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DEVELOPMENT OF TECHNOLOGY FOR THE PRODUCTION OF USEFUL JELLY CANDIES FROM CUCURBIT CROPS ON A NATURAL BASIS

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The object of the study are the fruits of cucurbits crops, as well as confectionery products based on the fruits of watermelons and melons. The fruits of watermelons and melons are not processed on an industrial scale for a number of reasons: the lack of technological solutions for primary processing and preparation for processing, the instability of raw materials for processing. The pulp of watermelons must be processed within 5 hours under certain conditions; in the pulp of melons, changes in microbiological indicators begin within an hour of storage at room conditions. Because fruits have a high moisture content, the solution for effective fruit processing is to bind this moisture with thickeners and produce jelly candies. Sweets made without antioxidants did not withstand the standard shelf life for jelly sweets, and the growth of mold fungi increased. The reason may be the low acidity of the raw material. Citric acid was added as an antioxidant. There were problems of taste and smell; citric acid interrupts the natural smell of raw materials. During the search, the powder of dried, red-fruited rowan was chosen. The finished product had a barely perceptible natural aroma, the powder did not affect the taste. There were inclusions in the cross-section, but the appearance became more attractive.

Jelly sweets without the addition of rowan powder had active mold growth on the 7th day of storage at a temperature of 22–25 °C; with the addition of rowan powder under the same storage conditions, they showed growth on the 16th day.

The finished product meets all physical, chemical, and microbiological standards. The shelf life of such jelly sweets at a temperature of +6 °C in sealed packaging is up to 30 days without mold formation

Keywords: cucurbits crops, jelly candies, vegetable raw materials, quality, safety

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1. Introduction

All components of fresh watermelons and melons are useful and can be processed, so it is desirable to devise a waste-free production where all parts of the fruit will be involved. The seeds of cucurbits crops are very nutritious – oil is extracted from them, which is subsequently used to prepare various medicines and dyes. Despite the fact that the pulp of the fruit is very watery, it is also processed. From it you can get concentrated juices, which are then used in the confectionery industry to give various products the appropriate color, taste, or aroma. Also, final processing products are produced, such as jams, marmalade, candied fruit, baby food puree, cereals, pastes. Pectin is obtained from the peel of watermelons and melons in special industries.

New varieties of melon are well suited for processing. So far, this is done at home. In 2018, a total of 20 tons of watermelon and melon processed products were produced: marmalade, jams, dried melons and candied fruits, juices, and pickled watermelons [1].

All over the world, there are practically no products based on fresh melons and cucurbits crops. There is not a single officially registered plant or enterprise whose main task is the processing of cucurbits crops and the production of finished sweet products based on them. This can characterize the relevance of this research topic.

2. Literature review and problem statement

Cucurbits crops play an important role in the human diet. Paying attention to the chemical composition of watermelons and melons, you can note that they have a large amount of vitamins and other useful substances. Also, melons and cucurbits crops have dietary and healing properties. They contribute to the rejuvenation of the body, remove "bad" cholesterol from it, normalize metabolism and help solve a number of problems associated with the deterioration of the gastrointestinal tract, liver, kidneys, urinary and cardiovascular systems [2]. However, when consumed fresh, the volume that is needed to solve these problems for a person cannot be consumed. The seasonality of fruits is also an issue. The technologies for obtaining useful frozen products from melon fruits are described. Therefore, the juice and pulp of cucurbits crops is ideal for the development of a healthy dessert as the main raw material [3]. It should be noted that the products are consumed cold, storage is energy-intensive. The process of defrosting is also not well understood; in some cases, during defrosting, melons have a sour smell.

Watermelon pulp is most often consumed only fresh. It is practically not used for the preparation of sweet dishes and culinary products. As an exception, watermelon fresh juices and concentrated juices, as well as pickled watermelon slices, can be produced. But these types of processing are not very popular among consumers. However, raw watermelons were rarely used before. Usually, various meals were prepared from them, plentifully sprinkling the pulp with various herbs, spices, and pepper. Several hundred years ago, such meals were incredibly popular and highly valued [4]. The compatibility of the fruit pulp of watermelons and melons with other food products and seasonings has not been sufficiently studied.

When developing a new technology for the preparation of jelly sweets based on cucurbits crops, agar-agar was used as a thickener since it is the most cost-effective in the production of jelly sweets, in comparison with other thickeners.

In the course of solving the problem of expanding the range of healthy food products using only natural ingredients, where cucurbits crops were used as the main raw material, a technology for preparing pickled melons was developed. As a result, a melon processing product was created that met all the quality and safety requirements, and also had a fairly long shelf life [5]. The disadvantage of this development is that it requires the use of unripe melon fruits, which in no way solves the problem of selling overripe and substandard fruits left in the fields.

The efficiency and methods of its increase in the use of the pulp of fresh and overripe fruits of watermelon and melon as the main raw material for the production of concentrates are described in [6]. However, only a theoretical possibility is described, moreover, concentrates are not the final product of processing.

The quality and safety of melon jelly marmalade with the addition of rowan juice was also assessed [7], where much attention was paid to organoleptic, chemical, and microbiological quality indicators. The developed technology for preparing a sweet meal, although it provides a solution to the problem of selling cucurbits crops from the fields, does not contribute to the implementation of the task of introducing resource-saving technologies into small farms. Also, the use of rowan juice interrupts the already little perceptible taste and smell of melon, and also makes the mixture more liquid, which requires the addition of more agar.

In [8], the issue of differences in the chemical composition of different varieties of watermelon was studied. It was established that there are differences, but they are not significant within the species, for example, fruits with yellow pulp differ from fruits with red pulp in lycopene content, moisture content varies in the range of 5–8 %. However, the study did not take into account such factors as the maturity and processing of raw materials, on which the quality of the final product strongly depends.

The results of many studies aimed at studying the methods of processing melons and cucurbits crops are the creation of a recipe for blended juices with natural additives [9, 10]. These works highlight the results of a study of the physical and mechanical properties of melon fruits and products based on them. Technologies have been created for the production of the following meals and products based on melon: compotes, juices, marinades, jams, frozen foods with the addition of natural fruits and berries. The developed recipes of blended melon juices and sorbet with natural fruit and berry additives are described in [11]. However, there are disadvantages associated with ignoring the use of watermelon pulp in the developed technology [11–14]. It should be noted that the possibility of using the pulp of watermelons and melons without separation from the juice is described in [14]. As a result, they received a product on a natural basis, which retained all the useful properties. However, the creation of Turkish delight on an industrial scale requires expensive equipment and incredible technology precision.

The issue of food safety of watermelon juice, which is a perishable product, was studied in [15]. In particular, the influence of various yeast strains on the quality of the product and the process of juice fermentation is described. Most strains have a negative impact on the quality of watermelon juice. However, only one influence factor was studied in the cited work.

In [7], the safety of cucurbits crops processing products was studied, limits and critical control points were established in the processing of melon fruits. The disadvantage is the lack of safety issues in the processing of watermelon fruits. Although the work touches upon the problem of selling melons and proposes a system of complex processing, it does not touch upon the idea of processing for the food industry.

In [16], the issue of the absence of processed products of melons and cucurbits crops and a solution method were studied. It has been established that the development of technology for processing watermelons and melons lags behind in many respects due to the lack of equipment for primary processing and preparation for processing. The paper proposes a solution for the production of pulp, seeds, and intact rind of watermelons. This enables small farms to speed up the peeling and seeding of watermelons, thereby allowing for further processing into food.

Marmalade recipes from melon puree and pulp have been developed [17, 18], however, the disadvantage of the proposed solutions is the complexity of the technological process. There are also many works on the processing of fruits of ripe watermelons and melons for food, such as jams, confiture, juices [12, 19–21], but no studies on the processing of unsold and overripe fruits have been found.

All this suggests the need for a study on the development of products from the fruits of watermelons and melons.

3. The aim and objectives of the study

The aim of the study is to develop a technology for the preparation of healthy jelly sweets based on the pulp of watermelon and melon fruits, using only natural ingredients. This will make it possible to use unsold ripe fruits in food production.

To achieve this goal, the following tasks were set during the work:

– to determine the optimal composition and temperature regime for the preparation of jelly sweets from melon and watermelon;

– to determine the quality indicators of jelly sweets;

– to determine the microbiological parameters of natural jelly sweets based on watermelon and melon.

4. The study materials and methods

The object of this study: quality indicators of jelly sweets based on the pulp of watermelons and melons.

The hypothesis of the study was as follows: the possibility of using rowan powder in the formulation of cucurbits crop jelly sweets as an antioxidant.

In order to determine the effect of the heat treatment process on the nutritional and biological value of melons and watermelons, mid-ripening varieties of melons and watermelons grown in the Republic of Kazakhstan were selected.

The following indicators of raw materials and finished products from watermelon and melon were determined: mass fraction of solids, mass fraction of protein, mass fraction of vitamin C, sugar content, total and active acidity, mycotoxins, toxic elements.

After analyzing all the data on antioxidants and preservatives, it was decided to use dried rowan fruits in this recipe, ground into powder, which contain a proportion of sorbic acid, because of the following:

– it is an absolutely natural supplement;

– it acts as an antioxidant and preservative at the same time;

– it is readily available for purchase.

Initially, the organoleptic properties of eight samples of watermelon pulp and melon pulp sweets were evaluated. The assessment was carried out on five indicators: appearance, texture, color, smell, and taste.

To determine the mass fraction of solids in the used watermelons and melons, an accelerated method was used – drying in an oven at a temperature of 130 °C. This method is based on the release of hygroscopic moisture from the object under study at a certain temperature. The method involves drying samples of raw materials and finished products at a constant temperature of 130 °C. Drying time – 100 minutes. Drying was carried out in the SESh-3M (RF) oven available in the laboratory [19].

An arbitration method was used to determine the mass fraction of vitamin C in the raw materials used. It is based on the redox reaction between ascorbic acid and the indicator – 2,6-dichlorophenolindophenol (Thielman's reagent). By the mass of the indicator, which was used for titration, the mass fraction of ascorbic acid was determined [19].

The sugar content was determined by the cyanide method. It is based on the ability of reducing sugars to reduce potassium ferricyanide (III) in potassium ferricyanide 3-aqueous (II) in an alkaline solution.

Determination of the mass fraction of fat was carried out by the method of fat extraction. From the analyzed sample of the product with a solvent and determining the mass fraction of fat after removing the solvent.

Active acidity was determined using a pH meter. The method is based on the potential difference between the electrode and the solution depending on the concentration of hydrogen ions in the solution.

Also, as part of the work, microbiological studies were carried out to find mesophilic aerobic and facultative anaerobic microorganisms, yeasts and molds in products to determine the compliance of product quality in accordance with regulatory and technical documentation.

Determination of the number of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM) was carried out by inoculation in an agar nutrient medium, followed by incubation, fixation of visible signs of the appearance of microorganisms, counting colonies using a special table of the most probable number (MPN).

Determination of the amount of yeasts and molds occurs by seeding the product in a nutrient medium, where, later, it turns out that the colonies of microorganisms belong to yeasts or molds.

The most important rheological characteristics for watermelon and melon products are viscosity, stickiness, and shear rate.

The obtained data were processed using a personal computer using the Ostwald de Wiel equation. Experiments carried out on a rotational viscometer Rheotest RN 4.1 made it possible to classify jelly sweets as pseudoplastic liquids.

The analysis of rheological characteristics was carried out in terms of viscosity and shear stress of jelly masses using a rotational viscometer under the constant shear rate mode [17].

Determination of the optimal technology for the preparation of jelly sweets was carried out by a full factorial experiment. The plan of the experiment for determining the optimal recipe was chosen as the central compositional plan for the preparation of jelly sweets from melon, the limits of change are given in Table 1. For x_1, the dose of adding powdered sugar in g is taken, for x_2 – the dose of adding agar-agar, for x_3 – the duration of heat treatment, minutes, for x_4 – the dose of added rowan powder, resulting – an assessment of organoleptic analysis, total score.

Table 1

Limits of change of input factors for melon jelly candies

Planning conditions	Limits of factor change			
	x_1, %	x_2, %	x_3, min	x_4, %
Main level	20	5	6	5
Variation interval	10	2	3	2
Upper level	30	7	9	7
Lower level	10	3	3	3

To develop the optimal recipe for jelly sweets from melon and watermelon, 3 significant indicators alternately changed – the amount of powdered sugar, the amount of agar-agar, and the duration of heat treatment. The maximum and minimum in each category were used.

To characterize or compare the results of observations, the arithmetic mean of the results was calculated; standard deviation; coefficient of variation characterizing the relative dispersion of the result, in percent. These calculations are made for each resulting factor.

The experiment was planned using the Statistica 12.0 software (USA). In the resulting planning matrix, according to which the experiment was carried out, each point was confirmed by three parallel experiments. After the experiment, the results were processed in MS Excel and Statistica 12.0 software. Visualization and optimization were carried out in the Statistica 12.0 program.

5. Results of research and development of technology for jelly sweets from cucurbits crops

5. 1. Determination of the optimal composition and temperature regime for the preparation of jelly sweets from melon and watermelon

Regression equations have been built that describe the dependence of the organoleptic assessment indicator on the selected factors:

$$y = 3.5643 + 0.3233x_1 + 0.498x_3 - \\ -0.0091x_1^2 + 0.0311x_1x_3 - 0.0972x_3^2. \quad (1)$$

Dependence on the dose of powdered sugar and processing time, R^2=0.97:

$$y = -4.7287 + 0.5535x_1 + 2.4743x_2 - \\ -0.011x_1^2 + 0.004x_1x_2 - 0.2727x_2^2. \quad (2)$$

Dependence of organoleptic evaluation on the introduction of a dose of powdered sugar and a dose of agar-agar, R^2=0.81:

$$y = -4.0179 + 0.5576x_1 + 2.0935x_4 - \\ -0.0089x_1^2 + 0.015x_1x_4 - 0.1982x_4^2. \quad (3)$$

Dependence of organoleptic evaluation on the dose of powdered sugar and the dose of rowan powder, R^2=0.88:

$$y = 1.4841 + 2.1943x_2 + 0.5627x_3 - \\ -0.2375x_2^2 + 0.0146x_2x_3 - 0.0648x_3^2. \quad (4)$$

Dependence of the organoleptic assessment on the dose of application of the gelling substance and the duration of heat treatment, R^2=0.75:

$$y = -3.216 + 2.3035x_2 + 2.4257x_4 - \\ -0.2375x_2^2 + 0.0062x_2x_4 - 0.2583x_4. \quad (5)$$

Dependence of organoleptic evaluation on the dose of application of the gelling substance and the dose of application of rowan powder, R^2=0.98:

$$y = 2.4567 + 0.3738x_3 + 2.115x_4 - \\ -0.0648x_3^2 + 0.0524x_2x_4 - 0.2583x_4^2. \quad (6)$$

Dependence of organoleptic evaluation on the dose of rowan powder and the duration of heat treatment, R^2=0.91.

All models were tested by Fisher's and Student's criteria and are adequate.

Fig. 1 shows the response surfaces of the overall organoleptic evaluation (taste, aroma, texture, stickiness) depending on the selected factors.

Fig. 2 shows the results of the analysis of the optimum desirability function.

Fig. 3 shows the technological scheme for the production of melon jelly candies.

The melon was cut in half, the seeds were removed, the skin was peeled, and the melon pulp was cut into small cubes or pieces of arbitrary shape. We shifted the pulp into a bowl, added powdered sugar.

It was left at room temperature (30–40 minutes). Next, we pur ed it.

Dried rowan fruits were crushed to a powder state and added to melon pulp puree.

The next step was to add the gelling agent, agar-agar.

The resulting mass was boiled at a temperature of 104–109 °C for 3–6 minutes or until the solids content was 75–77 %.

The boiled mass was cooled in a container until the molding temperature was reached (50–60°C).

From the resulting mass, cast into silicone molds.

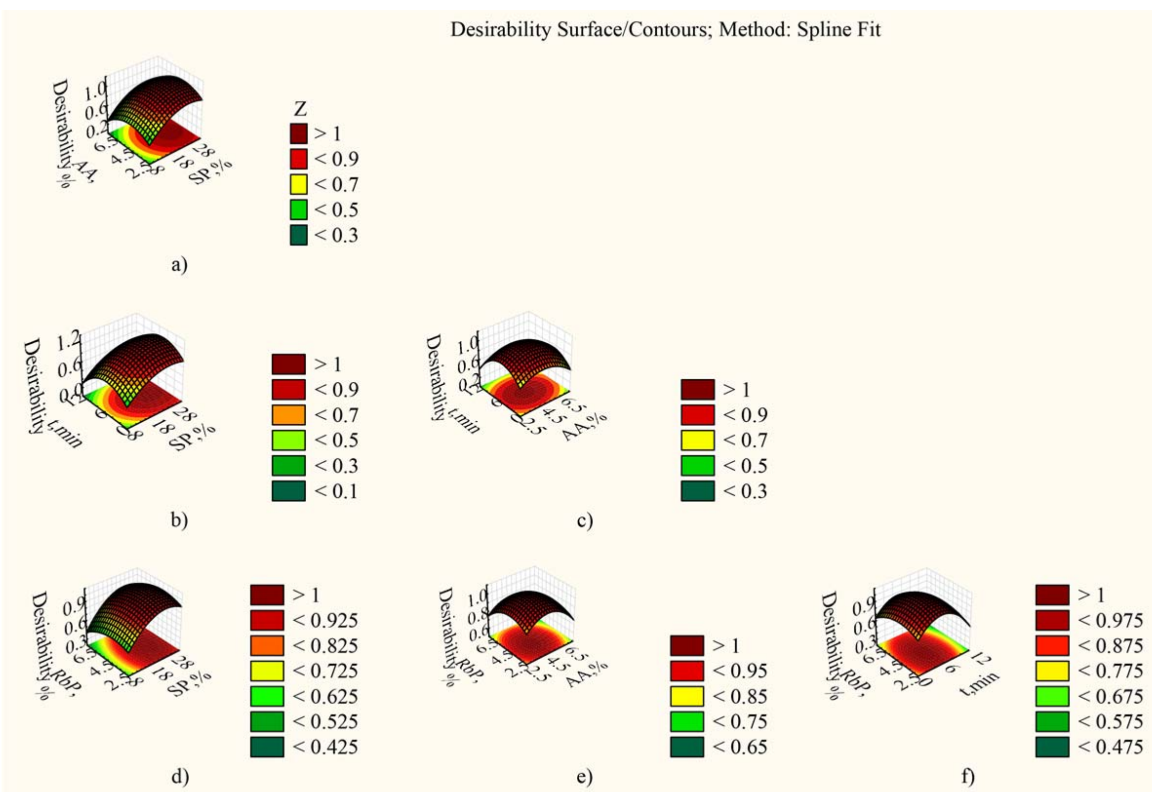

Fig. 1. Response surfaces of the organoleptic evaluation of melon jelly sweets: *a* — desirability functions depending on the dose of gelling agent and the dose of powdered sugar; *b* — desirability functions depending on the duration of heat treatment and the dose of powdered sugar; *c* — desirability functions depending on the duration of heat treatment and the dose of gelling agent; *d* — desirability functions depending on the dose of application of rowan powder and powdered sugar; *e* — desirability functions depending on the dose of application of rowan powder and gelling agent; *f* — desirability functions depending on the dose of rowan powder and the duration of heat treatment

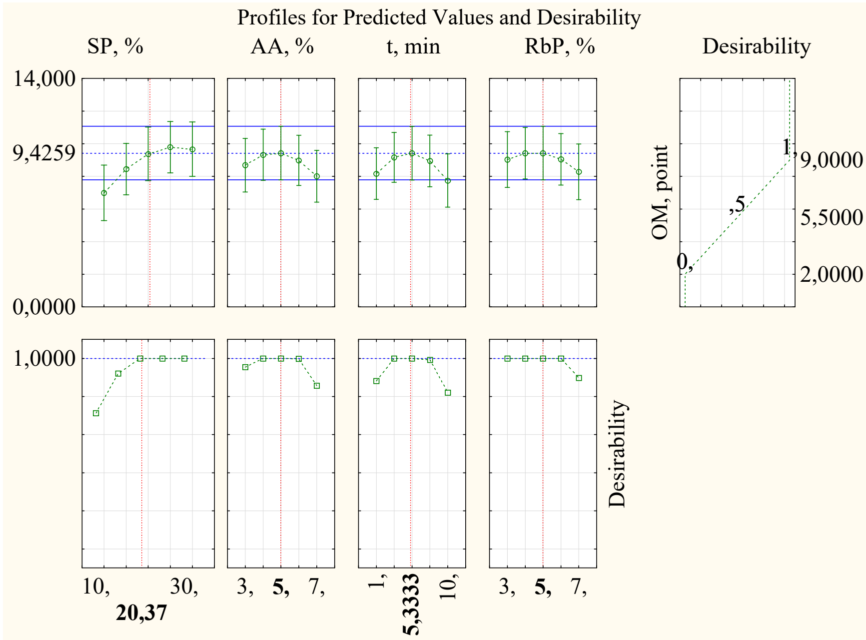

Fig. 2. Optimum desirability function for jelly candies

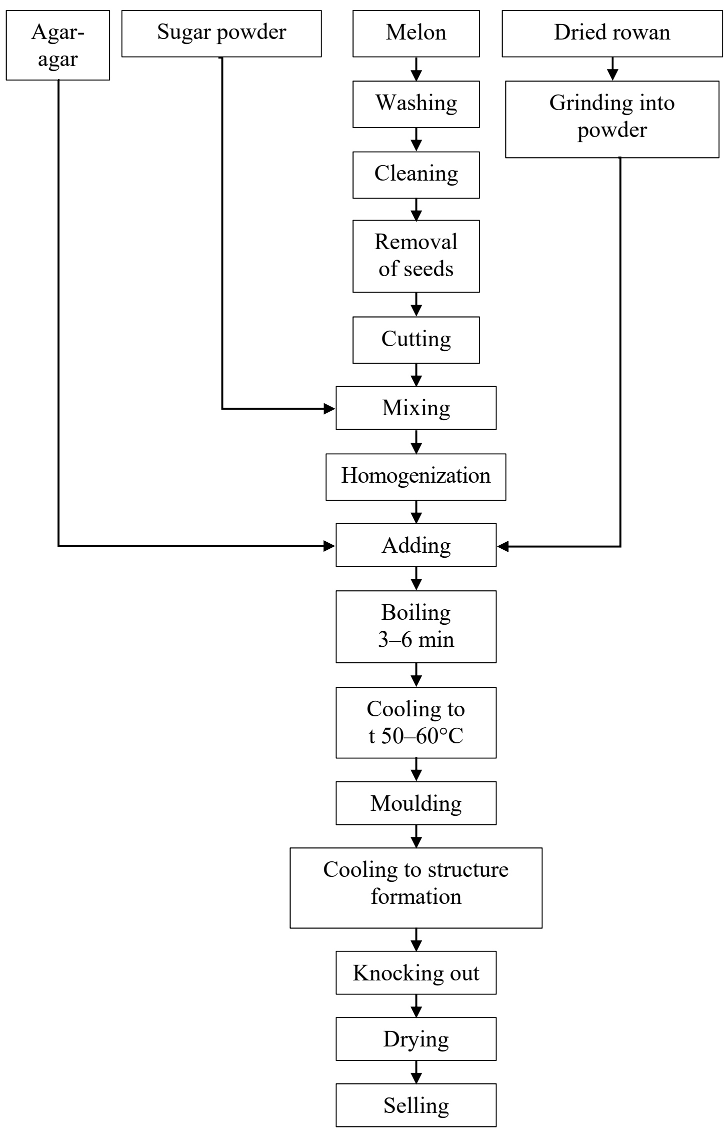

Fig. 3. Technological scheme for the preparation of melon jelly candies

In the cooling chamber, cool the sweets for structure formation at an air temperature of 15–18 °C for 40–90 minutes. The received sweets were knocked out of the molds and dried.

The implementation of this technological scheme makes it possible to obtain sweets that combine a gelatinous elastic structure of the body with a dense texture characteristic of dried fruits and candied fruits, which have useful properties due to selected gelling agents and a reduced calorie content relative to traditional confectionery.

The technological scheme for the preparation of sweet products from watermelon is shown in Fig. 4.

For the preparation of jelly candies from watermelon, a technological scheme was used similar to that shown in Fig. 3.

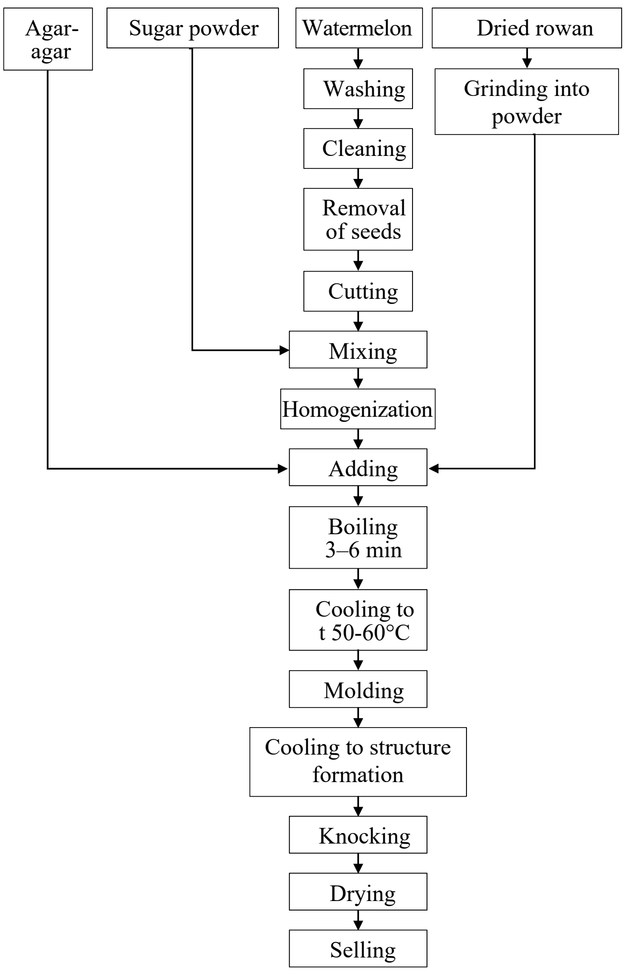

Fig. 4. Technological scheme for the preparation of jelly candies from watermelon

5. 2. Determination of quality indicators of jelly candies

The results of determining the active acidity in raw materials and products are given in Table 2.

Table 2

Active acidity in raw materials and products

Name	Acidity, Turner's deg
Watermelon pulp	2.6
Melon pulp	2.27
Watermelon jelly candies	2.24
Melon jelly candies	3.01

The results of determining the mass fraction of moisture and solids are given in Table 3.

Table 3

Mass fraction of moisture and solids in products and raw materials

Name	Mass fraction of moisture, %
Watermelon pulp	91.59
Melon pulp	87.74
Watermelon jelly candies	20.21
Melon jelly candies	23.54

The total amount of carotenoids in the jelly candy formulation (1240±0.35–810±0.21) μg/100 g was higher than in the control sample (713±0.19) μg/100 g. High levels of carotenoids in jelly candies can be the result of watermelon red pigment.

The results of experimental studies to determine the stickiness of finished watermelon and melon jelly sweets indicate that the indicator depends not only on the amount of added gelling agent but also on the type of raw material.

When processing the rheotest data, the value of plastic strength was obtained –49.62+2.1 kPa, which corresponds to purchased jelly sweets.

5. 3. Microbiological indicators of natural jelly candies based on watermelon and melon

Table 4 gives the results of the study of microbiological parameters of finished products.

Table 4

The results of microbiological analysis of raw materials and finished products on the 14th day

Name	QMAFAnM, CFU/g		Yeast, CFU/G		Mold, CFU/g	
	Norm	Product	Norm	Product	Norm	Product
Watermelon (raw)	No more than $5*10^3$	$5*10^3$	No more than 100	Not detected	No more than 100	Not detected
Melon (raw)	No more than $5*10^3$	$6*10^2$	No more than 100	2	No more than 100	Not detected
Watermelon jelly candies	No more than $5*10^3$	$5*10^2$	No more than 100	4	No more than 100	Not detected
Melon jelly candies	No more than $5*10^3$	$3*10^2$	No more than 100	3	No more than 100	Not detected

As can be seen from the results given in Table 4, jelly candies on day 14 show no growth of yeast and fungi under room storage conditions in paper packaging.

6. Discussion of results of the study of jelly candies from the fruits of melons

As a result of the analysis, response surface profiles were obtained, which show the optimal values in terms of organoleptic evaluation with varying factors and indicate that the duration of heat treatment (4 minutes) has the greatest effect on consistency. Optimal for a general organoleptic evaluation is 4.5 % agar-agar, 4.5 % rowan powder.

As follows from Fig. 2, the optimal values for the duration of the heat treatment are 5 minutes, the optimal values for the added thickener are 5 %, and for the dose of the applied red-fruited rowan powder, 5 %. In Fig. 2, the red dotted line marks the optimal values for improving the overall organoleptic evaluation of jelly candies. This is due to the fact that the fruits of watermelon and melon are rich in sugars, and the powder of red rowan has a high antioxidant activity.

Qualitative indicators of jelly sweets are given in Tables 2, 3. The high levels of carotenoids in jellies may be the result of watermelon's red pigment. According to the given data, in comparison with the control sample, which is melon pulp, the amount of nutrients in the developed recipe has increased:

– the calorie content of raw materials is 31.54 kcal;

– the calorie content of ready–made jelly candies based on melon: 97.23 kcal;

– the calorie content of the finished product increased by 65.69 kcal.

The developed recipe for jelly sweets based on watermelon pulp is superior to the control sample in all studied indicators:

– calorie content of the control sample is: 26.65 kcal;

– the calorie content of jelly sweets based on the pulp of watermelon is as follows: 88.65 kcal;

– the difference in calories is 62 kcal.

Compared to the control sample, the content of vitamin C in the developed product increased by 2.07 mg. The increase in this indicator was achieved by adding crushed dried rowan fruits to the product.

Of the two products created, the melon jelly has the higher calorie content.

The content of ascorbic acid in watermelon jelly candies is somewhat less. Given the fact that watermelon pulp itself initially contains a smaller amount of this vitamin, watermelon sweets can also be recommended for use as a source of vitamin C.

The acidity in the finished product is lower than in the raw material. This is due to the fact that the products have undergone heat treatment.

The mass fraction of solids in products is greater than in raw materials. This is due to the presence of a heat treatment process, as well as the addition of a gelling agent to the product, which binds free moisture.

In samples of natural jelly sweets (Table 4) based on cucurbits crops, in comparison with raw materials, the content of mesophilic aerobic and facultative anaerobic microorganisms is reduced. All indicators of microbiological analysis do not exceed the standards specified in the Technical Regulations of the Customs Union TR CU 021/2011 "On Food Safety".

A feature of this study is the possibility of processing unsold fruits of watermelons and melons into food. The proposed technology makes it possible to obtain sweets that meet the requirements of regulatory documents and with a sufficient shelf life. It should also be noted that without the addition of rowan powder, jelly candies did not have a proper shelf life. Therefore, the influence of rowan powder has been established, and a finished product has been obtained that meets the requirements.

The technology for the production of jelly sweets does not require the use of expensive equipment. Therefore, the question is raised about the implementation of the development in the work of small farms. The use of this technology will allow solving the problem of unsold melons and cucurbits crops, as well as processing overripe watermelons and melons unsuitable for long-distance transportation in the places of their cultivation.

The limitation is the seasonality of raw materials and the rapid deterioration of semi-finished products; it is not recommended to store unprocessed purified raw materials for more than 2 days even under refrigeration conditions. Also, based on the results of search experiments, the limits are the ranges of variation of the input variables.

In the future, it is planned to study the compatibility of melon-based jelly sweets with other in vitro food products in order to develop recommendations for consumption.

Conclusions

1. To develop the optimal recipe for jelly sweets from melon and watermelon, 3 significant indicators alternately changed – the amount of powdered sugar, the amount of agar-agar, and the duration of heat treatment. The maximum and minimum in each category were used. The optimal composition was revealed in the amount: powdered sugar – 30 g, agar-agar – 3 g, heat treatment time – 6 minutes. The balanced addition of all ingredients to the product gives the product an accepted taste and delicate aroma. The increased heat treatment time gives the product the desired consistency.

2. Shelf-life tests were carried out under standard conditions – at a temperature of +6 °C, as well as under extreme conditions – at a temperature of +21 °C. According to the test results, it was determined that jelly sweets under standard conditions in sealed packaging are stored for up to 30 days without mold formation. Under room conditions, the shelf life was reduced to 14 days without mold formation.

3. Microbiological indicators in the finished product do not exceed the norm and meet the standards. In watermelon jelly sweets, the indicators of QMAFAnM are $5*10^2$ CFU/g, in accordance with GOST 10444.15–94; yeast – 4 CFU/g, in accordance with GOST 10444.12–2013; mold – not detected, in accordance with GOST 10444.12–2013. In jelly sweets from melon, the content of QMAFAnM indicators is $3*10^2$ CFU/g, yeast – 3 CFU/g, mold is not detected.

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 and the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

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