# Energy efficiency increase of the initial milk processing

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**Abstract**. Condition of the dairy industry in the Russian Federation over the last years is characterized by a long-standing and continuously deepening downtrend in dairy production and cow population decrease. From the present day perspective, main objective for Russian livestock farmers, in the context of an import phaseout, is a dairy production increase. Presently at dairy farms in the Russian Federation 99% of freshly drawn milk is being cooled to 4.5°C by a refrigeration method. Refrigerators are complex machines that require skilled workforce for maintenance and operation, consume large amount of electrical energy (3.4 kWh per 100 kg of milk to cool down from 40 to 5°C). Price increase for energy resources, including electricity, is happening in all countries. Price increase is an objective process since commercial mineral deposits run short, their extraction decline, and price tag for extraction and delivery to the place where it can be processed and consumed is increasing. Within this context, any research study that focuses on specific energy resources decrease, including energy consumption for milk production and processing, is a critical task for the present day and for the foreseeable future.

## 1. Introduction

Currently, the Russian Federation is a world`s largest milk and dairy products manufacturer, but market value milk is a comparably small part in overall production – 57%, and livestock productiveness is twice as small as in developed countries [1]. Increase of market value milk production is a major task for any country, that has influence on the agricultural sector economy and on food supply level for the population.

At the present day, dairy industry of the Russian Federation has two major goals. First – de-crease imported dairy products dependence. Second - ensure increase of dairy products consumption by the population. First problem can be solved by substitution of imported products for domestically made products (moreover, in the Food Security Doctrine minimum threshold of domestic products share must be 90% in the overall commodity resources volume), and to achieve this goal it is necessary to increase market value milk production [1].

The second problem is clearly an extension of the first, therefore, it is necessary to increase production level of raw, primarily market value, milk, preserve demand for it at the same time [1, 2].

It is worth noting that cooled milk is still contaminated with bacteria, that fall into anabiosis state waiting for suitable temperature conditions, and some mesophilic bacteria types can repro-duce at

10°C. Bacteria begin rapid reproduction during temperature rise. Therefore, product quality suffers and its price drops [3-6].

In order to solve all formulated earlier problems, it is necessary to use special methods and technical means to eliminate bacteria.

Different economic zones have the following basic regulatory documents in use:

For the Russian Federation: FZ-88 and FZ-163 «Technical regulations on milk and milk products» - general and specific safety requirements; GOST R 52054-2003 «Cow`s milk raw» - general requirements for production of all milk product types [1].

For European Economic Union: «Council Directive 92/46 EEC laying down the health rules for the production and placing on the market of raw milk, heat-treated milk and milk-based products; Council Directive 2002/99 EC of 16 December 2002, Regulation (EC) 852/2004 of the European Parliament; Regulation (EC) 853/2004 of the European Parliament; Regulation (EC) 854/2004 of the European Parliament; Regulation (EC) 882/2004 of the European Parliament» [7,8].

For Custom Union: «TR CU 033/2013 Custom Union Technical Regulation. On Safety of Milk and Dairy Products» [1].

Table 1 presents a general safety criterion of raw milk in different economic zones.

Quantity determination of mesophilic aerobic and facultative anaerobic microorganisms (QMAFAnM) is applicable to quantity evaluation of sanitary indicator microorganisms' group. QMAFAnM is consist of different taxonomical groups of microorganisms – bacteria, yeast, mold fungi. Their total count is the evidence of hygienic and sanitary food condition, microbial content level. Optimum temperature for QMAFAnM growth is 35…37°C (in aerobic conditions); temperature limit of their growth is within 20…45°C [1, 7–11].

Abbreviation CFU stands for «colony forming unit» and represents quantity of bacteria that can develop full strength microbial colony [1, 7–11].

In order to reduce the number of bacteria in milk it is necessary to comply with sanitary rules of machine milking. However, as we know from papers [12-16], even small number of bacteria in milk can change its storage life, therefore, there is a need to take measures in order to eliminate or at least suspend bacteria growth in it.

The most effective and accessible for livestock farms is considered method of milk cooling and heating.

**Table1.** General safety criteria of raw milk in different economic zones [1, 3–5, 7–9, 19–23].

| Country, economic zone | Class of reductase test | QMAFAnM, (CFU/gr) |
|---|---|---|
| European Union | | $< 100\times10^3$ |
| USA | A/ | $< 100\times10^3$/ |
| | B | $100\times10^3…300\times10^3$ |
| Russian Federation | High grade/ | $< 300\times10^3$ |
| | I/ | $300\times10^3…500\times10^3$ |
| | II | $500\times10^3…4000\times10^3$ |
| Customs Union: (Republic of Armenia; Republic of Belarus; Republic of Kazakhstan; Kyrgyz Republic; Russian Federation) | | $100\times10^3…4000\times10^3$ |
| Ukraine | High grade / | $< 300\times10^3$ |
| | I/ | $300\times10^3…500\times10^3$ |
| | II | $500\times10^3…4000\times10^3$ |
| China | | $< 2000\times10^3$ |
| Australia, New Zealand | | $< 100\times10^3$ |

If milk is cooled down to 8…10°C, most of, found in milk, microorganisms' development sharply slows down, and if cooled down to 2…3°C – growth almost completely stops. When temperature goes down to minus 20°C and abrupt temperature change from plus 20°C to minus 20°C majority of micro-organism dies [17,18].

When milk is heated up to 50°C - 68% of bacteria dies, if milk stays for 20 minutes at this temperature more than 99% of all contained in it microorganisms die. For complete microorganisms and its spores elimination it is necessary to bring milk temperature to 120°C and keep at this level for 15…20 minutes [17, 18].

Basic technological technics for initial milk processing at farms consist of a set of actions, including purification, cooling, and, if necessary, pasteurization. All of this results in an original milk quality preservation and contained microorganisms suppression.

The most significant factor that influences bacteria growth and development – positive temperature. On the other hand, freezing results in slow product destruction, because ice crystals damage cell walls [17, 18, 24].

Light is essential for bacteria development, however, in the presence of ultraviolet light (sun light) bacteria die [25-27].

Level of acidity is very important for bacteria functioning – level of pH in milk has a key role and titratable acidity is not [25, 26].

Depending on oxygen demand microorganisms can be classified in the following way: aerobic, anaerobic, facultative aerobic/anaerobic – typical example is an ordinary lactic acid bacterium, micro-aerophilic.

Water is a major component in bacterial cell, besides water content in product, osmotic pressure of water has very important role as well. Nutrients are needed for the microorganisms development [28-30].

Milk cooling process consumes a large amount of energy, requires special equipment and its centralized maintenance.

There are several alternative methods of milk processing exists: treatment by ultraviolet light, ultrasound, electric infrared heating, electro treatment (electrochemical treatment), ultra-high pressure, bactofugation, sterilization and others [1, 18].

Therefore, goal of this paper is development and justification of design-and-technology parameters and operating mode of the batch type milk decontamination plant in the context of rational use of energy.

On the basis of the desired goal, we outlined following tasks:

- develop a technological scheme of milk decontamination by repeated ultrasound treatment;
- find rational operating modes and complex of design-and-technology parameters for the plant, that provide milk microbiologic characteristics improvement with as minimum as possible en-er-gy consumption.

## 2. Materials and Methods

Research study was conducted in accordance with the developed specific methods using modern equipment and measuring instruments. Main calculations and analysis of the research study results were run using mathematical statistic methods and regression analysis using active experimental design theory. All studies on physicochemical characteristics of milk were conducted in accordance with standard methods and in compliance with GOSTs:

- GOST R 52054-2003 «Cow`s raw milk. Specifications»;
- GOST 3624-92 «Milk and milk products. Titrimetric methods of acidity determination»;
- GOST 32901-2014 «Milk and milk products. Methods of microbiological analysis».

Resazurin reduction test was used to determine bacteria quantity. According to the method described in GOST 32901-2014 «Milk and milk products. Methods of microbiological analysis» bacterial count level was determined. Method is based on resazurin reduction by oxidation-reduction enzymes, discharged by microorganisms into milk.

Reductase test (also methylene blue reaction, resazurin test) - test method for bacterial contamination of non-pasteurized milk, based on dye discoloration in presence of bacteria metabolism byproducts. GOST 32901-2014 «Milk and milk products. Methods of microbiological analysis» allowed to use reactions with resazurin and methylene blue. Methylene blue reduction test is less accurate and lost popularity. Since 1929 resazurin is being used as an indicator of bacterial contamination in Persh and Simmert method (1929) [31].

## 3. Results

Study of layer-by-layer milk spoilage in the unsealed tank without an agitator system was carried out during summer period at a natural ambient air temperature of 16…20°C. Three tanks of 7 liters each were used. Objective of this study is milk spoilage character determination in differ-ent layers of liquid. Two main milk parameters were measured during the experiment: tempera-ture and quantity of CFU per unit volume of liquid. Table 2 presents experiment results.

Mathematical treatment of the experimental findings [32-34] allowed us to obtain adequate regression equation, which describes dependence of quantitative content of CFU per unit vol-ume of milk`s bottom layer liquid (Y, mln bacteria/ml) on storage life (X, h) with certainty R2 = 0.982.

$$Y = 0{,}0261X^5 – 0{,}5755X^4 + 4.641X^3 – 16.688X^2 + 26.077X – 13.292 \quad (1)$$

**Table 2.** Experimental study results.

| Sampling time (h) | Milk temperature in the top layer (TL) (°C) | Milk temperature in the bottom layer (BL) (°C) | Bacteria quantity in milk TL (mln bacteria/ml) | Bacteria quantity in milk BL (mln bacteria/ml) |
|---|---|---|---|---|
| 10 | 16.05 | 16.32 | 0.3 | 0.3 |
| 14 | 18.30 | 17.89 | 1.75 | 0.4 |
| 18 | 18.74 | 19.38 | 8.0 | 0.4 |
| 22 | 19.25 | 19.69 | 20.0 | 0.4 |
| 6 | 18.27 | 19.09 | 20.0 | 1.75 |
| 10 | 18.74 | 19.09 | 20.0 | 1.75 |
| 14 | 18.39 | 19.44 | 20.0 | 1.75 |
| 18 | 18.61 | 19.05 | 20.0 | 1.75 |
| 22 | | | 20.0 | 20.0 |

Figure 1 presents results of this experiment in graphical form.

## 4. Discussion

From the equation (1) and graphical interpretation (Figure 1) follows that top layer of milk gets spoiled faster. Therefore, during a study of milk treatment by ultrasound, ultraviolet light it is necessary to start milk radiation from the top and then go down to the bottom.

Down the line, this information can be used in the following developments: new technological scheme of milk decontamination by ultrasound and ultraviolet light repeated exposure; plant, with necessary number of radiators, which allows to decontaminate milk in the process of multiple decontaminations, and also to find rational operating modes and complex of design-and-technology parameters of the plant, that provide milk microbiologic characteristics improvement with as minimum as possible energy consumption.

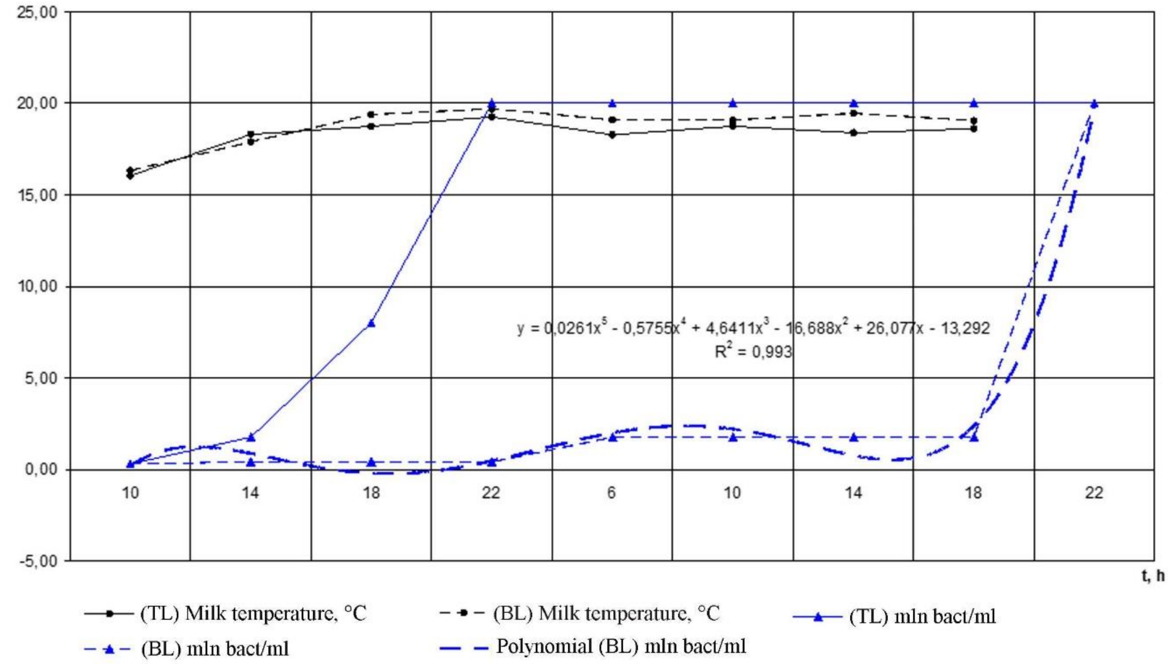


**Figure 1.** Dependence of bacteria quantity change in bottom a top milk layers in the tank at a specific temperature in the course of time.

## 5. Conclusion

On the daily basis milk cooling in the farms requires on average 1.37 kW/h (t/day) or for the farm OJSC «Krasnoe Znamya» Novosokolnichesky district of Pskov region of the Russian Federation – over the year period 3903 t of milk requires 132509 kW/h for preservation.

Milk in the unsealed tank begins to spoil from the top, therefore, experiments has confirmed where devices for alternative milk preservation methods (ultrasound, ultraviolet light and others) should be placed. In doing so, we can optimize their number and then fulfill power saving objective.

Milk spoilage process is described by the regression equation (1).

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