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# Studying the Influence of Acoustic Cavitation and Avalanche-Streamer Discharge on the Quality of Raw Milk in Order to Achieve the Pasteurization Effect

**Olga Krasulya[1], Kseniya Kanina[1], Nikolay Zhizhin[2], Nataliya Shlenskaya[3], and Alexandra Demid[4]**

[1]Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, Moscow, Russia
[2]Federal State Autonomous Scientific Institution «All-Russian Research Institute of Dairy Industry», Moscow, Russia
[3]Moscow State University of Food Production, Moscow, Russia
[4]Technology of Institute of Natural Science and Technology of «Murmansk State Technical University», Murmansk. Russia

Corresponding Author:
Olga Krasulya
okrasulya@mail.ru

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## Abstract

The article presents the results of the studies obtained in the investigation of the quality of milk processed with the use of physical methods of exposure - acoustic cavitation and avalanche-streamer discharge, in order to achieve a pasteurizing effect. It is shown that in the treatment of high-frequency ultrasonic oscillations (over 45 kHz) generated by an electric ultrasonic device of the submersible type of impulse action "Activator-150", the number of bacteria of the E. coli group decreased by almost 40%, which allows concluding that the chosen method of influence is effective for the destruction of sanitary and pathogenic (indicative) microflora in raw milk and achieve a certain pasteurization effect. Using low-frequency ultrasonic exposure (20-22 kHz) generated by the cavitation ultrasonic flow type reactor RKU, the raw milk indicators QMAFAnM (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms) and number of Coliform bacteria did not change after processing, as well as physical and chemical indicators, apart from the indicators of particle fineness. It can be stated that low-frequency ultrasonic cavitation treatment is not effective in terms of achieving a pasteurizing effect. In order to achieve a pasteurization effect by applying avalanche-streamer treatment we assessed its effect on QMAFAnM - the microbiological background of milk. The use of avalanche-streamer discharge does not have the expectation effect on the total number of microorganisms in milk. It is advisable to use high-frequency acoustic cavitation for microbial biota inactivation and avalanche-streamer discharge to reduce spore bacteria contamination.

**Keywords:** cow milk, acoustic cavitation, avalanche-streamer discharge, microbiological milk background, milk qualitative characteristics



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## 1. Introduction

Milk and dairy products occupy a significant part of the human total diet. High nutritional value of milk and dairy products is caused by containing substances necessary for human body in optimally balanced ratios and in digestible form. At the same time, milk is a favorable environment for microorganisms' growth and development, both inserted with ferments and coming from the outside [1].

Currently, to obtain high-quality and safe dairy products many different methods of processing raw milk are used: pasteurization, sterilization, ultra-pasteurization, as well as cavitation, ozone treatment, electromagnetic radiation, etc. Assessing their effectiveness, a decisive role plays reducing degree of bacterial contamination of raw milk and preserving biological value of the product [2].

The most common method of processing raw milk in Russia is pasteurization and sterilization, which ensure safe milk consumption. However, these methods are energy-intensive, require specific hardware and proper space. As an alternative in foreign practice are used acoustic and electromagnetic methods of processing of reduced milk and whey [3, 4]. In available information sources there is practically no information about the impact of acoustic treatment and avalanche-streamer discharge on the quality and safety of whole milk of different farm animals species, as well as the possibility of producing dairy products containing treated milk using the above methods, while maintaining their desired biological value [5, 6].

The possibilities of using different power of ultrasound and its application justification in milk and dairy products technologies are presented in the works of A.G. Galstayn [7], S.D. Shestakov, O.N. Krasulya [8], I.U. Potoroko [9], N.A. Tikhomirova [10], M. Ashokkumar [11], Bogdan Zisu[12], Pablo Juliano [13] and others scientists.

There are works of V.G. Yakunin [14], L.M. Makalsky [15] and others on the subject of using electromagnetic radiation, in particular avalanche-streamer discharge treated water. Taking into account all the above, the study of processing raw milk effect with the use of physical and chemical methods -- acoustic treatment and avalanche discharge -- is a scientific hot topic.

The aim of the work was to study the effect of acoustic cavitation and avalanche-streamer discharge on raw cow milk in order to achieve the pasteurization effect with its subsequent safe use in dairy products production.

## 2. Methods and Equipment

## 2.1. Methods

As the object of the study we used cow milk obtained from the Black-and-White cow breed. In milk processing the impact of the bactericidal phase was considered. After milking, to pass the bactericidal phase, the product was stored at the temperature in range 0 to +2 °C for 2-3 hours, and then physical and chemical effects were carried out.

## 2.2. Equipment

To process the samples, a low-frequency ultrasound generator - cavitation ultrasonic flow type reactor RKU (technical conditions: TU-5130-002-26784341-2008) was used, the manufacturer: Limited liability company «ProfiRestConsult», Moscow (Figure 1).

**Figure** 1: Equipment for cavitation treatment of milk: left -- low-frequency, right -- high-frequency.

The basic principle of RKU operation is the electronic conversion of energy from an electric industrial network into mechanical ultrasonic vibrations using the piezoelectric effect.

An electric ultrasonic device of the submersible type of impulse action "Activator-150", was used as a high-frequency generator of ultrasonic vibrations (Figure 1).

For the treatment of raw milk with application of avalanche-streamer discharge the device for plasma-chemical processing was used (Figure 2), which included the power source of the electric discharge plasma, the systems of liquid component preparation and gaseous component over the liquid in plasma-chemical reactor. As a source of electric discharge plasma, a device was used that provided combustion of electric discharge in continuous mode or in pulse-periodic mode.

The experimental setup consists of a reactor -1, inputs for solutions of milk and air-2, outlet pipes for purified milk-3 and air with ozone-8. Solutions for milk purification are fed

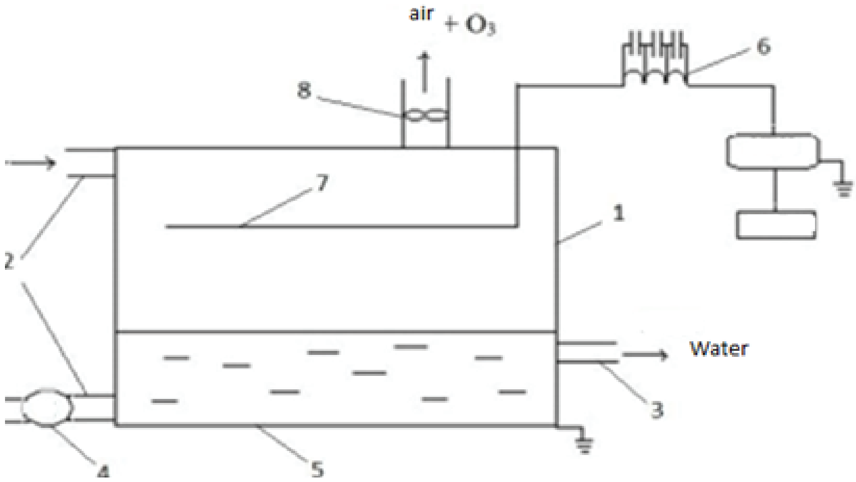


**Figure** 2: Experimental installation diagram of using avalanche -streamer discharge.

into a reactor with an electrically conductive base - 5. The source of high voltage through a resonance limiter- 6 provides 40 kV voltage supply to electrodes with a small radius of curvature - 7. Due to the limiter, voltage pulses of 0.5-1.0 ms with nanosecond front are formed on the electrodes. In the discharge gap an avalanche-streamer discharge occurs above the surface of the solution.

The use of avalanche-streamer discharge allows "bombarding" the surface of milk with ions and electrons. Average power of avalanche-streamer impact on 200 $cm^3$ of milk was not more than 120 W, and the power of its pulse impact was more than 120 MW.

All the above-mentioned equipment is of Russian-built.

## 2.3. Materials

To assess the quality characteristics of milk the following methods were used:

- Fat weight fraction determination, as per GOST standard 5867-90 [16];
- Protein weight fraction determination as per GOST standard 23327-98. [17];
- Protein weight fraction determination, as per GOST standard 179-90 [18]
- Milk density determination, as per GOST standard 3625-84 [19];
- Milk acidity determination, °T, as per GOST standard 3624-92 [20];
- Somatic cells count, as per GOST standard 54077-2010 [21];
- Moisture weight fraction determination, as per GOST standard 3626-73 [22].
- Lactose weight fraction determination, as per GOST standard P 54667-2011[23];

- Milk thermal stability determination, as per GOST standard 25228-82 [24];
- Effective viscosity determining method. The studies of structural and mechanical characteristics (SMC) were carried out using a rotary viscometer DV-II+Pro (Brookfield manufactory, USA) with standard set of spindles LV1-LV4, which ensure correct, reproducible measurement results. Was used Rheocalc 32 software, that allows creating control programs for DV-II+Pro. To measure the effectiveness of viscosity of raw milk was used spindle LV1 with sliding velocity 10 $s^{-1}$[25].
- Method of fat particles dispersion determining. «Determination of fat particles dispersion in raw milk». Determination was carried out using an optical microscope: to process the results of dispersion degree determination was used software package Altami Studio [26].
- Determination of fatty acid composition of milk and dairy products was carried out in accordance with GOST 32915-2014 « Milk and dairy products», using powerful gas-liquid chromatography [27].
- Organoleptic evaluation was carried out in accordance with GOST 282883-2015 [25].
- Microbiological indicators: the total amount of mesophilic anaerobic and facultative anaerobic was determined by GOST 32901-2014 [28]

Coliform bacteria were determined in accordance with GOST 32901-2014 [29];

Spores of mesophilic aerobic microorganisms at 30 °C, in 1 $cm^3$ -- in accordance with GOST 32901-2014 [28].

## 3. Results

The results indicated, that while processing of high-frequency ultrasonic vibrations (over 45 Khz), generated by electric ultrasonic device of the submerged type of impulse action «Activator -150», amount of coliform bacteria (E-COLI) decreased by almost 40% (Figure 3).

This allows concluding about the effectiveness of the chosen method of exposure to destruct sanitary-pathogenic (indicative) microflora in raw milk and to achieve a certain pasteurization effect (Table 1).

When using low-frequency ultrasonic exposure (below 20 kHz), which was generated by a cavitation ultrasonic flow-type reactor, the indicators of QMAFAnM (Quantity of Mesophilic Aerobic and Facultative Anaerobic Microorganisms) and the number of

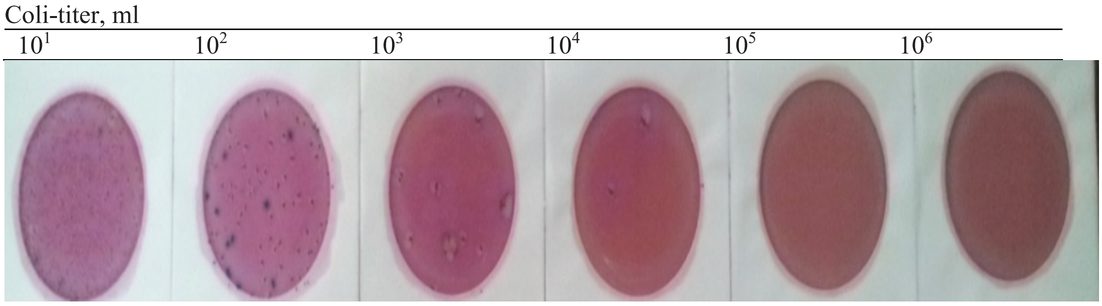


**Figure** 3: Results of high-frequency ultrasonic cavitation influence on viability of microorganism strains (Coliform bacteria).

Table 1: Results of physicochemical milk composition study depending on high-frequency ultrasonic cavitation treatment time.

| № | Milk indicators | Target value | Treatment time, minutes | | | |
|---|---|---|---|---|---|---|
| | | | 5 min | 15 min | 25 min | 30 min |
| 1 | Fat, % | 3,5±0,20 | 3,4±0,20 | 3,45±0,25 | 3,48±0,23 | 3,5±0,22 |
| 2 | Acidity, °T | 16±0,1 | 17±0,1 | 16±0,1 | 17±0,1 | 16±0,1 |
| 3 | Weight fraction of skimmed milk powder, % | 7,94±0,3 | 7,94±0,3 | 7,94±0,27 | 7,94±0,23 | 7,94±0,20 |
| 4 | Protein weight fraction, % | 2,83±0,24* | 2,83±0,24* | 2,82±0,25* | 2,81±0,30* | 2,82±0,27* |
| 5 | Density, °A | 25,6±0,10 | 25,6±0,10 | 25,5±0,16 | 25,4±0,30 | 25,5±0,25 |
| 6 | Dispersiveness of fat particles, um. | 3,60±0,1 | 2,90±0,1 | 3,02±0,26 | 5,26±0,03 | 6,23±0,05 |
| 7 | QMAFAnM, CFU/cm$^3$ | $5,29*10^2$ | $3,0*10^2$ | $3,10*10^2$ | $3,15*10^2$ | $3,2*10^2$ |
| 8 | Coliform bacteria, CFU/cm$^3$ | $3,26*10^2$ | $2,30*10^2$ | $2,22*10^2$ | $2,1*10^2$ | $2,09*10^2$ |

Coliform bacteria did not change after processing, as well as physical and chemical parameters of raw milk, except for the index of dispersion of fat particles (Table 2).

The data on the dependence of cow milk physicochemical parameters on the avalanche-streamer discharge treatment time are presented in Table 3.

## 4. Discussion

It can be argued that the low-frequency ultrasonic cavitation treatment is not effective in terms of achieving the pasteurization effect (Table 1), but some pasteurization effect can be achieved.

With low-frequency processing of milk in the installation power range from 450 to 600 W, the process of crushing of fat particles (homogenization) is noted (Table 2).

Table 2: Results of quality changes in raw milk on exposure to low-frequency ultrasonic acoustic cavitation.

| Milk quality indicators | Target value (untouched) | Processing power, % of the installed device capacity (1 kW) | | | |
|---|---|---|---|---|---|
| | | 45 | 60 | 80 | 100 |
| Fat, % | 3,77±0,20 | 3,77±0,20 | 3,77±0,25 | 3,77±0,23 | 3,77±0,22 |
| Acidity, °T | 16±0,1 | 16±0,1 | 16±0,1 | 16±0,1 | 16±0,1 |
| Weight fraction of skimmed milk powder, % | 7,94±0,3 | 7,94±0,3 | 7,94±0,27 | 7,94±0,23 | 7,94±0,20 |
| Protein weight fraction,% | 2,83±0,24 | 2,83±0,24 | 2,82±0,25 | 2,81±0,30 | 2,82±0,27 |
| Density, °A | 25,6±0,10 | 25,6±0,10 | 25,5±0,16 | 25,4±0,30 | 25,5±0,25 |
| Dispersiveness of fat particles, um. | 3,60±0,27 | 2,90±0,27 | 4,04±0,30 | 4,3±0,26 | 3,68±0,27 |
| QMAFAnM, CFU/ml | 513±0,16 | 483±0,13 | 526±0,12 | 518±018 | 523±0,25 |
| Coliform bacterias, CFU /ml | 326±0,2 | 298±0,015 | 332±0,32 | 314±0,16 | 398±0,36 |

Table 3: Dependence of cow milk physicochemical parameters on the avalanche-streamer discharge treatment time.

| Milk indicators | Target value (untouched) | Avalanche-streamer discharge treatment, sec. | | |
|---|---|---|---|---|
| | | 60 | 300 | 600 |
| Total nitrogen content, % | 0,530±0,03 | 0,508±0,01 | 0,504±0,01 | 0,567±0,05 |
| Protein weight fraction, % | 3,38±0,11 | 3,36±0,10 | 3,37±0,2 | 3,61±0,11 |
| Non-protein nitrogen weight fraction, % | 0,0310±0,006 | 0,0311±0,005 | 0,0312±0,006 | 0,0310±0,006 |
| Fat, % | 3,5±0,05 | 3,5±0,05 | 3,5±0,05 | 3,5±0,05 |
| Moisture weight fraction, % | 87,74±0,2 | 87,74±0,2 | 87,81±0,17 | 87,68±0,19 |
| Lactose weight fraction, % | 3,85±0,05 | 3,85±0,05 | 3,98±0,06 | 3,88±0,04 |
| Acidity, °T | 17±0,11 | 17,56±0,11 | 17,56±0,11 | 17,56±0,11 |
| Active acidity index (pH) | 6,69±0,17 | 6,66±0,15 | 6,66±0,15 | 6,66±0,18 |
| Density, kg/m$^3$ | 1,0278±0,61 | 1,0278±0,60 | 1,0286±0,15 | 1,0286±0,15 |
| Freezing point, minus °C | 0,535±0,20 | 0,536±0,18 | 0,534±0,19 | 0,536±0,2 |
| Somatic cells count, g/cm$^3$ | 174±0,10 | 173±0,11 | 174±10 | 173±0,10 |

From the nutrition science point of view, homogenization leads to better absorption of milk fat in the body, which is especially important for baby food. In the range of power of ultrasonic influence from 600 to 1000 W the sticking of fat particles and strengthening of agglomerates occurs; this effect is useful in technological process of butter production.

The results of the evaluation of physical and chemical parameters of raw milk after avalanche -streamer discharge show that the main indicators of quality remain unchanged, therefore, it can be concluded about the suitability of milk for further technological processing (Table 3).

In order to achieve the pasteurization effect due to the use of avalanche streamer exposure, its effect on QMAFAnM, the microbiological background of milk, was evaluated (Figure 4). It is shown that the usage of the avalanche-streamer method does not have an effect on the total number of microorganisms in milk and, therefore, its use, in order to achieve a pasteurization effect, is technologically impractical.

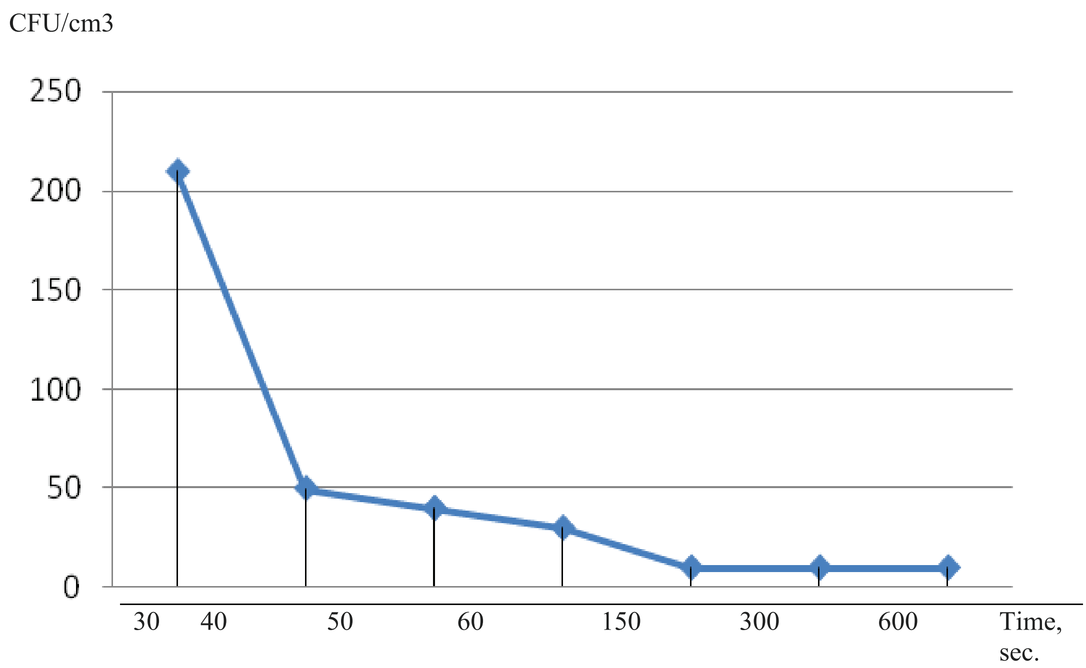


**Figure** 4: Change in number of spore-forming microorganisms in the process of avalanche-streamer discharge treatment.

## 5. Conclusion

It is established that spore forming bacteria are destructed by electronic systems, ozone and free oxygen, that are generated after avalanche-streamer discharge impact -- spore forming bacteria amount decreases significantly at irradiation time of 30 s, is 100 CFU / cm3, at 60 s exposure occurs further death of spore cells, their number is 10 CFU / cm3, i.e. decreases by an order of magnitude. With further increase in exposure time avalanche-streamer discharge cell loss is stopped and their amount stabilizes.

Thus, the results of the studies show that in order to achieve the pasteurization effect, a dual approach can be recommended: for inactivation of microbial biota it is advisable to use high-frequency acoustic cavitation, and to reduce contamination of spore forming bacteria - the use of avalanche-streamer discharge.

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## Conflict of Interest

The authors have no conflict of interest to declare.

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