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INFLUENCE OF ELECTROMAGNETIC RADIATION ON PHYSICOCHEMICAL INDICATORS OF RAW MILK MATERIAL AND ITS MICROBIOLOGICAL COMPOSITION

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One of the main directions of dairy cattle breeding is the use of promising milk processing methods that meet the requirements of technical regulations and standards and Sanitary Rules and Norms (SanRaN). The purpose of the experiment is to improve the quality and safety of dairy products by suppressing the development of microorganisms. In the course of conducted studies, it was determined that EMR had a significant effect on protein density and composition of milk. In the experimental sample the bactericidal effect of electromagnetic radiation was observed on yeast-like and microscopic mold fungi. During the study of protein fractions of milk, a difference was revealed in the following parameters: total nitrogen, protein mass fraction, non-protein nitrogen, and urea, as well as whey and casein protein content. In the experimental milk sample, the content of total nitrogen was significantly higher as compared with the control sample. Basing on the obtained data, it can be concluded that milk without EMR treatment features the decreased amount of milk protein due to the development of milk microorganisms, which used it as power sources. The organoleptic evaluation has shown that during the electromagnetic treatment of raw milk no negative changes in consistency, odor and taste were noted.

Key words: *electromagnetic radiation, protein fractions, density, yeast, mold fungi.*

In modern industrial technologies a significant role is played by non-traditional methods of milk-processing aimed at increasing the shelf life of products, improving their taste and reducing specific energy costs. In particular, in the production of milk and dairy products, physical methods are used to achieve the bactericidal effect on pathogenic microorganisms [1-4]. However, for the impact of innovative technologies it is necessary to study carefully the effect of such treatment on all components and properties of raw milk and dairy products produced from it, since milk is characterized by certain physical, chemical, organoleptic and technological properties. The quality and safety of milk largely depends on the degree of contamination by unwanted microorganisms.

The wide application of electrophysical methods of processing raw dairy material, in particular electromagnetic treatment, seems promising. The studies made it possible to obtain scientific data on the effect of electromagnetic radiation on microbiological composition and the related changes in the chemical composition of milk and dairy products, and also provided a theoretical basis for the obtained data. At the same time, the influence of the magnetic field on milk proteins has not been studied enough and it is of great scientific and practical interest. Researches made by Kostyuchenko N.V. and Fialkova D.M. (2012) revealed that the impact of the electromagnetic field of 15 mT on pasteurized milk leads to the enlargement of its protein particles. The size of the casein micelles increases in proportion to the duration of magnetization and the heating temperature of the magnetized milk [5].

When studying the electromagnetic and geomagnetic effects on the properties of milk, they came to the conclusion that when the milk was magnetized (electromagnetic machine

Molmag-1 with a magnetic flux of B = 20 mV), the parameters of titratable acidity and potential E significantly increased, and the viscosity and electrical conductivity parameters decreased [6, 7]. The thermal stability of milk did not change.

Studies made by Rodionov G.V. showed that electromagnetic radiation causes the strongest suppression of growth and development of milk microorganisms [2-4]. After EMR treatment the organoleptic properties of raw milk do not change, and the physico-chemical indicators show increased protein content and lower acidity.

The research results and their discussion

We have conducted a deeper study of the effect of electromagnetic radiation on the structure of milk components, in particular proteins. An electromagnetic pulse generator has been used in the study. It generates an alternating magnetic field that is created when an electric current is being supplied to the generator with a pulse length of 19.82 ms, a pause duration of 19.64 ms, a pulse voltage of 22 V and a processing time of 20 minutes (option 2). Option 1 - milk without exposure to the electromagnetic radiation (a control sample of the experiment). Milk treatment with the specified parameters was carried out in five replicates.

The physicochemical parameters of the raw milk samples of are shown in table 1.

Table 1

Physicochemical indicators of raw milk

Index	Variant of experiment	
	1 (without treatment)	2 (with treatment)
Mass fraction of fat,%	3,80 ± 0,15	3,80 ± 0,14
Mass fraction of total protein,%	3,06 ± 0,05	3,22 ± 0,06*
Mass fraction of lactose,%	4,57 ± 0,34	4,94 ± 0,35
Acidity, ° T	16,20 ± 1,01	16,30 ± 1,00
Cleanliness group	I	I
Density, kg / m3	1027,30 ± 0,04	1029,20 ± 0,05**
Freezing point, ° C	0,526 ± 0,050	0,521 ± 0,060
The content of somatic cells, in 1 cm3	22,4 ± 5,5	18,0 ± 3,4

* P≥ 0,95 ** P≥ 0,999

There were no significant differences in the main physicochemical parameters of the milk, with the exception of mass fraction of protein and density, which indicates that electromagnetic radiation did not affect these milk parameters.

EMR influenced the content and quality composition of protein in milk. It was revealed that mass fraction of the total protein after the EMR processing of milk was 3.22%, which is 0.16% more than in the control sample. The increase of milk density after the treatment is caused by the increase of milk protein content due to the difference in the density of milk components. The density decreases with increasing fat content and increases with the increase of protein content. The increase of protein content in milk after the exposure to EMR was also noted in studies of other researchers [2-4].

Some studies have revealed that electromagnetic radiation affects the qualitative

indicators of raw milk and milk products by suppressing the development of milk microorganisms. Like all living beings, microorganisms need sustenance that they receive from the external environment. It serves as a source of energy for their vital processes, or a material for constructing the constituent parts of the cell. In particular, microorganisms need sources of nitrogen nutrition. Along with mineral sources of nitrogen, many microorganisms can consume nitrogen of organic compounds, which at the same time serve as a source of carbon. Some microorganisms can assimilate amino acids and use them as building blocks [5]. Putrid bacteria cause the decomposition of protein substances. Mold fungi and actinomycetes also have the ability to decompose proteins. Yeast can use ammonium salts, amino acids and peptides as nitrogen sources [8].

In order to study the role of microorganisms in changing the protein content in cow milk we did a microbiological evaluation of milk according to the following parameters: total bacterial contamination (QMAFAnM), presence of E. coli bacteria (SHGK), heat-resistant lactic acid bacteria, yeast and mold fungi.

Table 2 shows the microbiological evaluation of raw milk treated with electromagnetic radiation of predetermined electric current parameters.

Table 2

Microbiological indicators of raw milk

Index	Variant of experiment	
	1 (without treatment)	2 (with treatment)
Total bacterial contamination, CFU / cm^3	$5,6 \times 10^5$	$4,5 \times 10^4$
Bacteria of Escherichia coli group (CGB), CFU / g	not detected	not detected
Heat-resistant lactic acid bacteria, CFU / cm^3	$1,6 \times 10^2$	$7,0 \times 10^1$
Yeast, CFU / g	$3,2 \times 10^3$	$1,2 \times 10^3$
Mold fungi, CFU / g	$1,5 \times 10^1$	$1,1 \times 10^1$

According to the table there was a significant increase in the number of microorganisms in the control sample (variant 1), while after EMR treatment there was a significant decrease in the total bacterial contamination of milk. Therefore, the processing of milk by electromagnetic radiation has affected and suppressed the growth and development of microorganisms.

We have studied the effect of electromagnetic radiation on different groups of microorganisms. In variant 2 the bactericidal effect of electromagnetic radiation on yeast-like and mold fungi has been noted, since a significant decrease in their quantity has been observed after the treatment. The effect of suppressing the growth and development of heat-resistant lactic acid bacteria can also be noted.

In general, it can be concluded that after electromagnetic processing of raw milk at given parameters of electric current (pulse duration 19.82 ms, pause time 19.64 ms, pulse voltage 22 V and exposure time 20 minutes), there was a significant decrease of bacterial contamination of the milk in the test sample (variant 2). In our opinion, this has also affected the physicochemical parameters of milk, noted above in table 1.

Due to the fact that the nitrogen compounds of milk serve as a source of nutrition for

microorganisms, we have determined the individual parameters of the protein composition of milk to study the nature of electromagnetic radiation effect.

It is known that milk proteins consist of casein (about 85% of total amount of proteins), lactalbumine (up to 13%) and lactoglobulin (about 2%), as well as lipoprotein shell of fat globules (small amount). Milk contains different non-protein nitrogen compounds such as urea, creatine, creatinine, uric acid, purine bases, amino acids, peptones, etc. The content of non-protein nitrogen in milk is about 0.05% [10]. The amount of free amino acids in milk is insignificant - 0.5 to 2 mg%. Many researchers have confirmed the presence of arginine, histidine, lysine, leucine, valine, glycine, aspartic acid, etc. in the milk [10].

The intensity of development of lactic acid bacteria in most cases depends on their need for various sources of nutrition, the presence of the necessary substances in the milk in free form and the available set of enzymes for decomposition and assimilation of these substances. Depending on the need for various sources of nitrogen C. Orla-Jensen has divided lactobacillus bacteria into three groups: bacteria that need a complex amino acid complex and vitamins (genus Thermobacterium); bacteria that develop well on cysteine and ammonium salts (genus Streptobacterium); bacteria that develop on ammonium salts as the only source of nitrogen (genus Streptocussus) [11].

For studying the protein composition in raw milk we have determined the following parameters: total nitrogen, protein mass fraction, non-protein nitrogen, urea and protein whey and casein fractions content.

Estimating the obtained data (Table 3) it can be noted that content of total nitrogen in the milk from experiment sample (variant 2) is 0.026% higher than in the control sample (variant 1). And the difference in this indicator is statistically significant, as well as the mass fraction of the total protein (Table 1), which shows the effect of electromagnetic radiation on the change in the content of total nitrogen in milk in variant 2 [11].

At the same time, the electromagnetic effect had an impact on the content of non-protein nitrogen. Although the difference of this indicator was not statistically reliable, it can be assumed that non-protein nitrogen, to which free amino acids belong, was also used to feed microorganisms, which is confirmed by our studies and studies of other researchers.

The main component of non-protein nitrogen compounds of milk is urea (40-60% or 15 to 30 mg% being normal). The urea content in the test sample (variant 2) increased by 0.1 mg% after the treatment, which is not considerable and not statistically significant (Table 3).

Table 3

Protein composition of raw milk, %

Index	Variant of experiment	
	1 (without treatment)	2 (with treatment)
Content of total nitrogen	0,480 ± 0,005	0,506 ± 0,006***
Non-protein nitrogen content	0,0311 ± 0,002	0,0346 ± 0,003
Urea, mg %	23,10 ± 0,04	23,20 ± 0,06
Whey Protein fractions	0,80 ± 0,20	0,83 ± 0,21
Casein protein fractions	2,06 ± 0,35	2,18 ± 0,34

*** P≥ 0,999

Whey and casein protein fractions were also not significantly different, as the whey fractions of the raw milk in the test sample (variant 2) has increased by 0.03% compared to

the control sample (variant 1), which is not statistically reliable. The statistically unreliable difference was also observed with the casein protein fractions of the raw milk of the test samples, since their content in variant 2 (with treatment) is 0.12% higher than in variant 1.

An analytical method for the identification of protein compounds of milk of various origins (polyacrylamide gel electrophoresis) revealed following results. The protein profile of the test samples is not significantly different. Nevertheless, some changes in the molecular weight of each fraction of casein (κ-, α_{s1}-, β- and α_{s2}-casein) and whey proteins (α-lactalbumin and β-lactoglobulin) in the test sample were noted (variant 2). The mass of these fractions increased slightly compared to the control sample, but since both fractions have similar molecular masses it is difficult to quantify each fraction of the milk protein.

Therefore, the electromagnetic radiation affected the milk protein, casein fractions in particular, on which the technological properties of milk largely depend, mostly its rennet coagulability, since the content of the κ- and β-casein fractions determines the coagulation time, and the quantity of α_s-casein - its density.

Based on the data obtained, it can be concluded that in the milk without EMR treatment the amount of milk protein decreased due to the development of milk microorganisms, which used it for their nutrition.

Many researchers believe that fat is not required for the development of lactic acid bacteria, as they grow equally well in whole and in skim milk. However, it has been determined that certain fatty acids affect the development of milk microorganisms. Practically free fatty acids and their salts do not significantly affect the energy of acidification of lactic acid bacteria in the production of fermented milk products, since milk usually contains a small number of them.

In our studies it has been determined that no significant changes in the fatty acid FFA are observed with electromagnetic treatment of raw milk, since the mass fraction of fatty acids is within the normal range.

Since the balance of saturated and unsaturated fatty acids in milk fat determines the consistency, melting point, odor, taste and redox properties, we conducted an organoleptic evaluation of raw milk, which showed that the visible negative changes in the organoleptic properties of raw milk after exposure to electromagnetic radiation were not noted.

The measurement of the content of micro- and macroelements in the studied milk samples also did not make it possible to determine the effect of electromagnetic radiation on the mineral composition of milk.

Conclusions

1. Electromagnetic radiation had no significant effect on the parameters of the chemical composition of milk and its physicochemical properties, with the exception of protein content in milk and its density. The mass fraction of the total protein after electromagnetic treatment was 3.22%, which is 0.16% more than in the control sample, this difference being statistically significant ($P > 0.95$). Significant differences in milk density in the control and test samples were noted: after treatment with EMR the density of milk increased by 1.9 kg / m^3 ($P \geq 0.999$).

2. Under the influence of electromagnetic radiation the growth of microorganisms was suppressed in raw milk. A significant decrease of yeast-like, microscopic mold fungi and heat-resistant lactic acid bacteria was noted.

3. Some changes in the molecular weight of each fraction of casein (κ-, α_{s1}-, β- and α_{s2}-casein) and whey (α-lactalbumin and β-lactoglobulin) proteins were noted in the protein profile of both control and test samples.

4. In the sample of milk with EMR treatment the total nitrogen content is 0.026%

higher than that in the control sample, the difference in this parameter being statistically significant ($P \geq 0.999$).

5. Analysis of the mass fraction of free fatty acids revealed that electromagnetic treatment of raw milk did not cause any significant changes in the composition of milk fat.

6. EMR-treatment of milk can be recommended as a promising method of reducing the overall bacterial contamination, improving the chemical composition of milk, which positively affects the quality and safety of dairy products.

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ВЛИЯНИЕ ЭЛЕКТРОМАГНИТНОГО ИЗЛУЧЕНИЯ НА ФИЗИКО-ХИМИЧЕСКИЕ ПОКАЗАТЕЛИ МОЛОКА-СЫРЬЯ И ЕГО МИКРОБИОЛОГИЧЕСКИЙ СОСТАВ

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Одним из приоритетных направлений молочного скотоводства является использование перспективных методов обработки молока, соответствующих требованиям ТР ТС и СанПиН. Цель эксперимента – улучшение качества и повышение безопасности молочной продукции за счет подавления развития микроорганизмов. В ходе проведённых исследований установлено, что ЭМИ-излучение оказало существенное влияние на плотность и состав белка в молоке. В опытном варианте наблюдается бактерицидное действие электромагнитного излучения в отношении дрожжеподобных и микроскопических плесневых грибов. В ходе изучения белковых фракций в молоке была выявлена разница по следующим показателям: общий азот, массовая доля белка, небелковый азот, мочевина и содержание сывороточных и казеиновых белков. В опытном образце молока содержание общего азота достоверно выше по сравнению с контролем. На основании полученных данных можно сделать вывод, что в молоке без обработки ЭМИ произошло снижение количества молочного белка вследствие развития микроорганизмов молока, которые использовали его в качестве источников питания. Органолептическая оценка показала, что при электромагнитной обработке молока-сырья негативных изменений консистенции, запаха и вкуса не отмечено.

Ключевые слова: *электромагнитное излучение, белковые фракции, плотность, дрожжи, плесневые грибы.*

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