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APPLICATION OF ULTRA-HIGH-TEMPERATURE PROCESSING OF RAW MILK TO IMPROVE CHEESE QUALITY

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ABSTRACT

The increase in natural cheese production has brought issues related to ensuring the production of high-quality competitive products to the fore. The development of the cheese market requires constant improvement of the existing methods of production and the search for new technological solutions, which will allow us to counterbalance the low quality of raw materials, which is currently a serious problem for domestic cheese production. A promising method of realising the benefits of high-temperature (HT) and ultra-high-temperature (UHT) milk processing in cheese making is the development of new types of cheese with a high moisture content; however, there are very few publications that discuss these approaches. The development of advanced technologies for the production of low-temperature second-degree solid cheeses with the use of HT and UHT processing, related to the improvement of the technological process and the equipment and technological scheme of production of solid cheeses. The main direction of the development of cheese production at the present stage is the improvement of existing technological processes, the development of resource-saving technologies and the improvement of the natural solid rennet cheese quality. The results of our research, related to the study of the composition and safety of milk raw materials, the impact of various technological factors on the cheese production process and the quality of the products obtained, are the basis for our resource-saving technology for the production of solid rennet cheese.

Keywords: milk; cheese; UHT processing; cheeseability of milk; cheese ripening

INTRODUCTION

Most dairies, including cheese-making companies, today experience some difficulties in ensuring the production of sufficient raw milk, which meets certain requirements, such as safety, nutritional and biological value, and technological properties. Fresh cow's milk contains all the nutrients and biologically valuable substances necessary for the human body in a well-balanced ratio and in easily digestible form (**Kuznytsov and Shyler, 2003**). When selecting milk for cheese making, it is necessary to take into account the quality and safety of milk, as well as the specific requirements for cheese. Milk for cheese making is considered to be according to the accepted technology, in compliance with the rules of sanitation, a high yield of a product of guaranteed quality can be obtained. Raw milk should not contain chemical or microbiological contaminants. "Cheeseability" is a complex characteristic of milk. One of the major requirements of cheese making is its ability to quickly deal with the formation of a dense clot that gives off serum and retains fat. A second fundamental requirement is that milk should be a good environment for the development of the required microflora for the formation of organoleptic indicators of cheese (**Kuznytsov and Shyler, 2003; Skott, Robynson and Uylby, 2005**) (Table 1). The protein content in milk determines the yield of cheese. When it comes to protein and its role in cheese production, protein-casein, the amount of which in milk is proportional to the total protein content, first of all is used in practice. The total protein content of milk is most often used as a criterion for milk cheese. If the degree of protein usage and consequently casein in the production of cheese decreases, it decreases the transition of fat to cheese and as a consequence increases the loss of fat with serum. This is confirmed by the data provided by **Hudkov (2003)**, according to which the decrease in casein content in milk by 0.23% in the production of Parmesan cheese is accompanied by an increase in fat loss with serum by 2.04% and, as a consequence, a decrease in cheese output by 0.62%.

Table 1 Comparative characteristics of milk and cheese in the composition of essential amino acids.

Amino acids	Amino acid content in proteins, mg.100g^{-1}	
	Standard	Cheese
Tryptophan	1.0	1.4
Phenylalanine + tyrosine	6.0	10.5
Leucine	7.0	10.4
Isoleucine	4.0	5.8
Threonine	4.0	4.8
Methionine + cystine	3.5	3.2
Lysine	5.5	8.3
Valine	5.0	6.8
Total	36.0	51.6

Table 2 Indicators of cheese-making capacity of milk raw materials in cheese-making.

Value	Indicators
Number of spores of lactose-fermenting microorganisms in 1 cc, no more	13
Sort, no lower	I
Class on rennet-fermentation test, no lower	II
Class on reductase test, no lower	II Class
KMAFANM, CFU in 1 cc	1 x 10^6
Number of somatic cells in 1 cc	500000
Acidity T, no more	18
Mass fraction of protein, no lower	2.8

Milk protein in essential amino acids is very close to the "ideal or reference protein" proposed by the World Health Organisation FAO/WHO **(Skott, Robynson and Uylby, 2005; Hudkov, 2003)**. Comparative characteristics of the most important essential amino acids of "reference protein", milk and cheese according to **Hudkov (2003)** are given in Table 2.

Any thermal action affects the components of milk and its physical and chemical properties. The degree of exposure mainly depends on the temperature regime and the duration of the temperature. The protein system has high heat resistance due to casein, which refers to heat-resistant proteins. Without coagulation, it withstands heating at a temperature of 140 °C for 10 – 20 min. The main mineral components involved in the rennet coagulation, as well as in the structure and texture of the cheese, are calcium and phosphorus. The last ones are in milk both in true solution and in colloidal form. In fresh raw milk, ~33% of calcium and 53% of phosphorus account for the true solution. In milk thermal treatment, a considerable part of soluble forms of phosphorus and in particular calcium becomes colloidal **(Tverdokhleb and Ramanauskas, 2006)**. The heat treatment changes the salt composition of milk and, first of all, the composition of calcium salts. These changes are due to the transition from the monomolecular form of hydrophosphates and calcium dehydrophosphates to poorly soluble calcium phosphate, which is aggregated and colloid deposited on casein micelles. In this case, there is irreversible mineralisation of the caseinate-calcium-phosphate complex, which causes a disruption of the structure of micelles and a decrease in the heat resistance of milk. Part of the calcium phosphate together with the denatured whey proteins form a milk stone.

A promising method of realising the benefits of HT and UHT milk processing in cheese making is the development of new types of cheese with a high moisture content; however, there are very few publications on this approach regarding the usage of HT and especially UHT milk processing.

Scientific hypothesis

This article proposes a way to increase the cheesiness of milk, increase the cheese yield and intensify the cheese ripening process by using HT and UHT processing of raw milk at temperatures above 100 °C. During HT processing, there is a high bactericidal effect, the transition of the whey proteins to milk curd, while improving the moisture-holding capacity of the curd and reducing the ripening time of the cheese. This will solve the problem associated with process improvements, increased yields and an expanded range of high-quality cheese with shortened maturation.

MATERIAL AND METHODOLOGY

We used a set of conventional and special physical, chemical, biochemical, physicochemical, microbiological, mathematical methods in this work, with graphic processing of the results corrected for work with milk raw materials and solid rennet cheeses. Industrial testing of the advanced equipment and technological scheme and developed technology of solid rennet cheese production from milk, which was HT processing, was carried out at the experimental unit, which was installed by the staff at the UMMU. The production of experimental batches, tasting and the sale of hard cheese using HT milk processing was carried out in the production conditions of the LLC "Litinskyi Dairy Factory", Litin City in the Vinnytsia Region of Ukraine. Substantiation of the selection of starters for the process of making rennet cheese with low temperature of the second heating from milk, which has been pre-treated and UHT treated, was considered using concentrates BK-Uglich-5A produced by the Experimental Biofabrication of Uglich, Russia and

ALU production TIMM Kiev, Ukraine. As the main bacterial starter, we used mesophilic lactic acid bacteria, which is used for cheeses with a low temperature of second heat. In addition, we also used ferments of thermophilic lactic acid sticks. The starter was used in various combinations. The peculiarity of the bacterial starter culture is that after HT treatment at 81 ±1 °C with a holding time of 25 s and UHT treatment at 120 ±1 °C with a holding time of 5 s, the milk was cooled to a temperature of 66 °C for 10 s and further cooled up to 10 °C, that is, until the milk matures. The cooled milk was stirred for 5 min to distribute the constituent components of the milk evenly and 0.1% of the main bacterial leaven made from a concentrate comprising *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *cremoris*, *Lactococcus lactis* subsp. *diacetilactis*, *Leuconostoc lactis* was added and left for 12 h for maturation (Table 3). After 12 h, the milk was heated to the fermentation temperature of 34 °C to make a different ratio of basic and additional fermentation: 0.7% basic and 0.1% additional, 1.5% basic and 0.3% additional, 2.0% basic and 0, 5% extra. As a result of the conducted research, it is established that with the increase of the total amount of bacterial starter culture, there is an increase in the acidity of the milk before settling, a decrease in the duration of the grain mixing after the second heating and an increase in the acidity of the serum at all stages of the technological process. For the fermentation of milk that has undergone HT processing, we conducted with some differences in comparison with the existing technological process, which is widely used in the production of natural rennet cheeses with a low second heat. The peculiarity of introducing bacterial starter cultures is that after HT treatment at 81 ±1 °C with a holding time of 25 s and UHT treatment at 120 ±1 °C with a holding time of 5 s. The milk was cooled to 66 °C for 10 s and further cooled up to 10 °C, that is, until the milk ripens. The cooled milk was stirred for 5 min to distribute the components of the milk evenly and 0.1% of the main bacterial starter made from concentrate was added, left for 12 h for maturation. After 12 h, the milk was heated to the fermentation temperature of 34 °C and made a different ratio of basic and additional fermentation: 0.7% basic and 0.1% additional, 1.5% basic and 0.3% additional, 2.0% basic and 0.5% extra.

In the technological process of cheese production, we used an experimental unit for HT steam contact processing of milk, mounted by the staff at TIMM UAAN, according to the agreement. The principle of operation of the pilot plant is shown in Figure 1.

Normalised milk was fed into the collection for normalised milk 2 and pump 7 was sent to the section 1-2 of the plate heat exchangers, where the milk is heated by the secondary steam coming from vacuum chamber 3, to a temperature of 35 – 40 °C. The heated milk from section 1-2 enters section 1-3, where it is heated by hot water, which has a temperature of 90 – 95 °C and is fed through automatic valve 9 from the water heating system to a temperature of 60 – 65 °C. In injection device 4, the heated milk is mixed with purified water vapor at a temperature of 140 – 160 °C.

The water vapor was purified before being mixed with milk, passing through a cyclone filter to separate condensed moisture droplets and mechanical impurities and metal-ceramic titanium filter inserts for microfiltration.

After HT heating with a holding time of not more than 3 s, the milk enters vacuum chamber 3, where it is instantly cooled to a temperature of 75 – 78 °C, with the vacuum depth in chamber 3 being 0.06 – 0.08 MPa. To ensure the rational use of the vacuum chamber heat, secondary steam pump M2 is supplied in sections 1-2 and 1-4 of the plate heat exchanger, where it is condensed by cooling upon contact with cold milk and water. The milk cooled in the vacuum chamber enters section 1-1 of the plate heat exchanger, where it is cooled to the fermentation temperature of 32 – 34 °C and goes to the cheese-making bath for fermentation. For the following technological operations, we used traditional equipment typically used for making cheese.

Statistic analysis

The experiments were performed in triplicate. The mathematical description of the technological process of cheese aging is a kind of regression equation found by statistical methods on the basis of experimental data. In the processing of experimental data for the significance level $p = 0.05$, such statistical criteria as the Cochran criterion were used to assess the homogeneity of the variances, the Student's test to evaluate the significance of the calculated coefficients, and the Fisher criterion to evaluate the adequacy of the obtained equation. As a result of the statistical processing of the experimental data, when determined the influence of the above technological factors on the moisture content of cheese by the Kohren criterion, it is determined that $0.2_p < 0.48_t$. This indicates that the resulting variance is homogeneous and there are no gross errors.After deriving the equation and determining the significance of the calculated coefficients according to the student's test, a regression equation was obtained, which describes the dependence of cheese moisture on such technological factors as the temperature of the second heating, the amount of added water for deoxidation and the mass fraction of salt in the product. Checking the adequacy of the coefficients of the equation by the Fisher criterion showed that $0.07_p < 9.3_t$. That is, the obtained regression equation adequately describes the process of cheese aging. Data processing, calculations and graphing were performed in MathCAD 2015.

RESULTS AND DISCUSSION

The main type of heat treatment of raw milk in the raw production industry is pasteurisation, which results in the reduction of pathogenic and technically harmful microorganisms to a safe level. The pasteurisation regimes of used raw milk in the production of hard rennet cheeses do not destroy all the microflora. Even milk pasteurisation at a temperature of 75 – 76 °C for 20 – 25 s, which corresponds to the upper limit of heat treatment of raw milk in the production of solid rennet cheeses, ensures the efficiency of neutralisation of heat-resistant bacteria by only 94.6%. The best results are obtained with high-temperaature (HT) and ultra-high (UHT) processing of milk with a holding time of 20 – 24 s **(Zolotyn, 1979)**.

Table 3 Characteristics of yeast lactobacilli used in this work.

Name of yeast	Manufacturer	Yeast stock LB	The Kind of yeast
Basic complex	Experimental biofactory. Uglich, Russia	*Lactococcus lactis* subsp. *lactis, Lactococcus lactis* subsp. *Lactococcus lactis* subsp. *diacetilactis, Leuconostoc lactis*	BC-Uglich-5A - There are diplococci, chains of cocci of different lengths
Additional	State experimental enterprise of bacterial fermentations TIMM	*Lactobacillus acidophilus* (residual race)	BZ "ANV" cocci present with sticks of different lengths

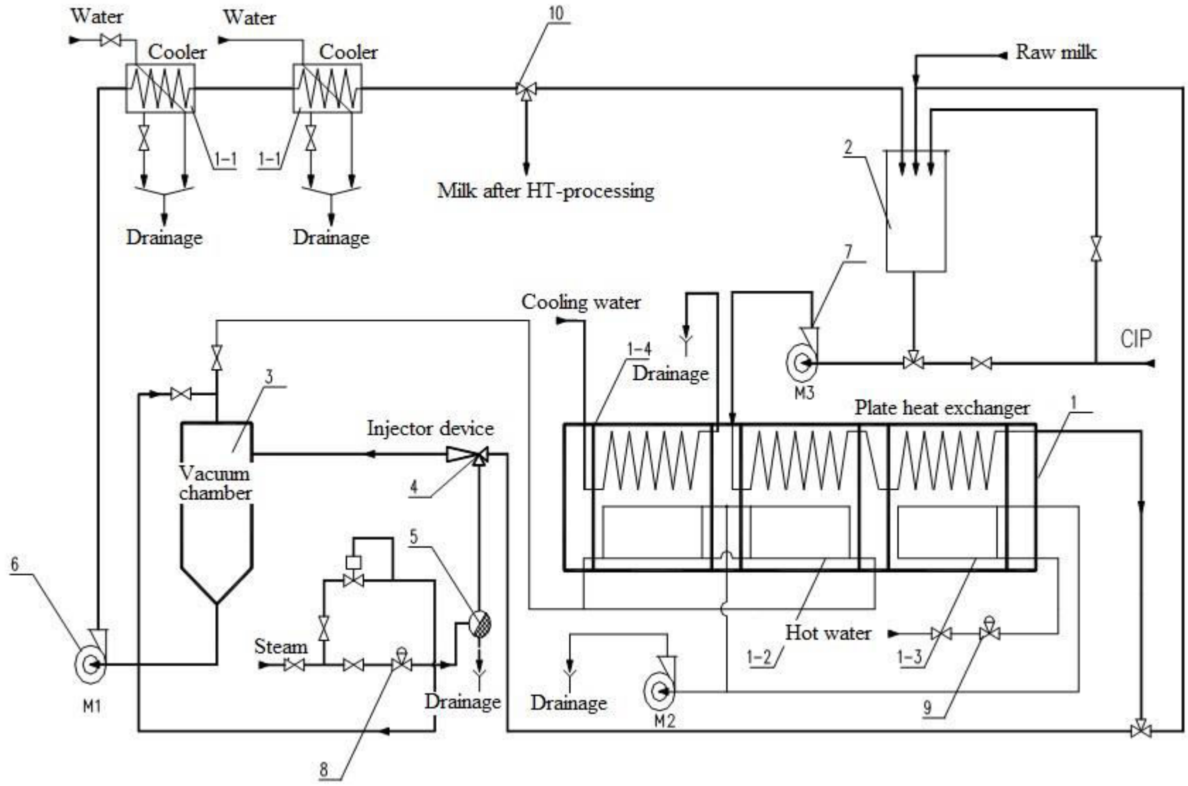

Figure 1 Scheme of sterilisation chamber for direct (steam contact) heating of milk by injection (injection) of steam into milk. Notes: 1-1 – coolers; 2 – collection of normalised milk; 1-2 – heat exchanger; 1-3 – heater; 3 – vacuum chamber; 1-4 – plate heat exchanger; 4 – injection device; 5 – valve; 6 and 7 – centrifugal pumps; 8 and 9 are valves; M1, M2 and M3 are pumps for pumping milk.

Table 4 Costing of 1 ton of cheese by cost items, UAH.

	Name of cost items	Cheese «Bravo»		Cheese «Litinskyi»
		HT	UHT	
1	Raw materials and basic materials	27196.60	26702.5	27974.10
2	Transportation and procurement costs	5229.89	5229.89	5229.89
3	Cost of packaging and packaging	930.26	930.26	930.26
4	Cost of auxiliary materials	39.50	39.50	39.50
5	Cost of energy costs	1080.90	1080.90	638.19
6	Basic and additional wages of production workers	377.63	377.63	377.63
7	Deductions on social insurance	140.40	140.40	140.40
8	Equipment maintenance and operating costs	453.16	453.16	453.16
9	Common production costs	736.38	736.38	736.38
10	Other production costs	180.69	178.45	182.60
	Production cost	36365.71	35869.07	36702.11
11	Administrative expenses	1454.63	1434.76	1467.85
12	Selling expenses	363.66	358.69	367.02
	Total cost	38184.0	37662.52	38536.98

The possibility of using short-term high temperatures is explained by the fact that living cells of microorganisms respond more quickly to high temperatures than components of milk. In other words, the rate of destruction of microorganisms in the short-term action of high temperatures is higher than the rate of chemical reactions and the destruction of the constituent components of milk over this period of time.

To conclude, HT and especially UHT treatment is a very effective way of destroying bacterial microflora and improving the quality of raw milk by such an indicator as a "contamination tank", which improves the raw material milk. However, it should be noted that under the influence of high pasteurisation temperatures, changes occur in the salt composition of milk raw materials, as well as in the structure and properties of proteins **(Tepel, 1979; Singh and Waungana, 2001; Kazumoto and Tetsuo, 1988; Bashaeva and Khaerdynov, 2008; Adámek et al., 2016)**. The usage of high pasteurisation temperatures of milk in cheese making is mainly limited to soft cheese technologies and is almost not used in the production of hard cheese **(Tverdokhleb and Ramanauskas, 2006; Horbatova, 1984; Khramtsov, Emelianov and Evdokymov, 2006)**. This leads to a deterioration of rennet coagulation and dehydration of the curd grain **(Khramtsov, Emelianov and Evdokymov, 2006)**.

Work on this topic was carried out at a working enterprise on the order of the same company for the development of technology for the production of new types of rennet cheeses with short maturation (20 days).

To improve the cheese making and sedimentation of the milk, which has undergone HT treatment, the application of a double dose of calcium chloride, rennet enzyme and 0.1%, the introduction of yeast in the amount of mesophilic lactobacilli 1.5% and thermophilic lactobacilli *L. acidophilus* – 0.3% for 12 h at 10 – 12 °C. It is proved that cheese is made of milk, which according to the rennet-fermentation test corresponds to three classes, after HT processing and provides the formation of high-quality indicators. The effect of bacterial starter composition on the maturation process and the quality of the cheese was investigated. It is established that the increase in the total amount of bacterial fermentation leads to an increase in the acidity of the milk before sedimentation, a reduction in the duration of grain mixing after the second heating and an increase in the acidity of the serum. The influence of technological factors on the process of ripening of rennet cheese with the low temperature of the second heat is investigated. Optimal technological parameters of ripening of rennet cheeses for obtaining a product with high organoleptic properties are established. The use of HT milk processing allows us to increase the yield of cheese, because part of the whey proteins goes into the clot, and then into the cheese, which increases its output and moisture-holding capacity. The use of highly effective bacterial starters, high moisture content in the product and the maturation of the product at elevated temperatures allow us to obtain cheese with a short maturation period of 25 – 30 days.

The economic efficiency from the implementation of the developed technology is 352.98 UAH for HT processing per 1 ton of Bravo cheese at UHT processing 869.6 UAH per 1 ton of Bravo cheese, which is achieved by reducing the cost of materials, by maximising the use of whey protein and increasing the mass fraction of moisture in the finished product and reducing the duration of maturation (Table 4). However, it is necessary to take into account the social effect of the introduction of the developed technology, which is that it allows the use of raw materials of personal peasant farms at the excess content of microorganisms of the second and third temperature groups in milk. This is while obtaining cheeses of guaranteed quality with high microbiological and topical in the modern period of development of the agrosphere of Ukraine in the period of market economy.

CONCLUSION

As a result of our research, the technological parameters of the production of solid cheese are substantiated and the influence of HT processing on the physical and chemical properties of raw milk is investigated.

1. For the first time in Ukraine the effect of HT and UHT processing on the process of coagulation of protein fractions of milk in cheese production was investigated.
2. It is established that at temperatures of heat treatment of milk (115 – 125 °C) and holding (20 – 24 s), 0.2% of whey proteins additionally pass into cheese curd and cheese (8 – 9%) increases.
3. It is established that the use of UHT milk treatment compared to traditional pasteurization regimens adopted in cheese making increases the antibacterial effect by more than 200 times.
4. Mathematical model of dependence of quality of firm cheese on technological factors is obtained.
5. Provision has been extended for data that affect the formation of quality indicators and the ability to store solid cheese from milk that has undergone HT and UHT.

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