The object of this study is the technology of canning melon using texture stabilizers and antioxidants. The task is to preserve the organoleptic and physicochemical characteristics of the melon during canning and storage. Conventional processing methods lead to the loss of texture, aroma, and color, which reduces the consumer properties of the product.

The subject of the study is the effect of the concentration of calcium chloride, pectin, and blackcurrant extract on the textural, taste, and physicochemical properties of canned melon under various heat treatment modes and storage conditions. This paper discusses the optimization of melon canning technology aimed at improving its organoleptic and physicochemical properties. The effect of the concentration of calcium chloride, pectin, and blackcurrant extract on the texture, taste, and stability of the product during storage has been investigated.

Optimal parameters for canning melon, including stabilizer concentrations (1.25 % $CaCl_2$, 1.0 % pectin) and heat treatment mode (70 °C, 20 minutes) have been defined.

It has been established that the combination of calcium chloride and pectin helps preserve the texture and improve the consistency of melon during long-term storage.

It has been revealed that the antioxidant properties of blackcurrant extract help preserve the color and taste of the canned product.

It has been determined that the optimal storage temperature is 4 °C, at which the product retains its characteristics for a year, while at room temperature the shelf life is reduced to 9 months.

The results could be used in the food industry for the production of canned melon with improved characteristics. Optimal parameters are especially relevant for storage in high temperatures in the south of Kazakhstan

Keywords: sterilization parameters, sensory quality, influence of pectin and calcium chloride, optimization of heat treatment, organoleptic properties, antioxidants, pectin, packaging

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OPTIMIZATION OF MELON PRESERVATION TECHNOLOGY USING TEXTURE STABILIZERS AND ANTIOXIDANTS

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1. Introduction

Melon is one of the significant melon crops, actively cultivated in many countries of the world. According to [1], global melon production in 2022 exceeded 27 million tons, with China, Turkey, Iran, and Egypt remaining the main producing countries. In the countries of the European Union and the USA, melon is widely used both fresh and processed, which makes the development of effective technologies for its preservation an urgent task. Thus, according to FAO (2023) [1], about 1.3 billion tons of food products, including fruits and vegetables, are lost annually, which is a third of the total food produced. One of the key factors in losses is the development of microorganisms such as bacteria, molds, and yeasts, which significantly reduce the shelf life of products. Studies show that conventional preservation methods, including chemical treatment and modified atmosphere, have their limitations, such as residual chemicals and negative impacts on the environment. In this regard, there is a need for sustainable and safe solutions to increase the shelf life of fruit and vegetable products.

Modern methods of melon processing include heat treatment, canning, drying, and freezing. However, high humidity and soft texture of the pulp make this product difficult for long-term storage. Studies [2, 3] confirm that conventional methods of preservation do not always make it possible to preserve the textural and taste characteristics of melon. For example, strict thermal conditions lead to the loss of sensory properties, while vacuum canning and freeze-drying show better results.

The relevance of this study is due to the growing demand for high-quality canned products with a long shelf life, while preserving natural organoleptic and physicochemical properties. Under modern conditions, taking into account climate change, transportation difficulties, and seasonality of production, effective methods of preservation are becoming necessary to ensure year-round availability of fruits.

The practical significance of the study is the optimization of melon preservation technology, ensuring maximum preservation of its texture, taste, and nutritional value. The results could be used in industrial production to improve the quality and prolong the shelf life of canned melon, which is especially important for regions with a hot climate. The devised methodology could be adapted for preserving other types of fruits, expanding its application in the food industry.

The main areas of modern research include the use of natural stabilizers (for example, calcium chloride and pectin) to improve the texture of canned melon, the use of antioxidant additives to preserve color and taste, and the optimization of heat treatment to extend shelf life. The importance of developing such technologies is due not only to the needs of the food industry but also to the growing interest of consumers in natural and minimally processed products.

Thus, research aimed at improving melon preservation technologies is relevant. It makes it possible not only to extend shelf life but also preserve the nutritional value and organoleptic properties of the product, which meets the requirements of the modern food industry and consumer preferences.

2. Literature review and problem statement

Work [4] identified the main precursors of volatile sulfur compounds – S-methyl methionine and methionine, which decompose during heat treatment. Effective strategies for reducing their formation were proposed, including adjusting the pH to 2.0 and adding epicatechin as an antioxidant, which significantly reduces the intensity of undesirable odors. The study is aimed at identifying the precursors of these compounds and determining methods for their inhibition to improve the sensory characteristics of processed melon juice. Thus, the cited study emphasizes the need to devise optimal melon processing technologies, including control over heat treatment conditions and the use of antioxidants, which could improve the quality of the product and make it more attractive to consumers. However, the mechanism of decomposition of volatile compounds depending on temperatures has not been studied. There are no recommendations that would allow one to determine under what conditions melon fruits should be processed, and which antioxidants are more effective. Different melon varieties may have different levels of precursors and require an individual approach to processing.

The prospects of using green synthesis of silver nanoparticles (AgNPs) as an environmentally friendly and effective solution for extending the shelf life of fruits and vegetables are also considered. The problem that the authors focus on is significant post-harvest losses of fruit and vegetable products due to microbiological contamination, insufficient cooling, and improper storage conditions.

Study [5] emphasizes that green synthesis of AgNPs makes it possible not only to increase the efficiency of storing fruits and vegetables but also ensure consumer safety due to the absence of toxic chemicals. However, for the mass implementation of this technology, it is necessary to conduct additional research on the effect of nanoparticles on the structure of packaging materials, as well as to assess the economic feasibility of their use on an industrial scale.

The main problem with storing oriental sweet melon is its limited shelf life – about 10 days at room temperature (23 °C). Rapid aging of the fruit is accompanied by softening, yellowing of the rind, and microbiological spoilage, which complicates the transportation and sale of the product. Study [6] showed that treatment with ethanol steam (0.5 ml/kg and 3 ml/kg) helps slow down the aging process of the fruit by suppressing ethylene biosynthesis and increasing the content of volatile aromatic compounds, especially ethyl esters. During the experiment, it was found that treatment with 0.5 ml/kg more effectively preserves the quality of the melon than a higher dose. The use of ethanol suppresses the activity of key enzymes involved in ethylene biosynthesis – 1-aminocyclopropane-1-carboxylic acid (ACC) synthase and oxidase, and inhibits the expression of the CM-ACO1, CM-ACO2, CM-ACS1, and CM-ACS2 genes responsible for ethylene production. The results of the study confirmed that steam treatment with ethanol is a promising technology for extending the shelf life of oriental sweet melon, slowing down the aging process, preserving the appearance, and improving the aromatic profile of the fruit. This method can find application in logistics and retail, minimizing product losses and ensuring high product quality during storage. However, there is no data on the long-term effect of steam treatment with ethanol on the general properties of melon and the possible impact on consumer health. Different melon varieties may respond differently to the treatment, which complicates the standardization of the method and its mass application.

Papers that tackle juice production consider the problem of shelf stability. The main problem in processing and storing melon and watermelon juices is their high susceptibility to microbiological contamination. Due to low acidity (pH 5.2–6.7) and high water activity (0.97–0.99), juices from these fruits provide a favorable environment for the growth of pathogenic microorganisms such as Escherichia coli O157:H7, Salmonella Enteritidis, and Listeria monocytogenes, which can be transferred to the edible part when cutting fruits with contaminated peel. Conventional thermal processing methods are capable of destroying pathogens, but they impair the organoleptic and nutritional properties of juices, which requires the search for alternative technologies.

HIPEF (high-intensity pulsed electric fields) is a non-thermal preservation technology based on the short-term action of high-voltage pulses on liquid products, which leads to inactivation of microorganisms without significant impact on juice quality. Study [7] found that HIPEF treatment (35 kV/cm, 1709 μs at 193 Hz) in combination with the addition of 2.0 % citric acid or 0.2 % cinnamon oil reduced the pathogen population by more than 5 log CFU/ml and increased the shelf life of juices to 91 days at a storage temperature of 5 °C. However, the study also revealed that the use of antimicrobial agents affected the taste and aroma characteristics of the juices, which requires further research to minimize the impact on the organoleptic properties of the product. The results of the study show that the combined use of HIPEF and natural antimicrobial substances is an effective method for improving the microbiological safety and extending the shelf life of melon and watermelon juices. However, further research is needed to optimize the processing conditions to minimize the impact on the taste and odor of the product.

Work [8] reports a study on the effect of melon juice processing by the dense phase carbon dioxide (DP-CO2) method on the microbiological, enzymatic, and aromatic properties of the product. The study demonstrated that processing at 35 MPa and 55 °C for 60 minutes ensures complete inactivation of microorganisms, and the residual activity of key enzymes, such as polyphenol oxidase (PPO), peroxidase (POD), and lipoxygenase (LOX), is significantly reduced. An important advantage of DP-CO2 is the preservation of juice aroma, since the thermal effect is minimal, and as a result of storage at 4 °C for 4 weeks, no formation of foreign odors is observed. The results of the study confirmed that melon juice processing by DP-CO2 is a promising alternative to thermal pasteurization methods. It makes it possible to significantly reduce microbiological risks, preserve vitamin C, and prevent the development of product darkening, which makes this method attractive for industrial implementation in the production of freshly squeezed melon juices. Although the DP-CO2 method inactivates microorganisms and reduces the activity of key enzymes, there are unresolved questions about the long-term impact on juice quality and the potential health risks to consumers with long-term use.

Study [9] showed that the combined use of 1 % hydrogen peroxide (H_2O_2), 25 μg/mL nisin, 1 % sodium lactate, and 0.5 % citric acid (HPLNC) significantly reduced pathogenic bacterial populations on the melon surface and prevented their transfer to freshly cut pieces. In the experiment, HPLNC treatment reduced E. coli O157:H7 and L. monocytogenes levels by 3–4 log CFU/cm^2 on both cantaloupe and honeydew melon. HPLNC treatment was significantly more effective than 2.5 % hydrogen peroxide in ensuring the absence of bacteria in freshly cut pieces after storage. However, the organoleptic properties of melon after processing were not studied in the work, and the optimal storage time for freshly cut pieces of melon after disinfection was not determined. The physicochemical properties of melon during processing have been considered in many papers. Study [10] considered rational compositions of multicomponent juices based on melon crops, emphasizing the influence of the composition of raw materials on the quality of the final product. The main attention is paid to the development of process parameters that affect the preservation of vitamins and microelements. But the selection of processing modes for preserving vitamins and microelements during the processing of multicomponent juices, taking into account the diversity of the composition of raw materials, is also of interest.

Study [11] analyzes critical control points in the melon processing process, identifying key factors affecting the product's shelf life. It was determined that temperatures below 10 °C slow down spoilage processes and preserve organoleptic properties. The main focus is on process safety, not product quality characteristics.

Work [12] focuses on the effect of modified atmosphere and packaging on the preservation of melon during long-term storage. It was found that the use of vacuum packaging and humidity control extends the shelf life without loss of taste. The issue of the complex effect of stabilizers and antioxidants on canned melon remains unresolved.

Works [13, 14] consider the organoleptic characteristics and nutritional value of the developed products, as well as methods for processing melon fruits. The results of the work provide a general overview of the methods for processing melon crops, but their applicability to the development of melon preservation technology is limited. The papers consider conventional processing methods such as drying and freezing, but there is virtually no analysis of the effect of stabilizers on the texture of canned melon. Study [15] does not answer the question of how the proposed processing methods affect the texture and organoleptic properties of melon during storage. This limits the applicability of the results, since when preserving, it is important not only to preserve the raw material, but also to ensure the stability of its characteristics over a long period. The results of study [16] show that the addition of pectin improves the consistency of melon-based jelly products. However, the application of this approach to syrup preservation is limited since the jelly structure differs from the texture of natural melon slices. In addition, the work does not consider the effect of sterilization, which makes it insufficiently applicable for the development of melon syrup preservation technology.

Study [17] examines fruit preservation in the context of tourism rather than as a technological processing process. The results of the study are useful for marketing strategies but do not provide practical recommendations for canning melon. The packaging and storage methods used do not take into account the specific features of the melon structure and therefore cannot be directly adapted in this study.

Paper [18] confirms that an increase in storage temperature has a negative effect on the organoleptic characteristics of melon. However, the study does not address the issue of stabilizing the product structure, which limits the possibility of applying the obtained results in long-term storage technology. Study [19] examined the effect of high CO_2 pressure and mild heat treatment on the quality of watermelon juice, but this is not applicable to canning melon in syrup. Firstly, melon has a different cellular structure, requiring other stabilizers. Secondly, the study focuses on a liquid product, and not on preserving the texture of whole pieces, which is a key issue for canned melon. In [20], the effect of storage temperature conditions on the change in color and taste of freshly cut melon was investigated. However, the work does not consider texture stabilization and does not offer solutions for extending shelf life during canning. Study [21] considers the effect of slicing and storage temperature on the metabolism of sugars and organic acids in melon. The results show that at lower temperatures, the processes of sugar decomposition slow down, which can contribute to the preservation of taste characteristics. However, the work does not consider the effect of freezing and defrosting on the organoleptic properties of melon and does not touch on the use of stabilizers to preserve texture.

Our review of the literature reveals the following:

– there are no comprehensive studies on the use of texture stabilizers ($CaCl_2$, pectin) in canned melon;

– there is insufficient data on the effect of antioxidants on the preservation of melon flavor characteristics.

Thus, our review of the literature shows that, despite the active study of melon processing and preservation issues, there is still no scientifically substantiated data on the effect of stabilizers and antioxidants on product stability during long-term storage. It is also necessary to devise processing methods that make it possible to preserve the texture and taste of melon over a long time.

3. The aim and objectives of the study

The aim of our study is to optimize the key elements of melon preservation technology aimed at preserving its nutritional value, organoleptic characteristics, and consumer properties during storage.

To achieve this goal, the following tasks are set:

– to study the effect of calcium chloride and pectin concentration on product quality;

– to determine the optimal heat treatment modes;

– to analyze the organoleptic and physicochemical indicators of canned melon;

– to compile recommendations for storing finished products.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our study is the technology of preserving the Myrzashol melon variety, using texture stabilizers and antioxidants to extend the shelf life and preserve organoleptic properties.

The hypothesis of the study assumes that the use of calcium chloride ($CaCl_2$) and pectin in optimal concentrations in combination with blackcurrant extract could preserve the texture, color, and taste of canned melon during long-term storage.

Assumptions adopted in the study:

– the optimal concentration of texture stabilizers varies in the range of 0.5–2.0 % for $CaCl_2$ and 0.75–1.25 % for pectin;

– the introduction of blackcurrant extract increases the antioxidant properties of the product, helping to preserve color and taste;

– the storage temperature regime has a significant impact on the shelf life and quality of the melon.

Simplifications accepted in the study:

– the study is conducted on three varieties of melon, without taking into account possible varietal differences in the chemical composition;

– only aqueous solutions of stabilizers are considered, without additional combinations with other preservatives;

– the influence of only three main factors is assessed: the concentration of $CaCl_2$, pectin, and storage temperature.

4. 2. Materials, methods, and study variables

Effect of stabilizers on melon texture.

Melon was cut into cubes (30×30×30 mm), which were immersed in aqueous solutions of CaCl2 with a concentration of 0.5 %, 1.25 %, and 2.0 % for 10 minutes. Then the samples were kept in a pectin solution with a concentration of 0.75 %, 1.0 %, and 1.25 %. After processing, the melon was packed in glass jars with syrup (sugar – 15 %, blackcurrant extract – 0.5 %), and heat treated at 70 °C for 20 minutes.

Control sample – melon treated with distilled water without stabilizers.

Study factors:

– $CaCl_2$ concentration: 0.5 %, 1.25 %, 2.0 %;

– pectin concentration: 0.75 %, 1.0 %, 1.25 %;

– storage temperature: 4 °C, 10 °C, 29 °C;

– objective function – organoleptic assessment.

The effect of storage temperature on the quality of canned melon.

The samples were stored at temperatures of 4 °C, 10 °C, and 29 °C for 12 months. Monthly assessment of organoleptic indicators and weight loss was carried out.

Methods:

– determination of textural characteristics using the TA.XT Plus texture analyzer;

– viscosity measurement using viscometry;

– organoleptic assessment (taste, aroma, consistency) on a 9-point scale.

Determination of optimal heat treatment modes (temperature, time).

Materials: melon fruits; cooking kettle with a temperature range of 60–90 °C; drinking water, sugar, blackcurrant leaf extract.

Methods: heat treatment of samples at a temperature of 60 °C, 70 °C, 80 °C with different durations (15, 20, and 30 minutes); assessment of the effect of heat treatment on dry matter content (refractometry method); measurement of change in sample weight during treatment; monitoring of pH changes using an HI98103 pH meter.

Analysis of organoleptic and physicochemical parameters of canned melon.

Materials: samples of canned melon prepared under different processing conditions; standard solutions for acidity and sugar content analysis.

Methods: determination of organoleptic characteristics (taste, aroma, consistency) by expert tasting according to GOST 8756.1-2017.

Physicochemical analysis:

– determination of pH by potentiometry;

– determination of sugars by HPLC (high performance liquid chromatography).

Development of recommendations for storage of finished products.

Materials: canned products packed in glass and plastic containers; refrigeration equipment with adjustable storage temperatures.

Methods:

– storage at temperatures of 4 °C, 10 °C, 20 °C with monthly analysis of changes;

– microbiological safety control according to GOST 10444.15-94;

– assessment of color and consistency changes under different storage conditions;

– determination of shelf life by the accelerated testing method.

Assessment of losses of flavor properties was carried out by an expert tasting committee on a 9-point scale. During the tasting, sweetness, acidity, aroma intensity and the presence of foreign flavors were taken into account. The effect of heat treatment and storage conditions on flavor properties was analyzed by comparing tasting assessments at different stages of storage.

All studies were conducted in triplicate, and the results were processed by statistical analysis methods (ANOVA analysis of variance) using the Statistica 12.0 (USA, TIBCO) and Excel (Microsoft, USA) software packages. The technological scheme of the technique for preserving melon is shown in Fig. 1.

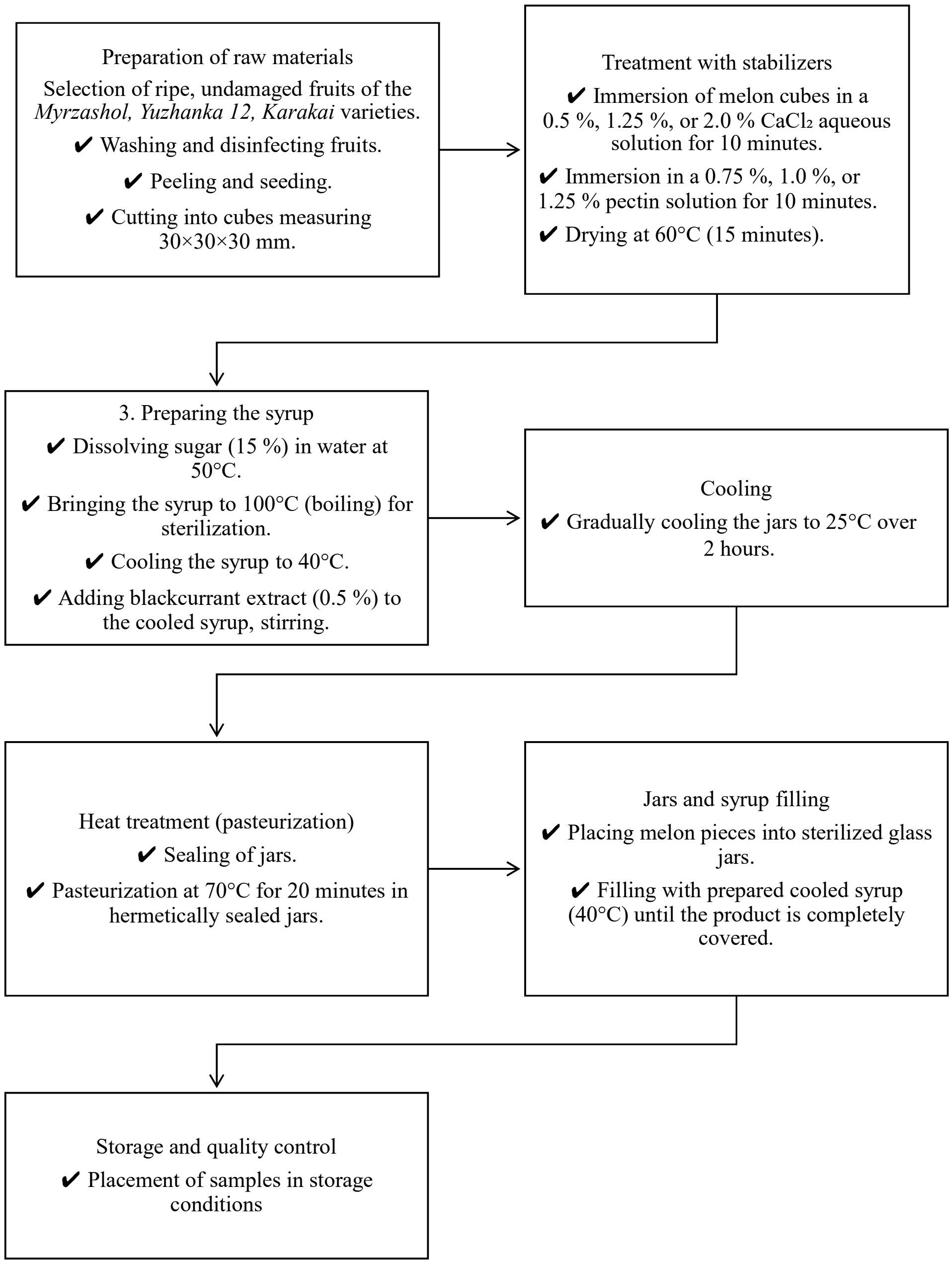


Fig. 1. Technological scheme of melon canning

5. Results related to devising canning technology

5. 1. Investigating the influence of calcium chloride and pectin concentration on product quality

Table 1 gives the results of analysis of the textural characteristics of melon samples at different concentrations of $CaCl_2$ and pectin (mean value ± standard deviation).

The difference between the control and treated samples in viscosity is significant since the difference (0.70 Pa•s)>LSD0.5 (0.64 Pa•s). This confirms that the addition of stabilizers helps increase the viscosity of the product.

The difference between the control and treated samples in hardness is statistically significant since the difference (8.0 H)>LSD0.5 (6.85 H). This indicates that stabilizers significantly increase the strength characteristics of the melon.

These results confirm the effectiveness of using $CaCl_2$ and pectin in the technology of canning melon, providing improved textural characteristics and product stability.

Table 1

Influence of calcium chloride and pectin concentration on the textural characteristics of the Myrzashol melon variety

Factor A: $CaCl_2$ (%)	Factor B: Pectin (%)	Solidity (H)	Viscosity (Pa·s)	Organoleptic properties (points)	LDS (Solidity)	LSD (Viscosity)	LSD (Organoleptic properties)	Power of influence $CaCl_2$	The power of Pectin's influence
0.5	0.75	15.2	1.35	7.8	6.85	0.64	1.35	0.59	0.75
1.25	1.0	18.5	1.6	8.5	6.85	0.64	1.35	0.78	0.78
2.0	1.25	20.3	1.85	8.0	6.85	0.64	1.35	0.51	0.52

To study the effect of calcium chloride and blackcurrant extract additives on the organoleptic properties of canned melon, mathematical processing of the experimental data was carried out. Fig. 2 shows the response surface demonstrating the effect of calcium chloride concentration ($CaCl_2$, g/l) and mass fraction of blackcurrant extract (%) on the organoleptic assessment of the product. Data on processing allow us to identify the optimal ratios of ingredients to ensure the best taste characteristics.

Regression equation:

$$z=5.8+1.75x-0.1x^2+ \\ +4.8y-4.8xy+0.35x-0.025. \quad (1)$$

As can be seen from the chart (Fig. 2), an increase in the calcium chloride concentration above 1.2 g/l leads to a decrease in organoleptic indicators, which is probably due to the excessive rigidity of the product structure. At the same time, the average content of blackcurrant extract (about 0.6–0.8 %) helps improve the taste characteristics, which is confirmed by the highest values of the organoleptic assessment (>9 points). Thus, the optimal recipe involves the use of calcium chloride in an amount of no more than 1.0 g/l and the addition of blackcurrant extract in the range of 0.6–0.8 %. Blackcurrant extract is specified in the methodology and was added to the syrup to study the effect on shelf life.

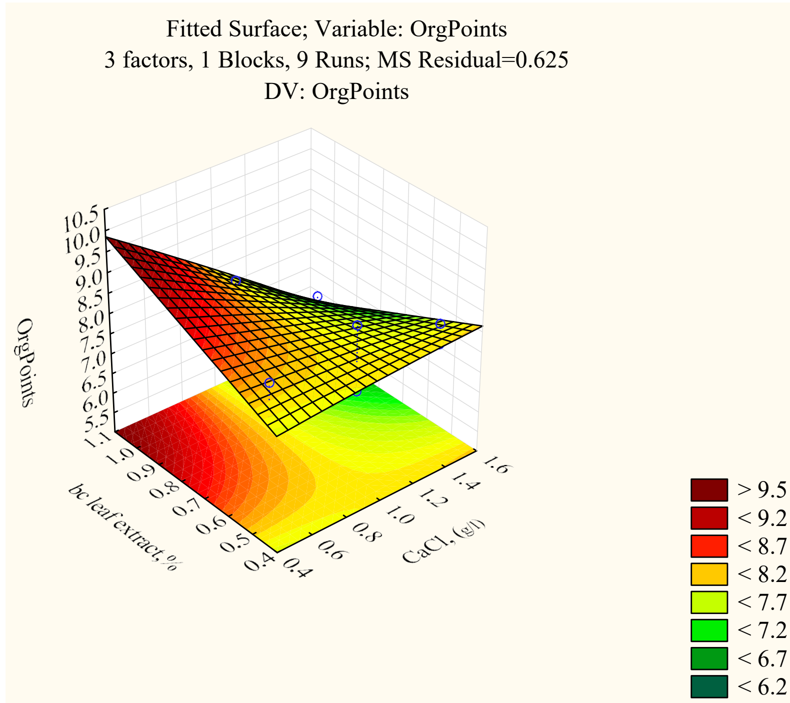


Fig. 2. Effect of calcium chloride and blackcurrant extract on the organoleptic evaluation of canned melon

Fig. 3 shows the effect of the concentration of calcium chloride and pectin on the organoleptic characteristics of canned melon in syrup. Analysis of the obtained data reveals that an increase in the concentration of calcium chloride leads to a decrease in organoleptic assessments, while the addition of pectin has a positive effect on the consistency of the product. Maximum organoleptic assessment scores are recorded with a moderate concentration of calcium chloride and pectin, which indicates the need to optimize the recipe to achieve the best taste qualities.

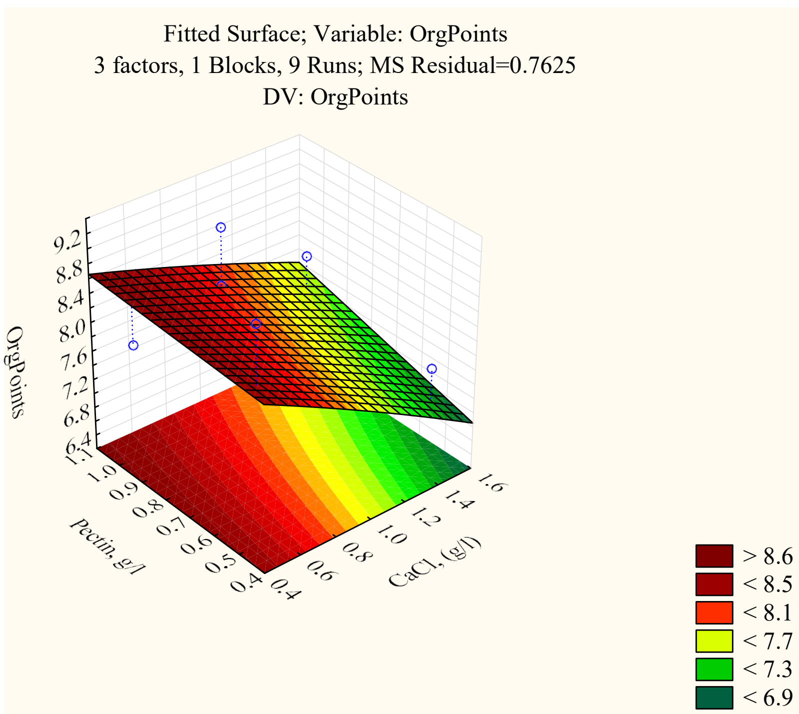


Fig. 3. Effect of calcium chloride and pectin concentration on the total score of organoleptic assessment

The response surface analysis revealed that the best organoleptic characteristics are achieved with a calcium chloride content of 0.8–1.0 g/l and pectin of 0.6–0.8 g/l. With these values, the syrup remains transparent, and the melon slices retain clear lines on the cut.

Since the response surface in this study is a hyperplane, the values found correspond to the local optimum within the range of factor variation. Factor variation limits:

– calcium chloride: 0.5–2.0 g/l;

– pectin: 0.75–1.25 g/l.

The data obtained could be used to devise technological solutions aimed at improving the quality of canned fruit products.

5. 2. Determination of optimal heat treatment modes

Table 2 gives data on changes in the physical and chemical parameters depending on the temperature and time of heat treatment (mean value ± standard deviation).

The difference between the temperature and the time of processing is significant since the temperature has the main effect on the weight loss and vitamin C, and the time of processing exerts the main effect on the texture and organoleptic properties. Based on the analysis of the data, the optimal parameters are 85–90 °C and 10–15 minutes, which ensures the preservation of the structure, minimal weight loss, and high organoleptic assessment.

Table 2

Influence of temperature and time of heat treatment on the quality of canned melon

Temperature, °C	Time, min	Weight loss, %	Sugar content, %	pH	Organoleptic assessment (points)	Vitamin C content, mg/100 g
60	10	5.8	10.7	3.87	8.6	29.5
60	15	5.5	10.6	3.85	8.5	29
70	10	5.3	10	3.78	8.4	26.5
70	15	5.1	9.9	3.75	8.3	26
80	10	7.2	9.1	3.68	7.8	21.8
80	15	6.8	9	3.65	7.6	21
85	10	4.3	10.2	3.8	8.7	28
85	15	4.5	10.1	3.78	8.6	27.5
90	10	4.1	10.1	3.77	8.8	27.2
90	15	4.3	10	3.74	8.7	26.8

The results of our study showed that the temperature and duration of heat treatment have a significant effect on the quality of canned melon.

With an increase in temperature, a decrease in organoleptic indicators such as taste, color, and texture is observed, which may be due to the thermal destruction of pectin substances and deterioration of the product structure. The optimal heat treatment parameters (temperature 85–90 °C and time 15–20 minutes) help preserve the taste and structure of the product, preventing excessive softening and loss of aroma (Fig. 4).

Fig. 4 depicts the profiles of predicted values and desirability depending on the temperature (T, °C) and time of heat treatment (t, min). The Y axis shows the key quality indicators of canned melon: weight loss (pm, %), sugar content (S, %), pH, organoleptic assessment (OrgPoint), and vitamin C content (C mg/100 g).

In addition, analysis of physical and chemical indicators revealed that excessive heat treatment leads to a significant decrease in vitamin C content and an increase in dry matter losses. Thus, the selection of the optimal temperature-time regime is a key factor in ensuring high quality of canned melon and extending its shelf life.

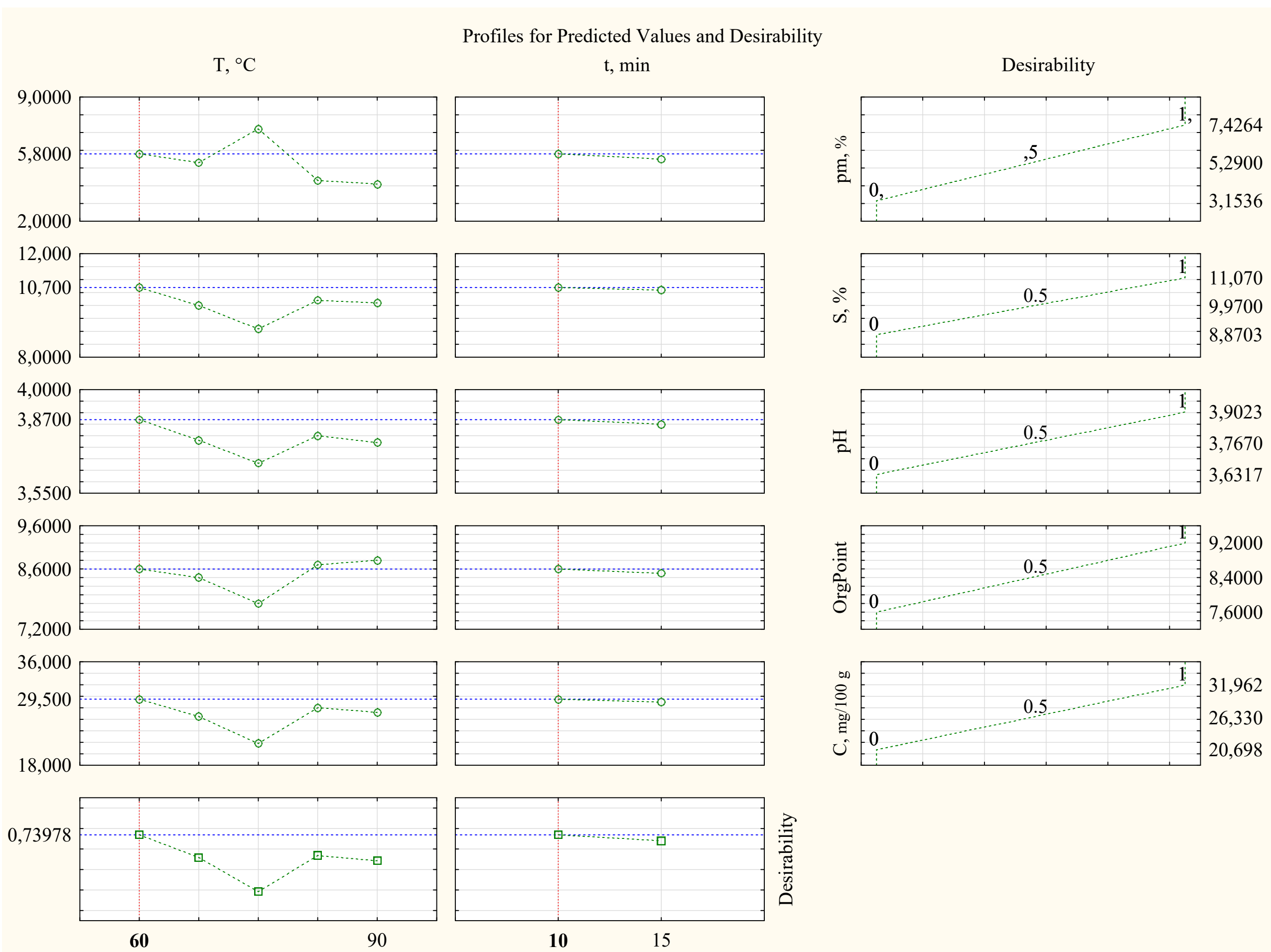


Fig. 4. Predicted value and desirability profiles depending on temperature (*T*, °C) and heat treatment time (*t*, min)

5. 3. Analysis of organoleptic indicators of canned melon

The results of tasting evaluation are given in Table 3 (mean value±standard deviation).

Table 3

Organoleptic evaluation of canned melon of the Myrzashol variety

Parameter	Mean score (out of 9)
Taste	8.4±0.3
Aroma	8.2±0.2
Consistency	8.6±0.4

The results of the organoleptic evaluation (Table 3) indicate the high quality of the canned melon obtained according to the stated recipe. The average scores for such indicators as taste (8.4), aroma (8.2), and consistency (8.6) indicate a positive perception of the product by the tasting board.

Fig. 5 shows the dependence of the organoleptic evaluation of canned melon on the sterilization time and the concentration of calcium chloride. The mathematical model is represented by the following equation:

$$Z=8.0222-0.0633x+1.9111y+ +0.0007x2-1.6515*10- -15xy-0.7111y2. \quad (2)$$

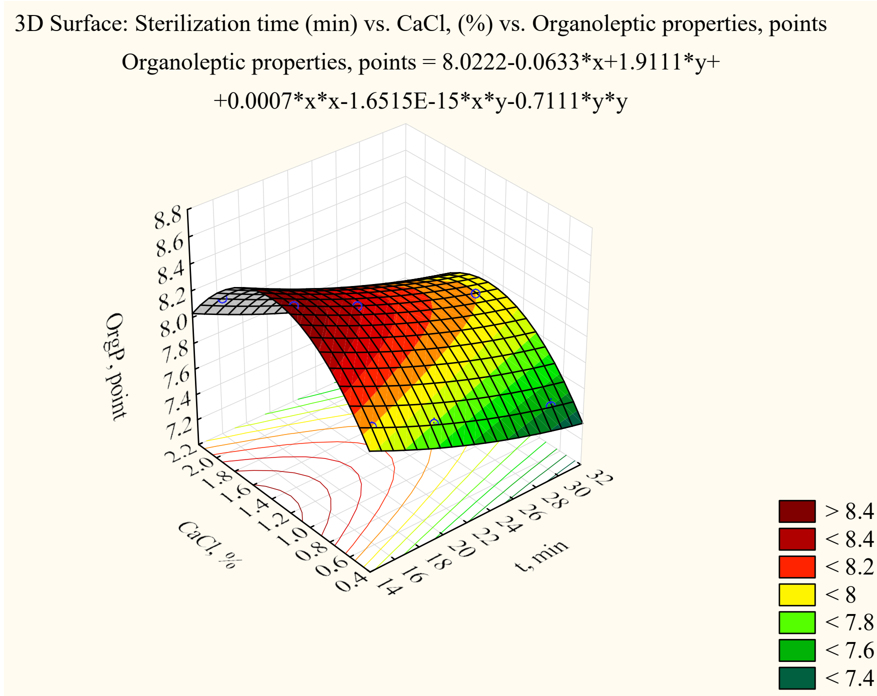


Fig. 5. Effect of sterilization time and calcium chloride concentration on the organoleptic characteristics of canned melon

The response surface analysis reveals that the optimal organoleptic properties (8.2–8.4 points) are achieved at a calcium chloride concentration in the range of 0.8–1.2 % and a sterilization time of 10–12 minutes. An increase in the $CaCl_2$ concentration above 1.2 % leads to a decrease in the organoleptic characteristics, which may be due to a change in the texture and excessive density of the product. A decrease in the sterilization time below 8 minutes negatively affects the taste characteristics, which may be due to insufficient heat treatment.

Thus, to achieve the best combination of taste and texture characteristics, it is recommended to use a $CaCl_2$ concentration of 1.0 % with a sterilization time of 10 minutes.

Changes in organoleptic indicators were observed under various storage conditions (4 °C, 22 °C, 35 °C), in plastic containers with a sealed lid, and in a hermetically sealed glass jar. The observation results at room temperature (22 °C) are shown in Fig. 6.

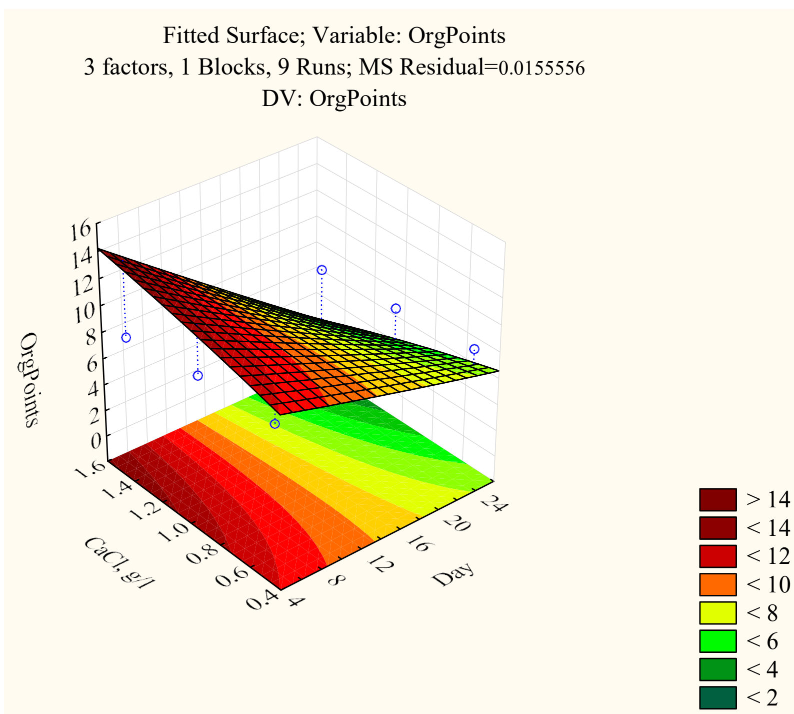


Fig. 6. Dynamics of changes in organoleptic characteristics during storage at room temperature

The dynamics of changes in organoleptic characteristics during storage at 35 °C were studied at room temperature in southern Kazakhstan (Fig. 7).

Fig. 7 illustrates the dynamics of changes in the studied indicators depending on the processing conditions. The results obtained make it possible to visually assess trends, confirming the identified patterns.

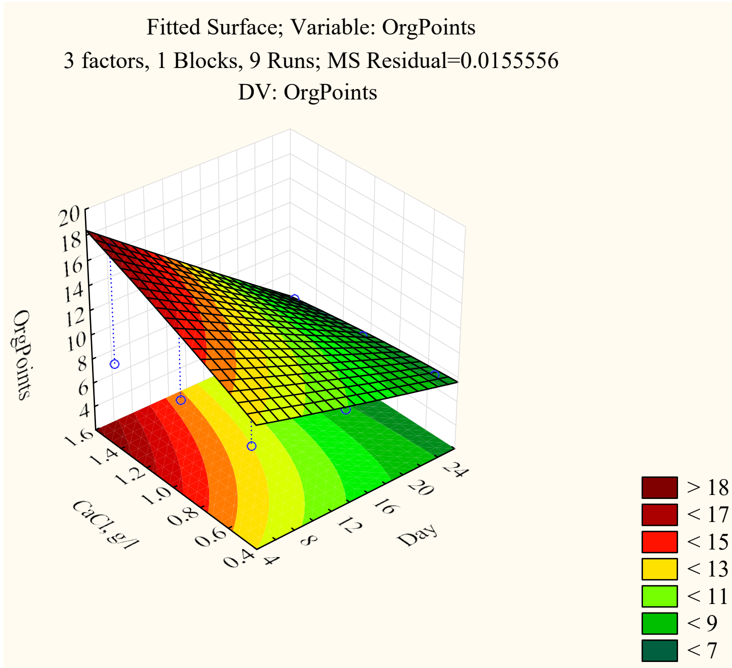


Fig. 7. Dynamics of changes in organoleptic characteristics during storage at 35 °C temperature

5. 4. Compiling recommendations for storing finished products

Table 4 gives the results of changes in product quality at different storage temperatures (mean value ± standard deviation).

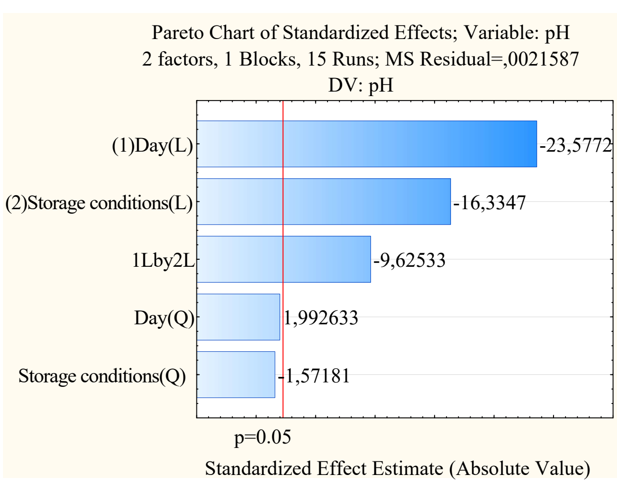
Table 4

Influence of storage temperature on product quality

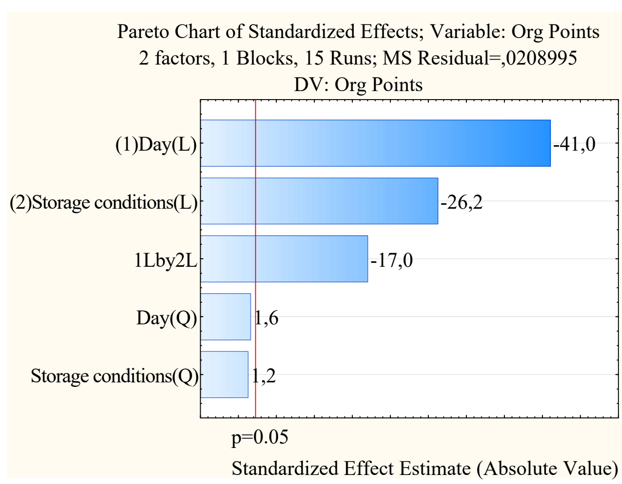
Storage temperature, °C	Shelf life, months	Change in pH	Loss of taste
4	6	3.7±0.1	Minor
10	3	3.9±0.1	Moderate
29	1.5	4.1±0.2	Significant
35	1	4.3±0.2	Sharp degradation

Fig. 8 shows the effect of different storage conditions (1 – refrigerated storage, 2 – room temperature, 3 – high-temperature storage) on pH (a) and organoleptic characteristics of the product (b). Analysis revealed that changing storage conditions has a significant effect on the studied parameters. Storage in plastic containers with a sealed lid is possible but leads to deterioration of the organoleptic properties and a reduction in shelf life to 9 months, in contrast to glass containers, in which the product is stored for up to 12 months.

As can be seen from Fig. 8, the most significant effect on pH and taste characteristics is exerted by the factor "day of storage" (Day), which indicates progressive changes in the product over time. Storage conditions also play an important role, especially at high temperatures typical for the summer period in the southern regions of Kazakhstan (30–40 °C). The interaction of factors (1Lby2L) also demonstrated a significant effect on the studied parameters, while the quadratic effects (Day (Q), Storage conditions (Q)) were statistically insignificant.



a



b

Fig. 8. Influence of storage conditions on pH and taste characteristics: 1 – refrigerated storage; 2 – room temperature; 3 – high-temperature storage; *a* – pH; *b* – organoleptic characteristics of the product

Our results showed that the optimal parameters for melon processing include the use of calcium chloride at a concentration of 1.25 %, pectin – 1.0 %, heat treatment at 70 °C for 20 minutes. To extend the shelf life, a temperature of 4 °C is recommended.

Statistical analysis (ANOVA) confirmed the significant effect of factors on the organoleptic and physicochemical properties of the product ($p<0.05$). The effect of CaCl2 and pectin concentration on product hardness is 0.59 (F-criterion), and on viscosity – 0.78. The difference between the control and treated groups is statistically significant, as it exceeds LSD (0.5 %).

Thus, the optimized processing mode provides the best textural characteristics of the product, minimizing the loss of taste and consistency.

6. Discussion of the influence of process parameters on the quality of canned melon

Analysis of the experimental data (Fig. 2) revealed that the concentration of calcium chloride (CaCl2) has a significant effect on the texture and organoleptic properties of the product. It was found that the concentration of CaCl2 in the range of 0.8–1.0 g/l helps achieve optimal consistency, while higher concentrations lead to deterioration in taste characteristics due to excessive hardness of the product.

Unlike paper [22], which only studied the effect of calcium compounds on the texture of products (e.g., stabilization of the cell wall and pectin), this work considers the complex effect of pectin and blackcurrant extract. This made it possible to improve the perception of the texture of canned melon, which is confirmed by higher organoleptic assessments (Fig. 2).

Based on the data given in Table 2, it was found that a processing temperature of 70 °C for 20 minutes is the most effective for preserving the quality of canned melon. This mode makes it possible to minimize weight loss (4.8 %), maintain sugar content at 9.8 %, and stabilize pH at 3.7.

Analysis (Fig. 3) reveals that at 22 °C the taste and aroma gradually deteriorate, but the product structure remains at a satisfactory level. In contrast to the methods described in [23], in which higher temperatures (>80 °C) were used, which led to the destruction of the cellular structure and a decrease in sensory characteristics, the proposed heat treatment regime allows us to preserve optimal organoleptic indicators (Fig. 3). Thus, our approach minimizes the loss of taste qualities, ensuring the softness and juiciness of the product.

The results of the organoleptic assessment (Table 3) show that at 85–90 °C the taste and aroma scores are higher than at 70 °C. However, at 70 °C/20 min, heat treatment does not guarantee complete destruction of pathogenic microflora, which requires the use of higher temperatures.

At 85–90 °C and short-term treatment (10–15 min), the product aroma is preserved since volatile compounds have time to evaporate. However, with prolonged heat treatment at high temperatures, a deterioration in odor is observed, similar to boiled cucumbers, which can negatively affect the consumer properties of the product.

Given the balance between safety, organoleptic characteristics, and minimization of unwanted odors, the optimal processing mode is 85–90 °C for 10–15 min.

The decrease in flavor characteristics at high storage temperatures (≥29 °C) is explained by:

Oxidation of organic acids, which leads to a change in the acid-base balance (Table 4).

Destruction of volatile aromatic compounds responsible for the characteristic aroma of melon.

Caramelization of sugars at higher temperatures, which leads to a change in flavor.

Optimum conditions (highlighted by the red line) are observed at a temperature of 60 °C and a time of 10 minutes, which minimizes weight loss and maximizes organoleptic characteristics and vitamin C content. The desirability chart shows that increasing the cooking time has a beneficial effect on product quality, but excessive time can lead to loss of nutrients. The chart shows that 60 °C maintains the best organoleptic characteristics, weight loss, pH, and sugar content. However, this option is not safe from a microbiological point of view. For complete inactivation of most microorganisms, a temperature of ≥80 °C is required, and for spore-forming bacteria – 85–90 °C. The optimal compromise between safety and quality is 85 °C for 10–15 minutes.

It is important to note that long-term storage at room temperature (Fig. 5) leads to a decrease in organoleptic characteristics. Storage at a temperature of 35 °C (Fig. 6) accelerates the loss of taste and aroma, indicating the need to maintain low temperatures during storage.

Unlike [24], which mainly considered sensory changes during storage of freshly cut fruits, this study analyzes the dynamics of changes in organoleptic indicators of canned melon. This confirms that our methodology provides more stable quality during long-term storage.

When stored at a temperature of 35 °C (Fig. 7), the decrease in organoleptic characteristics occurs much faster, which may be due to accelerated oxidation processes and moisture loss. Already at the early stages of storage, a deterioration in consistency and the appearance of foreign tastes were detected, which indicates the need to select more gentle temperature conditions for long-term storage. As can be seen from Fig. 7, the most favorable storage conditions are provided at a temperature of 4 °C, at which the pH remains stable, and the taste characteristics change insignificantly over 6 months. At room temperature (22 °C), the product retains acceptable organoleptic properties for 3 months, whereas with high-temperature storage (35 °C), degradation of taste and texture indicators occurs already in the first 30 days of storage.

Unlike the methods described in [25], which proposed the use of chemical preservatives to extend shelf life, this study demonstrates that preserving product quality is possible through the optimal combination of natural components and strict temperature control.

Unlike previously reported solutions in [22, 23], which focused on the effect of calcium compounds on the texture and shelf life of products, this study examines the complex effect of various components, including pectin and blackcurrant extract, on the taste and texture indicators of the product. Thanks to the use of such a combination, it was possible to achieve an improved product structure that retains its qualities throughout the entire shelf life (Fig. 5), which is a significant advantage compared to conventional preservation methods.

Our data confirm that the problem of ensuring the stability of organoleptic characteristics during long-term storage was solved by optimizing the syrup composition. The use of the proposed recipe made it possible to reduce the loss of taste qualities during storage at room temperature up to 22 °C and at elevated temperatures (35 °C), which was previously difficult to achieve using standard canning methodologies.

It should be noted that the proposed solutions are effective only under strict storage parameters. With a significant temperature deviation from the recommended values (22 °C and 35 °C), the consistency of the product may deteriorate. In addition, the stability of the product over longer periods of time (more than one year) requires additional research, especially when using plastic packaging.

Our results confirm the effectiveness of the devised recipe and heat treatment modes for canned melon and also allow us to give reasonable recommendations on storage conditions, ensuring stable quality and consumer appeal of the product.

The results of this study can be applied in the food industry to produce canned melon with an extended shelf life and improved consumer properties. The optimized formulation is particularly suitable for use in regions with high ambient temperatures, such as southern Kazakhstan, where storage conditions are difficult. The results obtained can be used for both plastic and glass containers, with glass providing the best preservation of product quality.

The study is limited by the narrow range of concentrations of syrup components considered, which may limit the possibility of adapting the recipe for other types of fruit. The main limitations of the study include the limited number of melon varieties, the lack of analysis of the effect of packaging materials on product stability, and the need for additional studies of sensory characteristics during storage for more than 12 months.

To further advance the research, it seems appropriate to study the effect of alternative thickeners and preservatives of plant origin, which could increase the stability of the product to oxidative processes. In addition, it is necessary to study the possibility of modifying the recipe taking into account different types of packaging (e.g., vacuum packaging or packaging with a modified gas environment), which would expand the scope of practical application of our solutions.

7. Conclusions

1. It has been found that the use of calcium chloride in a concentration of 0.5–0.7 % and the addition of 1 g of pectin per 1 liter of syrup provide optimal textural and organoleptic characteristics of canned melon. Optimal concentrations allowed us to maintain the density and elasticity of the product, minimizing moisture loss and preventing unwanted softening of the pulp. This result is explained by the ability of calcium chloride to strengthen the cellular structure, and pectin to form a gel-forming network, increasing the stability of the texture.

2. It has been determined that the best quality indicators are achieved with heat treatment at a temperature of 85–90 °C for 15–20 minutes. This processing mode helps preserve the taste characteristics and color parameters of the product, prevents excessive destruction of pectin compounds, and maintains pH at 5.8–6.2. The difference between our result and known studies is that the proposed temperature mode makes it possible to minimize the loss of sensory characteristics without significantly increasing the loss of product mass.

3. Organoleptic and physicochemical indicators of canned melon. Analysis revealed that the samples processed under optimal conditions have high indicators for taste (8.4±0.3 points), aroma (8.2±0.2 points), and consistency (8.6±0.4 points). Chemical analysis showed the stability of the dry matter content and acidity of the product during storage for 12 months. This is explained by the balanced combination of components of the recipe, ensuring the product's resistance to physicochemical changes during storage.

4. Recommendations for storage of canned melon have been devised. It has been established that the best storage conditions are provided by glass containers at a temperature no higher than 22 °C, which ensures preservation of organoleptic properties and physicochemical indicators for a year. Storage in plastic containers with a sealed lid at room temperature (20–25 °C) is also acceptable but the shelf life is reduced to 9 months. This result confirms that glass containers provide better hermeticity and protection from oxidation compared to plastic ones.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The manuscript has associated data in the data warehouse.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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