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INFLUENCE OF COMBINED EFFECT OF ELECTROMAGNETIC RADIATION AND ELECTROCHEMICALLY ACTIVATED WATER ON THE QUALITY OF MILK AND MILK PRODUCTS

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Competition in the milk market sets high requirements for the quality of milk and milk products, which for the most part depends on the production technology and preventative measures aimed at their improvement. That is why one of the priority areas of the dairy cattle breeding is the production of milk in compliance with sanitary-hygienic norms and requirements of processing enterprises.

In modern industrial technologies non-traditional ways of milk processing, such as infra-red irradiation, ultrasound, microwave and ultra-violet processing etc., are becoming significantly important. These methods are aimed at increasing the duration of products storage, the improvement of taste qualities and cutting energy unit costs. Complex processing of milk with electromagnetic irradiation and electrochemically activated water is one of the up-and-coming processing methods.

The goal of the conducted research is the improvement of the milk products quality due to selective suppression of undesirable microorganism spreading.

Cow milk of the State Standart 31449-2013 served as the research object.

The authors theoretically justified and experimentally proved the necessity of application of complex milk processing with electromagnetic irradiation and electrochemically activated water in the fermented dairy milk production in order to improve its consumer characteristics.

The strongest influence on the milk microbiological indicators was established during its exposure to electromagnetic irradiation under electric current with a pulse duration of 19.82 ms, a pause duration of 19.64 ms, a pulse tension of 22 V and an exposure period of 20 minutes and with water treated in the electric conditioner (cathode+anode).

The processing of milk with the aforementioned parameters of complex exposure influenced the external form and texture of the fermented dairy milk products manufactured from it.

The obtained results aimed at decreasing bacterial insemination of milk allowed to recommend using a device for cleaning a milk storage and transportation tank with water processed in an (cathode+anode) and exposingmilk to electromagnetic irradiation with optimal modes.

Key words: *electromagnetic pulse generator, electric water conditioner, electromagnetic radiation, electrochemically activated water, milk processing modes, microorganisms, dairy products*

Increasing the competitiveness of the domestic output of cattle breeding, improvement of its quality indicators is an essential direction for agricultural producers. Domestic production of equipment for effective bactericidal treatment of the milk, while at

maximum preserving its biologically valuable substances and its organoleptic qualities is an important task. [1, 12]

Infra-red radiation, ultrasound, microwave and ultraviolet and others [3, 4] comprise alternative methods of milk treatment. One of up-and-coming and less researched areas is the application of electromagnetic radiation and electrochemically activated water for this purpose.

The authors have developed a method and device for suppressing undesirable microorganisms in milk and milk products using electromagnetic radiation [5–8]. Studies showed that electromagnetic radiation does not affect the texture, taste, odor and color of raw milk, as well as its physical and chemical indicators. At the same time, electromagnetic radiation of milk contributes to lower general bacterial content. Different parameters of the electromagnetic radiation (the length of impulse and pauses, impulse voltage, the length of exposure) affected the character and strength of exposure on different milk microorganisms. The strongest effect on microbiological indicators of milk was noted during its exposure to electromagnetic radiation under parameters of electric current with an impulse of length of 19,82 ms, a pause length of 19,64 ms, an impulse voltage of 22 V and an exposure time of 20 minutes.

Research results and discussion

Exposure of milk to electromagnetic radiation with the aforementioned electric current parameters affected the appearance and texture of cottage cheese made out of it. The cottage cheese made from the untreated milk had soft, spready texture with tangible milk protein particles with small amount of separated whey, whereas the experimental sample had soft, crumbly texture without tangible milk protein particles, without whey separation. Control sample also had a higher acidity of 212,8°T, which is almost 18% higher than the experimental sample [2].

Cottage cheese sample, made out of milk, exposed to an electromagnetic impulse generator, had a 2×10^6 CFU/g higher number of fermented milk microorganisms as compared with the control sample. The amount of yeast and fungus in the sample after electromagnetic radiation decreased by $0,3\times10^1$ и $0,2\times10^1$ CFU/g respectively as compared with the control sample. There was 18% more cottage cheese produced from the milk exposed to the electromagnetic impulse generator as compared with the control sample.

The organoleptic index of yogurt, produced from milk exposed to electromagnetic radiation differed in appearance and texture. The control sample had homogenous texture, with partly broken down curd, whereas the experimental sample — homogenous texture with unbroken curd without whey separation. Significant difference in acidity was obtained. The acidity of the experimental sample was 20% less than that of the control sample.

Experimental sample of yogurt had 5×10^6 CFU/g more fermented milk microorganisms as compared with the control sample. E. Coli group bacteria were not found in both samples. The amount of yeast and fungus in the sample after electromagnetic radiation decreased as compared with the control sample by $0,3\times10^1$ CFU/g, respectively.

Milk exposure to electromagnetic radiation affected the organoleptic index of the acidophilin produced out of it. Experimental samples had clean, fermented milk taste and odor without off-flavors and odors, as well as white color, uniform across the whole mass, whereas the control sample had a sharp yeast flavor. Significant difference was obtained with respect to acidity: control sample had higher acidity of 125°T, which is almost 32% higher than the experimental sample.

The samples of acidophilin produced from milk treated on the electromagnetic impulses generator had 7×10^6 CFU/g more fermented milk microorganisms as compared with the control samples. The amount of yeast and fungus in the sample after electromagnetic radiation decreased by $0,3\times10^1$ и $0,2\times10^1$ CFU/g, respectively, as compared with the control sample.

Microbiological studies of the fermented milk products showed that products made from milk exposed to the generator of electromagnetic radiation impulses had insignificantly higher number of fermented milk microorganisms contained in the added milk ferment as compared with the control samples. At the same time, higher amount of lactic acid, and as a result, higher titrable acidity in the control sample were evidently caused by better spread of fermented milk bacteria, as it is a common fact that pasteurized milk microorganisms also tend to spread alongside with bacteria added with the milk ferment. The spread of thermo-resistant fermented milk rods has the biggest influence on the product quality. The initial milk contains relatively small number of them, and they barely act as acidifiers. Their number may reach substantial figures (up to 1 million and even 1 billion in 1 ml). As a result of this, acidity increases significantly faster than during spreading of fermented milk streptococcus. The product quality deteriorates. In particular, the differences of the experimental samples in appearance and texture were, in our view, caused by increased acidity of control samples.

The treatment of milk storage containers with electrochemically activated water obtained on the electric conditioner is also a non-traditional method of raw milk treatment. The water treatment device is a flowing electrochemical reactor with fittings for inflow and outflow of the treated water. The water is allowed to go through a tower (electric conditioner) made from quartz glass and filled with quartz sand and modified bast fiber [9–11].

The essence of the electrochemical activation of water is that diluted solutions of mineral salts during exposure to electric current receive and give electrons, going into metastable condition characterized by abnormal physical and chemical activitiy, which gradually diminishes over time (relaxes). During electrochemical activation of water, its oxidation-reduction potential changes, which is a measure of free energy of the oxidation-reduction reaction of chemical substances and is expressed by the variety of potentials, which are formed in this oxidation-reduction system. Besides that, the process of electrochemical activation of water is accompanied with thousand times decreased number of bacteria and viruses.

In order to study the influence of water produced with different methods on the electric conditioner, the research of the microbiological composition of cow milk was conducted, for which the water storage containers were treated with specially prepared solutions:

- solution № 1: water treated by the electric conditioner (cathode);
- solution № 2: water treated by the electric conditioner (anode);
- solution № 3: water treated by the electric conditioner (cathode+anode).

As a result of the research it was established that storage of milk in a container treated with electrochemically activated water as compared with milk in the untreated container significantly lowered the general bacterial insemination of milk. At that the most significant decrease, up to full killing of all bacteria occurred during the treatment of the milk storage container with a water solution obtained through the mixture of cathode and anode. Researched solutions greatly affected the spread of Staphylococcus aureus and lowered its concentration by 2,6–5,2 times as compared with the control sample. All studied working water solutions regardless of the method of milk treatment suppressed the

growth of Escherichia coli bacteria, yeast-like fungus of the *Candida albicans* kind and microscopic yeast fungi of the Penicillium and Aspergillus kinds. The biggest effect was produced by the water treated on the electric conditioner (cathode+anode).

Basing on the obtained results, it is recommended to cleanse the milk storage and transporting containers with water, treated at the electric conditioner (cathode+anode) with the aim of lowering the bacterial insemination of milk along with preserving its other quality and quantity characteristics.

In order to study the influence of combined method of milk treatment with electromagnetic radiation and electrochemically activated water on the quality of milk and milk products, the following analyses were conducted. The generator of electromagnetic impulses with the following electric current parameters was used for raw milk treatment: an impulse length — 19,82 ms, a pause length — 19,64 ms, an impulse voltage — 22 V, a treatment period — 20 minutes. Water treated at the electro-conditioner (cathode+anode) was used for treatment of the milk storage containers. Mechnikov curdled milk and yogurt were made from milk treated with the combined method.

Experimental samples of the obtained products were evaluated on the following indicators: organoleptic, physical and chemical-and-microbiological.

It has been established that the treatment of raw milk with the electromagnetic radiation generator and its storage in containers treated with electrochemically activated water did not affect the organoleptic, physical-chemical indicators and the composition of milk.

Organoleptic index of curdled milk are presented in Table 1. Data in the table gives evidence that sample # 1 (control) had non-dense gummy curd with non-uniform texture, with large amount of separated whey, whereas sample # 2 had moderately dense curd with unbroken texture, with small amount of separated whey.

Table 1

Organoleptic Index of Curdled Milk

Milk Treatment Modes	Indices		
	Texture and Appearance	Odor and Flavor	Color
Sample 1 (control, no exposure)	non-dense gummy curd with non-uniform texture, with large amount of separated whey	Sour, without off-flavors and odors	White with a creamy shade, uniform through the whole mass
Sample 2 (with ECA treated container and milk exposed to EMR)	moderately dense curd with unbroken texture, with small amount of separated whey	Clean, sour milk-like, without off-flavors and odors, distinct and tender flavor	White with a creamy shade, uniform through the whole mass

When determining organoleptic index of curdled milk, a tasting assessment of the product has been performed (Table 2). As a result of tasting the organoleptic index of curdled milk, it was established that sample # 2 received the highest grade (17,87 points). The experiment allowed to receive highest grade for the texture and flavor.

Table 2

Tasting Card of the Organoleptic Evaluation of Curdled Milk

Milk Treatment Modes	Indices, Grade				
	Color	Odor	Texture	Flavor	Overall Grade
Sample 1 (control, no exposure)	4,85 ± 0,10	4,50 ± 0,23	3,75 ± 0,12	4,50 ± 0,18	17,6 ± 0,63
Sample 2 (with ECA treated container and milk exposed to EMR)	4,77 ± 0,12	4,0 ± 0,23	4,58 ± 0,14	4,52 ± 0,14	17,87 ± 0,63

Physical and chemical indicators of the experimental samples of the Mechnikov curdled milk are presented in Table 3.

Table 3

Physical and Chemical Indicators of the Experimental Samples of Curdled Milk

Indices	Treatment Modes	
	Sample 1 (control, no exposure)	Sample 2 (with ECA water and milk exposed to EMR)
Fat Weight Content, %	3,8	3,75
Protein Weight Content,%	3,20	3,66
Total Nitrogen Content, %	0,50	0,57
Non-Protein Nitrogen Content,%	0,0293	0,0311
Whey Proteins Content,%	0,95	0,85
Moisture Content,%	85,41	87,38
Dry Solids Weight Ratio,%	14,59	12,62
Lactose Weight Content,%	4,30	4,45
Weight Content of Milk Fat-Free Solids, %	11,59	8,12
Active Acidity (hydrogen ionization value pH), ea.	4,25	4,18
Acidity, °T	114	90

Data analysis showed that fat ratio practically did not change. Protein ratio in the control sample is 0,46% lower as compared with the sample # 2 this is probably due to the use of milk proteins by microorganisms which number in untreated milk was higher. Amount of dry solids in curdled milk was 14,59 in the first sample, which is 1,97% higher

than in the first. After exposure, the lactose content increased by 0,15% as compared with the control sample, also the milk solids non-fat ratio decreased in the experimental sample by 3,47%.

Active acidity decreased by 1.67% in the second sample. A significant difference was obtained with respect to acidity: control sample had higher acidity of 114°T, which is almost 21% higher as compared with to sample # 2. Higher titratable acidity in the control sample was probably due to better development of thermoresistant fermented milk rods which are suppressed in combined milk treatment.

Microbiological indices of the experimental substances of curdled milk are presented in Table 4.

Table 4

Microbiological Indices of Curdled Milk

Indices	Treatment Modes	
	Sample 1 (control, no exposure)	Sample 2 (with ECA treated container and milk exposed to EMR)
Fermented milk organisms, CFU/g	$2,5*10^8$	$2,5*10^8$
Coliform bacteria, in 0,10 g of product	Not detected	Not detected
Yeast, CFU/g	$1,2*10^4$	Less than $1,0*10^1$
Fungi, CFU/g	Less than $1,0*10^1$	Less than $1,0*10^1$
Enterobacterium, in 1,0 g	Not detected	Not detected

Microbiological studies of the curdled milk samples showed that the quantity of fermented milk microorganisms in both samples is the same. Coliform bacteria and enterobacterium were not detected in either sample. Amount of yeast in the sample after electromagnetic radiation and electrochemically activated water decreased from $1,2\times10^4$ до $1,0\times10^1$ CFU/g. Control sample of the Mechikov curdled milk contained a large amount of yeast, which caused the sharp, sour hint.

Yogurt is a fermented milk product with an increased content of milk fat-free solids processed using a mixture of starter microorganisms of thermophilic fermented milk streptococci and a Bulgarian fermented milk rod, at that the total content of starter microorganisms in the finished product at the end of the expiration period is no less than 10^7 CFU in 1 g of the product.

Organoleptic indices of the yogurt are presented in Table 5.

Data presented the table shows that sample # 1 had sour taste without off-odors and flavors, white uniform through the whole mass, sample # 2 had clean, fermented milk without off-odors and flavors, white in color.

Experimental samples had outstanding features in appearance and texture. Sample # 1 had a uniform, gummy, sticky texture, curd slightly broken, with small amount of separated whey, whereas sample # 2 had a uniform, unbroken curd texture, moderately sticky without separation of whey.

Table 5

Organoleptic indices of the yogurt

Milk Treatment Modes	Indices		
	Texture and Appearance	Odor and Flavor	Color
Sample 1 (control, no exposure)	Uniform, gummy, sticky, curd slightly broken, with small amount of separated whey	Sour, without off-flavors and odors	White with a creamy shade
Sample 2 (with ECA treated container and milk exposed to EMR)	Uniform, moderately sticky with unbroken curd without separation of whey	Clean, sour milk-like, without off-flavors and odors	White with a creamy shade

When determining the organoleptic index of yogurt, a tasting assessment of the product has been performed (Table 6).

Table 6

Tasting Card of the Organoleptic Evaluation of Yogurt

Milk Treatment Modes	Appearance, color	Odor	Texture	Flavor	Overall Grade
Sample 1 (control, no exposure)	4,58 ± 0,18	4,27 ± 0,18	3,92 ± 0,14	4,42 ± 0,14	17,19 ± 0,64
Sample 2 (with ECA treated container and milk exposed to EMR)	4,69 ± 0,13	4,23 ± 0,26	4,38 ± 0,21	4,54 ± 0,14	17,84 ± 0,74

As a result of organoleptic evaluation of yogurt, it was established that sample # 2 treated with electrochemically activated water and electromagnetic waves. This provided for its higher grade for appearance, texture and flavor.

Physical and chemical characteristics of the yogurt are presented in Table 7.

The analysis of the obtained data showed that the protein ratio in yogurt in sample # 2 was increased by 0,38% as compared with control sample # 1 without exposure. Fat weight ratio remained the same and was 3,7% in both samples. Lactose content increased by 1,36%, whereas the weight ratio of milk fat-free solids decreased by 0,25% after exposure. Samples had significant differences in acidity index: Sample # 1 has 100°T acidity, which is 10% higher than sample # 2.

Microbiological indices of the experimental samples of yogurt are presented in Table 8.

The table data shows that the quantity of fermented milk microorganisms is the same in both samples. Coliform bacteria and enterobacterium were not present in either sample. The amount of yeast in the sample after electromagnetic radiation and electrochemically

Table 7

Physical and chemical indices of yogurt

Indices	Treatment Modes	
	Sample 1 (control, no exposure)	Sample 2 (with treatment of container with ECA water and milk exposed to EMR)
Fat Weight Content, %	3,7	3,7
Protein Weight Content,%	3,22	3,60
Total Nitrogen Content, %	0,51	0,57
Non-Protein Nitrogen Content,%	0,0294	0,0311
Whey Proteins Content,%	0,83	0,84
Moisture Content,%	87,05	86,80
Dry Solids Weight Ratio,%	12,95	13,20
Lactose Weight Content,%	3,94	5,30
Weight Content of Milk Fat-Free Solids, %	9,15	8,90
Active Acidity (hydrogen ionization value pH), ea.	4,19	4,18
Acidity, °T	100	90

Table 8

Microbiological Indices of Yogurt

Indices	Treatment Modes	
	Sample 1 (control, no exposure)	Sample 2 (with ECA treated container and milk exposed to EMR)
Fermented milk organisms, CFU/g	$2,5\times10^{8}$	$2,5\times10^{8}$
Coliform bacteria, in 0,10 g of product	Not detected	Not detected
Yeast, CFU/g	$1,2\times10^{4}$	Less than $1,0\times10^{1}$
Fungi, CFU/g	Less than $1,0\times10^{1}$	Less than $1,0\times10^{1}$
Enterobacterium, in 1,0 g	Not detected	Not detected
Microscopic slide	Streptococci in each field of vision	Streptococci in each field of vision

activated water decreased from $1,2\times10^4$ to $1,0\times10^1$ CFU/g. The amount of lactic acid is 5,3% greater, hence an increased titratable acidity in the control sample, evidently, were caused by better spread of fermented milk bacteria, as it is a common fact that pasteurized milk microorganisms also tend to populate during yogurt production alongside with bacteria added with the milk ferment.

Basing on the conducted research, the authors have developed a device for combined treatment of raw milk, which consists of electro-conditioner 1, tank for the electrochemically activated water 2, control unit 3, heating block 4, milk tube 5, milk receiving tank 6, which is supplied with a generator of electric current impulses 7 with console box 8. The device operates as follows. Water is supplied to the electric conditioner 1, after which it flows to tank 2 with the milk tube washing control unit 3 and heating block 4, where the water is heated to 50–60°C. Activated warm water from the tank is then supplied to milk tube 5, where after washing it flows out into sewage. The control unit performs an automatic process of washing under a set program with the help of a command set. After that the milk tube is washed, the water flows out of it into milk receiving tank 6, supplied with generator of electric current impulses 7 with console box 8, which controls the length of the impulses, pauses and output voltage of the impulse giving impulses of electric current to the source of electromagnetic field impulses, placed inside the milk receiving unit (fig. 1).

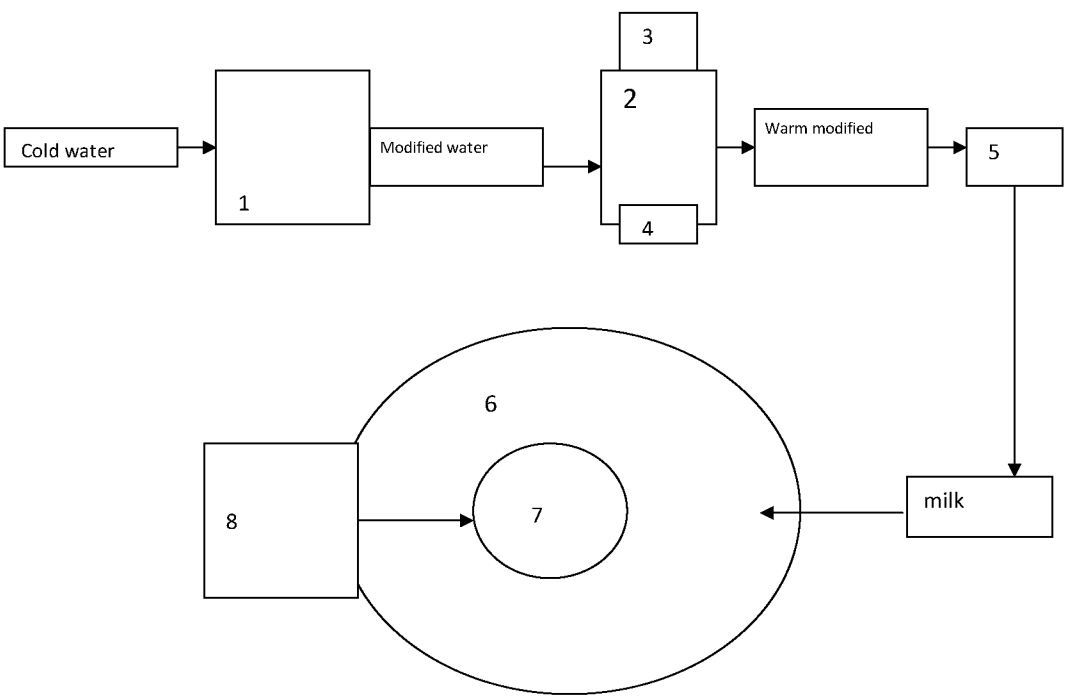

Fig. Structural diagram of the combined treatment of raw milk

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ВЛИЯНИЕ КОМБИНИРОВАННОГО ВОЗДЕЙСТВИЯ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ И ЭЛЕКТРОХИМИЧЕСКИ АКТИВИРОВАННОЙ ВОДЫ НА КАЧЕСТВО МОЛОКА И МОЛОЧНЫХ ПРОДУКТОВ

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Конкуренция на рынке молочной промышленности диктует высокие требования к качеству молока и молочных продуктов во многом зависящих от технологии производства и профилактических мероприятий, направленных на их улучшение. Поэтому одним из приоритетных направлений молочного скотоводства является производство молока, соответствующего санитарно-гигиеническим нормам и требованиям перерабатывающих предприятий.

В современных промышленных технологиях значительную роль приобретают нетрадиционные способы обработки молока, такие как ИК-излучения, ультразвуковая, микроволновая и ультрафиолетовая обработка и др. Они направлены на увеличение сроков хранения продуктов, улучшения вкусовых качеств и уменьшения удельных энергозатрат. Одним из перспективных методов является комплексная обработка молока электромагнитным излучением и электрохимически активированной водой.

Целью проведенных исследований является улучшение качества молочной продукции, за счет избирательного подавления развития нежелательных микроорганизмов.

В качестве объекта исследования послужило сырое коровье молоко ГОСТ 31449-2013.

Авторами теоретически обоснована и экспериментально подтверждена целесообразность применения комплексной обработки молока электромагнитным излучением и электрохимически активированной водой в технологии производства кисломолочных продуктов с целью улучшения их потребительских свойств.

Наиболее сильное влияние на микробиологические показатели молока было установлено при воздействии электромагнитного излучения при параметрах электрического тока с длительностью импульса — 19,82 мс, длительностью паузы — 19,64 мс, напряжении импульсов — 22 В и времени воздействия 20 минут и водой, обработанной на электрокондиционере (катод+анод).

Обработка молока с указанными выше параметрами комплексного воздействия оказала влияние на внешний вид и консистенцию приготовленных из него кисломолочных продуктов.

Полученные результаты позволили с целью снижения бактериальной обсемененности молока рекомендовать устройство для промывки емкости для хранения и транспортировки молока водой, обработанной на электрокондиционере (катод+анод) и обработки молока электромагнитным излучением с оптимальными режимами.

Ключевые слова: *генератор электромагнитных импульсов, электрокондиционер воды, электромагнитное излучение, электрохимически активированная вода, режимы обработки молока, микроорганизмы, молочные продукты.*

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