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DETERMINING THE EFFECT OF APPLE AND BANANA POWDERS DRIED BY SUBLIMATION ON THE QUALITY INDICATORS OF A SOUR MILK DESSERT DURING STORAGE

The shelf life of sour milk dessert has been substantiated based on the results of this study into the indicators of active acidity, water activity, enthalpy, and organoleptic properties. In addition, the content analysis of lactic acid bacteria and microbiological indicators in the finished product during storage was performed. It was found that the introduction of sublimated fruits together with whey protein concentrate reduces the water activity index from 0.984 to 0.972 by increasing the concentration of solids and product viscosity.

The active acidity indicator acts in combination with the water activity on the shelf life of food products. Active acidity during the study period was in the range of 5.4–4.2 pH units.

The biological and physiological value of the fermented milk product will increase due to the use of a starter culture containing microorganisms of bifidobacteria and lactobacilli, which include Streptococcus thermophilus, Lactobacillus delbrueckii ssp. Bulgaricus, Lactobacillus acidophilus, Bifidobacterium lactis, Lactobacillus casei, Lactobacillus rhamnosus, Lactobacillus paracasei, Bifidobacterium infantis. When storing sour milk dessert for more than 3 days, the number of bacteria came down and was 1.0×10^8 CFU/g on day 9, which meets the regulatory requirements.

Based on the results of microbiological indicators, the shelf life of the sour milk dessert was established, which should not exceed 5 days at a temperature of 4±2 °C.

The development and improvement of sour milk desserts using secondary milk raw materials is a promising area of scientific research. This would allow the development of waste-free technologies with the maximum use of useful components that are included in the secondary milk raw materials

Keywords: dessert, whey, skim milk, water activity, active acidity, lactic acid bacteria

Uliana Kuzmyk
Corresponding author
PhD, Associate Professor
Department of Technology Milk and Dairy Products**
E-mail: ukuzmik@gmail.com
Andrii Marynin
PhD, Associate Professor, Head of Laboratory*
Roman Svyatnenko
Researcher*
Yulia Zheludenko
Researcher*
Mykhailo Kurmach
PhD, Junior Researcher
Department of Porous Materials and Materials
L. V. Pisarzhevskii Institute of Physical Chemistry of the National Academy of Sciences of Ukraine
Nauky ave., 31, Kyiv, Ukraine, 03039
*Problem Scientific and Research Laboratory**
**National University of Food Technologies
Volodymyrska str., 68, Kyiv, Ukraine, 01601

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1. Introduction

The need to create functional dessert products with the introduction of secondary resources is relevant. First, the original formulations for dairy desserts are rarely used. The production of non-traditional types of desserts, such as multi-component dessert products, has no analogs on the market yet. Second, the use of whey as a raw material is relevant due to the current shortage of milk worldwide. An important aspect of the use of secondary milk raw materials, in particular whey, is that it will not only increase the biological value of the product but also reduce its cost.

Whey is a by-product in the production of protein dairy products. The main component of whey is lactose, about 70 % by weight of all solids. Whey contains a significant amount of biologically valuable whey proteins, free amino acids, and minerals. The content of whey proteins in whey reaches 0.5...1.5 %. The main ones are β-lactoglobulin (7...12 % of the total amount of milk proteins), α-lactalbumin (2...5 %), whey albumin, immunoglobulins, and components of the protease-peptone fraction [1].

Whey proteins (albumins and globulins) have valuable biological properties that contain the optimal set of vital amino acids. From the point of view of nutrition physiology, they approach the amino acid scale of the “ideal” protein, that is, a protein in which the ratio of amino acids meets the needs of the body. There is a small amount of fat in whey (0.05...0.4 %) but its value is that it is dispersed into balls with a diameter of less than 2 μm [1, 2].

The main macronutrients of whey are calcium, phosphorus, magnesium, potassium, sodium, chlorine, and sulfur (found in proteins).

Whey proteins contain the following trace elements: iron, copper, zinc, manganese, aluminum, selenium, iodine, and others.

Another secondary valuable biological raw material for the production of various foods is skim milk. It is obtained as a by-product in the process of separating milk. Skim milk contains all components of whole milk, except fat, which has an average content of 0.05 %. A feature of skimmed milk fat is a high degree of its dispersion. The average size of fat globules is 0.5...1.0 µm, which promotes its better assimilation. Given that skim milk contains the same amount of protein as whole milk, but much less fat, its use is recommended for the elderly and overweight people [3].

Therefore, the development and improvement of sour milk desserts using secondary milk raw materials is a promising area of research.

2. Literature review and problem statement

Dairy desserts are dairy products that are made with the addition of sugar or other sweeteners, food additives, stabilizers, fillers. They are characterized by a thick, homogeneous, viscous consistency.

Based on the market analysis, one can draw a conclusion about the prospects of research to improve the consumer properties of dessert products based on whey.

Desserts are made from pasteurized natural whey, concentrated, or condensed with or without the addition of low-fat cheese, sugar, semolina, fruit syrups, stabilizers. This group of products is intended for direct consumption [4, 5].

In work [6], the physical-chemical and rheological properties of dairy dessert with the addition of chickpea flour were studied. The results showed that the acidity of desserts varied depending on the type of flour. The physical-chemical and rheological properties changed with the addition of flour and longer shelf life. The texture of the dessert was measured, finding out that the samples showed non-Newtonian behavior. However, the microbiological parameters of dairy dessert with the addition of chickpea flour have not been studied, which is an important aspect when justifying the shelf life.

Sour milk dessert fermented products with bifidogenic properties are becoming increasingly popular [7]. The creation of symbiotic functional products using prebiotics – ingredients of natural origin, which are able to stimulate the development of probiotic cultures, is one of the promising areas for expanding the range of functional foods [8].

Dairy desserts with berry and fruit fillings are very popular. To expand their range, manufacturers are increasingly preparing desserts with the addition of components from non-traditional raw materials. Paper [9] investigated the use of pumpkin puree for dessert. Adding this filler could enrich the product with valuable pumpkin components. Pumpkin contains minerals, amino acids, vitamins, fiber. However, this research did not study how the proposed filler affects the physical-chemical properties of the dessert during storage.

There is a technology of milk pudding [10], which is produced from a pasteurized mixture of milk, sugar, stabilizers with the addition of flavoring and aromatic substances. Depending on the raw materials introduced into the mixture, flavoring and aromatic substances produce milk pudding of 3 % fat with vanillin, or with cocoa, creme brulee, coffee, as well as milk pudding of 1 % fat creme brulee or coffee. But the authors did not study the physical-chemical and microbiological parameters of the finished product.

The properties of dairy dessert with fiber separated from orange pulp have been studied. Proximal analysis shows that orange fiber has 59.1 % of the total dietary fiber, and the soluble fraction is 27.5 %, with high content of iron, phosphorus, and other nutrients. According to the results of physical-chemical and organoleptic parameters, it was found the need to add 5 % of orange fiber. Consumption of the newly developed dessert would increase the daily consumption of dietary fiber. In addition, the use of dietary orange fiber would reduce environmental pollution [11]. However, the indicator of water activity, which has an impact on the formation of structural and mechanical properties of dairy dessert with fiber, has not been studied.

Work [3] studied the rheological, organoleptic, and antioxidant properties of low-fat dairy desserts. The developed product includes skim milk powder, whey protein concentrate (WPC 80), sucrose, and carrageenan. The use of different amounts of whey proteins significantly affected the structure, rheological properties, and appearance of dairy desserts. It was found that the activity of dessert water decreased with the increasing content of whey protein concentrates. The use of whey proteins would involve secondary raw materials, which could promote waste-free production. However, the microbiological parameters of dairy dessert have not been studied. According to the results, it is possible to establish the compliance of microbiological indicators with regulatory requirements and their shelf life.

Replacing whey protein concentrates and isolates with ultrafiltration-derived liquid concentrates can be an excellent alternative for the production of innovative dairy products. Whey-based milk gels obtained by fermentation or acidification with gluconic-delta-lactone demonstrate a viscoelastic behavior, have functional and nutritional properties [12]. But the authors have not studied the process of fermentation of milk gels in the production of dairy products.

A milk dessert with date syrup and powder has been developed. When using such a filler, one does not need to add additional sugar, which will give the product dietary properties. Besides, dates (*Phoenix dactylifera L.*) are a source of biologically active substances [13]. However, this research did not study the effect of the filler on the physical-chemical properties of dairy dessert during storage.

There is the dessert containing milk, dried figs, and carboxymethylcellulose [14]. But the cited work did not study the microbiological characteristics of dessert, which affect the quality and safety of the finished product.

There are many dairy products the production of which involves the use of fruit and vegetable supplements.

It is known that vegetable and fruit raw materials are characterized by a high content of nutrients that exhibit functional properties. It is a source of various vitamins, amino acids, micronutrients, easily digestible carbohydrates, organic acids, volatile acids, and other biologically active substances.

Dry powders made from berries, fruits, and vegetables can be stored and used as fast-renewable foods or flavorings with organoleptic properties inherent in the raw material. When using them, it is possible to enrich the diet of consumers with new products of health effects due to fiber, pectin, which perform antioxidant functions in the human body [15, 16].

The high quality and biological value of finished sublimated products are explained by the fact that only fresh raw materials can be processed. The main advantages of sublimation drying, which makes its industrial application promising, are minimal biological and physical-chemical changes in the product since the process takes place at low temperatures. The products of sublimation drying can be stored for a long time in a suitable package at a positive temperature, that is, the need for refrigerated storage is excluded. In addition, the products easily absorb moisture (can be restored even in cold water), retain the original properties, color, taste, smell. The taste of the products hardly changes; the weight of products after drying considerably decreases, therefore, expenses for loading and unloading works and transportation decrease. Preservation of food by sublimation allows preserving their nutritional value [17].

In work [18], rutin, as the main component of flavonoids, was detected by dry layer chromatography in dry banana leaves. The results showed that banana leaves (*M. balbisiana*), a by-product of the food industry, can be used as an inexpensive and new source of rutin. However, the authors did not investigate the use of dried banana leaves in dairy desserts.

The effect of dry banana powder on the characteristics of common wheat pasta has been studied. It was found that the addition of powder in the amount of 3 % does not affect the organoleptic characteristics of pasta, increases the content of phenolic compounds and antioxidant capacity of products [19].

Natural products, which are rich in antioxidants, are increasingly in demand. In this way, the properties of yogurt with the addition of dry apple powder were studied [20] but the effect of dry apple powder on the microbiological parameters of yogurt was not examined.

The properties of yogurt with the addition of sublimation dried powders of persimmons and apples have been studied. It has been found that the addition of powders improves the moisture-retaining capacity and increases the nutritional value of the product [21].

Our review of scientific information showed that the introduction of sublimation dried apple and banana powders into the sour milk dessert requires further research. Namely, it is necessary to study the microbiological and physical-chemical parameters of the dessert during storage, which is an important aspect of the quality and safety of the finished product.

3. The aim and objectives of the study

The study aims to determine the effect of sublimation-dried apple and banana powders on the microbiological and physical-chemical parameters of the developed sour milk dessert during storage. This will make it possible to improve the standard process of sour milk product manufacturing and substantiate its shelf life.

This goal was accomplished by solving the following problems:

– to substantiate the shelf life of sour milk dessert by analyzing the indicators of active acidity, water activity, enthalpy, and organoleptic properties;

– to analyze the content of lactic acid bacteria in the finished product during storage;

– to study the microbiological parameters of sour milk dessert.

4. Materials and methods to study the quality indicators of sour milk dessert

The following raw materials were used for the production of experimental samples of sour milk dessert: skimmed milk with a mass fraction of fat not higher than 0.05 %, acidity not higher than 21 °T, obtained by the separation of whole milk under DSTU 3662:2018 "Raw cow's milk. Specifications". Whey protein concentrate obtained by the method of ultrafiltration (KSB-UV) under TU U 10.5-00419880-123: 2014. Quick-dissolving food gelatin, sublimation-dried apple and banana powder according to current regulations.

The technological process of sour-milk dessert production was carried out according to the technological scheme in the following sequence (Fig. 1).

Model samples were prepared as follows: dry whey protein concentrate was added in skimmed pasteurized milk at a temperature of 40–45 °C, sublimated fruits. The gelatin was pre-soaked in cold water for at least 30 minutes, then the solution was heated to a temperature of 60±5 °C with stirring until complete dissolution.

The resulting milk mixture at stirring was heated to 80 °C, a solution of gelatin was added and heated to 90 °C for 55±5 sec for pasteurization. Then the mixture was cooled to a temperature of 55–60 °C, stirred thoroughly, cooled to a fermentation temperature of 40±2 °C, direct sourdough was added, containing the microorganisms of bifidum- and lactobacilli, which include *Streptococcus thermophilus, Lactobacillus delbrueckii ssp. Bulgaricus, Lactobacillus acidophilus, Bifidobacterium lactis, Lactobacillus casei, Lactobacillus rhamnosus, Lactobacillus paracasei, Bifidobacterium infantis*.

The mixture was stirred for 15–20 min and fermented for 8 h to form a strong clot and an active acidity of 5.4 pH units. Next, the samples were cooled for 8–16 h to a temperature of 4±2 °C.

The study of water activity (*Aw*) (relative humidity, %) was performed at the water activity analyzer "HygroLab 2" (Rotronic, Switzerland) at a temperature of 20 °C in the measurement range 0...1 Aw (0...100 % rh) [22].

HygroLab 2 (Rotronic, Switzerland) is a desktop laboratory humidity and temperature analyzer with a display and control keys, to which 1 to 4 water activity probes are connected simultaneously. The analyzed sample is taken in a container and placed in the measuring chamber. A water activity probe is installed on top. The measurement cycle lasts 3–5 minutes, after which the display shows the values of water activity and temperature for each probe.

Determining the active acidity (pH) was carried out according to DSTU 8550: 2015. Determining the active acidity is carried out at a product temperature of 20±2 °C. To a clean, dry beaker, about 40 cm^3 of fermented milk product is taken, the electrodes are immersed in it, and, after 10...15 sec, the readings are taken from the scale of the device.

Organoleptic evaluation of sour milk dessert was performed by the method of describing open tastings, using a 10-point scale.

To determine the number of lactic acid bacteria, 1 cm^3 of a series of ten-fold dilutions in three parallel replicates was added to sterile skim milk, which was thermostated at 32±1 °C for 72 hours.

To determine the QMAFAnM, 1 cm^3 of appropriate dilutions were transferred to Petri dishes and filled with nutrient agar. The plates were thermostated at 30±1 °C for 72 hours.

To determine the number of molds, 1 cm^3 of dilutions were transferred to Petri dishes and filled with the Saburo agar. The plates were thermostated at 25±1 °C for 120 hours.

To detect BGKP, 1 cm^3 of the appropriate dilution was added to the Kessler medium, which was thermostated at 37±1 °C for 48 hours. Then the dashed method with a loop was used to sieve on Petri dishes with the Endo agar. The plates were thermostated at 48±1 °C for 24 hours.

To detect *Staphylococcus aureus*, 1 cm^3 of the appropriate dilution was added to the salt broth and thermostated at 37±1 °C for 48 hours. Then the dashed method with a loop was used to sieve on Petri dishes with the Baird-Parker agar. The plates were thermostated at 48±1 °C for 48 hours.

To detect the presence of pathogenic flora, including *Salmonella*, 25.0 g of the sample was added to 225 cm^3 of pre-concentration medium (buffered peptone water) and kept for 20 hours in a thermostat at a temperature of 37±1 °C. After that, 0.1 cm^3 of the obtained culture was transferred to a test tube containing 10 cm^3 of magnesium medium and 10 cm^3 to a flask containing 100 cm^3 of selenite medium. Both media were thermostated at 37±1 °C for 24 hours, then sieved onto Petri dishes containing diamond green agar and bismuth sulfite agar. The plates were thermostated at 37±1 °C for 48 hours.

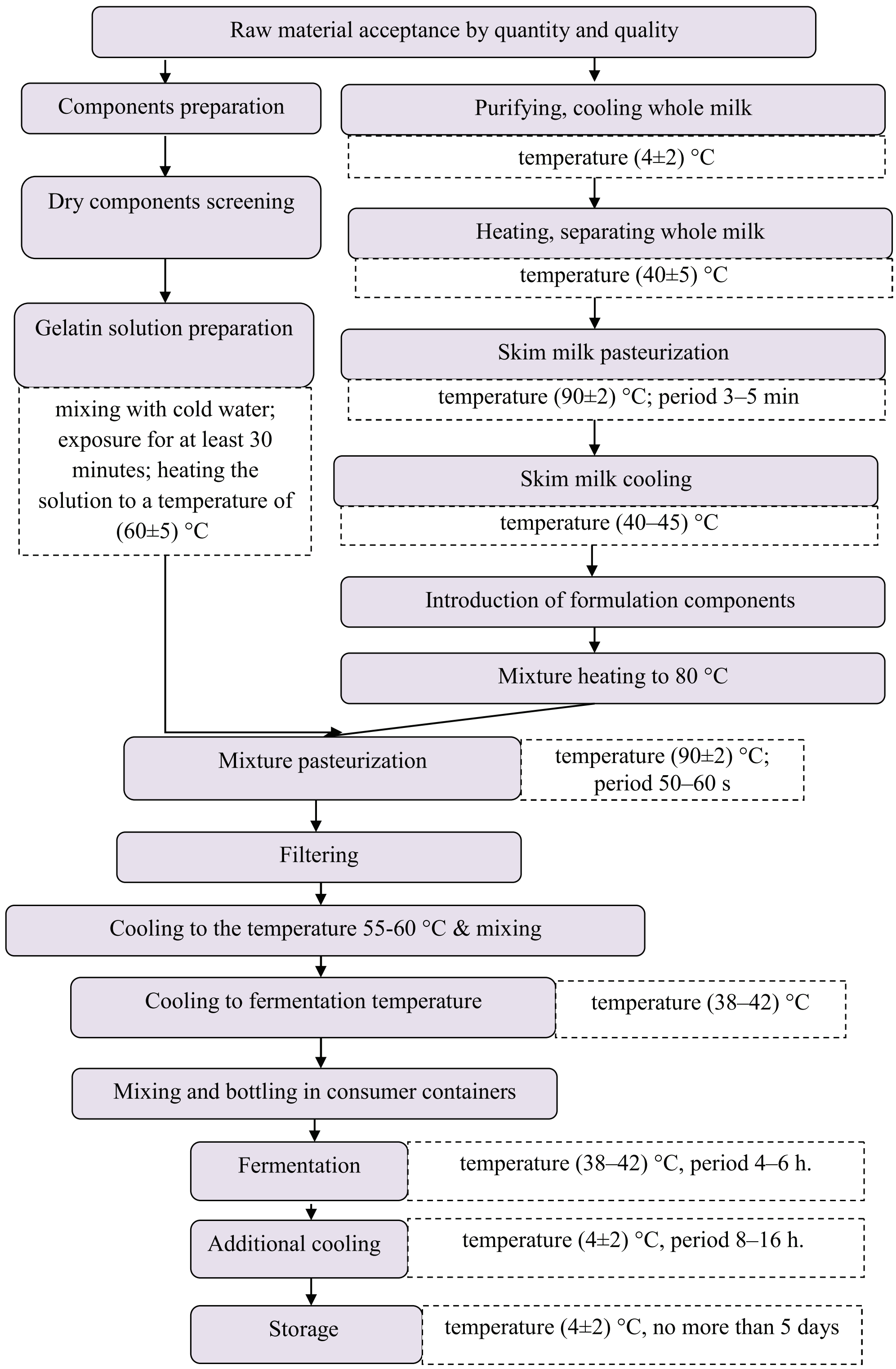

Fig. 1. Technological scheme of sour milk dessert production

5. Results of studying the quality indicators of sour milk dessert

5. 1. Substantiating the sour milk dessert shelf life based on the analysis of indicators of active acidity, water activity, enthalpy, and organoleptic properties

Water activity significantly affects the course of enzymatic, microbiological, and physical-chemical processes. According to its indicator, one can substantiate the correctness of the technological process of production and the shelf life of the finished product. For this purpose, the water activity index of sour-milk dessert was studied, the data obtained are shown in Fig. 2.

It was found that the water activity index in the developed sour milk dessert was 0.984, which is in the range for products with high humidity (*Aw*=0.9–1.0). The development of microorganisms, their growth rate, depend on the composition, properties of the product, and environmental conditions. The growth rate is primarily due to the presence of free moisture available to microorganisms. During 9 days of storage studies, the water activity index decreased from 0.984 to 0.972, which did not change significantly, confirming the stability of the properties of macromolecular compounds (starch, proteins, fiber solution) during storage.

The main physical-chemical indicator of sour milk products is active acidity. According to the results of the study of the active acidity of the dessert (Fig. 3), it was found that the rate decreased during storage from 5.4 to 4.2 pH units on day 9 of storage.

Therefore, it is advisable to store sour milk dessert for 5 days because, if stored for more than 5 days, the product acquires a sour taste due to excessive active acidity (4.2 pH units).

The enthalpy data on the sour milk dessert system are shown in Fig. 4.

The largest value of enthalpy is observed at the beginning of the shelf life, which is due to the formation of a strong frame of gelatin. After 5 days of storage of the product, there is a decrease in this indicator, which is due to the additional release of moisture.

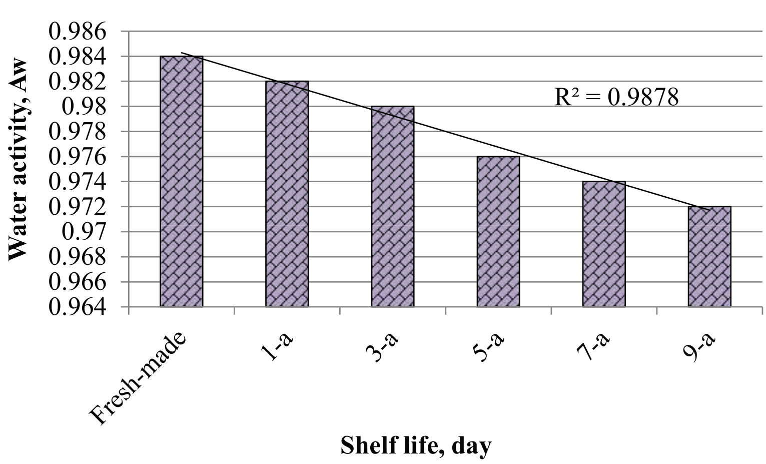

Fig. 2. Change in the water activity indicator of sour milk dessert during storage

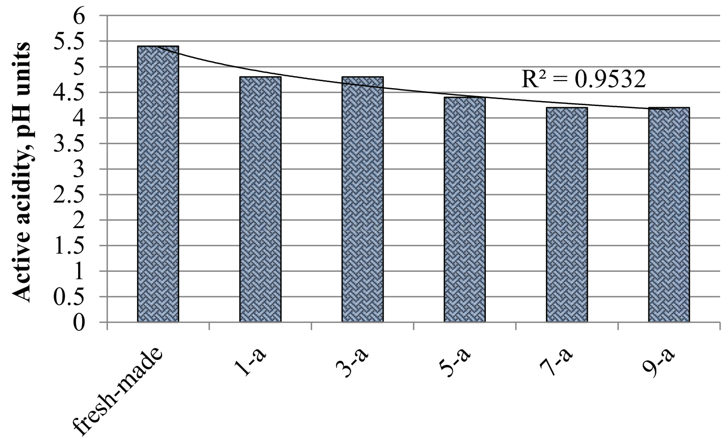

Fig. 3. Change in the active acidity of sour milk dessert during storage

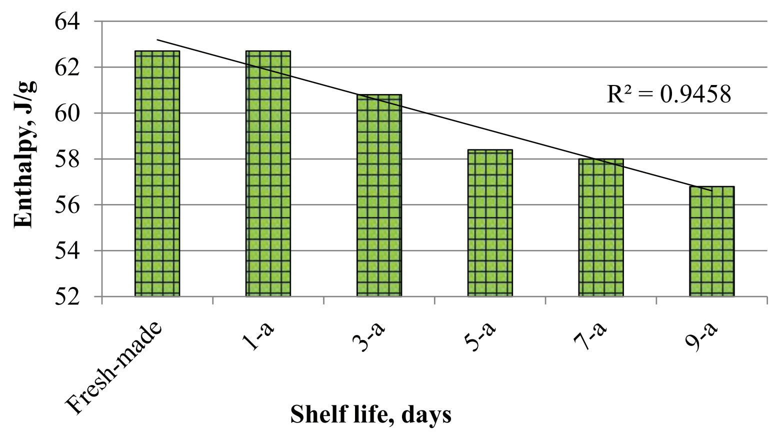

Fig. 4. Change in the enthalpy of sour milk dessert during storage

5. 2. Analyzing the lactic acid bacteria content in a ready product during storage

Fermentation cultures are a functionally necessary element in the technology of sour-milk products. The microflora of fermentation cultures determines the specific physical-chemical and organoleptic properties of fermented milk products, ensures their safety for consumption, preservation of quality characteristics during storage. The number of lactic acid bacteria and organoleptic characteristics of sour milk dessert during storage are given in Table 1.

Analyzing the data obtained from Table 1, it is established that the number of lactic acid bacteria increases during storage over 3 days. When storing sour milk dessert for more than 3 days, the number of bacteria decreased and, on day 9, was 1.0×10^8 CFU/g, which meets regulatory requirements. Whereas, according to the requirements, the number of lactic acid bacteria at the end of the shelf life must be at least 1.0×10^6 CFU/g. The taste and smell during storage remained sour milk, moderately sweet with a pronounced taste and aroma of sublimated fruit. The color is milky with a cream tint, uniform throughout the mass. The consistency is homogeneous, tender, the surface is glossy, jelly-like, and, on day 9 of storage, there was a slight separation of whey.

Table 1

The number of lactic acid bacteria and the characteristic of organoleptic indicators of sour milk dessert

Shelf life	Number of lactic acid bacteria, CFU/g	Organoleptic indicators	Appearance
fresh-made	7.0×10^{8}	Taste and smell are pure, sour-milk, moderately sweet, with a pronounced taste and aroma of sublimated fruit. The consistency is homogeneous, tender, the surface is glossy, jelly-like. Milk color with a cream tint, uniform throughout the mass	
Day 1	1.1×10^{9}	Taste and smell are pure, sour-milk, moderately sweet, with a pronounced taste and aroma of sublimated fruit. The consistency is homogeneous, tender, the surface is glossy, jelly-like. Milk color with a cream tint, uniform throughout the mass	
Day 3	1.1×10^{9}	Taste and smell are pure, sour-milk, moderately sweet, with a pronounced taste and aroma of sublimated fruit. The consistency is homogeneous, tender, the surface is glossy, jelly-like. Milk color with a cream tint, uniform throughout the mass	
Day 5	2.5×10^{8}	Taste and smell are pure, sour-milk, moderately sweet, with a pronounced taste and aroma of sublimated fruit. The consistency is homogeneous, tender, the surface is glossy, jelly-like. Milk color with a cream tint, uniform throughout the mass	
Day 7	2.5×10^{8}	Taste and smell are pure, sour milk, moderately sweet, with a pronounced taste and aroma of sublimated fruit. The consistency is homogeneous, tender, the surface is glossy, jelly-like. Milk color with a cream tint, uniform throughout the mass	
Day 9	1.0×10^{8}	Taste and smell are of sour milk, moderately sweet, with a pronounced taste and aroma of sublimated fruit. The consistency is homogeneous, tender, the surface is jelly-like, slight separation of whey. Milk color with a cream tint, uniform throughout the mass	

5. 3. Studying the microbiological indicators of sour milk dessert

Microbiological spoilage is a major food problem. Microorganisms that can cause spoilage of food include bacteria, molds, pathogenic microorganisms, and others. The results of the analysis of microbiological parameters of sour milk dessert during 9 days of storage are presented in Table 2.

The analysis of the obtained results allows us to elucidate the compliance of microbiological indicators of sour-milk dessert with normative requirements and to establish its expiration date. When the product is stored for more than 7 days, it leads to an increase in QMAFAnM and molds, which exceeds the regulatory requirements.

The number of pathogenic microorganisms, *Staphylococcus aureus,* and BGKP, were not detected during storage.

This indicates compliance with all appropriate sanitary and hygienic requirements in the manufacture of sour milk dessert, as well as its safety for consumption.

Table 2

Microbiological parameters of sour milk dessert during storage

Shelf life	Content of microorganisms				
	QMAFAnM, CFU/g	Molds, CFU/g	BGKP	Pathogenic microorganisms, incl. *Salmonella*	*Staphylococcus aureus*
Regulatory requirements	$\leq 1\times10^5$	<50	not allowed per 0.001 g	not allowed per 25.0 g	not allowed per 0.1 g
Fresh-made	8.0×10^3	<10	not found	not found	not found
Day 1	1.6×10^4	<10	not found	not found	not found
Day 3	3.3×10^4	<10	not found	not found	not found
Day 5	6.0×10^4	<10	not found	not found	not found
Day 7	9.2×10^4	<10	not found	not found	not found
Day 9	4.0×10^5	2.0×10^1	not found	not found	not found

6. Discussion of results regarding the quality indicators of sour milk dessert

In works [9, 11, 13], the use of vegetable fillers in the technology of dairy desserts was proposed but their effect on the physical-chemical parameters of products during storage was not studied. Therefore, in order to substantiate the shelf life of sour milk dessert, the water activity index was studied, which is one of the factors affecting the quality and microbiological safety of the product. This indicator also affects the formation of structural and mechanical properties of the product.

The addition of sublimation dried fruits with whey protein concentrate reduces the activity of water (Fig. 2) as it increases the concentration of dry matter and viscosity of the product. The sour-milk dessert contains vegetable raw materials with a high fiber content, which also slows down the process of whey separation due to the swelling of dry components.

Decreasing the activity of water increases the binding energy in the material and, as a rule, reduces the ability of microorganisms to use moisture for metabolism, reduces the rate of most chemical reactions responsible for spoilage of fermented milk products.

The indicator of active acidity acts in combination with the activity of water on the shelf life of food. The active acidity during the study period was in the range of 5.4–4.2 pH units (Fig. 3).

The effect of the proposed plant ingredients on the physical-chemical parameters of dairy products has been studied in [3, 6, 14, 20]. But the microbiological parameters of dairy products during storage have not been studied, which is an important aspect in substantiating the shelf life. The growth of most microorganisms can be prevented or slowed down by controlling their initial content, controlling the storage temperature, reducing water activity, and active acidity. According to the results of microbiological indicators (Table 2), the shelf life of sour-milk dessert has been established, which should not exceed 5 days at a temperature of 4±2 °C.

The total number of lactic acid bacteria (Table 1), which consists of the bifidobacteria and lactobacilli *Streptococcus thermophilus, Lactobacillus delbrueckii ssp. Bulgaricus, Lactobacillus acidophilus, Bifidobacterium lactis, Lactobacillus casei, Lactobacillus rhamnosus, Lactobacillus paracasei*, *Bifidobacterium infantis,* due to which it is possible to increase the biological and physiological value of the fermented milk product. This combination of bacteria is a symbiosis, as each of them enhances the action of each other. That is why the sourdough has some useful properties and helps restore and maintain the intestinal microflora, normalize digestion, stimulate the growth and activity of its microflora (bifidobacteria and lactobacilli), suppress harmful microorganisms.

The results of our research could be used to control the quality of sour milk products in the technology of products with high humidity. The results reported in this paper allow us to assert the possibility of implementation under actual production.

Thus, improving the technology of sour milk dessert by enriching the functional and technological ingredients is a promising area of research and needs further development.

7. Conclusions

1. Based on the analysis of the indicators of active acidity, water activity, enthalpy, and organoleptic parameters of sour-milk dessert, its shelf life up to 5 days at a temperature of 4±2 °C has been determined.

2. The content of lactic acid bacteria in the finished product during storage was studied. Thus, for the freshly made dessert, the content of lactic acid bacteria is 7.0×10^8 CFU/g; on day 3 of storage – 1.1×10^9 CFU/g; on day 5 of storage – 2.5×10^8 CFU/g, and on day 9 of storage – 1.0×10^8 CFU/g.

3. The microbiological indicators of sour-milk dessert have been investigated. Based on our results, the shelf life of sour-milk dessert of up to 5 days at a temperature of 4±2 °C has been determined.

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