., Zheng, Y., Sang, Y., & Gao, J. (2024). Pear pomace soluble dietary fiber suppresses fat deposition in high fat diet-fed mice by regulating the ADPN-AMPK/PPAR-α signaling pathway. In Journal of Functional Foods (Vol. 122, p. 106483). Elsevier BV. https://doi.org/10.1016/j.jff.2024.106483
31. McCalla, G., & Smith, B. (2024). Physiologic Effects of Hibiscus sabdariffa (Sorrel) on Biological Systems: Advances in Sorrel Research. In The Natural Products Journal (Vol. 14, Issue 7). Bentham Science Publishers Ltd. https://doi.org/10.2174/0122103155273914231206094057
32. Mierczak, K., & Garus-Pakowska, A. (2024). An Overview of Apple Varieties and the Importance of Apple Consumption in the Prevention of Non-Communicable Diseases—A Narrative Review. In Nutrients (Vol. 16, Issue 19, p. 3307). MDPI AG. https://doi.org/10.3390/nu16193307
33. Tan, S., Lan, X., Chen, S., Zhong, X., & Li, W. (2023). Physical character, total polyphenols, anthocyanin profile and antioxidant activity of red cabbage as affected by five processing methods. In Food Research International (Vol. 169, p. 112929). Elsevier BV. https://doi.org/10.1016/j.foodres.2023.112929
34. Wang, L., Sang, W., Xu, R., & Cao, J. (2020). Alteration of flesh color and enhancement of bioactive substances via the stimulation of anthocyanin biosynthesis in 'Friar' plum fruit by low temperature and the removal. In Food Chemistry (Vol. 310, p. 125862). Elsevier BV. https://doi.org/10.1016/j.foodchem.2019.125862
35. Alencar, J. C. G. de, Pinto, G. T. da S., Cerqueira e Silva, K. F., Santos, J. M. S., Hubinger, M. D., Bicas, J. L., Maróstica Junior, M. R., Petkowicz, C. L. de O., & Paulino, B. N. (2025). Pectin and pectic oligosaccharides (POS): Recent advances for extraction, production, and its prebiotic potential. In Trends in Food Science & Technology (Vol. 155, p. 104808). Elsevier BV. https://doi.org/10.1016/j.tifs.2024.104808
36. Tykhonenko, T., Guzyk, M., Tykhomyrov, A., Korsa, V., Yanitska, L., & Kuchmerovska, T. (2022). Modulatory effects of vitamin B3 and its derivative on the levels of apoptotic and vascular regulators and cytoskeletal proteins in diabetic rat brain as signs of neuroprotection. In Biochimica et Biophysica Acta (BBA) - General Subjects (Vol. 1866, Issue 11, p. 130207). Elsevier BV. https://doi.org/10.1016/j.bbagen.2022.130207

37. Carr, A. C., Vlasiuk, E., Zawari, M., & Lunt, H. (2024). Understanding the additional impact of prediabetes and type 2 diabetes mellitus on vitamin C requirements in people living with obesity. In Nutrition Research (Vol. 130, pp. 1–10). Elsevier BV. https://doi.org/10.1016/j.nutres.2024.08.001
38. Zeng, Q., Liao, M., Li, Y., She, F., & Zhang, P. (2025). Association between dietary vitamin E intake and incident cardiovascular disease, cardiovascular, and all-cause mortality: A prospective cohort study using NHANES 2003–2018 data. In International Journal of Cardiology Cardiovascular Risk and Prevention (Vol. 24, p. 200340). Elsevier BV. https://doi.org/10.1016/j.ijcrp.2024.200340
39. Yerenova, B. Y., Pronina, Y., & Medvedkov, E. B. (2016). Production of melon-based juices with enriching herbal supplements. Bulgarian Journal of Agricultural Science (Vol. 22, Issue 5, p. 840-848). https://www.scopus.com/record/display.uri?eid=2-s2.0-84991759010&origin=resultslist
40. Ashokkumar, V., Flora, G., Sevanan, M., Sripriya, R., Chen, W. H., Park, J.-H., Rajesh banu, J., & Kumar, G. (2023). Technological advances in the production of carotenoids and their applications– A critical review. In Bioresource Technology (Vol. 367, p. 128215). Elsevier BV. https://doi.org/10.1016/j.biortech.2022.128215
41. Beggs, M. R., Bhullar, H., Dimke, H., & Alexander, R. T. (2022). The contribution of regulated colonic calcium absorption to the maintenance of calcium homeostasis. In The Journal of Steroid Biochemistry and Molecular Biology (Vol. 220, p. 106098). Elsevier BV. https://doi.org/10.1016/j.jsbmb.2022.106098
42. Wynne, Z., & Falat, C. (2023). Disorders of Calcium and Magnesium. In Emergency Medicine Clinics of North America (Vol. 41, Issue 4, pp. 833–848). Elsevier BV. https://doi.org/10.1016/j.emc.2023.07.004
43. Nemeth, E., & Ganz, T. (2023). Hepcidin and Iron in Health and Disease. In Annual Review of Medicine (Vol. 74, Issue 1, pp. 261–277). Annual Reviews. https://doi.org/10.1146/annurev-med-043021-032816
44. Karki, N., Achhami, H., Pachhai, B. B., Bhattarai, S., Shahi, D. K., Bhatt, L. R., & Joshi, M. K. (2024). Evaluating citrus juice: A comparative study of physicochemical, nutraceutical, antioxidant, and antimicrobial properties of citrus juices from Nepal. In Heliyon (Vol. 10, Issue 23, p. e40773). Elsevier BV. https://doi.org/10.1016/j.heliyon.2024.e40773
45. Yan, Y., Zou, M., Tang, C., Ao, H., He, L., Qiu, S., & Li, C. (2024). The insights into sour flavor and organic acids in alcoholic beverages. In Food Chemistry (Vol. 460, p. 140676). Elsevier BV. https://doi.org/10.1016/j.foodchem.2024.140676
46. Robles, A., Fabjanowicz, M., Chmiel, T., & Płotka-Wasylka, J. (2019). Determination and identification of organic acids in wine samples. Problems and challenges. In TrAC Trends in Analytical Chemistry (Vol. 120, p. 115630). Elsevier BV. https://doi.org/10.1016/j.trac.2019.115630

Funds:
This research received no external funding.

Acknowledgments:
We express our gratitude and deep appreciation to Dr Emmanuel A. Essah, PhD, Associate Professor in Sustainable Technologies, University of Reading., for the valuable advice and comments on the article.

Competing Interests:
The authors declare no conflict of interest.

Ethical Statement:
This article does not contain any studies that would require an ethical statement.

AI Statement:
AI tools were not used

Contact Address:

Bibipatyma Yerenova
Affiliation: Kazakh National Agrarian Research University, Faculty of Engineering Technologies, Department of Technology and food safety, Abay Avenue,8, 050010, Almaty, Republic of Kazakhstan
Tel.: +7 777 224 5956
E-mail: erenova-fatima69@mail.ru
ORCID: https://orcid.org/0000-0001-8177-4566
Author contribution: conceptualisation, methodology, project administration, writing – review & editing

Yuliya Pronina
Affiliation: Almaty Technological University, Faculty of Food Technology, Department of Technology of bread products and processing industries, Tole bi street, 100, 050012, Almaty, Republic of Kazakhstan,
Tel.: +7 777 0591865
E-mail: medvezhonok_87@inbox.ru
ORCID: https://orcid.org/0000-0003-0395-3379
Author contribution: data curation, investigation, writing – original draft

Nikolay Penov
Affiliation: University of Food Technologies, Faculty of Technology, Department of Food Preservation and Refrigeration Technology, Maritza Blvd, 26, 4002, Plovdiv, Bulgaria
Tel.: +359 89 885 1696
E-mail: npenov@yahoo.com
ORCID: https://orcid.org/0000-0001-9117-285X
Author contribution: validation, software, formal analysis

Rada Dinkova-Hadzhiyski
Affiliation: University of Food Technologies, Faculty of Technology, Department of Food Preservation and Refrigeration Technology, Maritza Blvd, 26, 4002, Plovdiv, Bulgaria
Tel.: +359876198098
E-mail: rada.dinkova@gmail.com
ORCID: https://orcid.org/0000-0002-7523-3920
Author contribution: investigation, writing – review & editing

Nataliia Kondratiuk
Affiliation: Oles' Honchar Dnipro National University, Faculty of Chemistry, Department of Food Technology, Gagarin Avenue, 72, 49010, Dnipro, Ukraine
E-mail: kondratjukn3105@gmail.com
ORCID: https://orcid.org/0000-0002-0919-8979
Author contribution: data curation, writing – review & editing, visualisation

Aigul Almaganbetova
Affiliation: Kazakh National Agrarian Research University, Faculty of Engineering Technologies, Department of Technology and food safety, Abay Avenue, 8, 050010, Almaty, Republic of Kazakhstan
E-mail: erkemturmahan@yandex.ru
ORCID: https://orcid.org/0000-0002-3141-3049
Author contribution: investigation, writing – review & editing

Corresponding author: **Yuliya Pronina**