

# Study of the influence of the process of freezing milk on the safety of its properties of cheese suitability

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**Abstract.** The article presents the results of studies of the effect of freezing on the change in the physicochemical, microbiological and technological properties of goat milk and the preservation of its qualities of cheese suitability. A statistically significant dependence of the composition of milk on the duration of storage in a frozen state was revealed. There was no significant effect of freezing and defrosting modes on the quality indicators of milk. It has been established that changes in the technological properties of frozen goat milk after defrosting, such as the duration of coagulation and the ability to syneresis, are insignificant in comparison with defrosted cow's milk.

## 1 Introduction

Products made from goat milk belong to the premium sector and are in demand as dietary and hypoallergenic. The range of products is diverse – drinking milk, yoghurts, ice cream, but most of all, cheeses are made. Goat milk production is highly seasonal, especially in small farms. This necessitates its accumulation and reservation before processing for several days, and freezing is the most accessible way to preserve it [1, 2].

In the dairy industry, freezing is used to extend the shelf life of butter, cottage cheese, natural cheeses intended for the manufacture of processed and thermized cheeses. In a number of countries, cream is frozen in small quantities, which, after defrosting, is used in the manufacture of butter and food products [3-6]. Data on the effect of freezing on the properties of cheese suitability for both goat and cow's milk are practically absent in the literature. In milk, which is a complex polydisperse system, when the temperature drops below the cryoscopic temperature, all its components change. First of all, the process of water crystallization begins with the formation of crystallization centers and further growth of crystals, fat globules are deformed, their protective shell is damaged, torn and allows them to stick together, forming fat drops visible to the eye. After defrosting, the content of free fat in dairy products increases [8]. Works of a number of authors [9] showed that when cow's milk is frozen, casein micelles remain in their native state. Studies of buffalo milk showed a

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decrease in the level of  $\beta$ -casein in milk after storage at minus 20 °C for 20 weeks [10]. Freezing-induced destabilization of casein micelles occurs after long-term storage at temperatures above minus 15 °C. During defrosting, a protein precipitate may form. In addition, the precipitate of casein is accompanied by a decrease in the concentration of calcium, phosphorus and citrate ions. Lactose undergoes crystallization during freezing of milk, which contributes to the formation of casein flakes in frozen milk [7, 8]. It has been proven that high freezing rates contribute to a more uniform distribution of small ice crystals in the matrix of any product, while slow freezing usually leads to the formation of large needle-shaped ice crystals [11, 12]. The freezing process has an impact on the safety of milk. The works of a number of researchers found that freezing to minus 20 °C reduces the number of somatic cells by 29%. [13]. Researchers [14] did not find a statistically significant effect of freezing on the total number of viable cells of psychrophilic microflora

In addition to the general safety and quality requirements, milk for cheesemaking is subject to a number of additional requirements that are included in the concept of “cheese suitability”. An analysis of literary sources shows that there is no data on the effect of freezing and defrosting processes on the properties of goat milk, and there is not enough information on the effect of low-temperature reservation regimes on the indicators of cheese suitability of cow's milk.

Based on the relevance of the problem, the purpose of this work was to study the effect of the process of freezing and defrosting goat and cow's milk on the preservation of specific properties of cheese suitability.

## **2 Objects and Methods**

### **2.1 Research objects**

Goat milk-raw, frozen and defrosted goat milk, raw cow's milk, frozen and defrosted cow's milk.

### **2.2 Research methods**

2.2.1 Determination of the mass fraction of fat, protein, lactose, as well as mineral salts, density, acidity, freezing point and dry skimmed milk residue was carried out using MilkoScan FT 2 and Foss Analytical A/S instruments.

2.2.2 The control of mesophilic aerobic and facultative anaerobic microorganisms of raw milk was carried out according to the “Russian Standard GOST 32901-2014”. The method is based on counting colonies growing on a solid nutrient medium at a temperature of  $(30\pm 1)$  °C for 72 hours.

2.2.3 The determination of somatic cells was carried out according to the “Russian Standard GOST 23453-2014”.

2.2.4 The rennet test, which determines the ability of milk to rennet coagulation, was evaluated according to the “Russian Standard GOST 32901-2014”.

2.2.5 Method for studying the process of rennet coagulation: 800 cm<sup>3</sup> of the studied milk is added into measuring cups on 1 dm<sup>3</sup>; placed in a thermostat at a temperature of 37 °C; 1.0

cm<sup>3</sup> of an aqueous solution of rennet with an activity of 100 thousand AU is added to each sample. The unit fixes the values of the modulus of elasticity of the curd (G'). The installation is based on the “hot wire” method described in [15].

2.2.6 The syneretic ability of the gels was studied by adding 20 cm<sup>3</sup> of milk with rennet, prepared according to paragraph 2.2.5, into measured graduated centrifuge tubes with a volume of 40 cm<sup>3</sup>. The samples were kept in a thermostat at a temperature of 37 °C for 1 h. After the time had passed, the samples were centrifuged in a laboratory centrifuge for 20 min at 6000 rpm. The volume of whey released after centrifugation and the resulting curd was measured.

2.2.7 Mathematical processing of experimental data was carried out by methods of dispersion, correlation and regression analyzes using special software packages.

### 3 Results and discussion

In order to study the effect of freezing and defrosting regimes on the physicochemical, microbiological and technological properties of goat and cow’s milk, a three-factor experiment was carried out, where the variation factors were: the duration of storage of frozen milk (5 days and 35 days) – X<sub>1</sub>, the milk freezing temperature (minus (18±1) °C and minus (50±1) °C) – X<sub>2</sub>, and defrosting temperature ((10±1) °C, (20±1) °C and (40±1) °C) – X<sub>3</sub>.

After exposure in a frozen state and defrosting, physicochemical parameters, safety criteria and technological properties were controlled in milk. An analysis of the experimental data showed that the studied factors in the ranges of variation did not have a significant effect on the physicochemical composition of milk (Table 1).

**Table 1.** Physicochemical and microbiological parameters of goat and cow’s milk before freezing and after defrosting

Name of indicator	Before freezing		After defrosting	
	goat milk	cow’s milk	goat milk	cow’s milk
Mass fraction of fat, %	4.02±0.1	3.62±0.1	4.04±0.1	3.60±0.1
Mass fraction of protein, %	3.16±0.2	3.18±0.2	3.13±0.2	3.16±0.2
Nonfat dry milk, %	8.76±0.5	8.31±0.5	8.72±0.5	8.30±0.5
Mass fraction of lactose, %	4.61±0.1	4.72±0.1	4.58±0.1	4.70±0.1
Mass fraction of mineral salts, %	0.72±0.04	0.63±0.04	0.69±0.04	0.61±0.04
Density, kg/cm <sup>3</sup>	1029.14	1028.47	1028.34	1028.17
Number of somatic cells, thousand cells/cm <sup>3</sup>	1048±120	472±90	790±110	373±90
QMAFAnM, CFU/cm <sup>3</sup>	(1.6±0.4)×10 <sup>3</sup>	(7.8±0.7)×10 <sup>4</sup>	(2.2±0.5)×10 <sup>3</sup>	(1.1±0.9)×10 <sup>5</sup>

When studying the effect of freezing and defrosting modes on the number of somatic cells, a regression model {1} has been obtained, which allows us to conclude that the dependence is statistically significant. The main factor influencing the output parameter is the duration of milk holding in the frozen state (X<sub>1</sub>). Factors X<sub>2</sub> and X<sub>3</sub> are excluded from the

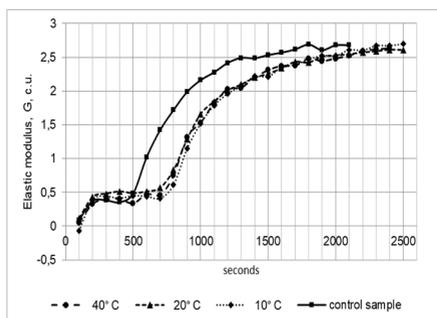
equation because they did not have a statistically significant effect on the output parameter. Freezing milk under the conditions of the experiment has caused a decrease in the number of somatic cells in comparison with the control by (18-30)%, depending on the duration of storage. The results obtained are consistent with the literature data [11]. However, it should be taken into account that the decrease in the number of somatic cells after freezing cannot be considered as a factor that increases the level of safety, because their number is only an indirect indicator of the inflammatory state, therefore, the control of the number of somatic cells when receiving milk should be carried out before freezing.

$$V=5,3 \cdot X_1 + 706,8 \quad \{1\}$$

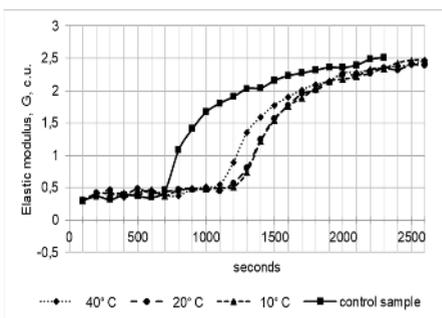
The process of freezing milk, regardless of its modes and duration of storage, in comparison with the control sample in the framework of this experiment, did not lead to statistically significant changes in the total bacterial contamination.

When assessing the compliance of milk quality with the requirements of cheese suitability, not only safety and quality indicators are important, but also technological properties, such as the ability to form a dense curd under the action of rennet and the ability of this curd, during further technological procedures, to dehydrate, i.e. to syneresis and release of a clear whey.

In order to study the technological properties of defrosted milk, a study was made of the process of its enzymatic coagulation. Milk was frozen at minus (18±1)°C and stored for 20 days; defrosting was carried out at (10±1)°C, (20±1)°C and (40±1)°C. Figures 1 and 2 provide the results of observations.



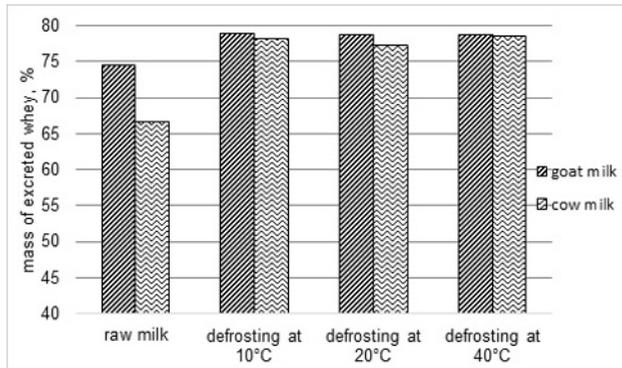
**Fig. 1.** The process of rennet coagulation of goat milk



**Fig. 2.** The process of rennet coagulation of cow's milk

It has been established that in the process of rennet coagulation of frozen milk after defrosting, the enzymatic phase is lengthened, which leads to an increase in the duration of coagulation and the time of curd formation. For goat milk subjected to freezing, the duration of the enzymatic phase of rennet coagulation increases by 36%, and for cow's one – by 64%. The temperature regimes of defrosting have not had an additional effect on the ability of both goat and cow's frozen milk to rennet coagulation.

Figure 3 shows the results of the influence of the milk freezing process on the syneretic properties of curds. The difference in the level of syneresis (the amount of released whey) between the control and experimental options for goat milk was (5±1)%, which is within the error of the method. At the same time, for cow's milk, the difference in the level of syneresis was (15±1)%, which is a statistically significant result.



**Fig. 3.** The amount of whey released from curds of goat and cow's milk

For both types of milk, a trend towards a decrease in the yield of rennet curd from frozen milk has been observed. This trend is more typical for cow's milk. The mass fraction of a curd obtained from frozen cow's milk is  $(35\pm 1)\%$  less than the mass fraction of a curd obtained from milk without freezing. For goat milk, this difference was  $(16\pm 1)\%$ .

## 4 Conclusion

As a result of the research, it was found that the freezing regimes, the storage time of frozen milk and the temperature regimes of defrosting do not have a significant effect on its physicochemical parameters and the level of bacterial contamination. It has been established that as a result of storing frozen milk, the number of somatic cells decreases, which can lead to falsification of the results of assessing the level of safety.

The data on the assessment of cheese suitability and technological properties of frozen milk show that after defrosting both goat and cow's milk, the ability to rennet coagulation deteriorates. At the same time, the reservation of milk by freezing has a lesser effect on the properties of cheese suitability of goat milk than cow's one.

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## References

1. A. A. L. Tribst, L. T. P. Falcade, M.M. de Oliveira, J. Dairy Sci., **102**, 4960-4971 (2018) <https://doi.org/10.3168/jds.2018-15715>
2. A.L. Ishevsky, I.A. Davydova, Theory and practice of meat processing, **2(2)**. 43-59 (2017) <https://doi.org/10.21323/2414-438X-2017-2-2-43-59>
3. A. Conte, J. Laverse, C. Costa, V. Lampignano, M.A. Previtali, M.A. Del Nobile, J. Food Process. Preserv., **41(6)**, 13235. (2017) <https://doi.org/10.1111/jfpp.13235>
4. I.C. Alberini, J. Food Process. Preserv., **39**, 1983-1991 (2015) <https://doi.org/10.1111/jfpp.12438>
5. M. Alinovi, G. Mucchetti, Food Sci. Technol., **124**, 109-137 (2020) <https://doi.org/10.1016/j.lwt.2020.109137>
6. Z. Yu, C. Qiao, X. Zhang, L. Yan, L. Li, Y. Liu, J. Dairy Sci., **104(4)**, 4108-4118 (2021) <https://doi.org/10.3168/jds.2020-19238>

7. A. Costa, G. Visentin, M. De Marchi, M. Cassandro, M. Penasa, J. Dairy Sci., **102(8)**, 7217-7225 (2019) <https://doi.org/10.3168/jds.2018-15378>
8. A. Tepel, *Chemistry and physics of milk*. 850 (2012) ISBN 978-5-904757-34-2
9. S.M. Gabera, An.-Gr. Johansenab, R.B. Schüllera, T.G. Devolda, El.-Ol. Rukkeä, S.B. Skeiea, Int. Dairy J., **101**, 104563 (2020) <https://doi.org/10.1016/j.idairyj.2019.104563>
10. M. Rutigliano, R. Gagliardi, A. Santillo, V. Diurno, A. Di Luccia, Int. J. Dairy, **86**, 36-38 (2018) <https://doi.org/10.1016/j.idairyj.2018.07.001>
11. M. Dalvi-Isfahan, P.K. Jha, J. Tavakoli, A. Daraei-Garmakhany, E. Xantha-kis, A. Le-Bail, J. Food Eng., **555**, 50-60 (2019) <https://doi.org/10.1016/j.jfoodeng.2019.03.011>
12. R. Bottiroli, C. Zhang, E. Aprea, V. Fogliano, K. Hettinga, F. Gasperi, J. Dairy Sci., **103(10)**, 8822-8828 (2020) <https://doi.org/10.3168/jds.2020-18415>
13. P.L.H. McSweeney, P.F. Fox, P.D. Cotter, D.W. Everett, *Cheese. Scientific bases and technologies*. 2 th Ed Elsevier: Academic Press. **1(21)**, 504-505 (2019) ISBN: 978-0-12-417012-4
14. P.F. Fox, A.L. Kelly, Int. Dairy J., **16(6)**, 517-532 (2006) <https://doi.org/10.1016/j.idairyj.2005.09.013>
15. I.T. Smykov, Food Systems, **1(2)**, 12-20 (2018) <https://doi.org/10.21323/2618-9771-2018-1-2-12-20>