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Original scientific paper

RESEARCH ON THE POSSIBILITY OF EXTENDING THE SHELF LIFE OF CHEESE RAW MATERIAL AND HEAT-TREATED CHEESE BY THEIR FREEZING FOR FURTHER USE IN HORECA

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KEY WORDS:

heat-treated cheese, cheese raw material, freezing, low-temperature storage, functional properties, shelf life

ABSTRACT

The article presents the results of a study of the regularities of changes in the functional properties and quality indicators of heat-treated cheeses made from frozen cheese raw material or frozen after thermomechanical processing for further use in HoReCa. The objects of the study were: Caliatto cheese — a semi-hard ripening cheese intended as the main raw material in the production of heat-treated cheese, as well as heat-treated «pizza-cheese», subjected to freezing at temperatures of -14 ± 2 °C and -55 ± 2 °C and low-temperature storage at a temperature of -14 ± 2 °C for 270 days, followed by defrosting at a temperature of 20 ± 2 °C. To confirm the possibility of using the freezing technique in order to increase the shelf life of both the original cheese raw material and heat-treated cheese, their microbiological and physicochemical indicators were determined by standardized methods. Studies of structural and mechanical (rheological) properties were carried out on a Weissenberg rheogoniometer, recording changes in the elastic modulus (G') and dynamic viscosity (η'). The length of the cheese thread, as one of the main functional properties of the «pizza-cheese», was assessed with a fork test after baking. Organoleptic characteristics were assessed by flavor, texture and appearance. Research results have shown that low-temperature storage of frozen cheese can be considered as a way to retard biological and physicochemical changes, which is a safe way to increase shelf life. Freezing cheese raw material increases the length of the cheese thread in proportion to the temperature and duration of the low-temperature storage. When obtaining heat-treated cheese from both unfrozen and frozen cheese raw material, a significant deterioration in the desired functional properties is observed. Thus, the receipt of heat-treated cheese from the original cheese raw material for further use in the production of pizza is justified only by economic feasibility. Freezing «pizza-cheese» at a temperature of -55 ± 2 °C, made from unfrozen cheese raw material, ensures the preservation of functional properties and increases the shelf life up to 150 days.

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1. Introduction

Currently, “pizza-cheeses” are the leading cheeses in terms of production growth, thanks to the development of the fast food system. The product, called “pizza-cheese”, in its composition and manufacturing technology differs significantly from traditional types of cheese, being between two groups — “cheese” and “processed cheese”, and its safety and quality indicators, including functional properties, are defined as raw materials and technological modes of thermomechanical treatment. The functional properties of “pizza-cheeses”, including stretchability (formation of a “cheese” thread), are the same mandatory quality indicators as microbiological, organoleptic and physicochemical criteria for their assessment. “Pizza-cheeses” form a special group of heat-treated cheeses (HC) as the main raw materials for which cheeses and other milk processing products, as well as food additives, are used. Heat-treated cheeses are produced by thermomechanical processing of raw materials at a temperature not higher than 72 ± 3 °C, which is the main distinguishing feature of the processed cheese production modes and ensures the formation of specific functional characteristics [1].

In the conditions of the developing cheese market for HoReCa and the seasonality of dairy production, the problem of extending the shelf life of both cheese raw material and heat-treated cheeses while maintaining quality indicators becomes extremely urgent. Domestic and foreign researchers have accumulated experience in extending the shelf life of various cheeses

using freezing and further low-temperature storage. In the practice of cheesemaking there are a number of freezing technologies for both traditional and processed cheeses, as well as curd grains. However, there is evidence that, as a result of freezing, the properties of the cheese raw material used for the production of processed cheeses can change significantly [2].

In a number of foreign countries, extensive research has been carried out to develop technology for freezing and further refrigerated storage of traditional types of cheese made from cow, goat and sheep milk. Many researchers are of the opinion about the need for relatively quick and deep freezing of cheeses to preserve organoleptic properties for 6 months at storage temperatures from -18 °C to -30 °C [2,3,4,5,6,7,8,9].

A. Conte et al. assessed the effect of the freezing speed and two-month low-temperature storage of Mozzarella cheese and found that high freezing speeds have a positive effect on the quality of the cheese. However, the authors noted a deterioration in the cheese texture, including porosity, which may be associated with the formation of ice and further protein dehydration [10].

Domestic authors also carried out research on the development of technologies for freezing and low-temperature storage of cheeses. Thus, studies carried out earlier at VNIIMS found out that freezing natural cheeses both at temperatures of -18 °C and -184 °C causes profound changes in the structure, which worsens their quality after defrosting. At the same

time, no significant changes occur in cheeses frozen at minus 18 °C: after defrosting, the structure of the cheese is restored to a satisfactory one. The influence of low-temperature storage of raw rennet cheeses, defrosting modes on the quality of processed cheeses produced from them has been established. In samples of processed cheese made from raw materials stored for 9 months at a temperature of minus 16 °C, a decrease in elastic and viscous properties was noted, which indicates a negative effect of freezing raw materials on the quality of the finished product. At the same time, slow defrosting of raw cheese at 20 °C makes it possible to obtain processed cheeses with satisfactory structural and mechanical properties and organoleptic characteristics [11].

However, until now there are no materials that make it possible to assess the influence of technological methods of freezing, low-temperature storage and defrosting, not only on the microbiological, structural and mechanical, physicochemical and organoleptic characteristics of both cheese raw material and heat-treated cheeses, but also on the functional properties of the finished product, the quality of which is usually assessed after high-temperature processing – baking pizza. Given the relevance of the problem, the purpose of this work is to study the patterns of change in quality indicators, including the functional properties of cheese raw material and heat-treated cheeses, frozen at different temperature conditions and subjected to long-term low-temperature storage, in order to extend their shelf life.

2. Materials and methods

When carrying out the research, samples of cheese raw material of Caliatra cheese and heat-treated cheeses, both industrially produced and produced in the experimental cheesemaking department of VNIIMS, according to previously developed technologies, were used as objects.

Samples packaged with weight of 250–300 g and packed in film were subjected to freezing at temperatures of minus 14 ± 2 °C and minus 55 ± 2 °C and further low-temperature storage at a temperature of minus 14 ± 2 °C for 270 days, followed by defrosting at a temperature of 20 ± 2 °C. Freshly produced cheeses not subjected to freezing and storage were used as control samples.

In the samples under study, standardized methods were used to determine the physicochemical parameters (titratable acidity and mass fraction of moisture), as well as bacterial contamination by the number of viable cells of mesophilic (KMAFanM) and thermophilic (KTAFanM) of aerobic and facultatively anaerobic microorganisms, coliform bacteria, yeast, and spore microorganisms.

Studies of structural and mechanical (rheological) properties were carried out on a Weissenberg rheogoniometer, recording changes in the elastic modulus (G') and dynamic viscosity (η'). Samples of cheese filling the space between the conical surface

and the plane were subjected to sinusoidally measured shear strain of known amplitude and frequency. The studies were carried out in the mode of periodic shear deformation with working bodies “cone-plane” with a diameter of 25 mm, with an angle at the apex of the cone of 0.034 radians, the amplitude of angular displacements of working bodies – 1.54·10⁻³ rad, which achieved the linearity of this mode. The measurements were carried out at frequencies f = 0.316; 0.500; 1.000; 1.990 s⁻¹. The sample was thermostated at 18 ± 3 °C directly in the rheogoniometer. The processing of experimental data was carried out in an automatic mode using a data collection and processing system using a specially developed program [11].

The length of the cheese thread, as one of the main indicators of the functional properties of “cheese for pizza”, was assessed with a fork test after baking [12,13,14]. For this, 100 g of chopped cheese was placed on a porcelain flat surface and sent to bake in an oven at 200 °C for 12 minutes. After the baking time, the cheese was cooled at room temperature for 1–3 minutes. Then the fork was immersed in the cheese by 1–3 mm and slowly, at a constant speed, lifted up until all the threads broke. Stretchability was assessed by the average length of cheese threads taken from three different locations in the melted cheese.

The organoleptic assessment of the cheeses, including the assessment of flavor, texture and appearance, was carried out according to a conventional scale.

3. Results and discussion

At the first stage of the research, there was a study of the effect of freezing, followed by low-temperature storage and defrosting of cheese raw material on changes in microbiological, structural and mechanical, physicochemical, organoleptic and functional properties, both of the initial cheese raw material and heat-treated cheeses produced from it.

Microbiological indicators of the safety of cheese raw material and heat-treated cheese, when determining the shelf life, require special attention. Table 1 shows the data on changes in the number of normalized groups of microorganisms in the process of low-temperature storage of frozen samples after defrosting. It should be considered that the inoculation of heat-treated cheese samples was carried out not immediately after production, but after 3–4 days, which provided conditions for the reactivation of cells that received a thermal shock during thermomechanical processing. Analysis of the obtained results shows that when samples are frozen at a temperature of minus 14 ± 2 °C, bacterial contamination (QMAFanM index) decreases on average by 0.5 orders of magnitude, and at a temperature of minus 55 ± 2 °C – by an order of magnitude, therefore, freezing modes have little effect on the safety of bacterial cells.

Table 1

Safety indicators of cheese raw material in the process of low-temperature storage and heat-treated cheese produced from it

Storage point, days	Freezing mode, °C	Storage mode, °C	QMAFanM, CFU/cm ³		Coliform bacteria		Yeast, mold, CFU/cm ³		Number of spores, MPN spore/cm ³	
			cheese raw material	HC	cheese raw material	HC	cheese raw material	HC	cheese raw material	HC
before freezing			3.0×10 ⁹	6.6×10 ⁸						
90	minus 14 ± 2		9.8×10 ⁸	1.8×10 ⁸						
	minus 55 ± 2		4.7×10 ⁸	2.5×10 ⁸						
180	minus 14 ± 2	minus 14 ± 2	9.4×10 ⁸	2.3×10 ⁸	absent in 0.1g		absent in 0.1g		absent in 0.1g	
	minus 55 ± 2		4.2×10 ⁸	9.6×10 ⁸						
270	minus 14 ± 2		2.4×10 ⁸	7.9×10 ⁷						
	minus 55 ± 2		2.8×10 ⁸	7.5×10 ⁷						

It was found that under low-temperature storage conditions, as expected, there are no signs of microflora development and microbiological safety indicators do not deteriorate. It can be assumed that when the cheese raw material is frozen, the most viable cells of thermophilic starter microorganisms are preserved, and when heat-treated cheese is obtained and the melting temperature is $72 \pm 3^\circ\text{C}$, these microorganisms survive and, having come out of the thermal shock, are able to resume their viability.

Figure 1 shows the data on changes in the number of thermophilic starter microorganisms, represented by bacteria of the species *Streptococcus thermophilus*, during the low-temperature storage of frozen cheese raw material and heat-treated cheese after defrosting.

Microbiological research data show that the cheese raw material was developed using *Streptococcus thermophilus* starter cultures, therefore the indicators of QMAFAnM and QTAFAnM (Quantity of Thermophilic Aerobic and Facultative Anaerobic Microorganisms) are almost identical. When frozen, the number of viable cells decreases on average by 0,5–1,0 order of magnitude and during further storage remains at the same level for up to 180 days. When receiving heat-treated cheese, the total number of viable cells decreases insignificantly: when receiving a product from unfrozen cheese raw material – on average by 1.0 order of magnitude, and during the production from frozen cheese raw material – by 0.5 order of magnitude.

The study of frozen samples of cheese raw material and samples of heat-treated cheeses produced from them did not establish the effect of the depth of freezing and the duration of low-temperature storage on the main physicochemical parameters, such as pH and mass fraction of moisture.

Figure 2 presents the results of studies of the rheological parameters of heat-treated cheeses made from frozen cheese raw material.

When studying the rheological parameters of samples with different periods of low-temperature storage, it was found that during storage, the modulus of elasticity (G') and dynamic viscosity (η') increase in samples produced from cheese raw material stored at low-temperature conditions up to 180 days, and decrease at longer storage. A decrease in the freezing temperature to minus $55 \pm 2^\circ\text{C}$ leads to slightly larger losses of G' and η' values during storage in comparison with the freezing mode of minus $14 \pm 2^\circ\text{C}$. It can be assumed that with an intense decrease in the freezing temperature, smaller water crystals are formed, which ensures the stability of the protein framework. In heat-treated cheeses made from cheese raw material for 270 days of storage, a slight decrease in elastic and viscous properties was noted. With the organoleptic assessment of the texture of these cheeses, an increase in the “incoherent” and “crumbly” texture and the appearance of new “mealy”, “plastic” and “non-layered” defects are noted. It was found that lowering the freezing temperature to minus $55 \pm 2^\circ\text{C}$ and storing frozen cheese raw material for more than 180 days leads to a deterioration in the texture of heat-treated cheeses.

In the course of the organoleptic evaluation, it was found that the change in the flavor of frozen cheese raw material occurs immediately after freezing and further defrosting. By 90 days of low-temperature storage in all samples of cheese raw material, an excessively sour flavor was noted against the fermented milk in the original cheese raw material, the intensity of the cheese flavor weakens, and a slight foreign taste appears. The influence of the temperature regimes of freezing cheese raw material on the flavor indicators of heat-treated cheese was not revealed.

Table 2 presents the results of studies of the effect of freezing, low-temperature storage with further defrosting of cheese raw material on the functional properties of heat-treated cheeses, including the length of the cheese thread after frying.

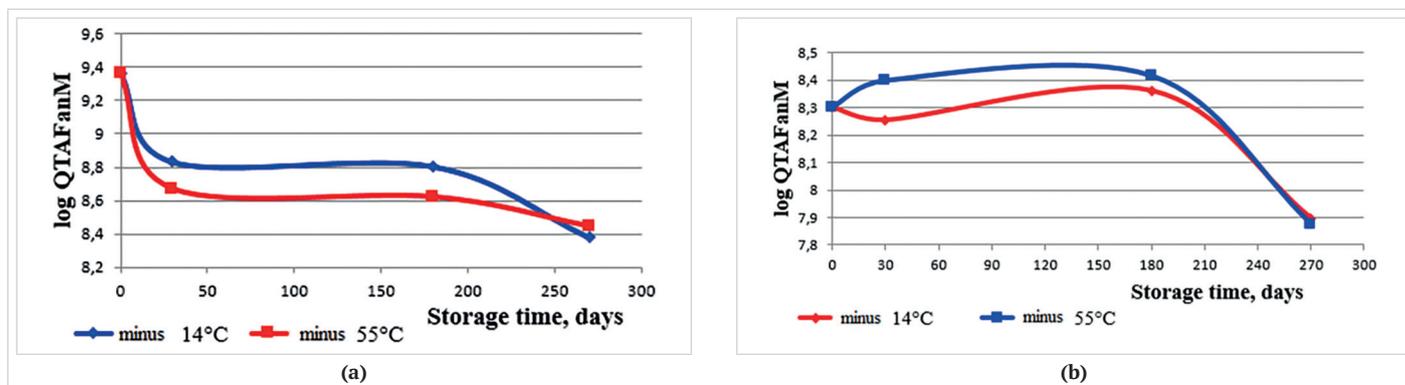


Figure 1. Change in QTAFAnM(a) of cheese raw material during low-temperature storage and (b) heat-treated cheese produced from it (point 0 – before freezing)

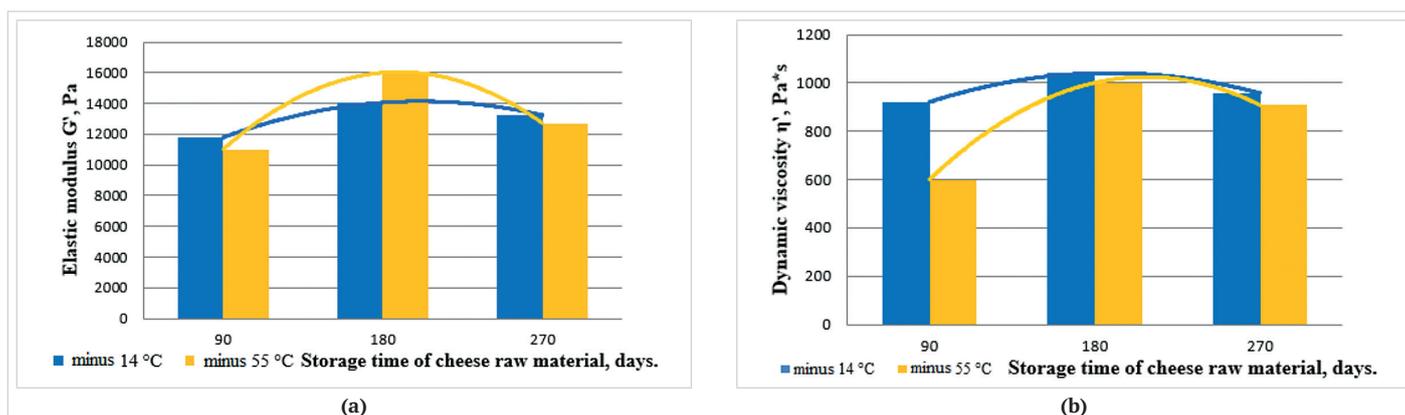


Figure 2. Change in modulus of elasticity (a) and viscosity (b) of heat-treated cheese made from frozen cheese raw material

Table 2

Length of cheese thread after frying cheese raw material and heat-treated cheese made from frozen cheese raw material

Storage point, days	Freezing mode, °C	Storage mode, °C	Length of thread of cheese raw material, cm	Length of cheese thread of heat-treated cheese made from cheese raw material, cm
Before freezing			25	12
90	minus 14±2	minus 14±2	40	10
	minus 55±2		40	12
180	minus 14±2		45	10
	minus 55±2		60	15
270	minus 14±2		50	12
	minus 55±2		50	15

From the data presented in Table 2, it follows that the process of freezing cheese raw material increases the length of the cheese thread in comparison with unfrozen cheese and improves this indicator during low-temperature storage for more than 180 days. A comparison of the two freezing temperatures showed that freezing to a lower temperature resulted in a longer cheese thread. With both modes of freezing, an increase in the viscoelastic and plastic properties of the cheese raw material was noted, which led to a more viscous-liquid product during the frying process.

When receiving heat-treated cheese from both unfrozen and frozen cheese raw material, a significant deterioration in functional properties is observed. The length of the cheese thread after baking is reduced by 2.5–5 times. Thus, the receipt of heat-treated cheese from the original cheese raw material for further use in the production of pizza is justified only by economic feasibility.

At the second stage, studies were carried out on the effect of freezing and low-temperature storage of heat-treated cheeses made from unfrozen cheese raw material in order to establish the possibility of increasing the shelf life and further use for Ho-ReCa. Freezing and further low-temperature storage modes were similar to those used in the previous series of experiments.

As a result of the studies carried out, it was found that the mass fraction of moisture in quickly frozen heat-treated cheese at a temperature of minus 55±2 °C and stored at a temperature of minus 14±2 °C for 150 days practically does not change. Slow freezing of pizza-cheese at a temperature of minus 14±2 °C and storage at this temperature results in a moisture loss of 1.5% after defrosting. Freezing speed and low-temperature storage have no effect on pH (Figure 3).

During the freezing and further low-temperature storage of heat-treated pizza-cheeses, the level of bacterial contamination tends to decrease slowly (Figure 4).

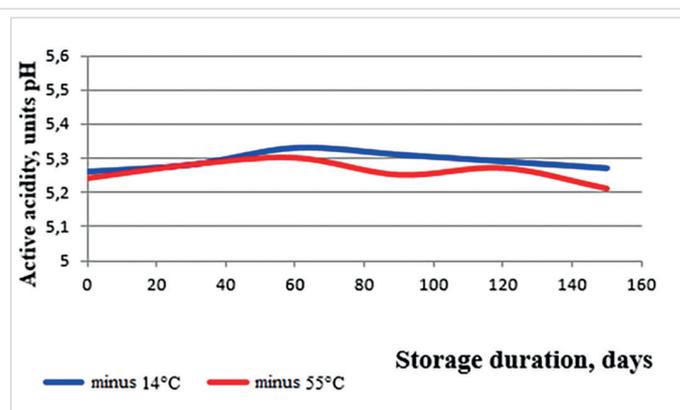
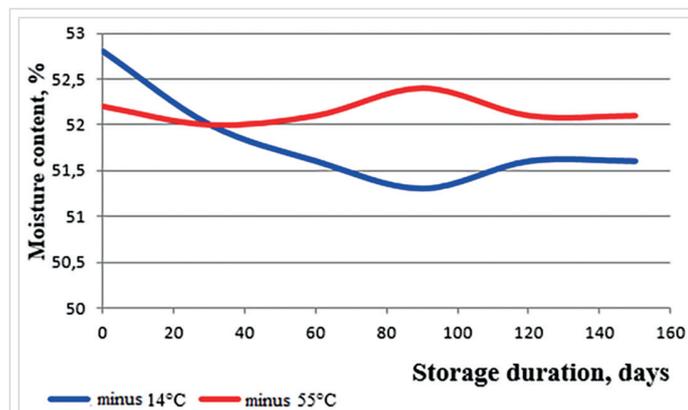


Figure 3. Change in the mass fraction of moisture and active acidity in heat-treated cheeses frozen at temperatures of minus 14±2 °C and minus 55±2 °C and stored at a temperature of minus 14±2 °C

Figure 5 shows the dynamics of changes in the structural and mechanical indicators of heat-treated cheeses during low-temperature storage.

During low-temperature storage under both freezing modes, the elastic modulus and dynamic viscosity tend to increase. At the same time, the absolute values of structural and mechanical indicators are higher for samples frozen at a temperature of minus 55±2 °C.

When evaluating organoleptic indicators, it was found that before freezing, heat-treated cheeses had a weakly expressed cheese, slightly acidic flavor and an insufficiently dense, slightly elastic, plastic texture of medium layering. After freezing without low-temperature storage, the sour flavor intensifies. In the samples of heat-treated cheeses, frozen at a temperature of minus 14±2 °C, softness appears, layering significantly decreases and elasticity disappears. During low-temperature storage, the sour flavor is enhanced and a slight off-flavor appears. In samples subjected to freezing at a temperature of minus 55±2 °C, the cheese flavor and original layering are preserved.

When evaluating the functional properties of heat-treated cheese after frying, it was found that the freezing process at a temperature of minus 14±2 °C without storage leads to a decrease in the cheese thread by about 1.5 times, and the freezing mode at a temperature of minus 55±2 °C increases the original length of the cheese thread. In this case, the further low-temperature storage of this cheese at a temperature of minus 14±2 °C in both cases does not affect the length of the cheese thread (Table 3). Freezing “pizza-cheese” at a temperature of minus 55±2 °C, made from unfrozen cheese raw material ensures the preservation of functional properties and increases the shelf life up to 150 days.

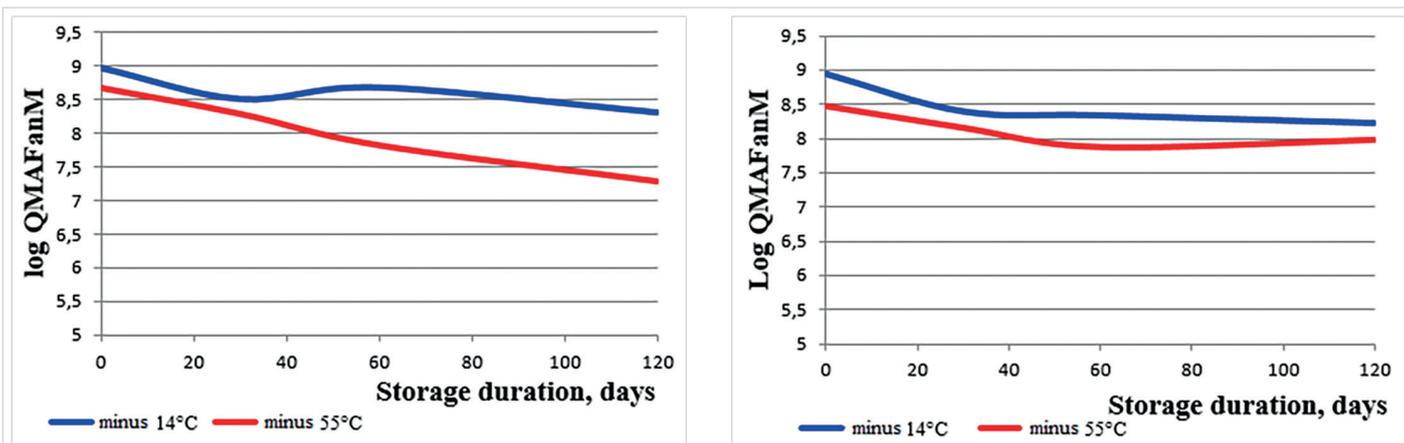


Figure 4. Change in QMAFanM and QTAFanM in heat-treated cheeses frozen at temperatures of minus 14±2 °C and minus 55±2 °C and stored at minus 14±2 °C

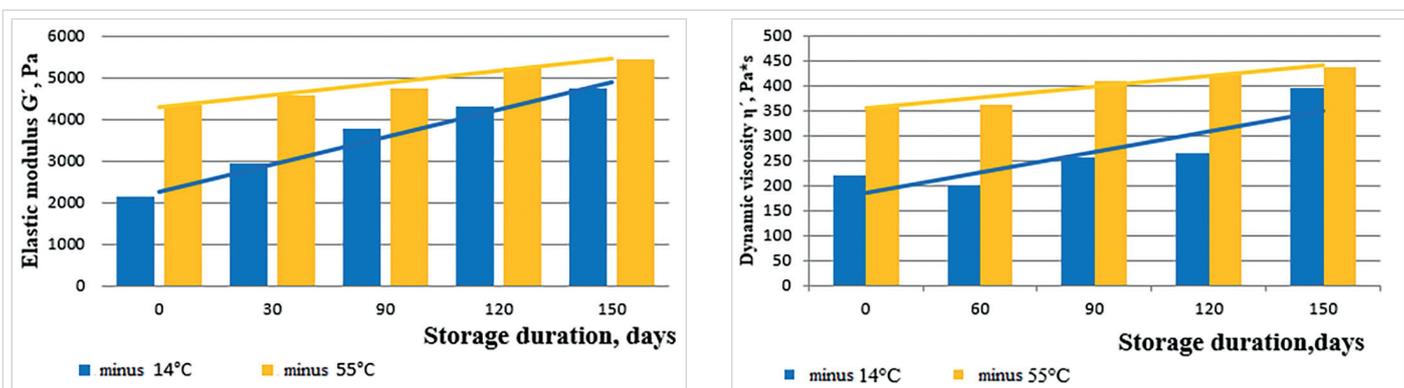


Figure 5. Change in the modulus of elasticity and dynamic viscosity of heat-treated cheeses frozen at temperatures of minus 14±2 °C and minus 55±2 °C and stored at minus 14±2 °C

Table 3

Change in the length of the cheese thread of heat-treated cheeses after freezing and low-temperature storage

Storage point, days	Freezing mode, °C	Storage mode, °C	Length of cheese thread, cm
before freezing			14
0	minus 14±2 °C	minus 14±2 °C	13
30			13
60			11
90			10
120			10
150			9
0	minus 55±2 °C	minus 14±2 °C	21
30			21
60			20
90			20
120			21
150			19

4. Conclusions

Thus, as a result of the studies carried out, it was found that the operations of freezing and low-temperature storage, followed by defrosting of both cheese raw material and heat-treated cheeses, affect both the quality indicators and functional properties, and the shelf life. At the same time, the direction and intensity of the influence depend on the selected

freezing and low-temperature storage modes, which, in turn, should be determined based on the indicators of microbiological safety and the quality of cheese raw material and heat-treated cheese. Using the freezing technique followed by low-temperature storage, you can increase the shelf life of cheese raw material up to 180 days, and heat-treated cheese for pizza up to 150 days.

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