TEHNICAL UNIVERSITY OF MOLDOVA

As a manuscript

UDC: 621.56 / .57 + 637.117 (043.3)

SLIPENCHI VICTORIN

IMPROVING THE ENERGY EFFICIENCY OF EQUIPMENT FOR PRIMARY PROCESSING OF MILK WITH THE USE OF NATURAL AND ARTIFICIAL COLD (FOR EXAMPLE OF THE NORTHERN REGION OF THE RM)

255.01 - TECHNOLOGIES AND TECHNICAL MEANS FOR AGRICULTURE AND RURAL DEVELOPMENT

Summary of the doctoral thesis in engineering sciences

CHISINAU 2022

The thesis was elaborated in department "Electrification of Agriculture, Mechanics and Design Basics" of the State Agrarian University of Moldova

Scientific leader:
VOLCONOVICI Liviu, doctor habilitat in technical sciences, university professor, SAUM
Reviewers officials:

1. **CEREMPEI Valerian,** doctor habilitat in technical sciences, associate professor, SAUM
2. **GUȚU Aurel,** Doctor of technical sciences, associate professor , SAUM
3. **LEU Vasile**, doctor in technical sciences,.CEO at SA,, Termoelectrica "

The composition of the Commission for the public defense of the doctoral thesis was approved by the SAUM Senate by decision of .03.12./2021 as follows:

1. **MARIAN Grigore,** chairman, doctor habilitat in technical sciences, university professor, SAUM
2. **VOLCONOVICI Liviu**, doctor habilitat in technical sciences, university professor, SAUM
3. **GOLOVANOV Nicolai,** Prof. Emeritus, PhD in Engineering, Technical University of Bucharest, Romania.
4. **CANTEMIR Lorin,** doctor of engineering, univ. prof. Corresponding member of the Romanian Academy of Sciences.
5. **GUȚU Aurel,** doctor of technical sciences, associate professor , SAUM
6. **LEU Vasile,** doctor of technical Sciences. CEO at SA „Termoelectrica"
7. **CEREMPEI Valerian,** qualified doctor habilitat in technical sciences, associate professor, SAUM

The defense of the thesis will take place on **.30.11.2022** at $13.^{00}$ in the Doctoral Committee meeting at: MD-2049, mun. Chisinau, UTM, str. Mircești 56, 3rd floor, room 318.

The doctoral dissertation and the abstract can be consulted on UTM website and on the website of ANACEC of the Republic of Moldova (www.anacec.md).

The summary has been sent to …../2022.

Chairman of the Doctoral Committee
doctor habilitat in technical sciences, university professor **MARIAN Grigore**,

Scientific leader
doctor habilitat in technical sciences, university professor **VOLCONOVICI Liviu**

Author **SLIPENCHI Victorin**

CONTENT

CONCEPTUAL REFERENCES OF RESEARCH

The topicality and importance of the issue addressed.

Due to the low technological level of most farms and the lack of modern milk processing equipment the quality of processed milk is in some cases still below the level At the same time the consumption of electricity at cooling 1 t of milk is essential and constitutes on average 20 ... 25 kWh , and the duration of the management by the operator of the processing process is over 2500 hours per year At the same time, losses of milk fat were fixed during processing milk on farms .

The technical requirements, which are constantly increasing compared to electrical equipment, the complexity and variety of automated systems and technological processes, require the development of a methodological basis for the synthesis of unified systems, the development of practical methods for justification and formation of these systems. , complexity and characteristics of the targeting object. Therefore, scientific research aimed at developing and developing the theoretical basis, methods for developing new efficient energy-saving technologies, technical means and the unified electrified system, which provides an intensification of the technological process of milk processing on farms, are relevant and have an important role in the national economy.

The purpose of the paper consists in the elaboration of the methodology, calculation methods and mathematical models of the milk cooling processes and the accumulation of natural and artificial cold to substantiate the operating regimes and parameters of the system with low electricity consumption using the ecological and combined seasonal installations throughout the year .

Research objectives:

- current study and development trends of technological processes and equipment for primary milk processing
- elaboration of the calculation methodology and methods of formation and structural-functional organization of the automated technological processes with reduced electricity consumption at the primary milk processing with the argumentation of the parameters
- elaboration of mathematical models and methods for calculating milk cooling processes in capacitive and flow chillers, as well as for the accumulation of natural and artificial cold in mixing and non-mixing regimes of the refrigerant in cold accumulators.
- study of the dynamic, energetic and automation regimes of the equipment of the lines for the primary processing of milk with the use of natural and artificial cold.
- elaboration and implementation of automated installations combined with natural and artificial cold with the use of automatic graphs, determination of the duration of use of natural cold in the cold period of the year for the northern region of the Republic of Moldova.
- elaboration of the method and algorithm for the identification of the control equipment of the milk processing system, the non-operation of which leads to the most essential emergency situations and their

evaluation by determining the technological damages.

Research hypothesis.

Based on the development of energy saving technologies, technical means and an electrified system of technological lines for milk processing, the proposed methodology is proposed, according to which the lines are considered as a single complex object of interaction of several elements - technological, energy factors , operational, which influence milk quality and technical, economic and reliability indicators.

The scientific and methodological bases, mathematical models and practical methods for milk processing have been developed, providing an intensification of the milk processing process on farms, while improving its quality. and energy, environmental and operational characteristics.

Synthesis of research methodology consists in the elaboration of the methodology, calculation methods and mathematical models of the milk cooling processes and the accumulation of natural and artificial cold to substantiate the operating regimes and parameters of the system with low electricity consumption with the use of ecological and combined seasonal installations throughout the year. ..

At the same time, the research methodology includes:

- research of the dynamic, energetic and automation regimes of the equipment of the lines for the primary processing of milk with the use of natural and artificial cold.

- elaboration and implementation of automated installations combined with natural and artificial cold with the use of automatic graphs and determination of the duration of use of natural cold in the cold period of the year for the northern region of the Republic of Moldova.

Summary of thesis chapters

Chapter 1 includes the current study and development trends of technological processes and equipment for primary processing of milk using natural and artificial cold. The peculiarities of the meteo-climatic conditions in the north of the Republic of Moldova are analyzed, the electrical equipment, the characteristics of the technological lines and the development trends of the automated technological processes for the primary processing of milk are studied. The purpose and objectives of the research are formulated.

In Chapter 2 the calculation methodology and methods for the formation of automated technological processes with low electricity consumption for the primary processing of milk were elaborated with the substantiation of the parameters

In Chapter 3 mathematical models and methods for calculating technological processes for cooling milk with the use of natural and artificial cold are developed. Mathematical methods have been developed for the process of cooling milk in flow coolers and capacitive coolers by mixing and not mixing the refrigerant in accumulators with natural and artificial cold. The mathematical model and the calculation method of the process of accumulation of natural and artificial cold in the cold accumulator were proposed.

In Chapter 4 the research of the dynamic, energetic and automation regimes of the equipment of the lines for the primary processing of milk with the use of natural and artificial cold is carried out (on the example of the northern region of the Republic of Moldova). The structural-functional schemes, the automatic graphs and the operating algorithms of the ecological seasonal installations and the combined installations for the whole year were elaborated. The results of the evaluation of operating, technological and energy indices are presented. At the same time, the duration of use of seasonal installations with natural cold in the cold period of the year in the north of the Republic of Moldova was determined.

Implementation of scientific results

The research results were implemented at the farm in Corbu village, Dondușeni district and at the UASM farm. The theoretical component of the research is implemented within the project20.80009.5107.04"Adapting sustainable and environmentally friendly technologies for the production and storage of agricultural products" for the period 2020-2023. The theoretical approach of the research carried out is used in the lectures and practical lessons "Renewable energy sources in the agricultural sector ”and“ Design of electrification systems in the agricultural sector ”respectively for students of years 3 and 4, as well as during lectures and practical lessons at the master's degree“ Automation of technological processes in the agricultural sector ”of FIATA within UASM. The research results were published in 2 useful monographs for specialists in the field of energy efficiency in the agricultural sector.

Approval of results obtained andof the theoretical and practical value of the paper were discussed and approved in 8 national and international conferences and 4 scientific seminars at the Faculty of Agricultural Engineering and Auto Transport of UASM The main results of the thesis are presented in 33 publications, including 2 monographs,

The main results of the research were presented, discussed and approved in the annual reports during the extended meeting of the department "Electrification of Agriculture, Mechanics and Basics of Design", of the Faculty ofAgricultural Engineering and Car Transport of UASM, 2018- 2021.

The materials presented in the thesis were presented at the following scientific events: International Scientific-Practical Symposium “Achievements and Perspectives in Agricultural Engineering and Car Transport” Volume 45. 2015. Chisinau, Republic of Moldova; 7-Международной научно-технической конференции молодых ученых и специалистов. Москва: ВИЭСХ, (РИНЦ), 2017. 1 (22) / 2017; MOLDOVA ENERGY International Conference-2016 Regional Development Aspects Edition III. . Chisinau, Republic of Moldova:

ASM, September 29-October 1, 2016;International Scientific Symposium "Achievements and Perspectives in Agricultural Engineering and Auto Transport", dedicated to the 85th anniversary of the founding of the State Agrarian University of Moldova Chisinau 2018;Scientific Conference of Students and Master Students, 73rd EditionState Agrarian University of Moldova Chisinau 2020Международная научно-техническая конференция "Доктрина продовольственной безопасности России: холодильные технологии как основа хранения сельскохозяйственной продукции» 29 июня 2020 года. МГУТУ имени К. Г. Разумовского, Москва, Россия;Scientific Conference of Students and Master Students, 74th editionState Agrarian University of Moldova Chisinau 2021;Symposium "Regulation of the use of natural resources: achievements and perspectives" Dedicated to the 70th anniversary of the founding of the Faculty of Cadastre and Law October 2021; Scientific Conference of Students and Master Students, 75th editionState Agrarian University of Moldova Chisinau 2022.

The most relevant results of the thesis were presented in the national journals “Agricultural Science”, of UASM (2017-2021), and “Journal of Engineering Science” of TUM (2020) and the international journal, EMERG - Energy. Environment. Efficiency. Resources. Globalization ”, AGIR Publishing House, Romania (2020).

The results of the research for the years 2020-2022 within the project "Adaptation of sustainable and ecological technologies for food production and storage in quantitative and qualitative aspects according to the integrity of the crop system and climate change" were discussed and approved at UASM Senate meetings.

The main results of scientific research have been published in the monograph”Возобновляемые источники энергии: состояние, ближайшая перспектива, технология и электрооборудованand in the monograph"The first stage of the construction of the building and the construction of the building site", UASM, Chisinau 2019.

Thesis publications. The research results are reflected in 33 scientific papers, including 2 monographs, 8 articles in international journals and 23 articles in national journals.

The volume and structure of the thesis consists of introduction, 4 chapters, general conclusions and recommendations, bibliography with 125 titles, 6 annexes, 142 pages of basic text, 71figures, 30 tables, 127 formulas.

Keywords: technological line, installation with natural and artificial cold, milk cooling, mathematical models, calculation methods, operating algorithm, automatic graphs.

THESIS CONTENT

The Introduction defines the topicality and topic of the thesis, the purpose and objectives of the paper, the scientific novelty, the theoretical importance and the applicative value of the paper, the main results of the paper, the implementation of the results and their approval.

1. CURRENT STUDY AND DEVELOPMENTAL TRENDS OF TECHNOLOGICAL PROCESSES AND EQUIPMENT FOR PRIMARY PROCESSING OF MILK WITH THE USE OF NATURAL AND ARTIFICIAL COLD.

Chapter I includes:

- peculiarities of the meteorological-climatic conditions in the north of the Republic of Moldova.
- the current study and development trends of automated technological processes and technical means of primary milk processing lines on farms.
- analytical study of the electrical equipment of the technological lines for milk processing and the ways to improve them
- the characteristics of the automated technological lines for milk processing as control objects
- study of the influence of the operating regimes of the electrical equipment on the quality indicators of the processed milk.

- According to the Fifth Report of the Intergovernmental Panel on Climate Change, the average air temperature at the Earth's surface has risen by 0.9 °C over the last 130 years, and on the European continent it is even more significant, amounting to more than 1 °C. Each of the last three decades has been successively warmer than the previous ones, and the first decade of the 21st century has been the warmest in the series of instrumented observations. [1]

Regionally, the average temperature has also undergone significant changes. Thus, in the northern part of the Republic of Moldova it is 9.1 °C (Briceni), while in the southern part (Cahul) it reaches the value of 11.1 °C. According to Fig. 1. the number of days with daytime temperatures below 0ºC in the territory decreases and constitutes on average 77-79 days compared to the previous periods researched when the winter duration varied in the limits of 95 - 105 days in the north, 80-95 days in the center, 75 - 85 days in south [1]

Evolution of maximum, average and minimum temperatures. of the atmospheric air for the years 2011-2020 for mun, Bălți are presented in chapter 4, Fig.4.9 of the thesis. Analogously, the evolutions of the atmospheric air temperatures for the town were obtained. Briceni and the town. Soroca.

Has been established:

-for mun.Bălti the number of days with atmospheric air temperature t ≤0 °C during 10 years varies from 45 days to 116 days.

-for the town of Briceni the number of days with t≤ 0 ^{0}C over a period of 10 years varies from 58 days to 104 days,ΔT = 46 days;

-for the town of Soroca the number of days with t≤ 0 ^{0}C over a period of 10 years varies from 67 days to 99 days,ΔT = 32 days;

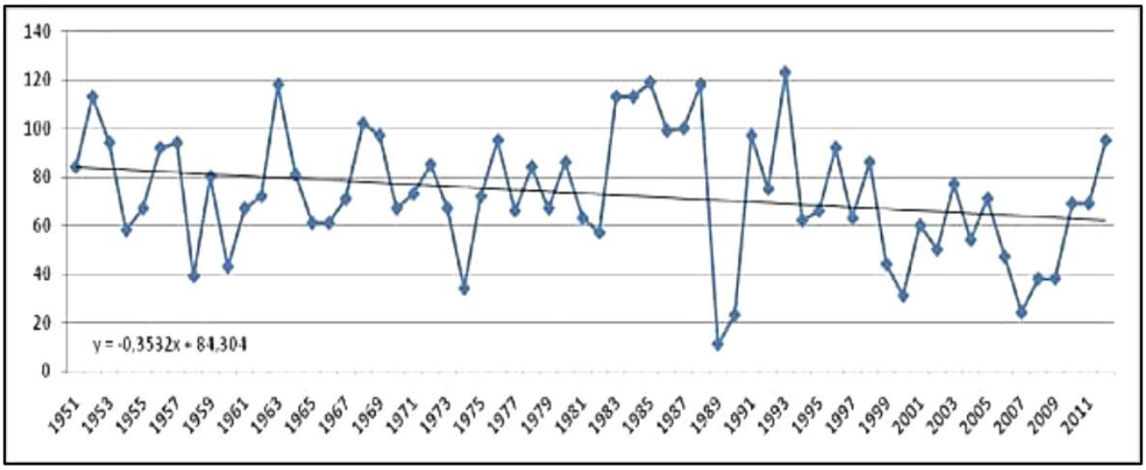


Fig. 1. Number of days with daytime temperatures ≤ 0 °C (number of days, St. Balti) [1]

Existing technological lines for milk processing on farms do not meet the complex of functional, energy, environmental, technical and economic requirements. The equipment used has a large area of contact with the environment. An example of such equipment is the SMI-500 scale with the BM-1000 milk collection tank. All of them have open tanks for collecting and weighing milk. The milk storage and storage system is outdated and should be replaced with modern meters. Cooling the milk to 10 ° C maintains bacteriological stability for 5 ... 6 hours, and up to 4 ... 6 ° C - over 24 hours [7].

The use of the latest technologies and technical means significantly changes the structure technological lines, their modes of operation and their control methods, which leads to a significant complication of the control algorithms of the milk processing process and consequently of the automation systems. Individual units, such as a pump control system for directing milk, refrigerant, and control units for milk mixing devices in the storage process, require a high switching frequency. In this regard, it is necessary to move to a new base of elements with high reliability indicators.

Automated milk processing lines with low electricity consumption that meet modern requirements have become complex multifactorial objects. Therefore, traditional research methods, applicable to relatively simple systems, are inefficient in this case [72,73]. In scientific developments, new research methods using computer technologies, modern achievements in mathematics and electronics are poorly used. Typically, research is limited to considering two-factor simplified models, which does not make it possible to use modern automated systems with complex connections. The results of the paper will allow researchers to master the methods of mathematical modeling of complex systems and the methods of research and optimization of multifactorial processes.

- Currently, the milk processing technology lines are equipped with a large number of intermediate collection and regulation tanks (RCR). Existing devices for the recording and control of milk flows do not meet the requirements for primary milk processing. SMI-500 milk scales with a capacity of BM-1000, used in some farms "break" the process flow. The total capacity of the line is 30% higher than the volumes required for the placement and storage of daily Mz milk production on farms [77]. This increases the contact area of the milk with the surface of the Sec dairy equipment and its air, which affects the quality values of the milk fat, as a significant amount of milk fat is placed on the walls of the RCR dairy equipment. [78.79]
- Thus, the use of control and adjustment devices forthe evidence and pumping of milk makes it possible to reduce the total capacity of the RCR by 6 times, by 1.3 and 12.1 times it allows to reduce the contact surface of the milk with the technological equipment of the line and the surrounding air [101]. At the same time, it reduces the bacterial contamination of milk from 347 to 299 thousand b / ml [102], reducing the necessary production areas and the metal consumption of the technological equipment by up to 30%. The use of devices for controlling and regulating milk flows instead of non-adjustable ones makes it possible to exclude RCR from the technological process of milk processing and ensures its processing in a closed flow with a reduction of 50% of the operator's working time. [103]

2. CALCULATION METHODOLOGY AND PROCESS FORMATION METHODSAUTOMATED TECHNOLOGIES WITH REDUCED ELECTRICITY CONSUMPTION FOR PRIMARY PROCESSING OF MILK WITH THE BASIS OF PARAMETERS

Chapter II includes:

- the method of forming automated technological processes with low electricity consumption in milk processing using natural and artificial cold.
- formation of automated technological lines with low electricity consumption for milk processing on farms.
- calculation methodology and substantiation of the parameters of the system with low consumption of milk cooling electricity with the use of seasonal action installations.
- calculation methodology and substantiation of the parameters of the system with low consumption of milk cooling electricity with the use of combined action facilities throughout the year.

In the scientific methods currently used to analyze the operation of technological lines, they are usually examined autonomously, apart from any connection with the systems that interact with them. In the study of mechanical and energy relationships, the influence of the environment can be neglected. However, when studying the system, taking into account the effect of technological equipment and the environment on the quality indicators of processed milk, on the characteristics of the technological process, a systematic approach is needed, new methods of scientific research, to assess the complex relationships between processes. processing technology, technical means and the environment.

When developing low-power automated technological processes for milk processing, the structure of technological systems and control systems changes significantly. Therefore, new methodological approaches are needed that would allow the processing process to be intensified and take into account the wide variety of complex relationships between technological line connections, including the influence of electrical equipment parameters on milk quality indicators as well as energy requirements. environmental and operational.

In line with the improvement of the values of the parameters of the technology and the technical means of primary milk processing, it is desirable to carry it out in the following directions:

- ensuring the primary processing and transport of milk in 'closed' flows under conditions with a minimum number of adjustable storage tanks, with a minimum contact with the air and the inner surface of the processing equipment.
- the development of environmentally friendly, low-energy sources of natural and artificial cold cooling systems for milk and relatively "cheap" cooling systems due to the use of these sources.
- increase the level of automation and create adjustable links for the processing, transport and storage of dairy products.

In order to substantiate the parameters of the technical means and technologies with low electricity consumption and their operating regimes, including the automated accumulation of natural and artificial cold, a method has been developed, which allows, in the process of synthesizing the systems, to significantly simplify the calculations. and the quantitative assessment of individual links and the line as a whole and therefore significantly reduce the intensity of work in search of optimal solutions.

For a quantitative assessment of low-power technologies, including the automated accumulation of natural and artificial cold, a system of indicators is proposed that may characterize individual links or a technological line as a whole. The method is based on the use of a system of unit indicators C_u, complex C_c and generalized complex indicators C_{cg} that characterize different properties of the studied system.

Unit indicators C_u include indicators that vary during system operation according to a random law (eg milk temperatures $t^\circ{}_{L1}$, refrigerant t° af 1 and ambient air t° 0; storage capacity W_a, etc.). As complex indicators C_c are taken the indicators that characterize the energy properties C_w and economic C_e of the system. The Generalized Complex Indicator (ICG) C_{cg} quantitatively characterizes the absolute technical level of the system as a whole.

The key functions for which the justification and selection of low-energy technologies and technical means are based on two criteria: C_w energetic and C_e economic.

$C_w = C_{cg} \rightarrow \min$, where $C_u \leq C_{per}$ (1)

$C_e = C_{cg} E_v \rightarrow \min$ (2)

where C_{per} is the allowable value of the unit indicator; E_v is a coefficient that takes into account the real economic effect of variant V.

According to the first criterion, the key function is developed when it is necessary to verify the selected energy saving strategy. According to the second criterion, the key function is developed when several strategies for the Cw function have been selected and it is necessary to choose the most efficient one.

In order to form automated technological lines with low electricity consumption and for a rational combination of the use of natural and artificial cold in different localities of the Republic of Moldova, a method is proposed to substantiate the most efficient variant of a low energy cooling system. depending on the variant of completing the line with the machine (with technical means) and the average temperature of the atmospheric air during the cold yearΔ ° Cin the area of the object. The nomogram is represented graphically in the coordinatesC_w - n - Δ ° C, where n is a discrete value of the machine line completion option; The degree of utilization of the potential of natural cold and the optimal combination of cold for natural and artificial in the technological lines in the one-day and annual cycles are determined using the C_w electricity saving module.

$C_w = Q_{fa} / Q_{fn}$, (3)

where Q_{fa}, Q_{fn} is the cooling capacity of the artificial source and the natural cold source, respectively, kW.

The required power of the Nfa a rechargeable refrigeration system of the artificial cold source Qfa, depending on the capacity of the natural and artificial cold accumulators Vacf, is determined from the developed nomogram [10], elaborated in the coordinates Q_{fa}– N_v– V_{acf}, where N_v - the installed power of the electrical equipment of the refrigeration system, kW; V_{acf} is the capacity of the natural and artificial cold accumulator, m 3.

The mathematical description of the functional-structural organization of the system is based on the generalized tree of functions [106] (Table 2.1 in the thesis) and on the structure of automated technological lines with low electricity consumption for milk processing (Table 2.2 in the thesis), taking into account options for supplementing the technical means (Table 2.3 of the thesis) and the existing standard schemes. As a result, the main standard versions of automated technology lines with low electricity consumption for different farms have been formed, which vary in terms of livestock and their productivity, the technology adopted, as well as the architectural and planning solutions (Fig. 2.7 ... 2.13 of the thesis). These variants are a modification of the well-known standard variants [], to which are added new modules (links), including those that use natural cold. A unified set of electrical equipment for such lines will cover all possible varieties and many technological options for the equipment that is used in the Republic of Moldova [56,57].

According to the proposed methodology, in order to verify the main provisions, the elaboration of automated technological processes with low consumption of milk processing electricity was carried out. In order to assess the technical level and select the optimal options for the execution of the technological lines, a set of complex, complex, and generalizing indicators for low-power links and milk evidence links was determined.

It has been established that the use of seasonal actuators (IAS) is recommended if the temperature of the refrigerant in the accumulator does not exceed 4 °C. The storage capacity of the IAS must ensure that the milk cools from the first milking. The time between milking should be sufficient to charge the natural cold storage (AFN) battery. The capacity of the tank determines the storage capacity of the IAS.

The combined cooling system (IAC) milk cooling system provides for the use of both natural and artificial refrigeration, generated by a rechargeable refrigeration system (IF).

In the cold season, the plant operates as an IAS. In the hot season, the IF cools the agent in the AF cold storage battery, which is then used to cool the milk. The stationary one, which is in operation on the farm, can be used as IF, as well as the rechargeable one, with a cooling capacity, including at night, using a preferential tariff for electricity. The connection and disconnection of the IF is carried out by a time control or by a control from the temperature sensors of the refrigerant in the combined battery. The required power of the IF depends on its operating mode together with the AF

Cooling technology does not require changing the existing patterns and equipment used to cool the milk.

Based on the analysis performed was proposed the method of determination of technical and energy characteristics of a line with reduced consumption of electrical energy.

3. MATHEMATICAL MODELS AND METHODS OF CALCULATING TECHNOLOGICAL PROCESSES FOR COOLING MILK WITH THE USE OF NATURAL AND ARTIFICIAL COLD.

Chapter III includes:

- milk cooling regimes and accumulation of natural and artificial cold.Technological requirements and restrictions.
- the mathematical model and method of calculating the process of cooling milk in a flow cooler by mixing the refrigerant in the cold storage.

- mathematical model and method of calculating the process of cooling milk in a flow cooler without mixing the refrigerant in the cold storage.
- the mathematical model and method of calculating the cooling process of milk in a capacitive cooler by mixing the refrigerant in the cold storage.
- the mathematical model and method of calculating the cooling process of milk in a capacitive cooler without mixing the refrigerant in the cold storage.
- the mathematical model and method of calculating the process of accumulation of natural and artificial cold in the cold accumulator.

In order to justify the parameters and efficient operating regimes of a low-power cooling system with IAS and IAC, two main regimes have been investigated:

- milk cooling regime using batteries with natural and artificial cold (AF)

$$C_A = f\,(t^0_{Ll}, t^0_{L2}, t^0_{af1}, t^0_{af2}, t^0_0, q_{af}, T_r, M_L), \qquad (4)$$

where C_A is the ratio of the amount of water (refrigerant) in the V_{acf} cold storage to the amount of chilled milk M_L; t^0_{Ll} - initial temperature of milk, before cooling, 0_C; t^0_{L2} - final milk temperature, after cooling, ^0C; t^0_{afl} is the temperature of the refrigerant at the inlet to the outlet or at the outlet of the cold storage and evaporator of the refrigeration system, ^0C; t^0_{af2} is the temperature of the refrigerant at the exit of the cooler, ^0C; t^0_o - atmospheric air temperature (outside), ^0C; q_{af} is the productivity of the AF refrigerant pump, (m^3 / h); T_r is the cooling time of the milk, h; M_L - the amount of chilled milk, m^3;

- kingsaccumulation of natural and artificial cold

$$Q_S = f\,(t^0_{Ll}, t^0_{L2}, t^0_{afl}, t^0_{af2}, t^0_0, q_{af}, T_p, T_a, M_L), \qquad (5)$$

where Q_S is the cooling capacity of the system: or of the rechargeable refrigeration system, thousand kcal / h; Tp- break time between milking, h; Yours is the duration of cold accumulation, h

In order to develop mathematical models of milk cooling processes, cold storage and energy balance analysis of the system, the following technological requirements and restrictions are introduced:

1. The final temperature of the milk at the outlet of the chiller in flow after cooling t^0_{L2} differs from the temperature of the water (refrigerant) at the inlet

in t^0_{af1} flow cooler with 2^0C [ ]

$$t^0_{L2} = t^0_{af1} + 2. \qquad (6)$$

2. From the operating conditions of the flow cooler, it results

$$q_{af} / q_l = 3, \qquad (7)$$

q_l- milk pump productivity, m 3 / h; q_{af} - refrigerant pump productivity, m^3 / h;

3. The temperature of refrigerated milk t_{L2} must not exceed 6°C.

$$t^0_{L2} < 6°C; \qquad (8)$$

4. The cooling time of Tr milk must not exceed 2 hours

$$T_r < 2 \text{ hours}; \qquad (9)$$

5. The milk entering for cooling is pre-cooled to 16 ° C

$t^\circ_{L1} = 16^\circ C$; (10)

6. The duration of accumulation of cold Ta must not exceed the duration of the break between milking Tp: for two milking - 10 hours; for three milks - 4 hours.

$T_a < 10$ h - for two milks, (11)

$T_a < 4$ h - for three milks. (12)

7. We neglect the heat loss, $\Delta Q = 0^\circ C$,

8. At the first stage of the milk cooling process, the initial temperature of the refrigerant t° af 1 is considered to be equal to the temperature of the outside air t° 0, provided that 0<t °0 <3°C

$t^\circ_{af1} = t^\circ 0,\ 0 < t^\circ 0 < 3^\circ C$. (13)

9. C_{TL}, C_{TA} - the specific thermal capacities of milk and water, respectively, kJ / (m^3 · °C), we consider them equal $C_{TL} = C_{TA}$.

10. When filling the capacitive cooler to half its capacity, the cooling time T_r must not exceed 2 hours, ie

$T_r < 2$ hours; $M_L = 1.25T$; $T_r = 3T$, (14)

where T is the constant cooling time, h (3T = 2 h, T = 0.67 h)

11. The heat transfer coefficient during the cooling process is equal to 1.87 kcal/h·m^2·°C[]

$c = C_{TL} / T = 1.25 / 0.67 = 1.87$ kcal / h · m^2 ·°C (15)

12. V_r of the capacitive cooler is taken according to the passport data and is equal to 0.25m^3

$V_r = M_L / 5 = 0.25\ m^3$ (16)

The process of cooling milk in a flow cooler by mixing the refrigerant in AF and how cold is stored in AF was examined in order to determine the amount of refrigerant needed to cool 1 tonne of milk to 6°C. and the refrigerating capacity of the QIF refrigeration system

The point of intersection of the two curves $C_A = f(t^\circ_{af1})$ and $C_A = f(t^\circ_{af1})$ (Fig. 2) is a solution to the given problem and a rational variant of the milk cooling process in a chiller in flow by mixing the refrigerant in an accumulator with natural cold.

$$C_A = [\mathrm{In}(\frac{t^o_{L1} - t^o_0 - 2}{t^o_{L1} + 2t^o_{af1} - 2})]^{-1} = [\mathrm{In}(\frac{11}{13 - t^o_{af1}})]^{-1}, \quad (17)$$

$$C_A = \frac{V}{M_L} = \frac{t^o_{L1} - t^o_{L2}}{t^o_{af1} - t^o_0} = \frac{9}{t^o_{af1} - 2}. \quad (18)$$

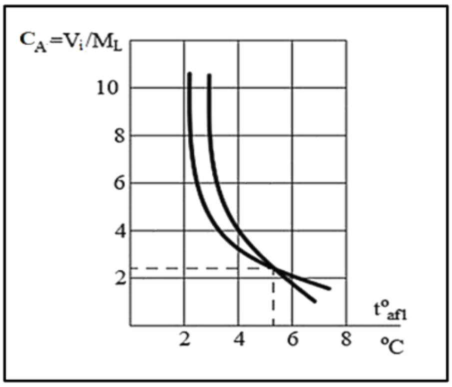


Fig. 2 Dependence of the AC ratio of the volume of refrigerant in the cold storage tank V to the amount of chilled milk ML on the temperature of the refrigerant in the storage room with natural cold t°_{af1}

For two milks a day

Q_{af} = [M_L($t^0_{L\,1}$ - 6)] / T_a = [10^3 (16 - 6)] / 10 = 0, 9 thousand kcal/h

For milking technology three times

Q_{af} = [M_L($t^0_{L\,1}$ - 6)] / T_a = [10^3 (16 - 6)] / 4 = 2,5 thousand kcal/h

Thus, compared to the traditional method of cooling the milk, the artificial accumulation of cold in the breaks between milking makes it possible to reduce the cooling capacity of the refrigeration system 5 times in the case of two milks and 2 times in the case of three milks per day.

If the cold reserve in supercooled milk t°_{L2} = 4 ... 6°C (approximately 2°C) is actually used, it is possible to add milk heated to t°_{Ll} = 16°C and thus milk with t°_{L2} = 6°C. In this case, the temperature of the refrigerant in the AF will increase by more than 4°. Under these conditions, it is possible to determine the productivity of the qaf refrigerant pump, which ensures the optimum cold storage regime at the refrigeration system (AF reload regime).

$$q_{\,af} = \frac{C_A \cdot M_L}{4} \cdot \mathrm{In}\frac{t^\circ_{sr} - 2}{t^\circ_{sa} - 2}, \qquad (19)$$

where q_{af} is the productivity of the refrigerant pump in the cold storage regime of the refrigeration system or the productivity of the refrigerant pump of the refrigeration system, (m^3 / h); t° sr is the temperature of the refrigerant in AF at the end of cooling the milk, °C; t° sa - the temperature of the refrigerant at the end of storage, °C.

La $t^\circ_{L\,1}$= 16 °C și $t^\circ_{L\,2}$= 6 °C, we obtain

$$C_A = \left[\mathrm{In}\frac{t^\circ_{L1} - t^\circ_{sa} - 2}{t^\circ_{L1} - t^\circ_{sr} - 2}\right]^{-1} = \left[\mathrm{In}\frac{14 - t^\circ_{sa}}{14 - t^\circ_{sr}}\right]^{-1}, \qquad (20)$$

$$C_{A1} = \frac{V}{M_L} = \frac{t^\circ_{L1} - t^\circ_{L2}}{t^\circ_{sr} - t^\circ_{sa}} = \frac{10}{t^\circ_{sr} - t^\circ_{sa}}. \qquad (21)$$

By setting the temperature of the refrigerant at the end of its accumulation t°_{sa}, it is possible to determine the value t°_{sr} at which C_A = C_{A1}, the results of the calculation are shown in Fig. 3. which shows the dependencies C_A=f (t°_{sa}) and q_{af} = f (t°_{sa}) for different values of processed milk M_L.

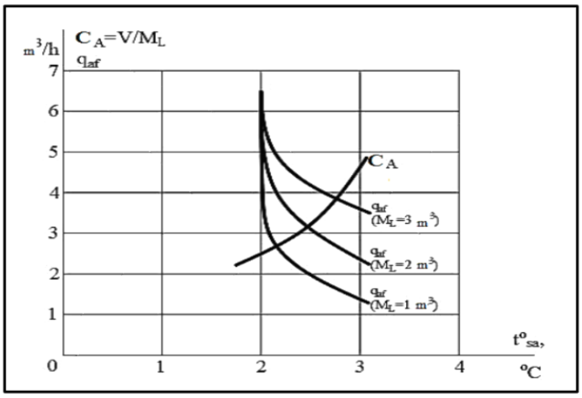


Fig. 3. Dependence of the productivity of the refrigerant pumps q_{af} and C_A on the ratio of the volume of the refrigerant in the accumulator V to the quantity of chilled milk M_L of the final temperature of the refrigerant during the accumulation of cold $t°_{sa}$

As can be seen from the graph, with an increase in the value of the storage temperature $t°_{sa}$, the productivity of the q_{af} refrigerant pump decreases exponentially, and the C_A ratio increases. If we start from the condition that $q_{af} = C_A$, then the points of intersection of the curves are the optimal option for choosing the parameters of the refrigerant pump and the final temperature of the refrigerant during the accumulation of cold $t°_{sa}$ during T_a.

Thus, when the refrigerant is mixed in AF, the actual use of the cold reserve in the supercooled milk allows to reduce the ratio between the volume of the refrigerant and the amount of chilled milk 2.1 times and the productivity of the qaf refrigerant pump of 1.4 ... 1.7 times compared to the method of cooling milk, when the cold reserve of overcooled milk is not used.

The process of cooling the milk in a flow cooler with non-mixing cooling of the refrigerant in AF was analyzed to determine the amount of refrigerant required to cool 1 tonne of milk to 6 ° C and the refrigerating capacity of the refrigeration system. Q_{IF}

In the non-mixing mode of the refrigerant in AF during milk cooling with a refrigerant having a temperature t_{afl} = 2..4°C, the temperature of the chilled milk will be below 6°C (t L 2 <6 °C), because some from the cold it will disappear with the cooled milk. For optimal use of the cold reserve and to ensure that the milk cools to 6°C ($t_{L2} = 6°C$), the ratio between the amount of refrigerant V and the amount of chilled milk ML must be equal to

$$C_A = \frac{V}{M_L} = \frac{t^o_{L1} - 6^oC}{t^o_{L1} - t^o_{L2}} = \frac{3 \cdot (t^o_{L1} - 6^oC)}{t^o_{L1} - t^o_{af1} - 2} \qquad (22)$$

Then, taking into account the technological requirements and constraints adopted previously we get

$$C_A = \frac{V}{M_L} = \frac{3 \cdot (t^o_{L1} - 6^oC)}{t^o_{L1} - t^o_{af1} - 2} = \frac{3 \cdot (16-6)}{16-2-2} = 2{,}5, \qquad (23)$$

$$t^0_{af\,2} = (t^0_{L\,1} + 2\, t^0_0 - 2) / 3 = 6{,}0\ °C, \qquad (24)$$

$$q_{af} = V / T_a = (C_A \cdot M_L) / T_a = (2{,}45 M_L) / 4 = 0{,}63 M_L \qquad (25)$$

In Fig. 4 shows the dependence $C_A=f(t_{af1})$ obtained under the limit conditions indicated in the thesis.

Thus, the required ratio of the volume of refrigerant to the amount of chilled milk for cooling 1 ton of milk to 6°C will be 2.46, at $t°_0 = 2°C$. The temperature of the refrigerant in the AF at the end of the cooling process will be $t°_{af2} = 6.0$ °C. With the efficient use C_A of the cold reserve in supercooled milk, the ratio between the amount of refrigerant and the amount of A_C refrigerated milk and the productivity of the refrigerant pump in the cold storage mode qaf la in unmixed mode will be reduced by 1.2 times. .

Compared to the refrigerant mixing regime in AF, the refrigerant non-mixing regime allows a 3.3-fold reduction in the productivity of the refrigerant pump in the cold storage regime q_{af} and, consequently, in the refrigeration capacity of the refrigeration system.

The process of cooling the milk in a capacitive cooler by mixing the refrigerant in AF and the cold storage regime in AF were examined to determine the amount of refrigerant needed to cool 1.25 tonnes of milk to 6°C. and the cooling capacity of the Q_{IF} refrigeration system

As a result, it was found that for cooling milk in a capacitive cooler from 16°C to 6°C by mixing the refrigerant in AF for 2 hours, the optimal C_a ratio between the volume of refrigerant V and the amount of chilled milk M_L would must be $C_a = 3$, and the productivity of the refrigerant pump is $q_{af} = 4\ m^3 / h$. In this case, the temperature of the refrigerant must be $t°_{af1} = 2.4°C$. In the cold storage regime of the refrigeration system, the productivity of the qaf refrigerant pump is reduced 2 times and is $q_a = 2\ m^3/ h$.

The cooling capacity of the Q_{IF} refrigeration system of the cooling system for cooling 1 tonne of milk for the whole cycle to $T_p = T_r = 2h$ for existing standard lines will be

$Q_{IF} = [\ M_L \cdot (\ t^0_{L\,1} - 6\ )\ ] / T_p = [\ 1{,}25 \cdot (\ 16 - 6\ )\ ] / 2 = 6, 25$ thousand kcal / h

For cooling systems using a natural cold accumulator, the cooling capacity of the Q_{IF} refrigeration system for its recharging is determined taking into account the accepted technological requirements and the restrictions set out above. Given that $T_a < 10$ hours - for two milks per day, $T_a < 4$ hours - for three milks per day, respectively, we obtain:

For two milking technology

$Q_{IF} = [\ M_L \cdot (\ t^0_{L\,1} - 6\ )\ ] / T_a = [\ 1{,}25\ (\ 16 - 6\ )\ ] / 10 = 1{,}25$ thousand kcal / h

For three milking technology

$Q_{IF} = [\ M_L \cdot (\ t^0_{L\,1} - 6\ )\ ] / T_a = [\ 1{,}25\ (\ 16 - 6\ )\ ] / 4 = 3, 13$ thousand kcal / h

Thus, compared to the traditional method of cooling the milk, the artificial accumulation of cold in the breaks between milking makes it possible to reduce the cooling capacity of the refrigeration system by about 5 times for two milks and about 2 times for three milks.

Table 1 shows the comparative characteristics of the parameters of the natural and artificial cold accumulator: the ratio between the volume of the refrigerant and the volume of C_A chilled milk, the productivity of the qaf refrigerant pump for reloading AF and the storage temperature t° $_{af1}$, depending on the cooling method. of milk. The most effective is the non-mixing refrigerant regime, which allows the accumulation of cold up to a lower temperature ($t°_{af1}$ = 2°C) with a minimum ratio of refrigerant volumes to milk (C_A = 2.5) . With the efficient use of the cold reserve in supercooled milk, the ratio of the amount of refrigerant to the amount of C_A refrigerated milk and the productivity of the q_{af} refrigerant pump during the accumulation of cold in the unmixed refrigerant mode,

Table:1Comparative characteristics of cold storage parameters, refrigerant pump productivity for AF reloading and storage temperature by milk cooling method.

Cold battery parameters	Cooling method			
	Flow cooler		Capacitive cooler	
	With mixing	No mixing	With mixing	No mixing
C_A	3.0	2.45	3.0	1.9
$t°_{af1}$,° C	2.4	2.0	2.4	2.0
q_{af}, m3 / h	2.0-ML	0.63-ML	2.0	0.6

The full correspondence between the charging time of the AF and the quantity of chilled milk can be obtained if, depending on the quantity of milk and its temperature, the setting of the charging time is changed, with a specific minimum consumption of electricity. In order to implement such a regulatory law, it is necessary to use a microcontroller, which controls the milk record and directs its processing .

4. STUDY OF THE DYNAMIC, ENERGY AND AUTOMATION REGIMES OF THE LINE EQUIPMENT FOR THE PRIMARY PROCESSING OF MILK WITH THE USE OF NATURAL AND ARTIFICIAL COLD (FOR EXAMPLE OF THE NORTHERN REGION OF THE RM).

Chapter IV includes:

- research of the dynamic regimes of the technological line for milk processing with low electricity consumption.
- research on the energy regimes of the technological lines for milk processing.
- investigation of damages in cases of refusal of the electrical equipment system of the technological lines for primary milk processing.
- determining the duration of use of installations with natural cold for cooling milk in the cold period of the year in the north RM.
- elaboration of structural-functional schemes, automatic graphs and algorithms for the operation of ecological seasonal installations and combined installations for the whole year with the use of natural and artificial cold.

- the results of the evaluation of the operating, technological, energy and prospects for the use of installations with natural and artificial cold.

- Analyzethe dynamic operating modes of the technology line machine with low-power technology indicate that the air separator milk pump 1 control unit, distributor pump 2, coolant pump 3, and thermos tank mixing device , has a high frequency of operations ($3 * 10^{-5}$ - $2 * 10^{-6}$ operations) [ ], which in the process of using the relay-based machine through contacts affects the operability and reliability of the electrical equipment of the links and of the whole system as a whole. . Therefore, in order to improve the quality of operation of the line, its reliability, it is necessary to use indicators of high reliability, using combined control circuits, including relay contact elements and contactless elements made on integrated circuits.

- In Fig. 4.3 ... 4.5 of the thesis are presented the diagrams of the electricity flows of a typical technological line and, respectively, of a line with low electricity consumption, for the hot and cold seasons of the year. The values of the obtained electricity flows are indicated in tables 4.1, 4.2, 4.3 and 4.4 of the thesis.

The analysis of the components of the energy balance equation shows that there are reserves for improving the energy characteristics of the technological lines for milk processing. These reserves include the use of the thermal energy of the milk supplied for processing ΣW_1 (average 266 kWh / day). The use of natural cooling of air and water to cool milk is also a great reserve. This operation consumes an average of 282 kWh per day, which represents 28% of the total amount of energy consumed by the line for daily processing of milk.

In the cold season, the use of natural cold systems allows milk to be cooled without the use of toilet compressors, W_{AP} circulating water pumps and W_4 cooling tower fans. In addition, with this technology, the need for a cooling tower disappears as the condenserThe refrigerator is cooled by running water, which is heated during the cooling process and is intended for the technological needs of the farm.

In the hot season, due to the preliminary cooling of the milk, the energy consumption for its cooling is reduced by about 40%, and the cooling capacity and the installed capacity of the refrigeration machine are reduced by 2 times. This saves at least 155 kWh of electricity per day.

The comparative energy characteristics of a typical milk processing technology line and of a low-power line are shown in Table 4.4. from the thesis

Thus, the use of natural and artificial cold accumulators in the technological lines for milk processing, generates a great economic effect and does not require significant capital costs and modifications of the existing electrical equipment systems.

- In order to reduce the impact of damage caused by failure of line links and the system of electrical equipment operating in real farm conditions, the reliability of the links should be increased through the use of combined control systems using contactless elements and contact relays, made in a specially protected design and with a high probability of operation without refusals. With this base of elements we have the possibility to reduce the value of the damages by about 5 ... 10 times [33,106].

- The duration of use of natural cold installations for cooling milk in the north of the Republic of Moldova was determined using data from the last 10 years from the weather stations in Balti municipality, t. Briceni and the town. Soroca. Installations with natural cold (water accumulators) can be used up to t temperature≤ 0 0C in water mixing regime in the designated installations and up to t≤ 5 ^{0}C in non-mixing water mode.

In Fig.4.9 of the thesis are presented data on the atmospheric air temperature during the cold period of the year, for the years 2011-2020, mun. Bălți and analogous for t. Soroca and town. Briceni. As an example, Fig. 4 shows the values of atmospheric air temperatures for the cold period of the year (November, December) 2020.

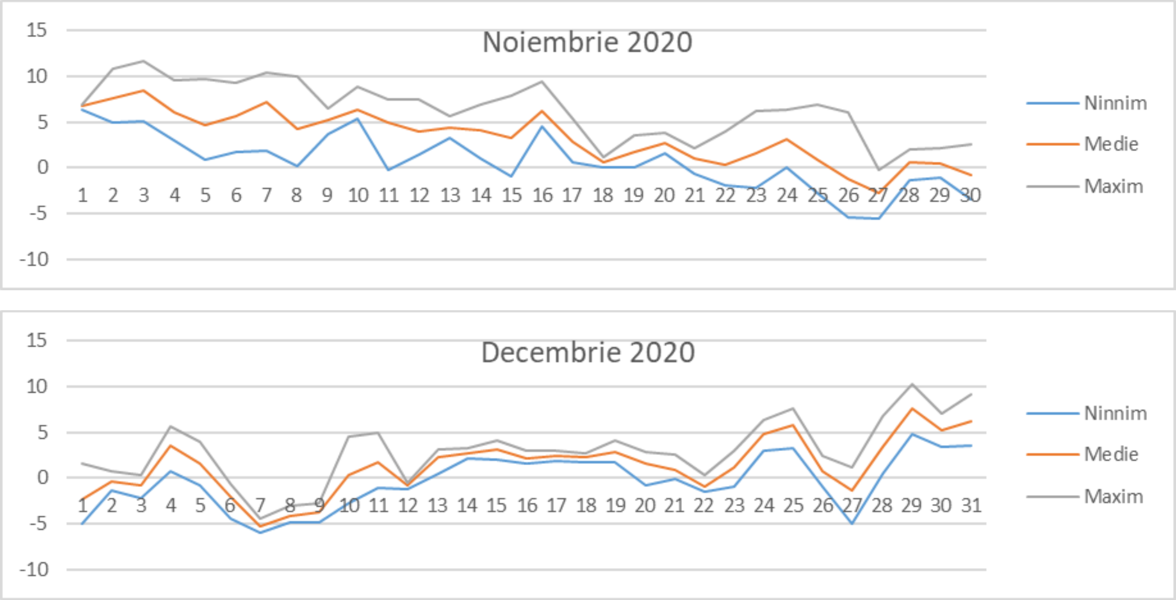


Figure 4 Atmospheric air temperatures during the cold period of the year 2020, Bălți municipality

Tables 4.7, 4.8 and 4.9 of the thesis show the number of days in the cold period of the year with t ≤ 0 ^{0}C andt ≤ 5 ^{0}C for the years 2011-2020, respectivelymun. Bălți, or. Briceni and the town. Soroca.

For the municipality of Bălți (Tab.4.7):

- the number of days with t ≤ 5 ^{0}C over a period of 10 years varies from 136 days to 182 days;
- the number of days with t ≤ 0 ^{0}C for 10 years varies from 45 days to 116 days;

It was found that for the north of the Republic of Moldova (mun. Bălți, or. Briceni and the town. Soroca),the use of installations with natural cold in a non-mixing mode of water in the installation is possible from 4.5 months to 6 months.

In mixed water mode in installations with natural cold they can be used only from 45 days (1.5 months) to 116 days (3.9 months).

The non-mixing regime of water in installations with natural cold allows to increase the duration of use of installations in the north of the Republic of Moldova by 1.5 - 3 times compared to the mixing regime of water.

- Structural-functional schemes for cooling milk with the use of natural and artificial cold are presented in Fig.5 In the cold period of the year for atmospheric air temperature cooling of milk takes place from the water accumulator 3, Fig.5.a In the warm period of cooling water in the accumulator 3 takes place from the refrigeration installation 2, Fig.5.b

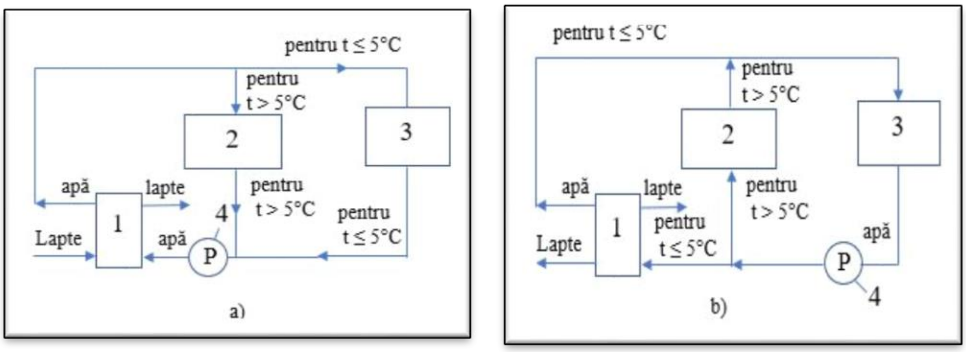


Fig.5 Structural-functional schemes for cooling milk using natural and artificial cold. a- with seasonal installation; b- with combined installation for the whole year.

1-flow cooler; 2-refrigeration system with compressor; 3-water accumulator; 4-water pump. In Fig.6 and Fig,7 are presented the technological scheme with the use of seasonal operating installations (IFS) and the technological scheme with the use of combined operating installations for the whole year.

The automatic graphs elaborated according to the seasonal installation for cooling the milk with flow coolers are presented in Fig. 4.13-4.16 from the thesis. As an example are shown Fig.8 and Fig 9.

The automatic graphs elaborated according to the combined installation for cooling the milk with flow coolers are shown in Fig. 4.16-4.20 from the thesis.

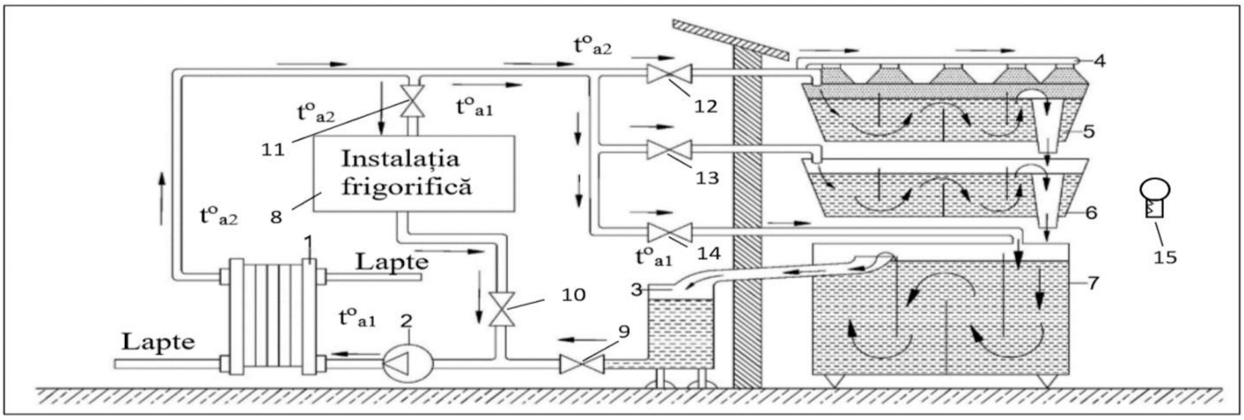
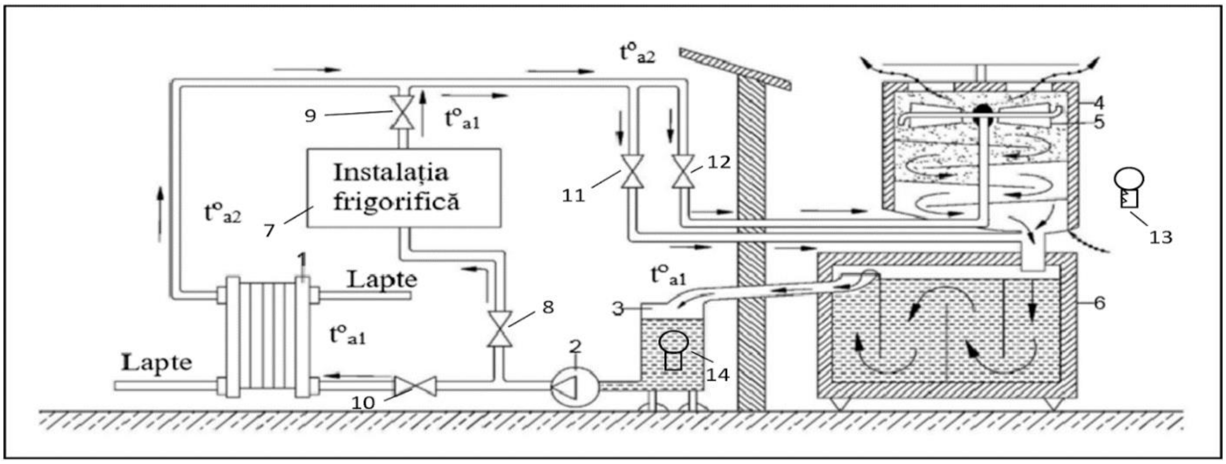


Fig.6 Technological scheme of a low-consumption milk cooling system with the use of seasonal operating facilities (IFS) for the northern region of the Republic of Moldova 1 - flow cooler; 2 -

pump; 3 - intermediate tank; 4 - natural cold battery (AFN) spray block; 5 - the upper tank of the AFN; 6 - the migloc tank of AFN; 7- the lower tank of the AFN. 8-refrigeration 9,10,11 12,13 and 14-electric valves, 15-air temperature transducer, refrigerant; refrigerant from IF



,

Fig. 7 Technological scheme of a low-consumption milk cooling system using combined operation facilities (IFC) for the northern region of RM 1 - flow cooler; 2 - pump; 3 - intermediate tank; 4 - spray block; 5 - spray pipes with aerodynamic plates; 6 - natural and artificial cold storage. 7-, refrigeration system, 8,9,10,11 and 12-electric valves, 13-air temperature transducer
→ refrigerant; --- → artificial cold storage regime; → air

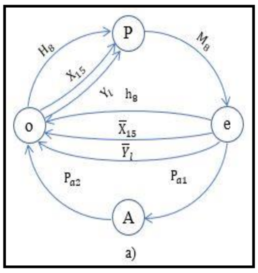


Fig. 8 Automatic graph of the M_8 refrigeration system

where: O; P; IT; A - operating conditions of the M_8 refrigeration system, respectively shutdown, start-up, operation and breakdown;

M_8 - refrigeration system (with compressor);

H_8 and h_8 - respectively the start and stop command;

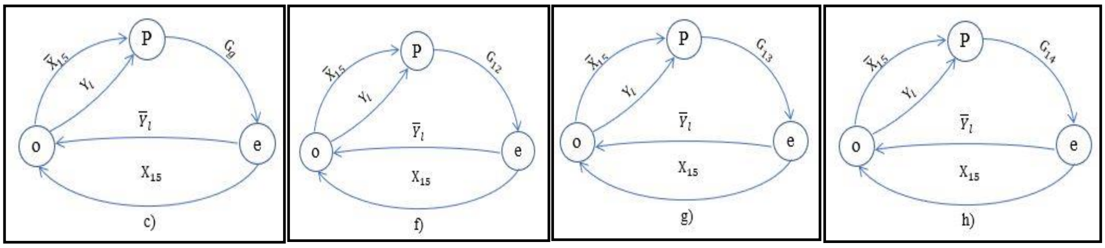
$\bar{h}_8$ - no signal from the stop button;

x15, x̄15– the presence and absence of the signal from transducer 15;

Y_1,$\bar{Y}$- presence and absence of signal from pump 1;

Pa1 and Pa2 - the presence of emergency signals;

$\bar{P}a_1$ and $\bar{P}a_2$ - lack of emergency signals;



c) f) g) h)

Fig.9 Automatic graph of valves 9, 12, 13 and 14 in the thesis

where: O; P; L; - operating states of valves 9,12, 13 and 14, respectively stop, start and work; X15, X̄15 - the presence and absence of the signal from the atmospheric air temperature transducer 15;

Y_1,Ȳ- presence and absence of signal from pump -1;

Based on the automatic graphs and logical algebra, the operating algorithms of the ecological seasonal installation and the combined installation for cooling the milk all year round with the use of natural and artificial cold were developed.

Operating algorithms according to automatic graphs Fig. 4.13 ... 4.16 and Figs. 4.17 ... 4.20 of the thesis have the form:

- Ecological seasonal installation algorithms for cooling milk in flow coolers.

$$Y_8 = (H_8 + X_{15} \cdot Y_l) \cdot \bar{h}_8 \cdot \bar{P}_{a1} \cdot \bar{P}_{a2} \cdot M_8$$
$$Y_2 = (Y_l + H_2) \cdot \bar{h}_2 \cdot \bar{P}_{a1} \cdot \bar{P}_{a2} \cdot M_2$$
$$Y_9 = \bar{X}_{15} \cdot G_9;\ Y_{10} = X_{15} \cdot G_{10};\ Y_{11} = X_{15} \cdot G_{11};$$
$$Y_{12} = \bar{X}_{15} \cdot Y_l \cdot G_{12};\ Y_{13} = \bar{X}_{15} \cdot Y_l \cdot G_{13};\ Y_{14} = \bar{X}_{15} \cdot Y_l \cdot G_{14};$$

- Combined plant algorithms for cooling milk in year-round flow coolers.

$$Y_7 = (H_7 + X_{13} \cdot Y_l) \cdot \bar{h}_7 \cdot \bar{P}_{a1} \cdot \bar{P}_{a2} \cdot M_7$$
$$Y_2 = (Y_l + H_2) \cdot \bar{h}_2 \cdot \bar{P}_{a1} \cdot \bar{P}_{a2} \cdot M_2$$
$$Y_8 = X_{13} \cdot Y_l \cdot G_8;\ Y_9 = X_{13} \cdot Y_l \cdot G_9;\ Y_{10} = Y_l \cdot G_{10};$$
$$Y_{11} = (X_{13} + Y_l) \cdot G_{11};\ Y_{12} = (X_{13} + Y_l) \cdot G_{12};$$

Analogously, the automatic graphs were elaborated. 4.21 ... 4.28 of the thesis and the operating algorithms for cooling milk in capacitive coolers.

- Ecological seasonal installation algorithms for cooling milk in capacitive coolers.

$$Y_8 = (H_8 + X_{15} \cdot X_{16}) \cdot \bar{h}_8 \cdot \bar{P}_{a1} \cdot \bar{P}_{a2} \cdot M_8$$
$$Y_2 = (X_{16} + H_2) \cdot \bar{h}_2 \cdot \bar{P}_{a1} \cdot \bar{P}_{a2} \cdot M_2$$
$$Y_9 = \bar{X}_{15} \cdot X_{16} \cdot G_9;\ Y_{10} = X_{15} \cdot X_{16} \cdot G_{10};\ Y_{11} = X_{15} \cdot X_{16} \cdot G_{11};$$
$$Y_{12} = \bar{X}_{15} \cdot X_{16} \cdot G_{12};\ Y_{13} = \bar{X}_{15} \cdot X_{16} \cdot G_{13};\ Y_{14} = \bar{X}_{15} \cdot X_{16} \cdot G_{14};$$

- Combined plant algorithms for year-round cooling of condenser milk in capacitors.

$$Y_7 = (H_7 + X_{13} \cdot X_{14}) \cdot \overline{h}_7 \cdot \overline{P}_{a1} \cdot \overline{P}_{a2} \cdot M_7$$

$$Y_2 = \left(H_2 + X_{14} \cdot \overline{X}_{13}\right) \cdot \overline{h}_2 \cdot \overline{P}_{a1} \cdot \overline{P}_{a2} \cdot M_2$$

$$Y_8 = X_{13} \cdot X_{14} \cdot G_8; Y_9 = X_{13} \cdot X_{14} \cdot G_9; Y_{10} = X_{14} \cdot G_{10};$$

$$Y_{11} = \left(\overline{X}_{13} + X_{14}\right) \cdot G_{11}; Y_{12} = \left(\overline{X}_{13} + X_{14}\right) \cdot G_{12};$$

In Fig.10 is presentedthe seasonal installation with natural cold for cooling the milk from the farm from Corbu village, Dondușeni district, andin Fig. 11 - the installation combined with natural and artificial cold for the whole year,

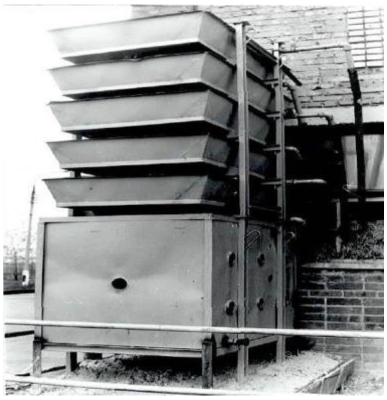


Fig. 10 Seasonal installation with natural cold (farm from Corbu village, Dondușeni district)

It was established that for **t = 3… 4 °C** and the number of sections **n = 6** the temperature of the chilled milk is 5.6… 6.0 °C, so it does not exceed the required milk storage temperature. For the number of sections **n = 5** the temperature of chilled milk exceeds 6.0°C (6.3… 6.5 °C)

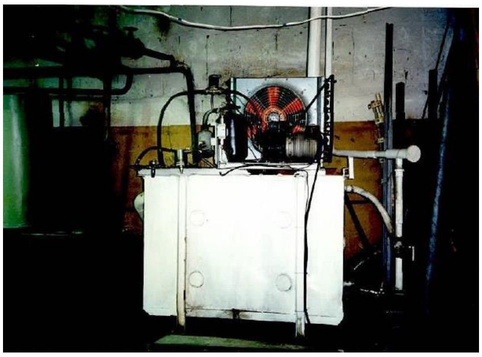


Fig. 11 Combined installation with natural and artificial cold (farm from Corbu village, Dondușeni district).

The specific electricity consumption for milk cooling (kwh/t) using the natural cold accumulator in the cold period of the year is presented in table 2.

Tabelul 2 The specific electricity consumption for milk cooling (kwh/t) using the natural cold accumulator in the cold period of the year. (t ≤ 0°C)

Date	Atmospheric air temperature, ^{0}C	The amount of milk milked daily, t	Daily electricity consumption, kWh	Specific electricity consumption, kWh/t
05.02.21	-2	0,4	0,24	0,6
06.02.21	-6	0,3	0,21	0,7
07.02.21	-5	0,3	0,21	0,7
08.02.21	-8	0,4	0,24	0,6
09.02.21	-6	0,4	0,32	0,8
10.02.21	-3	0,4	0,28	0,7

The results of the evaluation of the energy indices from the farm from the village of Corbu r-nul Donduseni are presented, Tab 3.

Table 3.Energy indices of the installation

Cooling mode	Experimental clues						Calculation indices	
	temperature			power, kw	working time, h	Energy consumed, kw.-h	Mass of chilled milk, t	Specific electricity consumption, kW.h/t
	Temperature air 0C	milk temperature, 0C						
		initial	the final					
1. Cooling the milk using the cold accumulator, (cold period of the year)	-1 ... - 4	16	6	1.5	0.4	0.6	0.4	1.5
2. Cooling milk using a refrigeration system (cold period of the year)	-1 ... - 4	16	6	2.5	3.0	7.5	0.4	18.75
Cooling the milk using a refrigeration system (Warm period of the year)	21	16	6	2.5	6.0	15	0.4	37.5
Cooling the milk using a refrigeration system and a cold accumulator (Warm period of the year)	21	16	6	2.5	3.2	8.0	0.4	20.0

In the future, given that the Republic of Moldova is an agricultural country, it is extremely important to use natural and artificial cold and to store fruits and vegetables. In this field I have published over 15 scientific articles [33,35,36,37,39 , 42,47,48,49,50,52,62.81,82,85,103 of the thesis], including 2 monographs.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The lack of a systematic scientific basis on the issue of obtaining high-quality dairy products on farms prevents the development of concrete, substantiated proposals and recommendations for the development of progressive automated milk processing technologies. New methodological techniques and practical methods are needed for the synthesis of low-power automated technologies, technical means and a unified system of electrical equipment, which will ensure the intensification of the milk processing process on farms and which will guarantee the production of dairy products of the required quality. with improved energy, environmental and operational characteristics.

A systemic approach is needed between the technological processes of primary milk processing, the technical means and the environment.

2. For a quantitative assessment of low-power technologies, including the automated accumulation of natural and artificial cold, a system of indicators is proposed that may characterize individual links or a technological line as a whole. The method is based on the use of a system of unit indicators C_u, complex C_c and generalized complex indicators C_{cg} that characterize different properties of the studied system.

Unit indicators C_u include indicators that vary during system operation according to a random law (eg milk temperatures $t°_{L1}$, refrigerant $t°_{af1}$ and ambient air $t°_{0}$.). As complex indicators C_c are taken the indicators that characterize the energy properties C_w and economic C_e of the system. The Generalized Complex Indicator C_{cg} quantitatively characterizes the technical level of the system as a whole.

3. When forming automated technological lines with low electricity consumption with an optimal proportion of the use of natural and artificial cold on the energy criterion C_w, a method is proposed that allows the foundation of the most efficient variant depending on the variant of completing the line with machinery and the average temperature of the atmospheric air $\Delta°C$ during the cold time of the year in the area where the object is located (Fig. 2.2). The nomogram is graphically represented in the coordinates C_w - n - $\Delta°C$, where n is a discrete value of the option to complete the line with equipment.

4. Developed mathematical models of the process of cooling and accumulating milk with the use of natural and artificial cold make it possible to substantiate the parameters of the cooling system, establishing a link between the main parameters of low-power technical means with milk processing technology and air temperature. environment, minimizing electricity consumption and optimizing the capacity of natural and artificial cold storage capacity.

5. It was established that, compared to the traditional method of milk cooling, the regime of artificial cold accumulation, carried out during the breaks between milkings, makes it possible to reduce the cooling capacity of the rechargeable refrigeration plant by up to 5 times for two milkings and up to 2 times for three milkings.

The use of the cold reserve in the supercooled milk with the mixing of the refrigerant in the AF, allows reducing the ratio between the volume of the refrigerant and the volume of the chilled milk by at least 2 times, and the productivity of the refrigerant pump by 1.4 ... 1.7 times compared to the traditional method of cooling milk.

6. The most efficient regime is the displacement of the refrigerant without mixing in the AF, which allows the accumulation of cold up to a temperature lower than 2 ° C with a minimum ratio between the volume of the refrigerant and milk C_A = 2.45. With the efficient use of the cold reserve in supercooled milk, the ratio between the amount of refrigerant and the amount of chilled milk and the productivity of the refrigerant pump during the accumulation of cold in unmixed

mode in AF are reduced by 1.2 times. Compared to the mixing regime, the non-mixing regime of the agent in AF allows at least 2 ... 3 times the reduction of the cooling capacity of the rechargeable refrigeration system.

7. The operating algorithms developed on the basis of automatic graphs and logical algebra of the ecological seasonal installation with 6 sections and the combined installation for the whole year with the use of natural and artificial cold allow to ensure the cooling of milk up to the storage temperature $t \leq 6\ ^{0}C$ with a specific consumption of electricity of 0.6-0.8 kWh/t in the cold period of the year and 20 kWh/t in the warm period of the year.

8. For the north of the Republic of Moldova, the number of days with $t \leq 5\ ^{0}C$ is between 133 days and 186 days. In this case, the use of natural cold installations in non-mixing water regime is possible between 4.5 - 6 months. The unmixed mode of water in the installations with natural cold allows to increase the duration of use of the installations in the north of the Republic of Moldova by 1.5 - 3 times compared to the mixed mode of water.

9. The duration of operation of the IF and the specific consumption of electricity for 7 months (April-October) are reduced on average by approx. 16%, when the direction of movement of the refrigerant flow changes in the milk cooling regimes (from bottom to top) and cold accumulation (top to bottom) in the cold accumulator.

10. In perspective, considering that RM is an agrarian country, it is extremely important to use natural and artificial cold, not only for cooling milk, but also for preserving fruits and vegetables. In this field, I have published more than 15 scientific articles and I am co-author of 2 monographs. It was found that regardless of the reliability category of the electricity supply of the warehouse for keeping fruits and vegetables, the power of the transformer 10/0.4kV up to 40 kVA is reduced by one step.

The sections of cables and conductors 0.4 kV external and internal of the warehouse for keeping fruits and vegetables, respectively, are reduced by one step and by two steps.

Based on the research carried out, it is recommended:

1.to submit to AIPA the promotion of the realization of installations with natural and artificial cold by subsidizing the farmers in the field

2. the automation of milk recording and pumping, which makes it possible to reduce the total capacity of intermediate collection and regulation tanks (RCR) by 6 times. RCR, allows 1.3 and 12.1 times to reduce the contact surface of milk with the technological equipment of the line and the surrounding air. At the same time, it allows to reduce the bacterial contamination of milk from 347 to 299 thousand b/ml, reducing the necessary production surfaces and metal consumption of technological equipment up to 30%. The use of devices for control and regulation of milk flows instead of non-adjustable ones makes it possible to exclude RCR from the technological process of processing milk and ensures its processing in a closed flow with a 50 percent reduction in the operator's working time. The main advantage of IMRF is the fact that, using them in technological lines, it allows the use of the milking plant and the technological line in a single flow transport system and the milk processing process is carried out in a closed flow completely isolated from the ambient air (Fig 1.8 of the thesis).

3. for the electric machine system of the milk pump of the air separator, of the refrigerant pump, as well as the control unit for the mixing device of the milk tanks, which have a high frequency of triggers about 3*10-5 -2 *10-6 1/h to increase reliability indicators using combined control circuits, including equipment based on contact relays and non-contact elements made on integrated microcircuits, logic elements and magnetically controlled contacts.

4. to use the reasoned technical means that ensure the charging of the natural and artificial cold accumulators of the cooling system up to their design values, the regulation of the real power of the natural and artificial cold sources according to the temperature of the refrigerant and the minimum energy consumption of cold accumulated in the milk cooling process.

5. the use of mathematical models developed to optimize the parameters of water accumulators in common with refrigeration installations for cooling milk both in flow coolers and in capacitive coolers.

6. the use of milk pre-cooling from 32 to 16°C in the hot season, with the aim of reducing the cooling capacity and the installed capacity of the refrigerating equipment by at least 30...40%, which allows saving at least 30 kWh of electricity per day for milk cooling.

7. introducing into the UTM study plan the theoretical approach to the research carried out in the courses of lectures and practical lessons "Renewable sources of energy in the agricultural sector" and "Design of electrification systems in the agricultural sector" for students of the first cycle, as well as in the course of lectures and practical lessons in the II cycle "Automation of technological processes in the agricultural sector". Specialists in the field of energy efficiency in the agricultural sector should be familiar with the research results published in 2 monographs.

BIBLIOGRAPHY

1. Sîrbu Rodica The influence of agrometeorological conditions in the formation of vine productivity on the territory of the Republic of Moldova Academy of Sciences of the Republic of Moldova Institute of Ecology and Geography as a manuscript czu 551.583.1: 634.8 pag.130, Chisinau, 2015

2. Волконович, Л., et al. Автоматизация ресурсосберегающих технологических процессов в сельском хозяйстве.Monograph Chisinau: Tipografia A.Ș.M.pag.430.

3. Volconovici, L., Creţu, V.,. 1. Volconovici, A., Milk cooling with the application of natural and artificial cold Monograph. Chisinau: Editura Tehnica Info, 2009. ISBN: 978-9975-63-278-2.

4. ISO5707: 2007. Milking machine installations - Construction and performance, The International Organization for Standardization, Geneva, Switzerland, 2007. National Agency for Energy Regulation of the Republic of Moldova [online]. Accessed: 3 May 2020. Available: http://www.anre.md/tarife-in-vigoare-3-204

5. Козловцев, А.П., Квашенников, В.И., Шахов, В.А. Предпосылки использования комбинированного аккумулятора природного холода на основе фазовоперехон В: Достижения науки и техники АПК. 2017, N 7, pp. 66-68.

6. Коршунов, А.Б., Иванов, В.В. Энергосберегающий модуль для охлаждения молока с использованием природного холода и хладоносителем ум. В: Вестник ВИЭСХ / Всерос. науч.-исслед. ин-т электрификации сел. хоз-ва. Москва, 2016, N 2 (23), p. 127-131. ISSN 2304-5868. Доступен:https://vestnik.viesh.ru/journal/vypusk-2-23-2016/

7. Коршунов, А.Б., Коршунов, Б.П. Аккумуляционные установки для охлаждения молока на фермах. В: Вестник Всероссийского научно-исследовательского института механизации животноводства. 2019, N3 (35). c. 114-117. ISSN 2226-4302. Доступен:https://cyberleninka.ru/article/n/akkumulyatsionnye-ustanovki-dlya-ohlazhdeniya-moloka-na-fermah

8. Volconovici L., Creţu V., Volconovici A., Zvonkii V., Cușnir M. Mathematical model of the ecological system with electricity consumption for milk cooling in the Republic of Moldova. Proceedings of the 8th International Conference on electromechanical and power systems. Sielmen: sn, 2011.

9. Мусин А., Марьяхин Ф., Учеваткин А. Влияние режимов работы электроприводов технологической линии на показатели качества молока. 2012. Vol. 63, pp. 17-26.

10. Бруздаева, С.Н., Гудкова, Т.Ю. Энергосберегающая комбинированная установка для охлаждения молока с использованием вторичных источни. В: Аграрная наука и образование на современном этапе развитияматериалы VIII Международной научно-прак. 7-8 February 2017 г. - Ульяновск. 2017, ч. 1., p. 54-57..

11. Volconovici, L., Crețu, V., Volconovici, A., Zvonkii, V., Cușnir, M .. Experimental researches of the ecological system for cooling of milk with low energy consumption. Proceedings of the 8th International Conference on electromechanical and power systems. Sielmen: sn, 2011.

12. Побединский В., Волконович Л., Дайку А., Модель и принципы биотехнологического мониторинга производства молока на учебно-экспериментальном комплексе. International Scientific Symposium "Achievements and Perspectives in Agricultural Engineering and Auto Transport", dedicated to the 85th anniversary of the founding of UASM, Chisinau 2018 p, 133-138

LIST OF THE AUTHOR'S PUBLICATIONS ON THE THESIS

- **Monographs**

1. Волконович Л., Стребков Д., **Слипенки В.**,et al.Возобновляемые источники энергии: состояние, ближайшая перспектива, технология и электрооборудова. Monograph, Chisinau “Tehnica-Info” Publishing House 2009, ISBN 978-9975-63-279-9 стр. 403
2. Волконович Л., Кушнир М., **Слипенки В.** et al. Применение холода для охлаждения молока и хранения плодоовощной продукции. Monograph. Государственный аграрный университет Молдовы. Chisinau, 2019, ISBN 978-9975-56-625-4. (637.133.1 + 664.8.037): 621.565, str.764

- Articles in recognized foreign journals

3. Волконович Л., Волконович А.,**Слипенки В.**, et al. Определение продолжительности использования энергосберегающих установок естественного и искусственного холода для хранения фруктов и овощей на территории Республики Молдова. In: Инновации в сельском хозяйстве, № 22, 2017, стр.58-65, ISSN 2304-4926

4. Волконович Л.,**Слипенки В.,**Кушнир Н., et al. Analytical Structural Analyzing Therapeutic Structural Fructuring and Extracting with Extracting and Extracting In: Инновации в сельском хозяйстве. № 22, 2017 стр. 65-72, ISSN 2304-4926

5. Волконович Л.,**Слипенки В.** et al. Определение и оценка параметров процесса хранения фруктов и овощей с применением естественнога хол In: Инновации в сельском хозяйстве. № 23, 2017 стр. 40-47, ISSN 2304-4926

6. Волконович Л., Волконович А.,**Слипенки В.** et al. Разработка алгоритмов управления процесса хранения фруктов и овощей с применением естественлога х. In: Инновации в сельском хозяйстве, № 23,2017 стр. 48-56, ISSN 2304-4926.

7. Волконович Л., Слипенки В.,**Слипенки В.**et al. Методика определения оптимальных сроков хранения фруктов и овощей с применением естественного и иск. In: Инновации в сельском хозяйстве. № 24,2017 стр. 44-49, ISSN 2304-4926

8. **Слипенки В.**, Volconovici A., Chirsanova A. et al. Determining the duration and efficiency of use of installations with natural cold for milk cooling in the Republic of Moldova. In: EMERG - Energy. Environment. Efficiency. Resources. Globalization, vol. 6, №.2, pp. 24-38, 2020, doi: 10.37410 / EMERG.2020.2.02

9. **Слипенки В.,**Volconovici A., Cernei M., et al. Structural and functional diagram, automatic graphs and operating algorithms of the natural and artificial cold receiver / accumulator for milk

cooling. In: EMERG - Energy. Environment. Efficiency. Resources. Globalization, vol. Vol. 6, № 4, pp. 13-22, doi: 10.37410 / EMERG.2020.4.0

10. Daicu A., Volconovici A., Slipenchi V. et al. Combined automated installation deployment for milk cooling. In: Journal of Engineering Science, vol. XXVII 3, TUM, 2020 pp. 65-75, doi: 10.5281 / zenodo.3949666

- **Articles in magazines from the National Register of profile magazines, category B**

11. Волконович, Л., Кушнир, М .., **Слипенки В** Применение естественного и искусственного холода для охлаж. Agricultural science. : UASM, 2017. No 2 (2017)

12. Волконович Л., Кушнир М., **Слипенки В**. Comprehensive analytical analysis of non-toxic engineering materials for the production of non-toxic materials. In: Agricultural Science, no. 2 (2017) pp. 92-99

13. Chirsanova A.,**Slipenchi V**., Volconovici A. et al. Расчет толщины намораживания льда в льдохранилищах систем естественного холода для охлаждения моло In: Agricultural Science, no. 1 2020, UASM, pp. 127-136

14. Волконович Л.Ф., Волконович А.Л., **Слипенки В.Е.** . Методика определения оптимальных сроков хранения фруктов и овощей с применением естественного и иск. In: Инновации в сельском хозяйстве. Теоретический и научно-практический журнал 3 (24) / 2017 p, 44-49

15. **Слипенки В**. Оценка параметров процесса хранения фруктов и овощей с применением естественного холода на террит. Государственный Аграрный Университет Молдовы. In: Agricultural Science, no. 1 (2019) pp. 147-153 ISSN 2587-3202 (electronic)

16. Волконович Л., Стёпка О, **Слипенки В.**et al. Математическая модель и производственные испытания установок сезонного действия для охлаждения моло In: Agricultural Science, no. 1 2016, UASM, pp.126-134, ISSN 1857-0003.

17. Волконович Л., Кушнир М., **Слипенки В.**et al. Определение эффективности при модернизации биотехнических систем с учётом ситуации экономическог. In: Agricultural Science, № 2 2016 UASM, p.104-110 УДК 631.171.1 ISSN 1857-0003

18. Волконович Л.Ф., **Слипенки В.Е**., et al. Применение естественного и искусственного холода для охлаждения молока. In: Agricultural Science, № 2,2017, UASM p. 84-91 УДК 637.117.02 ISSN 1857-0003

19. Anatolie Daicu**, Victorin Slipenchi**, Onorin Volconovici et al. Contributions to the elaboration of technical means for the automation of food preservation processes with the use of natural cold. In: Agricultural Science, №. 2 2019, UASM. pp. 95-102, doi: 10.5281 / zenodo.3625515 CZU: 664.84 / .85.037.1: 004

20. Anatolie Daicu**,** Augustin Volconovici, **Victorin Slipenchi**, et al. Combined automated installation deployment for milk cooling. In: JES, Journal of Engineering Science, vol. XXVII 3, UTM, 2020 pp. 65-75, doi: 10.5281 / zenodo.3949666 UDC 004.9: 621.565: 637.

21. **Slipenchi Victorin**et alt. Development of automated refrigeration system with low electricity consumption for cooling milk. In: Agricultural Science, №. 1 2020, UASM, pp. 107-114, doi: 10.5281 / zenode. 3947164 CZU: 637.133.1.

- **Articles in national collections**

22. Волконович Л., Кушнир М.,**Слипенки В.** et al. Исследование временных режимов работы системы электрооборудования звеньев технологической линии линии In: Materials of the International Scientific Symposium "Efficient use of hydro-land resources in current conditions - achievements and perspectives" dedicated to the 65th anniversary of the founding of the Faculty of Cadastre and Law Chisinau 2016 p.251-255 6ДК637.13.02, ISBN 978-9975- 64-285-9.

23. Волконович Л., Волконович А., **Слипенки В.** et al. Imitation methods for high-performance biotechnological systems. In: International conference "Energy of Moldova - 2016 Regional Aspects of development" 29 September -1 October 2016 - Chisinau, Republic of Moldova 409 Государственный Аграрный Университет Молдовы Министерство Сельского Хозяйства и Пищевой Промышленности Республики Молдова.

24. Волконович Л., Волконович А.,**Слипенки В.**et al. Technological and economic resources of biotechnology systems in the field of technology. In: International conference "Energy of Moldova - 2016 Regional Aspects of development" 29 September -1 October 2016 - Chisinau, Republic of Moldova 409 Государственный Аграрный Университет Молдовы Министерство Сельского Хозяйства и Пищевой Промышленности Республики Молдова.

25. Кушнир М., Волконович А., **Слипенки В.** et al. Non-slip energy-saving режимов режимов работы технологических линий обработки молока. In: Materials of the International Scientific Symposium "Efficient use of hydro-land resources in current conditions - achievements and perspectives" dedicated to the 65th anniversary of the founding of the Faculty of Cadastre and Law Chisinau, 2016 p.256-261 УДК 637.13.02, ISBN 978- 9975-64-285-9.

26. Волконович Л., Волконович А., **Слипенки В.** et al. Исследование ущербов при отказах системы электрооборудования технологических линий обработки мол In: Materials of the International Scientific Symposium "Efficient use of hydro-land resources in current conditions - achievements and perspectives" dedicated to the 65th anniversary of the founding of the Faculty of Cadastre and Law Chisinau, 2016 p.262-265 63ДК 637.13.02, ISBN 978- 9975-64-285-9.

27. Cuşnir M., Ucevatchin A., **Slipenchi V.** et al. Complex analysis of automated technological processes for milk cooling, energy efficient. In: Scientific Papers Volume 51, Agricultural Engineering and Car Transport, Materials of the International Scientific Symposium "Achievements and Perspectives in Agricultural Engineering and Car Transport", dedicated to the 85th anniversary of the founding of the State Agrarian University of Moldova, Chisinau 2018 p, 374 -382, CZU 637.13.02 CZU 082: 378.663 (478-25) = 135.1 = 161.1, U 56

28. Волконович Л; Волконович А; **Слипенки В** ; Analytical analysis of the electrolytic electrolytic electrolytic electrolytic liquid and liquid. State Agrarian University of Moldova Scientific Papers Volume 55, Cadastre and Law Chisinau, 2022. pp. 335-340

29. Волконови А .; Скрипник Е ..; **Слипенки В** .; Особенности, цели и задачи исследований автоматизировнных технологических линий обработки молока как объектов управления State Agrarian University of Moldova Scientific Papers Volume 55, Cadastre and Law Chisinau, 2022 pp. 367-372

30. Волконович А .; Волконович О. **Слипенки В..**Аналитический обзор и анализ тенденций развития автоматизированных технологических процессов и технических средств линий обработки молока на фермах State Agrarian University of Moldova Scientific Papers Volume 55, Cadastre and Law Chisinau, 2022 pp.381-398

31. **Слипенки В .;**Кирсанова А .; Волконович А .; . Анализ процесса учета, транспортировки, очистки и охлаждения молока на фермах State Agrarian State University Of Moldova Scientific Works Volume 55, 3 pp.

32. **Слипенки В .;**Кирсанова А .; Малай Л.; Передовой зарубежный и отечественный опыт развития технологий и линий первичной обработки молока на фермах din Moldova State Agricultural University де Scientific Papers Volume 55, Cadastre and Law Chisinau 2022.pp.360-365

33. Ursatii Nicolai, **Slipenchi Victorin**. Milk pre-cooling solutions in the collection process from home producers. Theses of the 75th scientific conference of students, masters and doctoral students. – Chisinau: CE UASM, 2022. P. 13

ADNOTARE

La teza de doctor în științe tehnice cu tema „Îmbunătățirea eficienței energetice a echipamentelor pentru prelucrarea primară a laptelui cu utilizarea frigului natural și artificial (pe exemplul regiunii de nord a RM).", Slipenchi Victorin, Chișinău, 2022

Teza este constituită din introducere, 4 capitole, concluzii generale și recomandări, bibliografie cu 125 titluri, 6 anexe, 142 pagini de text de bază, 71 de figuri, 30 tabele, 127 formule. Rezultatele cercetărilor sunt reflectate în 33 de lucrări științifice, inclusiv 2 monografii, 8 articole în reviste internaționale si 23 articole în reviste naționale.

Cuvinte-cheie: linie tehnologică, instalație cu frig natural și artificial, răcirea laptelui, modele matematice, metode de calcul, algoritm de funcționare, grafuri automate.

Scopul lucrării constă în elaborarea metodologiei, metodelor de calcul și modelelor matematice a proceselor de răcire a laptelui și de acumulare a frigului natural și artificial pentru fundamentarea regimurilor de funcționare și parametrilor instalațiilor sezoniere ecologice și combinate pe tot parcursul anului.

Noutatea și originalitatea științifică constă în contribuția metodologica si elaborarea modelelor matematice și metodelor de calcul a procesului de răcire a laptelui în răcitoare capacitive și în flux si acumulare de frig natural si artificial în regimuri de amestec și neamestec a agentului frigorific în acumulatorul cu frig

Problema științifică importantă soluționată: îmbunătățirea indicilor tehnici, energetici, economici și de mediu ai procesului de răcire a laptelui și acumulare a frigului natural și artificial, în baza elaborării modelelor matematice și metodelor de calcul în corelație cu temperaturile aerului atmosferic pentru nordul RM.

Semnificația teoretică a lucrării constă în contribuția metodologică și în elaborarea modelelor matematice si metodelor de calcul la fundamentarea sistemului cu consum redus de energie electrică la răcirea laptelui cu utilizarea instalațiilor sezoniere ecologice și combinate pe tot parcursul anului pentru nordul R M .

Valoarea aplicativă a lucrării: au fost îmbunătățiți indicatorii tehnici, energetici, economici și de mediu a instalațiilor cu frig natural și artificial pentru nordul R. M.

Implementarea rezultatelor științifice. Rezultatele cercetărilor au fost implementate la ferma din s.Corbu r-l Dondușeni si la ferma UASM. Componenta teoretică a cercetării este implementată în cadrul proiectului 20.80009.5107.04 „Adaptarea tehnologiilor durabile și ecologice de producere și păstrare a produselor agricole " pe perioada 2020-2023. Abordarea teoretică a cercetărilor efectuate se utilizează în cursurile de prelegeri și lecții practice„Surse regenerabile de energie în sectorul agrar" și „Proiectarea sistemelor de electrificare în sectorul agrar" respectiv pentru studenții anului 3 și 4, precum și în cursul de prelegeri și lecții practice la masterat "Automatizarea proceselor tehnologice în sectorul agrar" a FIATA din cadrul UASM. Rezultatele cercetărilor au fost publicate în 2 monografii utile pentru specialiștii din domeniul eficienței energetice în sectorul agrar.

АННОТАЦИЯ

Диссертация состоит из введения, содержит 4 главы, общие выводы и рекомендации, библиографию из125 названий,6 приложений,142 страниц основного текста, 71 рисунка, 30 таблиц, 127 формул. Результаты исследования отражены в 33 научных статьях, в том числе в 2-х монографиях, 8 статьях в международных журналах и в 23 статьях в националъных журналах.

Ключевые слова:технологическая линия, установка естественного и искусственного холода, охлаждение молока, математические модели, методы расчета, алгоритмы функционирования, автоматные графы.

Цель работы:.состоит в разработке методологии и методов расчета и математических моделей процесса охлаждения молока и аккумулирования естественного и искусственного холода с обоснованием режимов функционирования и параметров экологических установок сезонного действия и комбинированных установок круглогодового действия.

Научная новизна и оригинальность работы состоит во вкладе в методологии и разработке математических моделей и методов расчетов процессов охлаждения молока в емкостных и проточных охладителей и аккумулирование естественного и искусственного холода в режиме смешивания и вытеснения холодоносителя в аккумуляторе холода.

Научная проблема состоит в улучшении технических, энергетических и экономических показателей процесса охлаждения молока и аккумулирования естественного и искусственного холода, на основе разработанных математических моделей и методов расчета во взаимосвязи с температурой атмосферного воздуха на севере Республики Молдова.

Теоретическая значимость работы состоит в методологическом вкладе и в разработке математических моделей и методов расчетов для обоснования системы с минимизированными затратами электроэнергии с использованием экологических установок сезонного действия и комбинированных установок круглогодового действия.

Практическое значение работы: улучшены технические, энергетические, экономические и экологические показатели установок с естественным и искусственным холодом для севера Р.М.

Внедрение научны результатов. Результаты исследований были внедрены на фермах с. Корбу Дондюшанского р-на и в ГАУМ. Теоретическая составляющая исследования внедрена в проекте 20.80.009.5107.04 "Адаптация устойчивых и экологических технологий производства и хранения плодоовощной продукции с точки зрения количества и качества в зависимости от целостности системы растениеводства и изменение климата» на период 2020 - 2023гг. Теоретические исследования используются в курсах лекциях и практических занятиях "Возобновляемые источники энергии в аграрном секторе» и в "Проектирование электрических систем в аграрном секторе» для студентов 3 и 4 курсов, а так же в курсах лекций и практических занятий по автоматизации технологических процессов в аграрном секторе, для магистров ГАУМ.

Результаты исследований были опубликованы в 2-х монографиях полезные для специалистов в области энергетической эффективности в аграрном секторе.

ANNOTATION

In the doctoral thesis in technical sciences with the topic “Improving energy efficiency an equipment for the primary processing of milk using natural cold and artificial (on the example of the northern region of the Republic of Moldova).”, Slipenchi Victorin, Chisinau, 2022

The thesis consists of an introduction, 4 chapters, general conclusions and recommendations, bibliography with 125 titles, 6 annexes,142 pages of basic text, 71 figures, 30 tables, 127 formulas. The research results are reflected in 33 scientific papers, including 2 monographs, 8 articles in international journals and 23 articles in national journals.

Key words: technological line, natural and artificial cold installation, milk cooling, mathematical models, calculation methods, operating algorithm, automatic graphs.

The aim of the thesis is to develop the methodology, calculation methods and models mathematics of the processes of cooling milk and the accumulation of natural and artificial cold for substantiation of operating regimes and parameters of ecological seasonal installations and combined throughout the year.

The scientific novelty and originality consists in the methodological contribution and the elaboration mathematical models and methods for calculating the milk cooling process in capacitive coolers and in the flow and accumulation of natural and artificial cold in mixing and non-mixing regimes of the agent refrigerator in the cold storage

The important scientific problem solved: the improvement of technical, energy, economic and environmental consequences of the process of cooling milk and accumulating natural and artificial cold, based on the development of mathematical models and calculation methods in correlation with atmospheric air temperatures for the north of the RM.

The theoretical significance of the thesis consists in the methodological contribution and in the elaboration mathematical models and calculation methods to substantiate the system with low consumption of electricity for cooling milk with the use of ecological and combined seasonal installations on all year round for the north R M.

Applicative value of the thesis: technical, energy indicators have been improved, economic and environmental conditions of natural and artificial cold installations for northern RM

Implementation of scientific results. The research results were implemented at farm from Corbu village, District Dondușeni and at the SAUM farm. The theoretical component of the research is implemented in the project 20.80009.5107.04 „Adaptation of sustainable technologies and ecological production and storage of agricultural products” for the period 2020-2023. Addressing Theory of the research conducted is used in the lectures and practical lessons “Sources renewable energy in the agricultural sector” and “Design of electrification systems in the agricultural sector agrarian” respectively for the students of the 3rd and 4th year, as well as during the lectures and practical lessons at master's degree "Automation of technological processes in the agricultural sector" of FIATA within SAUM. The research results were published in 2 useful monographs for specialists in the field of energy efficiency in the agricultural sector.

SLIPENCHI VICTORIN

IMPROVING THE ENERGY EFFICIENCY OF EQUIPMENT FOR PRIMARY PROCESSING OF MILK WITH THE USE OF NATURAL AND ARTIFICIAL COLD (FOR EXAMPLE OF THE NORTHERN REGION OF THE RM)

255.01 - TECHNOLOGIES AND TECHNICAL MEANS FOR AGRICULTURE AND RURAL DEVELOPMENT

Summary of the doctoral thesis in technical sciences

Approved for printing: 28.09 .2022 A4 paper size
Offset paper. Digital printing. Circulation 30 copies
Printing sheets: 2.0 Order no.13

UTM Publishing Center
Chisinau, 42 Mircești Street
goal. 022-432-575