STUDYING EFFECT OF ELECTROMAGNETIC TREATMENT ON MILK TECHNOLOGICAL PROPERTIES

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Abstract. Milk quality supplied to the processing plant depends on many factors, including rennet coagulability, heat resistance, and viscosity, which are difficult to influence by tightening regulatory requirements. Sanitary and hygienic indicators are important, the empirical expression of which is titratable acidity and bacterial contamination. This determines the urgency of finding ways to control the raw milk quality, ensuring the production of natural and safe dairy products. For these purposes in the Stavropol State Agrarian University studies were carried out about the magnetization effectiveness of biological fluids by a device for magnetic processing of food solutions. The device design is a pipe of molding polyamide, a magnetizing coil, a steel tubular core — an internal pipeline and a cylindrical body, which is a magnetic conductor, with removable end caps, a thread connected to it and serving as pole pieces for both pairs of poles. Input parameters were chosen: milk temperature, exposure time of the magnetic field and voltage. The operation mode of the device is continuous by a voltage of 220 V, $\cos\varphi = 0.7$. The power consumption is 25 W, the outer diameter is 32 mm, the number of turns of the magnetizing coil is 6200. The output parameters were set: titrated acidity, time rennet clotting, heat resistance, and viscosity. The obtained experimental values were compiled into an array of data and subjected to cluster analysis by Statistica and Statistica Neural Networks. The results of mathematical processing allowed us to establish the optimal values of the factors at which the technological properties of milk are improved. The positive effect of electromagnetic processing on rennet coagulability will improve the quality of the finished product and reduce the cost for milk-clotting ferment. In addition, the heat resistance of the treated milk increases and its titration acidity decreases.

Keywords: magnetization, milk, quality, electromagnetic, mathematical, processing.

Introduction

Milk, being a biological fluid, due to the presence of charged particles, primarily ions, has a certain electrical conductivity. The magnetic devices are environmentally friendly, with low installation cost and they do not need energy. Therefore, the effect of magnetic induction onto milk has a particular interest. It is known that the quality of milk coming to the processing enterprises depends on many factors, including those that are difficult to influence by tightening regulatory requirements. For example, fodder off-flavours of milk depend on the regions, where the waste of alcohol and sugar production, silage, strongly smelling herbs are used for feeding. In this regard, the problem of quality improvement through the influence the physical factors on milk, in particular, by an electromagnetic field has particular relevance. According to [1-3], processing milk by the device, which is a magnetic core, inside of which bolts are fixing pole tips with windings located on them (Fig. 1), significantly improves the sanitary and hygienic indicators of milk.

In particular, the bacterial contamination after milk treatment by the temperature 22 ºC decreased from 500 to 300 thousand per cm^3, the content of somatic cells decreased by half, and the titratable acidity decreased from 18.5 ºT to 16.5 ºT [2]. At the same time, the authors note that the milk density increased from 1027 $kg \cdot m^{-3}$ to 1028.3 $kg \cdot m^{-3}$, that actually occurred, an increase in the components mass fraction raising the milk density (proteins, lactose, ash) [4-6]. But it is obvious that this is not a completely explainable phenomenon, which requires additional study.

At the Institute of Technical Thermophysics of the National Academy of Sciences of Ukraine [4] the technology and equipment are developed that allow to manage a number of important parameters of the milk condition, such as acidity, heat resistance, gas content, aggregation, and bacterification. The technology is based on using the principle of discrete-pulse input of energy and implemented in one- and two-stage apparatuses by multiple vacuuming in a certain temperature mode. In the devices evaporation and condensation mode processing is carried out [7-9]. At first, the milk is vacuumed by low temperatures, then heated to the pasteurization temperature and again vacuumed. After treatment in the evaporative-condensation mode, the gas content is reduced to 1-10 ml in 1 liter. It should be noted that degassing as a result of vacuum treatment provides a decrease in acidity on 1-3 ºT (before treatment – 22 ºT, after treatment – 19 ºT), in addition, the rate of acidity increasing during storage was slowed down; reduction of bacterial contamination, deep deodorization and increasing milk taste, and oxygen removal contribute to preservation of vitamin C. Along with decreasing the titrated acidity, an increase in the active acidity (pH) was observed, the most drastic change occurring by the pasteurization temperatures over 85 ºC [10;11].

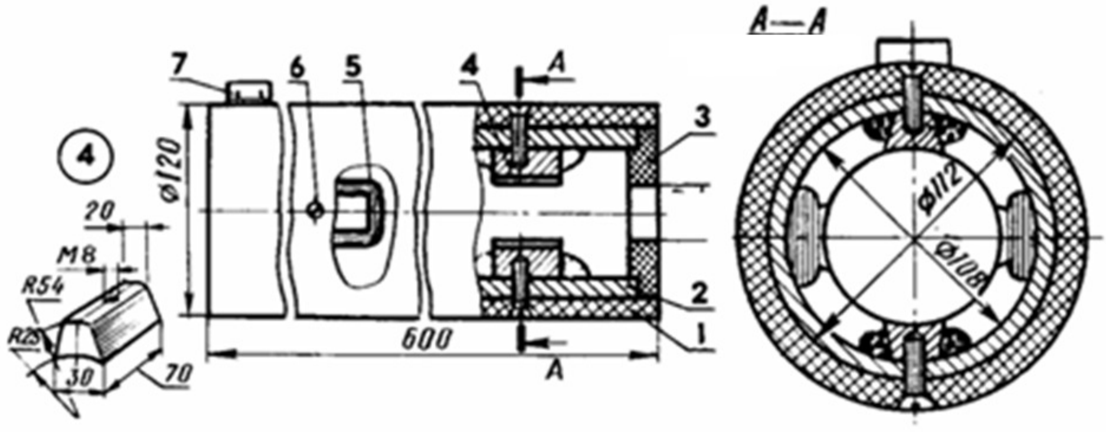

Fig. 1. **Apparatus for electromagnetic processing of milk:** 1 – electric protective housing (of a 600 mm section of a polyethylene pipe 120 × 4); 2 – magnetic conductor (of a 540-mm segment of a steel water-gas pipe 112 × 2); 3 – electrical protection bungs-lid (30 mm textolite, 2 pieces); 4 – pole tip (St3, depending on the required magnetic field strength – equidistant from each other 2, 3 or 4 pairs); 5 – coil-winding (314 turns of the wire sew-2 or PE with a diameter of 0.83); 6 – M8 screw with countersunk head (4, 6 or 8 pcs., respectively); 7 – terminal strip

Effect of reducing the rate of growth of acidity can be explained by two reasons. First, it is removing the milk volatile components, including oxygen, and secondly, as a result of partial microflora suppression [12]. Presumably, microflora suppression occurs as a result of microorganism destruction by abrupt pressure drop. In the condensation mode milk enters from the atmosphere into the vacuum chamber. At the same time the pressure decreases 10 times. In cells of microorganisms there are gas bubbles, which, when the pressure drops, dramatically increase their volume, breaking the cell wall or stretching it. Into the growing vesicle intracellular fluid evaporates, which leads to disruption of the entire cell structure. In the evaporation mode, when the milk with the pasteurization temperature enters the vacuum chamber, the remaining cells are destroyed not only by bubble expansion, but also under the influence of the effects accompanying adiabatic boiling. The microorganism decomposition products are partially evaporated and removed from the system, herewith reducing the overall level of milk contamination.

Using evaporation-condensation treatment allows affect onto the least studied and a practically uncontrollable parameter of the milk state – heat resistance [13;14]. The authors of this method suggested that during evaporation-condensation treatment into adiabatic boiling up the loose protein shell is sort of "shaken off" from the fat globules [15].

The process of homogenization in evaporation-condensation mode fundamentally differs from high-pressure homogenization. Fat globule dispersion in a vacuum apparatus takes place by the evaporative mode under adiabatic boiling up. Under hydrodynamic instability action in the inter-bubble plasma space, defects of the large fat globule shells appear. Part of the fat remains in the plasma. Due to this, fat new droplets of small sizes can form membranes on the surface of vapor bubbles. Under destroying vapor bubbles, the fat membranes formed also small size fat globules. This is confirmed by the presence of a large ball number with a size less than 1 micron by observing the structure of homogenized milk under a microscope. Possibilities of the evaporation-condensation processing of milk, effects that accompany it, make it possible to take a new approach to traditional technologies for producing dairy products, to make significant changes in their regulations and to obtain products with improved or new qualities. The described effects are used in the following technologies [16]. In production of pasteurized milk with an extended shelf life, where mild homogenization and deep deodorization make it possible to obtain products with high palatability. Most pronounced this appears in low-fat milk production. In production of fermented milk drinks the energy consumption for homogenization reduced 2.5 times, and suppression of extraneous microflora contributes to the starter culture development. In production of condensed canned milk the product quality improves and its shelf life increases. In production of sterilized milk the volume of raw material base increases. In production of cheeses, especially the soft ones, the yield of the finished product increases by 6-8 %, and fat loss with whey is reduced. All technologies were industrial tested; there is documentation for milk production.

Materials and methods

Similar device was developed at the Stavropol State Agrarian University. The device design contains placed coaxially: a pipe from injection molding polyamide, a magnetizing coil, a steel tubular core – an internal pipeline and a cylindrical body, which is a magnetic conductor with removable end caps, connected to it by thread and serving as pole pieces for both pairs of poles (Fig. 2).

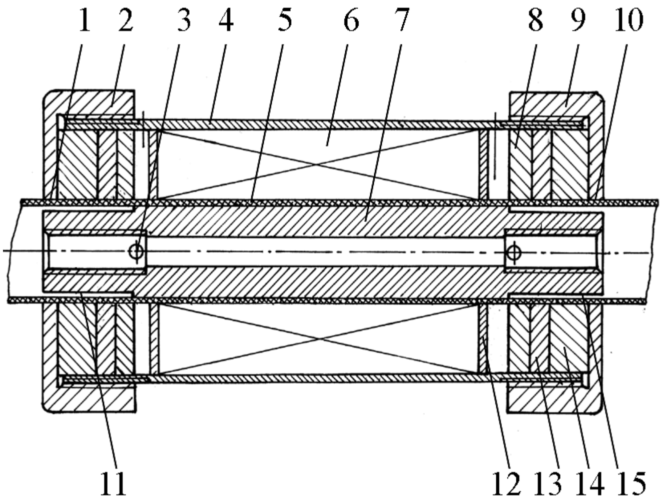

Fig. 2. **Device for water magnetization:** 1 – pipeline from molded polyamide; 2 – magnetizing coil; 3 – core; 4 – body; 5 – end caps; 6 – pole lugs; 7 – radial holes for supplying water to the treatment area; 8, 9, 10 – ferromagnetic rings; 11 – core steps; 12 – coil cheek

When the magnetic coil 2 is powered by alternating current, an electromagnetic field is created in the working gap, which changes direction with a frequency equal to the frequency of the current, without changing the position of the power lines. The electromagnetic field intersects the volume of the fluid moving in as a thin layer, perpendicular to the magnetic field lines.

This technical solution formed the basis of the device for magnetic processing of food solutions (UMOPR) (Fig. 3).

Fig. 3. **Device of magnetic processing of food solutions (UMOPR)**

Milk processing by a magnetic field was carried out on a special device – a device for the magnetic treatment the food solutions (UMOPR) according to a three-factor experiment plan (Table 1).

Table 1

Planning matrix of 3-factor experiment and values of measured parameters for milk electromagnetic processing

№	X_1	X_2	X_3	T, °C	τ, s	U, V	Y_1 K acidity, °T	Y_2 τ rennet clotting, s	Y_3 V serum, ml	Y_4 T heat resistance, degree	Y_5 t time, s
1	-1	-1	-1	11	20	90	22	28	8.0	1	16.3
2	-1	+1	-1	11	50	90	24	24	8.2	1	18.7
3	+1	-1	-1	25	20	90	23	30	8.0	2	18.2
4	+1	+1	-1	25	50	90	22	28.5	8.0	1	17.4
5	-1	-1	+1	11	20	210	21	32.5	8.8	1	16.9
6	-1	+1	+1	11	50	210	22	31	8.3	2	17.6
7	+1	-1	+1	25	20	210	23	17	8.2	1	17.1
8	+1	+1	+1	25	50	210	22	27	8.2	1	18.3
9	-1.682	0	0	6	35	150	23	35.5	8.6	1	18.1
10	+1.682	0	0	30	35	150	20	15.5	8.4	2	17.9
11	0	-1.682	0	18	10	150	23	17	7.8	1	15.6
12	0	+1.682	0	18	60	150	20	22	8.0	1	17.2
13	0	0	-1.682	18	35	50	22	28	8.2	1	18.5
14	0	0	+1.682	18	35	250	22	25	8.0	1	18.0
15	0	0	0	18	35	150	20	30	8.2	1	17.2
16	Without treatment			-	-	-	23	32.5	8.6	2	20.1

The milk temperature varied in the range from 6 to 35 ºC, the time of exposure to the magnetic field – from 10 to 60 s, the voltage – from 50 to 250 V.

The obtained experimental values were compiled into an array of data and subjected to cluster analysis by Statistica and Statistica Neural Networks.

Results and discussion

In the milk subjected to electromagnetic treatment titrated acidity, rennet clotting, heat resistance and viscosity mixed with the "mastoprim" preparation were determined [17, 18]. It was established that electromagnetic treatment affects the studied properties of milk. Under certain treatment regimes shortening of rennet coagulation was noted and, at the same time, deterioration of the heat resistance. The results were processed by a neural network in order to optimize the parameters of milk processing.

The neural network view is shown in Fig. 4.

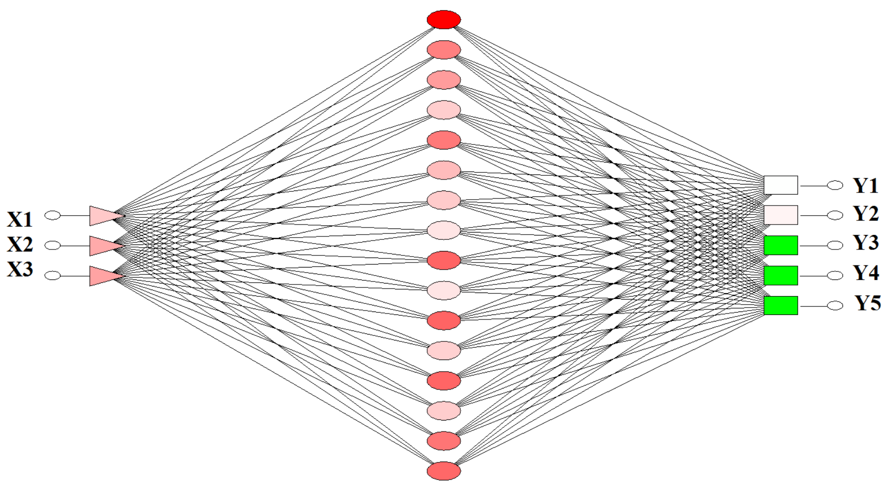

Fig. 4. **Neural network for processing results**

As a result of the neural network processing the created virtual factor array, which was divided into cluster zones, was introduced as the standard, and close clusters selected (Fig. 5).

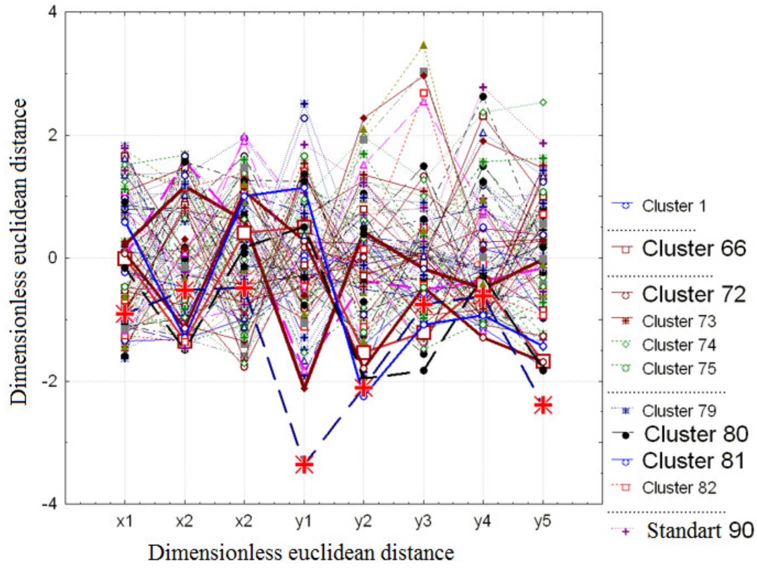

Fig. 5. **Neural network factor array**

Data analysis of each cluster allowed to establish the optimal values of the factors at which the milk technological properties are improved. Milk temperature – 18.2 ºC, processing time – 38.4 s, voltage – 140.75 V.

Milk processing by the electromagnetic field was carried out according to the established optimal conditions and its physicochemical and technological properties were determined (Table 2).

Table 2

Milk physicochemical and technological properties after electromagnetic treatment

Indicator	Titratable acidity, ºT	Rennet coagulation duration, min.	Heat resistance, group
Before processing	22	32.5	II
After processing	20	14	I

Electromagnetic processing of milk led to a decrease in the titrated acidity by 2 ºT. However, at the same time, the investigated milk, which was classified as rennet-limp and practically unsuitable for cheese production, was significantly improved in its technological properties after magnetic processing and was characterized as medium-curd. Obviously, this is due to the polarization of cations and anions in milk, contributing to the improvement of rennet coagulability.

Conclusions

As a result of the experiment, a significant reduction time of milk rennet coagulation (2.3 times) was obtained, which in the future will reduce the consumption of milk-clotting enzyme in the production of cheese. In this case, the electromagnetic treatment of milk improves its heat resistance and reduces its titratable acidity from 22 to 20 ºT.

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