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IMPROVEMENT OF TECHNOLOGY AND MEANS OF PRIMARY MILK PROCESSING

35.04.06.01 Technologies and technical means in agriculture

ABSTRACT

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The thesis can be found in the university library.
The author's abstract was prepared on June 8, 2017.

Secretary of State
Attestation commission A. G. Pavlov

GENERAL CHARACTERISTICS OF WORK

Relevance of work. Milk of farm animals is a valuable food product. Cow's milk contains more than 200 components, the most important of which are digestible proteins, fats, carbohydrates, mineral salts, vitamins and many other substances that are important to ensure normal growth and functioning of the human body. It is used for baby food and as a dietary and therapeutic product in case of anemia, tuberculosis, gastritis, poisoning, diseases of the liver, kidneys, gastrointestinal tract.

On Russia's entry to the World Trade Organization our dairy industry found itself in a very difficult position. The existing requirements for the quality and safety of milk of highest sort in Russia were in 7-10 times lower than in the countries of the WTO. According to the standards of European Union milk that corresponds to our requirements of 1-st and 2-nd class is considered unfit for consumption and must be disposed of. Currently 90% of all milk produced in the Russian Federation is of such kind.

The existing traditional milk cooling system does not allow to fulfill the requirements of the new standards of quality. One of the main problems is the cooling time of fresh milk, which is according to the Russian standards is from 2 to 3 hours. Such cooling time cannot stop the growth of harmful microflora, the increase of toxins, and exclude the influence of these factors on the quality of milk. Instant cooling technology of milk from the temperature of +35° C to + 4°C lowers these harmful effects in comparison with 2-3 hours of cooling.

Existing technologies and plants for milk cooling do not meet the requirements of agricultural production and have a number of disadvantages: big metal consumption, low reliability, high electricity consumption; negative impact on the environment, etc. So the problem of application of systems for milk-cooling using natural cold requires further research and development.

One of the effective ways to reduce energy costs, improve the reliability of cooling systems and ecological purity of milk cooling on farms is the development and application of energy-saving combined primary milk processing systems.

The aim of the research was to reduce the energy costs of primary milk processing and to preserve the initial quality of the product.

Research objectives:

- to develop the classification of methods and means of primary processing of milk;
- to develop and justify the combined system of primary milk processing using flow chillers and the use of spent refrigerant for animal drinking;
- to substantiate the operation modes of the milk cooling system with the use of natural cold;
- to develop the algorithm for determining the loss of material resources from a decrease in the quality of milk and a mathematical model of the process of cooling milk using natural cold;
- to carry out a technical and economic assessment of the use of a combined milk cooling system with the subsequent use of refrigerant for animal drinking.

Object of the research: technological processes of primary processing of cow's milk.

The subject of research: the dependence of milk quality indicators on the operating conditions of equipment used in primary milk processing.

Scientific novelty of dissertational research:

- classification of methods and means of primary processing of milk;

- a combined primary milk processing system with flow through coolers, by means of cooling with water, used later for the drinking of animals;

- an algorithm for determining the loss of material resources from a decrease in the quality of milk and a mathematical model of the process of cooling milk using natural cold;

- modes of operation of the milk cooling system using natural cold.

Practical significance. Using a combined system of primary milk processing with flow-through refrigerant allows to maintain the initial quality of the product and reduce energy costs by half.

The results of the dissertation research can be used by enterprises operating equipment for primary milk processing, research organizations in developing methods and means of primary milk processing, as well as in the educational process of universities.

The main scientific provisions of the thesis, put on defense:

- a combined primary milk processing system with flow-through coolers, by means of cooling with water, used later for the drinking of animals;

- an algorithm for determining the loss of material resources from a decrease in the quality of milk and a mathematical model for the process of cooling milk using natural cold;

- modes of operation of the milk cooling system using natural cold;

- evaluation of technical and economic efficiency of the combined primary milk processing system.

The reliability of the results is confirmed by the use of modern methods and equipment, a sufficient number of experiments, the correspondence of experimental data to theoretical studies, the publication of results in journals, and the introduction in the animal-breeding enterprise of “Golitsyno” JSC in the Nikiforovsky district.

Approbation of work. The main provisions and results of dissertational work are presented and approved: at the sessions of the department "Agroengineering" of the FGBOU VT TSTU in 2016-2017; At the international scientific-practical conference in Podolsk.

Publication of research results. According to the results of the thesis, 4 works were published.

Structure and scope of the dissertation. The thesis consists of an introduction, four chapters, a conclusion, a list of literature. The work is presented on 73 pages of typewritten text, contains 20 figures, 8 tables, a list of literature from 63 titles, including 3 in a foreign language.

CONTENT OF MASTER'S DISSERTATION

In the introduction, the relevance of the topic under consideration is justified; The goal, object and subject of research are defined; Scientific novelty and practical significance are formulated.

The first chapter provides an overview of the methods and means of primary processing of cow's milk, as well as the analysis of their work and a comparative characteristic.

The main disadvantages of natural cold plants are: large metal consumption, low level of unification; limited cooling capacity due to the relatively small contact surface of the ambient air with the refrigerant, low efficiency of evaporative cooling of plants, a small range of operating temperatures of refrigerant, and efficient operation of such plants is achieved only in the cold season.

The second chapter examines the theoretical basis for assessing the level and reserves of the use of agricultural machinery and equipment. The evaluation on the criteria of operating costs, intensity of loading, energy intensity, material consumption and labor intensity of processes were developed by B.S. Sviryaevsky, G.V. Vedenyapin, F.S. Zavalishiny, Yu.K. Kirtbay, S.A. Iofinov and other authors. However, these criteria characterize, mainly, the intensity of their use. They are often in conflict with the criteria for the quality of technology, which largely determines the efficiency of production. In the subsequent works of N.P. Tishaninov, M.V. Shakhmayeva, D.N. Sahakyan, A.N. Vazhenkna, V.M. Zemsky and other authors, the methodology of developing solutions for the use of technology has been further developed. But the tasks of using equipment for primary milk processing in them are not considered.

The primary milk processing system is one of the most energy-intensive stages of its production. It consumes about 1/3 of the consumed electricity and amounts to 35 kW per 1 ton of fresh milk. Energy saving due to the use of energy-saving cooling systems with the use of natural cold makes it possible to significantly reduce these indicators.

The bactericidal phase is determined by the formula:

$$t_b = \frac{7{,}22 \cdot 10^6}{Б_0 2^{(0{,}1T_П)^{1{,}61}}}, \qquad (1)$$

where $Б_0$ is the initial bacterial contamination;

$T_П$ - temperature of milk storage.

Bacterial seeding during storage $T_П < t_b$:

$$Б = Б_0 \cdot (6{,}35 \cdot 10^{-5} \cdot T_П^{3{,}82} \cdot t_П + 1), \qquad (2)$$

with $T_П > t_b$:

$$Б = Б_0 \cdot (6{,}35 \cdot 10^{-5} \cdot T_П^{3{,}82} \cdot t_П + 1) \cdot \left(2^{t_П - t_б / 2{,}13 - 0{,}046 T_П + 1} - 1\right), \qquad (3)$$

The algorithm for determining the loss of material resources from a decrease in the quality of milk is shown in Figure 1.

From the analysis performed in accordance with the evaluation algorithm it follows that, depending on the volume of milk received, the remoteness of farms and complexes from milk receiving points and consumers of dairy products, from climatic conditions and the availability of modern technology, without harmful effects on the environment, it is possible to develop combined technological systems (CTS) with the use of sources of cold and heated water for the drinking of animals.

When justifying the proposed schemes, the following requirements should be taken into account: the quality of milk as a result of processing should not be reduced, the cost of milk and the level of impact on the environment should not be increased. Thus, the CTS is a function of the following factors:

$$KTC = f\left(W, S, K, T_T, Э_K\right) \tag{4}$$

where *W*- annual milk production, tones;

S- the distance from the milk producer's enterprise to the point of reception or use, km;

K- climatic conditions - the number of days in a year with positive and negative temperatures, ° C;

T_T - availability of modern equipment for processing milk;

$Э_K$ - degree of impact on the environment,%.

Natural cold can significantly reduce these indicators.

The bactericidal phase is determined by the formula

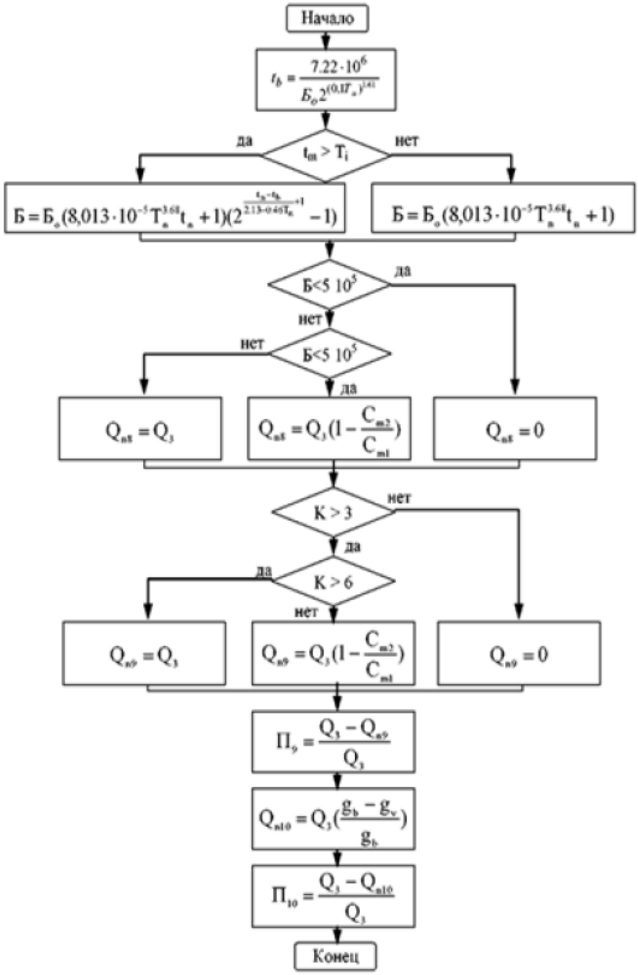
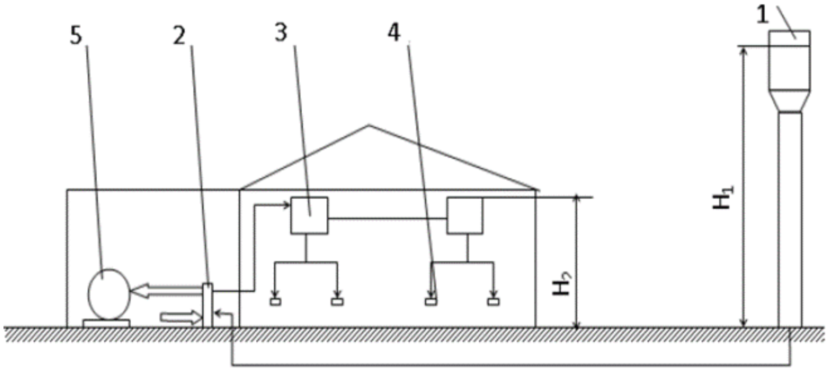


Figure 1 - Algorithm for determining the loss of material resources from the decline in the quality of milk

To improve the quality of milk and save energy, a variant of the combined technological system for pre-cooling milk in a flow with the use of flow chillers, collection of preheated water in intermediate tanks and its further use for animal drinking has been developed (Figure 2).



1 - water tower; 2 - flow cooler; 3 - intermediate capacity; 4- automatic drinking bowl; 5 - milk cooling tank

Designations: →- cooling water; ⇒- Milk.

Figure 2 - Diagram of a combined system for cooling milk and watering animals

The primary processing system works as follows. Water from the water tower 1, located at a distance from the cowshed, is fed through the pipeline underground to the flow cooler 2. Through the cooler 2, the fresh milk also passes and thereby gives heat to the cold water, while heating it, and itself is pre-cooled and enters the Tank-cooler. Heated water enters the intermediate tanks, located at a certain height, which allows you to feed water to the drinking bowls of 4 animals.

When assessing the efficiency of the use of equipment, the values of operational-technological and energy indicators should be reduced to the amount of processed products.

The total cost of the technological process, reduced to the amount of milk:

$$R = Q_{П} + Q_{ПТ} + Q_{ПЭ} + Q_{у}, \qquad (5)$$

Where $Q_{П}$ is the cost of the production process, rubles;

$Q_{ПТ}$ - costs of using labor resources, rubles;

$Q_{ПЭ}$ - costs of using energy resources, rubles;

$Q_{у}$ - the cost of using the resource equipment, rubles.

The generalized indicator of the efficiency of the use of equipment for primary milk processing is:

$$П_{об} = (Q - R/Q) \quad , \qquad (6)$$

In order to increase the efficiency of milk production, it is necessary that the processing equipment operates in a mode that ensures optimal conditions for cooling and storing milk. Given that the costs of the process should be lower than the technological effect of this process, we write the following condition:

$$(C_1 - C_2) \cdot Q > З_T \quad , \qquad (7)$$

Where C_1, C_2 - prices for the sale of milk of the 1st and 2nd sort, respectively;

Q - the amount of milk;

$З_T$ - costs of the technological process.

To determine the limits of the efficiency of using the equipment, we write equation (7) in the form:

$$\left(C_1 - C_2\right) \cdot Q = \left(C_y K T_p\right) / T_r + C_e N_e h_e T_p + C_p T_p K \quad , \qquad (8)$$

following:

$$C_y / T_r = \left(\left(C_1 - C_2\right) \cdot Q - C_e N_e h_e T_p - C_p T_p K_и\right) / \left(T_p K\right) \quad , \qquad (9)$$

To achieve the aim of the work, we constructed a nomogram, shown in figure 3.

To determine the efficiency of the equipment using the "cost-resource" parameters, we perform the following operations.

1. In the coordinates Q- *П*$_1$, we set the milk quantity $Q = 0{,}5$ and draw the horizontal line to the line corresponding to the difference in the milk prices of the first and second sorts $\Delta C = 100$ rub. Then we draw the vertex from the obtained point to the intersection with the axis *П*$_1$. The point obtained on the *П*$_1$ scale characterizes the technological effect, i.e., $П_{1=}$ 100 rub.

2. To count the costs of energy supply for the process, we work with the coordinates *Q-Tp, Tp-Ze* and Ze- *П*$_1$: from the known value of *Q,* we draw the horizontal line to the intersection with the line $T_x = 24$ hours,, then from the point on the line T_x draw the vertical to the axis T_p, then to the line C_e, corresponding to the cost of 1 kW per h of equipment operation. From the point on the line C_e we draw the horizontal line to the axis Z_e, we get $Z_e = 23$ rub. The value obtained on the scale corresponds to the costs for the energy supply of the process. In order to subtract costs from profit, it is necessary to find the intersection point of the horizontal drawn from the point on the axis Z_e and the inclined guide emanating from the point on the axis *П*$_1$, obtained in point 1, then from the resulting intersection point to raise the vertical to the axis $П_2$, we get $П_2 = 85$ rub.

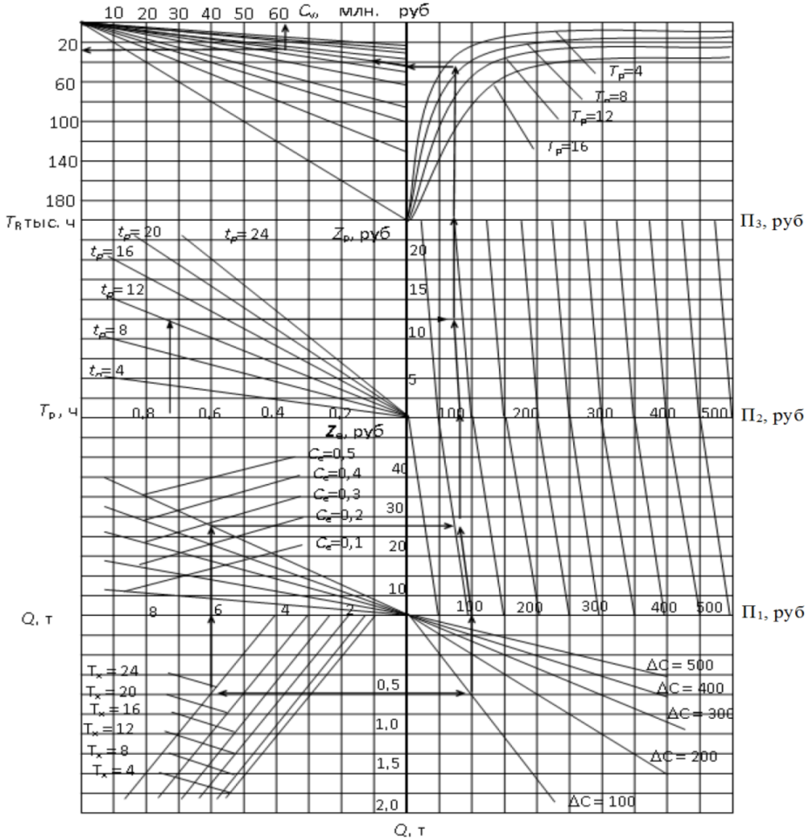


Figure 3 - Nomogram of determining the boundaries of effective use of equipment for primary processing of milk

3. To take into account the costs of using labor resources, we work in the coordinates *Cp* - *Zp, Zp* - *П*₂. After setting the cost of the 1st hour of the 1st employee's work on the $C_p = 0{,}72$ ruble scale, we draw the vertical to the line $t_p = 12$ h, then from the resulting point draw the horizontal to the axis Z_p and then, to the crossing with the guide line outgoing from the point on the axis $П_2$, and then from the resulting point, we draw the vertical up to the axis $П_3$.

Received value $П_3 = 70$ rub. characterizes profit taking into account the costs of energy supply and labor payment.

4. To determine the efficiency of the equipment using the "cost-resource" parameters, we use the coordinates $П_3 - C_y / T_R$, $C_y - T_R$: from the value on the $П_3$ axis, we draw the vertical to the curve of $T_p = 8$ hours, from the resulting point, draw the horizontal to the axis C_y / T_R. From the value of C_y / T_R we pass to the line leading to the origin of the coordinates $C_y - T_R$. Moving along this line, we determine the resource at a known cost, or vice versa, the cost at a given resource, ensuring the efficient operation of the equipment. That is, with a resource of 24 thousand hours, the cost will be 62 million rubles.

The third chapter contains the program and methodology of experimental studies, the operating regimes of the combined system of primary milk processing are justified.

The experimental sample should be a model of a typical primary milk processing system simulating the pre-cooling of milk using natural cold and the movement of refrigerants for real animal farms. The combined system should include typical devices and structures used on livestock farms (milk pump, as a release - capacity with milk, temperature sensors, control unit, etc.).

To determine the operating modes of the combined system: the height and the productivity of the water tower, a loss calculation was performed in the system.

From technological and economic considerations, it is most appropriate, when the productivity of primary processing systems is equal to the productivity of the corresponding systems of milking cows or is somewhat less than the latter. The required capacity Q of the milk processing system is determined by the formula:

$$Q = \frac{m \cdot G \cdot c \cdot k_p}{365 \cdot \rho_л \cdot T_ц}, \qquad (10)$$

Where m - the number of cows on the farm;

G - average annual milk yield per cow, kg;

C - the coefficient of the monthly unevenness of milk supply, is characterized by the ratio of the maximum monthly milk yield to the average monthly indicator, c= 1,1 -0,6 in the calculation we accept *c=1,2*;

k_p- the coefficient of unevenness of a single milk yield. With a three-fold milking $k_p = 0{,}55 - 0{,}6$, with a double - $k_p = 0{,}82 - 0{,}9$,we take $k_p = 0{,}85$;

$\rho_л$ - coefficient that takes into account the lactation duration of cows, $\rho_л = 0{,}8 - 0{,}82$ in the calculation we take $\rho_л = 0{,}8$;

$T_ц$ - the duration of the cycle of single milking, $T_ц = 1{,}5 - 2$ hours, in the calculation we take $T_ц = 1{,}5$ hour.

The need of a farm in water for the drinking of animals is determined by the presence of groups of animals and the average daily water consumption rates according to the formula:

$$Q^{в}_{ср.сут} = \sum_{i=1}^{n} m_i \cdot q_i, \qquad (11)$$

Where m_1 is the number of animals of the i-th species.

q_1 - the water norm per animal of the i-th species, litters;

n - number of species of animals.

The water pipe is divided into outer and inner sections of length, respectively, 200 and 150 m. For each section we determine the maximum water flow per second. The water flow rate per second for the water-pipe section is:

$$Q^{в}_{\max .c} = S \cdot V \ , \tag{12}$$

Where S- the cross-sectional area of the water pipe, m^2;

V- water velocity, m / s. The speed of water in pipes with diameters up to 300 mm is recommended to be taken within a range of up to 1,25 m / s. In the external pipeline it is not recommended to install pipes with a diameter of less than 50 mm, in the calculation we take for the outside – V=0.1 m / s, the inner section - V=0.4 m / s.

When moving in pipes, water meets two types of resistance: friction along the length of the pipeline and local resistance. Total head losses in the water supply are determined by the formula:

$$\sum h_{в} = h_{тр} + h_{мс} \ , \tag{13}$$

Where $h_{тр}$ - pressure loss to overcome frictional forces along the pipe, m;

$h_{мс}$ - loss of pressure to overcome local resistance, m.

The height of the location of the water tank is determined by the condition of ensuring the necessary pressure at the most remote (dictated) point of consumption, using the equation of U. Bernoulli:

$$H_{б} = H_{св} + \sum h \ , \tag{14}$$

Where $H_{б}$- the height of the bottom of the water tank above the surface of the earth, m;

$H_{св}$ - free head, m. In the external water supply system on farms, the free head according to SNiP must be at least 10 m. For the water supply network, the corresponding values of free heads should be as follows: for automatic drinking bowls not less than 4 m, for water taps - 2 M. Free heads on the inputs to the production premises are set in accordance with the water costs that they provide.

The results of the calculations are given in Table 1.

Table 1 - Results of the calculation of the water tower

Indicator	Unit of measurement	External site	Internal site	Water supply
Water flow speed	m/s	0,1	0,4	-
Pipe diameter	m	0,05	0,025	-
Length of the site	m	200	150	350
Frictional losses along the length	m	0,041	0,98	1,021
Losses for local resistance	m	0,004	0,12	0,124
Total losses	m	-	-	1,145
Free height	m	-	-	10
Tower height	m	-	-	11,145

The developed experimental model was introduced in the animal-breeding farm of JSC "Golitsyno" in the Nikiforovsky district of the Tambov region.

In the fourth chapter the calculation of the economic efficiency of the milk pre-cooling scheme is presented.

The economic effect in the sphere of operation and production is determined by comparing the costs of cooling the milk with an energy-saving system using natural cold and the movement of coolants (a new version) and installing milk cooling using only artificial cold (base variant):

$$Э = З_Б - З_Н \text{ ,} \quad (12)$$

Where $З_Б$, $З_Н$ - the resulted expenses, accordingly on base and new variants, rubles.

The resulted expenses are defined under formulas:

$$З_Б = Е_Н \cdot К_Б + И_Б \text{ ,} \quad (13)$$

$$З_Н = Е_Н \cdot К_Н + И_Н \quad (14)$$

Where $Е_Н = 0{,}15$ is the normative coefficient;

$К_Б, К_Н$, - capital investments according to the basic and new options, rub;

$И_Б, И_Н$, - total operating costs, respectively, for the base and new options, rubles.

The carried out technical and economic calculation shows that the introduction of a combined milk cooling system using natural cold allows one to get an annual economic effect of at least 25758 rubles (in March 2017 prices). The results of the calculation are presented in Table 2.

Table 2 - Technical and economic indicators of compared versions of milk cooling systems

The name of indicators	Unit of measure ment	Basic	New
Capital expenditures	rub.	495000	550000
Amount of deductions for depreciation	rub.	61875	68750
Amount of deductions for current repairs	rub.	23760	26400
Amount of deductions for capital repairs	rub.	18810	20900
Operator's salary	rub.	25550	25550
Energy costs	rub.	76814	31201
Total operating costs	rub.	206809	172801
Incomplete operating costs	rub.	144934	104051
The resulted expenses	rub.	281059	255301
Annual economic effect	rub.	–	25758
Economic effect for the period of service	rub.	–	73665
Payback period	years	–	2,5

CONCLUSION

1. Analysis of the current state of milk cooling made it possible to justify the feasibility of developing a combined system for primary milk processing on farms using natural cold and the subsequent watering of animals, as well as the possibility of reducing electricity consumption.
2. A technological scheme for primary milk processing has been developed, which makes it possible to reduce operating costs by using water for animal drinking.
3. An algorithm has been developed to determine the loss from the reduction of the quality of milk during its primary processing.
4. The modes of operation of the combined system for primary milk processing using natural cooling at outdoor temperatures t less than + 24 ° C, switching on the pulsed mode of operation at a temperature of minus 3.8 ° C, are determined and justified, which makes it possible to reduce consumption of electricity for cooling one ton of milk by 15-17 kW.
5. The carried out technical and economic calculation showed that the introduction of a combined technological system for the primary processing of milk, cooling milk with the use of natural cold for the Tambov region makes it possible to obtain an annual economic effect on a farm of 50 cows at least 25,758 rubles with a payback period of 2.5 years .
6. Combined primary milk processing systems are recommended to be introduced into the production process of farms to reduce electricity consumption, as well as to maintain the quality of the product.

Prospects for further development of the topic

The use of natural cold and cold carriers with a low freezing point to cool the milk.

The main results of the thesis are published in the following papers:

1. Dorovskikh, V.I. Rationale for rational regimes for using equipment for primary milk processing / V.I. Dorovsky, V.P. Kapustin, D.V. Dorovsky, Al-Lami Sadek Fenzhan Hasnavi // Science in Central Russia. - 2016. - No. 3 (21) - pp. 9-15.
2. Dorovskikh, V.I. Basis of the criteria for assessing the efficiency of the use of equipment for primary milk processing / V.I. Dorovsky, D.V. Dorovsky, Al-Lami Sadek Fenzhan Hasnavi // Science in Central Russia. - 2016. - No. 5 (23) - P. 67-73.
3. 41. Kapustin, V.P. Rationale for the operating modes of the combined cow milk cooling system / V.P. Kapustin, Al-Lami Sadek Fengzhan Hasnawi, DA Chernetsov // The rural machine operator. - 2017. - №4. - FROM..
4. Chernetsov DA, V.P. Kapustin, Al-Lami Sadek Fenzhan Hasnawi,null