TECHNICAL UNIVERSITY OF MOLDOVA

With manuscript title

CZU: 631.371:621.31:637.117(043.3)

URSATII NICOLAI

INCREASING THE ENERGY EFFICIENCY OF NATURAL AND ARTIFICIAL COLD FACILITIES AT MILK COLLECTION POINTS

255.01 - TECHNOLOGIES AND TECHNICAL MEANS FOR AGRICULTURE AND RURAL DEVELOPMENT

Doctor of engineering science dissertation summary

CHISINAU 2023

The thesis was developed within the "Manufacturing Engineering" department of UTM

Scientific leader:
VOLCONOVICI Liviu, dr. hab., prof. univ. UTM;

Official references:

1. STIOPCA Oleg, dr., conf. univ., UTM;
2. GOLOVANOV Nicolae, dr. ing., prof. emerit, Universitatea Politehnică din București;
3. LUCACHE Dorin-Dumitru, dr. ing., prof., Universitatea Tehnică “Gheorghe Asachi”, Iaşi.

Composition of the Commission for public support of the doctoral thesis:

1. MARIAN Grigore, președinte, dr. hab., prof. univ., UTM;
2. POPESCU Victor, secretar, dr., conf. univ., UTM;
3. VOLCONOVICI Liviu, dr. hab., prof. univ. UTM;
4. MAZURU Sergiu, dr. hab., conf. univ. UTM;
5. STIOPCA Oleg, dr., conf. univ., UTM;
6. GOLOVANOV Nicolae, dr. ing., prof. emerit, Universitatea Politehnică din București;
7. LUCACHE Dorin-Dumitru, dr. ing., prof., Universitatea Tehnică “Gheorghe Asachi”, Iaşi.

The thesis public support will take place on 20.09.2023 at 13:00 in the meeting of the Doctoral Commission within the Doctoral School of the Technical University of Moldova at the address: MD-2045, Republic of Moldova, Chisinau municipality, 9/8 Studentilor Street, block study no. 6, room 6-210.

The doctoral thesis and the abstract can be consulted at the Technical-Scientific Library of UTM, on the UTM website (www.repository.utm.md) and on the ANACEC website (www.anacec.md).

The summary was sent on 21.08.2023

Scientific Secretary of the Doctoral Commission,
dr., conf. univ. **POPESCU Victor**

Scientific supervisor,
dr. hab., prof. univ. **VOLCONOVICI Liviu**

Author **URSATII Nicolai**

CONTENTS

CONCEPTUAL ELEMENTS OF THE RESEARCH

Timeliness and importance of the addressed problem. The epidemiological crisis and the emerging energy problems, both in the Republic of Moldova and at the international level, increase the economic burden of agro-food producers. Energy and food systems are deeply interconnected. About 30% of global energy is consumed by agro-food production and processing systems. Energy is also responsible for a third of the greenhouse gas emissions of agro-food systems. Both systems must be transformed to meet current and future demand for food and energy in an equitable, sustainable manner in terms of energy efficiency and environmental protection [1].

The main task of producers in the primary processing of agro-food products and, in particular, of dairy products is to maintain their quality, which directly depends on the storage temperature provided by the refrigeration facilities [2].

Research in the field of food preservation techniques is directed towards the design and development of refrigeration installations that use natural cold or natural cold combined with artificial cold, as well as modern computing technologies for controlling cooling processes and regimes and accumulating cold in optimal amounts , which will reduce the consumption of electricity in the cooling process and lead to the increase of technical-economic efficiency and the saving of electricity [3]. The mentioned objectives were analyzed through several scientific papers [4 ... 9], which confirmed that their implementation is very beneficial from an ecological and technical-economic point of view.

The agricultural reform has led to the liquidation of large cattle farms in the Republic of Moldova, since the independence of the Republic of Moldova until now which has significantly reduced the volume of milk at the national level. Due to these circumstances, domestic dairy processing companies had to set up milk collection points from domestic producers. Based on previous research, it was established that the milk collected from individual producers is kept at the collection points from 3 to 12 hours, depending on the volume collected in one shift and the frequency of its transportation to the processing plants.

In most rural areas, the milk is collected and cooled in two shifts, in the evening and in the morning, after which the milk is transported to the processing plant.

From a legislative point of view, the technical and hygienic requirements for collection points in the Republic of Moldova are aligned with European requirements. But, in practice, due to the financial factor, the milk collection points were equipped with refrigeration installations of outdated manufacture, and in some cases even with second-hand refrigeration installations.

The scientific results presented by researchers from the European Union show that the electricity consumption of typical milk cooling facilities varies from 17.6 to 24.3 kWh for cooling one thousand liters of milk, depending on the energy class of the facility [11]. It should also be mentioned the low level of reliability of these installations, which results in frequent breakdowns, the increase in the volume of adulterated milk and the pollution of the environment because freon is used as a refrigerant [12, 13].

Therefore, reducing electricity consumption and increasing the reliability of the cooling system at milk collection points on the territory of the Republic of Moldova is extremely necessary and current.

The aim of the paper. Increasing the energy efficiency of the installation with natural and artificial cold at the milk collection points in the Republic of Moldova.

Refrigeration facilities used at milk collection points in the country served as the object of the research. The object of the research is the theoretical-practical aspect chosen for a thorough study of the ways of increasing the energy efficiency using natural and artificial cold with the approach of the issue related to the ecology and sustainability of agriculture in the Republic of Moldova.

The research subject includes study problems and the qualitative and quantitative estimation of the constructive technological parameters of the research object through the efficiency of the use of natural and artificial cold in the milk cooling process, with low electricity consumption.

The objectives: analysis of the current state regarding the use of natural and artificial cold in the milk cooling process and the identification of solutions to increase the energy efficiency of refrigeration facilities for milk collection points in the Republic of Moldova; development of mathematical models and methods for calculating the technological and constructive parameters of the plant with natural and artificial cold for cooling milk; concretization of the energy, operation and control regimes of the ecological milk cooling facility; implementation of the experimental facility with natural and artificial cold at a milk collection point in the country; establishing the optimal technological parameters for the pre-cooling and cooling of milk at the collection points.

Research hypothesis. The possibility of using natural cold as a renewable source available throughout the country, in order to reduce electricity consumption in the milk cooling process. In the case of confirming the increase in energy efficiency, it becomes opportune to establish the attractiveness and competitiveness of natural cold.

Research methodology. The researches were carried out within the departments "Electrification of Agriculture, Mechanics and Design Bases" UASM, "Manufacturing Engineering" UTM and at the milk collection point managed by GȚ "Harabari Andrei Victor", through:

- the study of bibliographic data, with the elucidation of shortcomings in the field;
- analysis of the statistical data of the State Hydrometeorological Service and the National

Bureau of Statistics;

- conducting experiments with the use of electronic control devices, electric meter

type SL03A 3F (0.5-100 A) 220-400 V, thermometer type TP-300 with measuring range -50^{o}C ... +300^{o}C, temperature sensor PT1000 with measuring range -50^{o}C ... +300^{o}C and PH-mobile milk meter - HI98162.

The veracity of the obtained data was ensured by the use of research methods approved in the field, the repeatability of tests and the use of research equipment validated in the department "Electrification of Agriculture, Mechanics and Design Bases" UASM.

Summary of the thesis: the thesis consists of annotations in Romanian, English and Russian, list of abbreviations, list of tables and figures, introduction, four chapters, general conclusions and recommendations, bibliography and anexes.

The introduction presents the actuality and importance of the research topic, the aim and objectives of the thesis, the synthesis of the research methodology and the justification of the chosen research methods, the implementation and approval of the scientific results.

Chapter 1 includes generalities regarding ways to reduce electricity consumption for cooling and storing milk, the situation regarding the level of development of the milk production branch in farms and households from independence until now in the territory of the Republic of Moldova.

Due to the fact that, the total volume of milk produced in households is significantly higher than in farms, the arrangement and operation of milk collection points and the process of milk collection, cooling, storage and delivery were analyzed by the collection points in the Republic of Moldova.

In order to formulate the purpose and objectives of the research, different solutions were analyzed that would lead to the increase of energy efficiency at the collection points.

The milk cooling systems were analyzed from an energetic and constructive point of view, scientific works were studied that indicate the advantages of implementing permanent magnets on the rotor of the asynchronous motor driving the compressor of refrigeration installations, using ecological milk cooling installations with low consumption of electricity and milk pre-cooling systems to reduce electricity consumption. At the same time, the solutions to reduce electricity consumption in the distribution network through the use of photovoltaic systems were analyzed.

Chapter 2 includes the theoretical aspects regarding the determination of the technological-constructive parameters for the development of the ecological milk cooling facility proposed for the collection points in the country.

The calculation methodology and the substantiation of the constructive parameters of the ecological plant for cooling milk with natural cold, using an intermediate refrigerant (water or brine) and the thermally insulated cold accumulator, were developed.

Mathematical models and calculation methods of the flow cooling process of the intermediate refrigerant with the accumulation of natural cold in the thermally insulated cold accumulator, of the process of cooling milk with natural cold in a capacitive cooler and of the precooling process of ice milk during its mobile collection from home producers.

Chapter 3 presents the basic components included in the structural scheme of the ecological milk cooling facility with low electricity consumption, proposed for development for the collection points.

Structural schemes, automatic graphs and operating algorithms of electrical components in ecological installations were elaborated.

It was established that the automatic graphs and operating algorithms developed for the cooling process of the intermediate refrigerant allow the assembly of the electrical scheme for the automation of the cooling process, switching from one regime to another, depending on the temperature of the environment and the intermediate refrigerant, ensuring its cooling up to temperatures below +4^{o}C. The structural scheme, the automatic graph and the operation algorithm of the milk cooling regime with intermediate refrigerant, allow ensuring the optimal operation of the milk cooling process by monitoring the temperature of the milk, ensuring its cooling to the preset storage temperature below +6^{o}C.

The electricity flows of the electromechanical equipment in the PCL were analyzed, which allowed the establishment of the estimated consumption and losses of electricity for each piece of electrically operated equipment, depending on the duration of its operation, but also the establishment of the energy consumption for the operation them in common depending on the cooling regime.

The operation, automation and control regimes of the cooling process of the intercooler with air and the cooling of milk with intercooler were argued.

The duration of use natural cold in the milk cooling process at the collection points for the Northern Development Region of the country was determined.

Chapter 4 presents the experimental refrigeration plant for cooling milk with basic technical parameters, which is implemented at the milk collection point managed by GȚ "Harabari Andrei Victor".

Based on the experimental data, the actual specific consumption of electricity at PCL was established, during the cold period of the year when the ambient temperature is ≤+4^{o}C.

The study of the technical-economic efficiency of the milk cooling process using the ecological installation with low electricity consumption at the milk collection points was carried out.

Experimental trials were carried out on milk pre-cooling using ice boxes in the mobile collection vessel to pre-cool the milk during collection. The precooling process has been found to reduce the electricity consumption of the PCL plant.

The feasibility study was carried out regarding the implementation of the On-Grid type photovoltaic system at PCL GȚ "Harabari Andrei Victor" and the investment for an ice machine was also included in the study.

The thesis ends with the presentation of general conclusions and recommendations.

Implementation of scientific results. The research results were implemented at the milk collection point managed by GȚ "Harabari Andrei Victor" in Corbu village, Dondușeni district. The theoretical component of the scientific research was implemented during the years 2020-2022 in the institutional scientific project: 20.80009.5107.04 (2020-2023) "Adaptation of sustainable and ecological technologies for the production of fruits under quantitative and qualitative aspects according to the integrity of the culture system and climate change" and in the lecture courses on the subjects "Design of electrification systems in the agricultural sector", "Renewable energy sources in the agricultural sector" from the study program of the first cycle, as well as in the lecture course "Automation of technological processes in the agricultural sector ” from cycle II, at the Department of Agricultural Electrification, Mechanics and Design Basics within the UASM.

The approval of the obtained results and the theoretical and practical value of the thesis were approved within:

- the 2021 royal scholarship competition for scientific achievements, organized by the Royal House of Romania - as a result of which the merit scholarship of King Michael I was obtained;

- the scientific conference of students, master's and doctoral students on 23.03.2022 organized at FIATA by UASM - where the 1st place classification Diploma for research results was obtained;

- the plenary session of 30.03.2022 of the 75th conference of students, masters and doctoral students of UASM - where the Diploma of Excellence for research achievements was obtained;

- the International Scientific Symposium "Regulating the use of natural resources: achievements and perspectives" dedicated to the 70th anniversary of the founding of the Faculty of Cadastre and Law, UASM-2021, based on the presented scientific report;

- four scientific seminars organized at the Department of Agricultural Electrification, Mechanics and Design Bases of FIATA;

- the extended meeting of the UTM "Manufacturing Engineering" department from 16.12.2022, by presenting the thesis at the primary stage;

- the meeting of the scientific seminar of the UTM Doctoral School on 31.03.2023, by presenting the thesis and recommending it for public support.

THESIS CONTENT

In the Introduction, the actuality of the research theme, the purpose and objectives, the scientific novelty, the theoretical importance and the applied value of the thesis, the main results of the work, the implementation of the results and their approval are defined.

1. Analysis of the current situation and identification of solutions to increase energy efficiency at milk collection points

It includes:

- general information on ways to reduce electricity consumption when cooling and storing milk;
- the current situation regarding milk production in the Republic of Moldova;
- the current situation regarding milk collection points on the territory of the Republic of Moldova;
- analysis of the process of collection, cooling, storage and delivery of milk in the collection points in the north of the Republic of Moldova;
- analysis of milk cooling systems from an energetic and constructive point of view;
- the study regarding the advantages of implementing permanent magnets on the rotor of the asynchronous motor driving the compressor of the refrigeration plant;
- the study regarding the use of ecological milk cooling facilities with low electricity consumption;
- milk pre-cooling systems to reduce electricity consumption;
- analysis of solutions to reduce electricity consumption from the network at milk collection points with the use of photovoltaic systems.

From independence to the present, according to the data of the National Bureau of Statistics (BNS) (see table 1.1), a continuous decrease in the number of cattle on the territory of our country has been attested. Thus, from 395,000 heads in 1991 to 67,100 heads in 2023. During this period, the reduction of the cattle herd reaches values of approx. 5.9 times.

Local milk processing and processing companies are based on the raw material collected from home producers through collection points equipped with refrigeration facilities, as an example the one shown in Fig. 1.1, which are located in rural areas.

Currently, according to the information of the National Agency for Food Safety (ANSA), 43 milk processing units are authorized on the market of the Republic of Moldova. These units, having no other alternatives, created milk collection points from the population, collecting approximately 90% of the processed raw material.

In total, 669 milk collection points from the population are functional and with proper documents on the territory of the country.

The process of collecting milk from home producers in rural localities in the north of the Republic of Moldova usually takes place in two shifts - in the evening and in the morning. The milk collected in the evening shift is cooled and stored in the PCL until the morning of the next day.

The volume of milk collected in the morning shift is chewed with the milk collected in the evening shift and cooled to a temperature of +6 ... +8°C, after which it is pumped into the specialized tanker truck and transported for processing.

The average electricity consumption required to cool 1000 liters of milk at the PCL in the north of the Republic of Moldova was determined to be 20.9 kWh. Replacing the refrigeration installations used in PCL with modern installations foresee high costs and the use of the existing ones have a high electricity consumption, limited cooling performance due to the relatively small contact surface of the atmospheric air with the refrigerant and low efficiency of the use of evaporative cooling, as well as low level of reliability.

Currently, the specialized literature presents the results of research on the implementation of natural cold in the cooling process of agri-food products, which allow a significant reduction of energy costs in the cooling process during the cold period of the year.

At milk collection points in European countries where they are equipped with centralized water supply systems, in order to reduce electricity consumption when cooling milk and to heat water for the needs of the technological process, milk pre-cooling systems with flow coolers are used (see Fig. 1).

Pre-cooling with water from the centralized system reduces the general and operating expenses of the PCL by significantly reducing the duration of milk cooling with the refrigeration plant, since the milk enters the cooling container at a temperature of +12 ... +18°C.

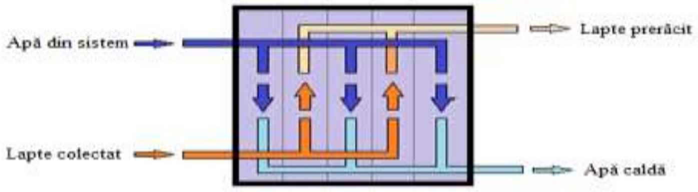

Fig. 1. Milk pre-cooling system with in-flow cooler

Based on the analyzes carried out, the thesis proposes the development of mathematical models and methods for calculating the technological and constructive parameters of the installation with natural and artificial cold for cooling milk; concretization of the energy, operation and control regimes of the ecological milk cooling facility; implementation of the experimental facility with natural and artificial cold at a milk collection point in the country; establishing the optimal technological parameters for the pre-cooling and cooling of milk at the collection points and carrying out a feasibility study regarding the implementation of the On-Grid type photovoltaic system at PCL GȚ "Harabari Andrei Victor".

2. Aspects regarding the determination of the constructive technological parameters of the ecological milk cooling installation

It includes:

- general notions regarding milk cooling processes with natural and artificial cold;
- the development of the calculation methodology and the substantiation of the constructive parameters of the ecological plant for cooling milk with natural cold;
- initial requirements for the development of mathematical models of the milk cooling process and the intermediate refrigerant;
- development of the mathematical model and calculation method of the flow cooling process of the intermediate refrigerant with natural cold;
- development of the mathematical model and calculation method of the milk cooling process with AFI from the cold accumulator;
- the calculation methodology and the mathematical model for the pre-cooling of milk with ice in the process of mobile collection from domestic producers.

In the milk cooling process in the capacitive cooler, the cooling of the AFI (water or brine) during the cold period of the year is proposed to be carried out by means of a seasonal natural cold capture and storage facility, which is equipped with a heat exchanger (radiator with fan) mounted outside the PCL with AFI storage in a thermally insulated cold accumulator.

The cooling of milk with the intermediate refrigerant in the cold accumulator for direct cooling installations can be carried out through the walls of the capacitive cooler or by installing an additional heat exchanger made of food grade stainless steel in the capacitive milk cooling tank, and for indirect cooling installations the combination of the existing cooling with the proposed cooling circuit.

The developed calculation methodology allows establishing the constructive parameters of the air-AFI flow cooler, the fan and the pump in relation to the storage capacity of the thermally insulated cold accumulator.

For cooling milk with natural cold, two heat exchangers and a cold accumulator are required. The first exchanger is intended to cool the AFI (water or brine) which is stored in the thermally insulated cold accumulator. To justify the parameters of the mentioned exchanger and the cold accumulator (AF) the dependence is established:

$$C_{AFN} = f(t_{ia}, t_{ea}, t_{iafr}, t_{eafr}, q_{afr}, q_{ar}, T_{raf}, V_{af}, V_{ae}). \qquad (1)$$

The second exchanger provides for the cooling of the milk in a capacitive heat exchanger with the natural cold from the thermally insulated cold accumulator:

$$C_{IFC} = f\left(t_{il}, t_{fl}, t_{iafc}, t_{eafc}, q_{af}, T_{rl}, V_{af}, V_l\right). \qquad (2)$$

For the development of the mathematical models of the milk cooling process, of the intermediate refrigerant and for the analysis of the energy balances of the cooling systems, the following requirements are imposed:

- the initial temperature of the milk after collection $t_{il} = +19^oC$;
- the final temperature of the cooled milk $t_{fl} = +6^oC$;
- the temperature of the cooled intermediate refrigerant $t_{fafr} = t_{iafc} = +4^oC$;
- the initial temperature of the intermediate refrigerant $t_{iafr} = +14^oC$;
- ambient temperature $t_{ia} \leq +4^oC$ și $t_{ia} < t_{iafr}$;
- the operation of the flow exchanger provides that $t_{fafr} = t_{ia} + 2$;
- milk cooling time $T_{rl} \leq 2h$;
- heat loss is neglected;
- the specific heat of AFI (water) at constant pressure is equal to that of milk $c_{af} = c_l = 4{,}185\ kJ/kgK$;
- specific heat of air at constant pressure $c_a = 0.8382\ kJ/kgK$;
- according to specialized literature, constant cooling time $T = 0.67h$ or $3T = 2h$ and the volume of AFI from the IRC walls will be $V_{arc} = 0.2 \cdot V$.

Based on the submitted requirements, the mathematical models for both cooling processes were developed.

The mathematical model and calculation method of the AFI cooling process in a radiator (R) with forced flow cooling by the fan (V) and the ideal mixing of the AFI (water or brine) in the thermally insulated cold accumulator (AFT), determines the ratio of the volume of air required to cool a volume of AFI and the time required to cool the agent to +4°C, at the ambient temperature of +2°C. In Fig. 2 shows the technological diagram of the cooling process of AFI in a radiator with forced cooling in flow, with ideal storage and mixing in a thermally insulated cold accumulator proposed for implementation at PCL in the Republic of Moldova.

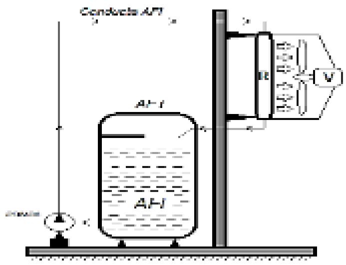

Fig. 2. Technological scheme of the natural cold capture and storage process

The energy balance equation for the flow cooler (radiator) for AFI cooling is given by the relation:

$$q_{af} \cdot c_{af}\left(t_{iafr} - t_{fafr}\right) = q_a \cdot c_a(t_{ea} - t_{ia}). \quad (3)$$

Based on the imposed initial conditions, the following relations are obtained on the basis of which the curves are drawn: $C_{AFN} = f(t_{ia})$ și $C'_{AFN} = f(t_{ea})$ Fig. 3:

$$C_{AFN} = 10 \cdot \left[ln(\frac{t_{iafr} - 2}{t_{iafr} - t_{ia} - 2}) \right]^{-1} = 10 \cdot \left[ln\left(\frac{12}{12 - t_{ia}}\right) \right]^{-1}, \tag{4}$$

$$C'_{AFN} = \frac{V_{ae}}{V_{af}} = \frac{5 \cdot \left(t_{iafr} - t_{fafr}\right)}{t_{ea} - 2} = \frac{5 \cdot (14 - 4)}{t_{ea} - 2} = \frac{50}{t_{ea} - 2}. \tag{5}$$

The point of intersection of the curves $C_{AFN} = f(t_{ia})$ și $C'_{AFN} = f(t_{ea})$ shown in Fig. 3 represents the optimal solution of the AFI cooling process in a flow-cooling heat exchanger stored in a thermally insulated natural cold accumulator, for further use in milk cooling.

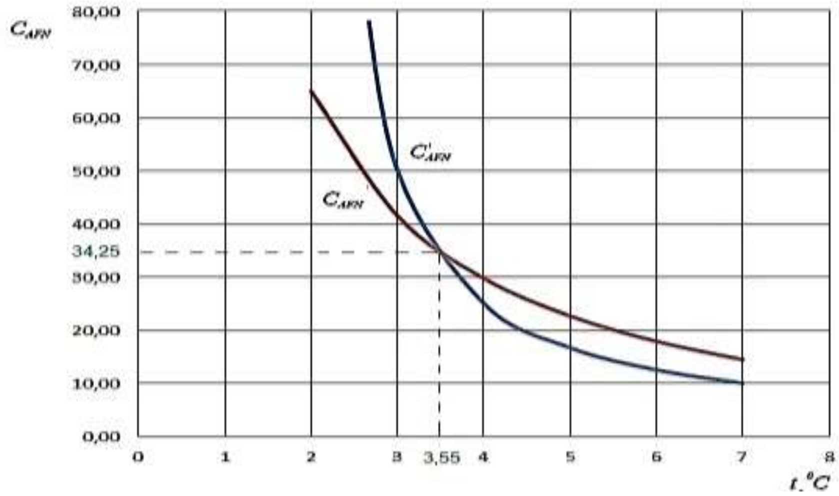

Fig. 3. The ratio between the estimated volume of air required for cooling the volume of AFI depending on the ambient temperature.

The optimal ratio is determined C_{AFN} to bring the AFI temperature in the naturally cold thermally insulated accumulator to temperature <+4°C:

$$C_{AFN} = 10 \cdot \left[ln\left(\frac{t_{iafr} - 2}{t_{iafr} - t_{ia} - 2}\right) \right]^{-1} = 10 \cdot \left[ln\left(\frac{12}{12 - t_{ia}}\right) \right]^{-1} = 34.25. \tag{6}$$

To cool the AFI in a flow heat exchanger from the temperature of +14°C to +4°C with the air temperature at the entrance to the heat exchanger of +2°C, an equivalent volume of air 34.25 times greater than a AFI.

Regarding the cooling time of 2.2 cubic meters of AFI from the temperature of +14°C, having the calculated and initial parameters $q_{afr(apa)} = 3.0\ m^3/h$ și $q_{aer} = 600\ m^3/h$ va fi:

$$T_{traf} = \frac{V_{af}}{q_{afr}} \cdot N_{cp} = \frac{2.2}{3} \cdot 8.36 = 6.1 ore. \tag{7}$$

Mathematical model of the natural cold milk cooling process in a Capacitive Cooler (IRC), where the AFI (water or brine) from the AFT is pumped through the walls of the IRC

In Fig. 4 presented the technological diagram of the milk cooling process with natural cold.

The purpose of developing the mathematical model is to establish the required volume of AFI in non-mixing mode with a horizontal herd for cooling milk from the initial temperature of +19°C to the storage temperature of +6°C in an IRC with the established cooling time $T_{rl} = 2\,ore$.

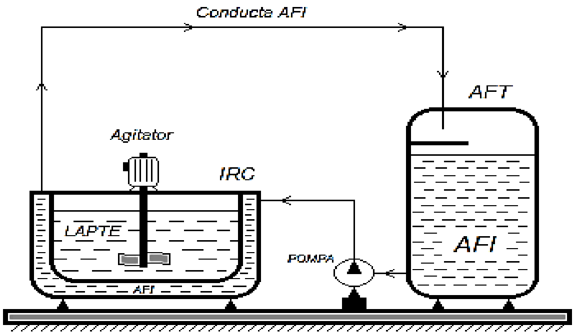

Fig. 4. Technological scheme of the milk cooling process in a capacitive heat exchanger with natural cold from AFT

The energy balance equation in the milk cooling process in the IRC will be:

$$\frac{V_l}{T_{rl}} \cdot c_l \cdot \left(t_{il} - t_{fl}\right) = q_{af} \cdot c_{af} t_{iafc}. \quad (8)$$

From the relationships obtained in the thesis and the initially submitted requirements, it is determined that for the cooling of milk in IRC with natural cold at PCL with milk collection in two shifts, the ratio of the volume of AFI from AFT and the total volume of cooled milk will be:

$$C_{IFC} = \frac{V_{af}}{V_l} = \frac{2.155}{0.7} = 3.1. \quad (9)$$

When developing the ecological milk cooling plant with low electricity consumption based on the existing IRC at PCL, a natural cold accumulator with the AFI storage capacity 3.1 times higher than the IRC capacity is needed.

Taking into account that during the warm period of the year the temperature of the milk after collection is much higher than that indicated in the initially imposed requirements, a generalized mathematical model was developed that allows the determination of the ice requirement for pre-cooling the milk in the mobile collection process up to the preset temperature of +19. .. +20°C. The model is based on clearly defined fundamental principles and assumptions.

For the development of the mathematical model, the following requirements are put forward:

- the temperature of the freshly collected milk $t_{0lp} = +27^oC$;
- the average temperature of the environment during the warm period of the year $t_{mv} = +25^oC$;
- preset precooling temperature $t_{pr} = +20^oC$;
- the initial temperature of the ice $t_{ig} = -18^oC$;
- the melting temperature of ice $t_{0g} = 0^oC$;
- the latent heat of ice $\lambda_g = 332 \cdot 10^3 J/kg$;
- specific heat of water equal to that of milk $c_{apa} = c_l = 4185\, J/kgK$;

- specific heat of ice $c_g = 2100 J/kgK$.

The total amount of ice required to cool the fresh milk from the initial temperature to the preset pre-cooling temperature can be determined from the heat balance:

$$Q_g = Q_l + Q_r, \tag{10}$$

and: – heat flow of ice

$$Q_g = Q_{g1} + Q_{g2} + Q_{g3} = m_g(c_g \cdot (t_{0g} - t_{ig}) + \lambda_g + c_{apa} \cdot (t_{pr} - t_{0g})); \tag{11}$$

– heat flow of milk

$$Q_l = m_l \cdot c_l \cdot (t_{0lp} - t_{pr}); \tag{12}$$

– mobile tank heat flow

$$Q_r = A_{rm} \cdot K_{rm} \cdot (t_{mv} - t_{pr}); \tag{13}$$

Based on the equations obtained, the ratio between the mass of ice and that of milk was established for the precooling of milk from the temperature of +27°C to the precooling temperature of +20°C to the ambient temperature of +25°C will be:

$$K_g = \frac{m_g}{m_l} = \frac{23.48}{360} = 0.065. \tag{14}$$

Since the temperature of the environment is variable, the graph of the dependence between the mass of ice and that of the temperatures of the environment for different amounts of milk was elaborated.

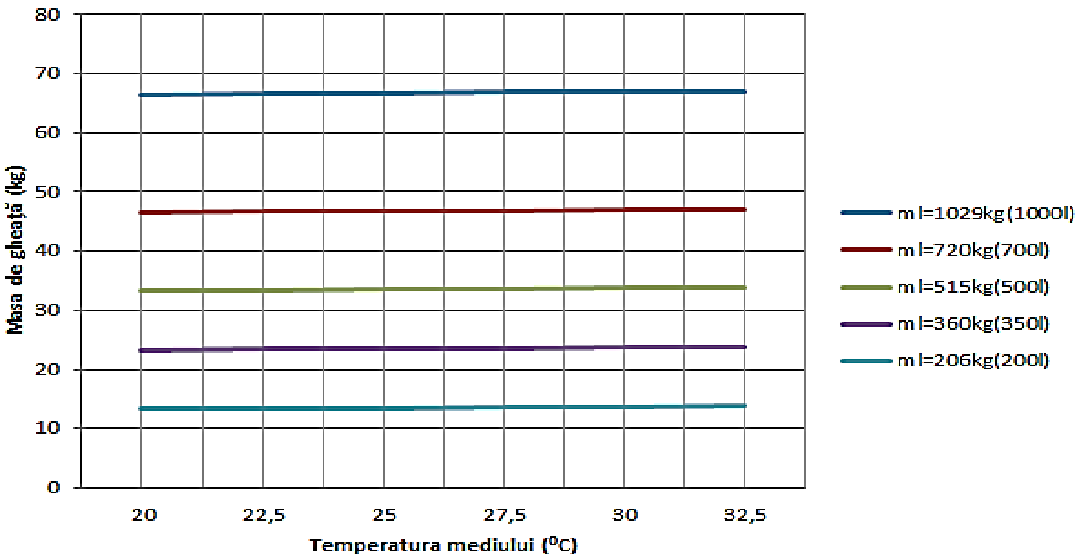

Fig. 5. Dependence of the amount of ice for different amounts of milk in relation to the temperature of the environment

From Fig. 5 it can be seen that the influence of the ambient temperature in the milk pre-cooling process in the mobile tank is low, the maximum difference of ice required to pre-cool the same amount of milk does not exceed the mass of 0.6 kg in the ambient temperature range from +20 to + 32.5°C. This is because the pre-cooling process does not take long.

3. The study of the energy regimes of operation and control of the ecological milk cooling plant

It includes:

- development of the ecological milk cooling facility with low electricity consumption;
- the structural schemes of the automatic graphs and the operating algorithms of the electrical components of the ecological milk cooling plant;
- argumentation of operating regimes, automation and control of the cooling process of the intermediate refrigerant;
- argumentation of the operating regime, automation and control of the milk cooling process with intermediate refrigerant;
- analysis of electricity flows of PCL equipment;
- the study of energy flows in the cooling regime of the intermediate refrigerant with the ecological installation with natural cold;
- the study of energy flows in the cooling regime of the intermediate refrigerant with the ecological installation with natural and artificial cold;
- the study of energy flows in the cooling regime of the intermediate refrigerant with the ecological installation with artificial cold;
- the study of energy flows in the milk cooling process with AFI from the thermo-insulated cold accumulator;
- determining the period of use of natural cold in the milk cooling process at the collection points in the north of the country.

The refrigerating equipment for cooling milk is the main consumer of electricity in the process of processing dairy products. The primary milk cooling stage accounts for approximately 27-30% of the electricity consumed.

The analysis of electricity consumption at PCL, carried out by us in several localities in the northern area of the Republic of Moldova, showed that the average consumption of electricity at PCL in the north of the Republic of Moldova is approx. 21 kWh for cooling 1000 liters of collected milk.

In order to reduce electricity consumption and harmful emissions in the environment, the operation, energy and control regimes of the ecological installation proposed in Fig. 6.

The proposed installation is based on four working regimes, three of them are intended for AFI cooling and one milk cooling regime. Its operation is divided into two control circuits, the control with the cooling regimes of the AFI and the control of the milk cooling process.

AFI cooling regimes depend on the time of year and ambient temperatures, being divided into:

- the AFI cooling regime with FA, mainly this regime is intended for the warm period of the year when the IFFA cools the AFI which is later used to cool the milk;
- the cooling regime with natural and artificial cold of the AFI, which is provided for the transitional periods from warm to cold temperatures of the year and vice versa;
- the natural cold cooling regime of AFI, seasonal regime for the cold period of the year that excludes the use of IFFA.

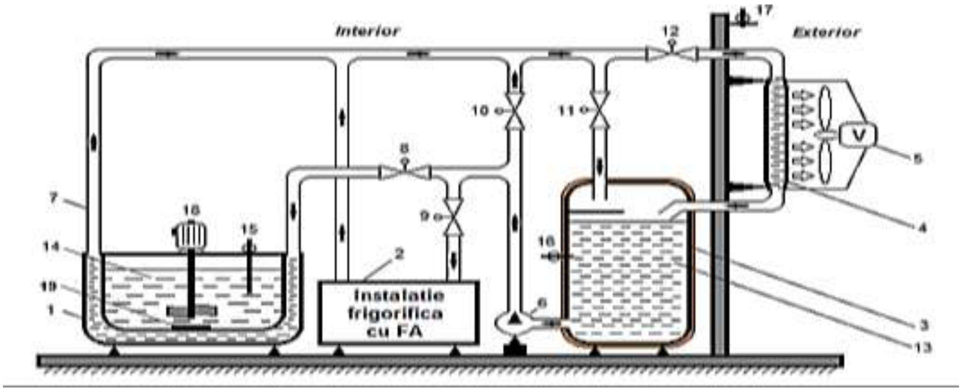

Fig. 6. Ecological installation for cooling milk with low electricity consumption

1 - capacitive heat exchanger, 2- refrigeration system with artificial cold, 3- thermally insulated cold accumulator, 4- flow heat exchanger, 5- fan, 6- pump, 7- intermediate refrigerant pipe, 8,9, 10,11,12- valves with electric drive, 13- intermediate refrigerant, 14- milk, 15,16,17- temperature sensors, 18- stirrer, 19- pressure sensor.

The milk cooling regime is provided for the whole year using the AFI from the thermally insulated cold accumulator in which cold is accumulated using the cooling regimes of the AFI.

Based on the installation proposed in Fig. 6, the structural schemes of the automatic graphs and the operating algorithms for the electrical equipment in the PCL are established.

For the development of automatic graphs of functional electrical equipment in the milk collection and cooling process, it is necessary to use all the work stages that provide for stopping (O), starting (P), operation (F) and failure (D) of electrical equipment (E) basic via the following command and control elements:

H - the command to start the electrical circuit of the AFI cooling process;

S - the command to start the electric circuit of the milk cooling regime;

(commands and are independent and cannot work simultaneously, these being coordinated by the mode switch "AFI cooling" or "Milk cooling" position)

h - command to stop the electrical circuit of the AFI cooling process;

$\bar{h}$ - lack of command to stop the electrical circuit of the AFI cooling process;

s - the command to stop the electric circuit when cooling the milk;

$\bar{s}$ - lack of command to stop the electric circuit when cooling the milk;

$\bar{t}$ - lack of signals from temperature sensors;

E - functional electrical equipment subject to automation;

R_a - the emergency mode signal;

$\bar{R}_a$ - lack of emergency mode signal;

v - the presence of the "open" signal of the valve;

$\bar{v}$ - the presence of the "closed" signal of the valve;

M_a - operation signal of the milk stirring motor;

$\bar{M}_a$ - lack of operation signal of the milk stirring motor;

g - the signal from the pressure sensor regarding the presence of milk in a volume of at least 15% of the capacity of the refrigerating tank;

$\bar{g}$ - lack of signal from the pressure sensor.

For the proposed ecological installation, it is recommended to program the sensors with the presence of signals at the temperatures: $t_{16} \geq +4^oC,\ t_{17} \leq +6^oC$ provided that $t_{16} \geq t_{17}$, and in the milk cooling process $t_{15} \geq +6^oC$.

The cooling regime of the intermediate refrigerant with artificial cold (RFA) through the proposed ecological installation will be implemented during the warm period of the year when the ambient temperature measured with the temperature sensor (17) will be higher than 6^{o}C. In this regime, valves (9) and (11) transmit an "open" signal and (8), 10) and (12) transmit a "closed" signal. The cooling process will end when the AFI temperature measured by the sensor (16) will be lower than +4^{o}C.

The scheme of the automatic graph of the cooling regime of the intermediate refrigerant with artificial cold is presented according to Fig. 7.

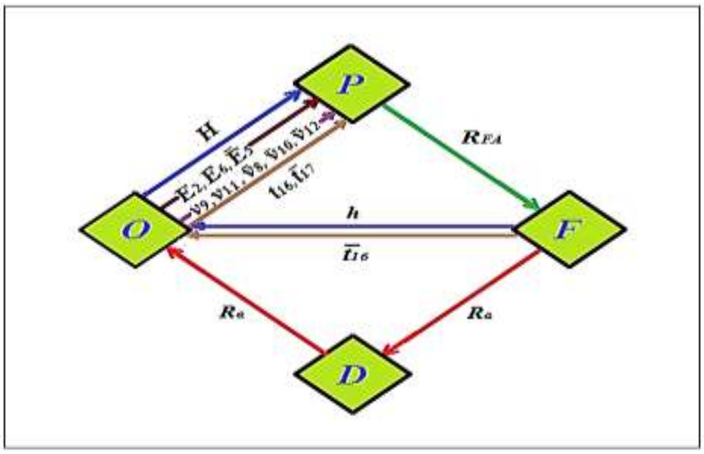

Fig. 7. Grafulu automat a regimului de răcire a AFI cu FA

The algorithm of operation of the cooling regime of AFI with FA is presented with the relation:

$$F_{FA} = (H + E_2 + \bar{E}_5 + v_9 \cdot v_{11} \cdot \bar{v}_8 \cdot \bar{v}_{10} \cdot \bar{v}_{12} + \bar{t}_{17}) \cdot E_6 \cdot \bar{R}_a \cdot t_{16} \cdot \bar{h}. \quad (16)$$

If the temperature sensor signal (17) appears in the temperature range from +6°C to +4°C and the sensor signal (16) is maintained, the installation will switch to the combined AFI cooling regime with natural and artificial cold, then the valve (12) will switch to the "open" position and (11) will move to the "closed" position and the air fan (5) will connect. This regime works until the ambient temperature falls below +4°C. The automatic graph for the combined regime shown in Fig. 8 supports signal changes, but the stop conditions remain the same as in the case of the previous regime.

This regime is characteristic of transitional periods of time between the warm and cold seasons, and vice versa.

The cooling regime with natural and artificial cold is presented by the operation algorithm given by the relationship below:

$$F_{FC} = (H + E_2 + E_5 + v_9 \cdot v_{12} \cdot \bar{v}_8 \cdot \bar{v}_{10} \cdot \bar{v}_{11} + t_{17}) \cdot E_6 \cdot \bar{R}_a \cdot t_{16} \cdot \bar{h}. \quad (17)$$

In the cold period of the year when the temperature of the environment controlled by the temperature sensor (17) is <+4°C, the refrigerating installation switches to AFI cooling mode with natural cold. The cooling process of the intermediate refrigerant takes place by pumping it with the help of the pump (6) through the flow heat exchanger (4) and the thermally insulated cold accumulator (3) with the valves (10) and (10) open. In this regime, valves (8), (9) and (11) are closed and IFFA (2) is disconnected. Forcing the cooling of the AFI through the exchanger (4) takes place with the help of the fan (5). This process takes place until the AFI temperature monitored by the temperature sensor (16) reaches below +4°C.

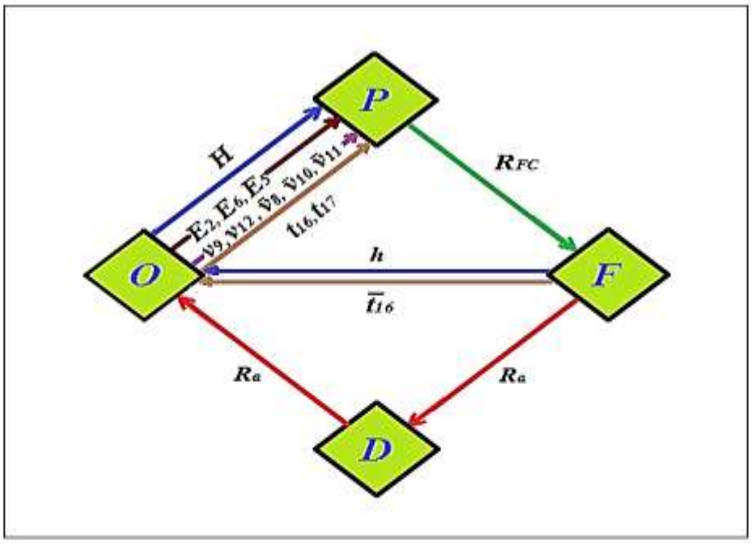

Fig. 8. Automatic graph of the AFI cooling regime with combined cold

The requirements for the control parameters of the cooling regime of the AFI with the use of natural cold are:

- presence of temperature sensor signals (16) and (17), where (17) has values <4°C;

- equipment (5) and (6) functional in the cooling process;

- functional valves (10) and (12).

Based on the imposed requirements, the automatic graph scheme presented in Fig. 9

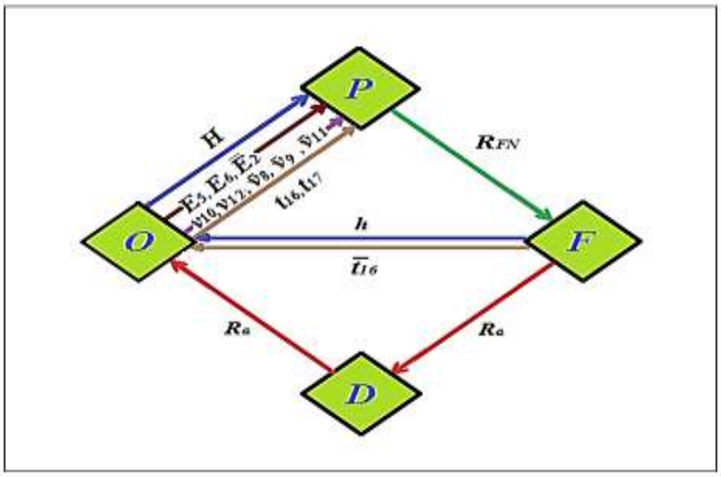

Fig. 9. Automatic graph of the AFI cooling regime with natural cold

The operating algorithm of the ecological installation in the cooling regime of AFI with natural cold is developed based on Fig. 9 and has the form:

$$F_{FC} = (H + E_2 + E_5 + v_9 \cdot v_{12} \cdot \bar{v}_8 \cdot \bar{v}_{10} \cdot \bar{v}_{11} + t_{17}) \cdot E_6 \cdot \bar{R}_a \cdot t_{16} \cdot \bar{h}. \tag{18}$$

The analysis of the automatic graphs obtained for the ecological milk cooling plant with low electricity consumption for the cooling regimes with natural, combined and artificial cold of AFI allows the realization of a system of operating algorithms on the basis of which the electrical scheme of command, control and of force of the installation:

$$\begin{cases} F_{FA} = (H + E_2 + \bar{E}_5 + v_9 \cdot v_{11} \cdot \bar{v}_8 \cdot \bar{v}_{10} \cdot \bar{v}_{12} + \bar{t}_{17}) \cdot E_6 \cdot \bar{R}_a \cdot t_{16} \cdot \bar{h} \\ F_{FC} = (H + E_2 + E_5 + v_9 \cdot v_{12} \cdot \bar{v}_8 \cdot \bar{v}_{10} \cdot \bar{v}_{11} + t_{17}) \cdot E_6 \cdot \bar{R}_a \cdot t_{16} \cdot \bar{h}. \\ F_{FN} = (H + E_5 + \bar{E}_2 + v_{10} \cdot v_{12} \cdot \bar{v}_8 \cdot \bar{v}_9 \cdot \bar{v}_{11} + t_{17}) \cdot E_6 \cdot \bar{R}_a \cdot t_{16} \cdot \bar{h} \end{cases} \tag{19}$$

The second control circuit of the proposed installation provides for the command and control of the milk cooling process with AFI cooled by the first circuit.

To start the milk cooling regime, it is necessary to go to the start command of the electrical circuit S and to have the signal of the temperature sensor (15) present

Then automatically the valves (8) and (11) go to the "open" position and (9), (10) and (12) to the "closed" position.

The milk cooling regime will be ensured if the AFI temperature will be less than or equal to +5^{o}C to have the possibility to cool the milk to the storage temperature <+6^{o}C.

In the milk cooling process the basic electrical equipment is the pump (6) which pumps the cold AFI stored in the thermally insulated cold accumulator through the walls of the capacitive milk cooling heat exchanger. As a result of these conditions, the automatic graph of the milk cooling process will have the form Fig. 10.

Following the elaboration of the automatic graph schemes, it was established that in the process of switching from the AFI cooling regimes to the milk cooling regime, the common electrically operated elements are the AFI pump and the valves, these being interconnected between the electrical circuit one and two, which can be seen from the operation algorithm of the milk cooling regime:

$$F_{RL} = (S + v_8 \cdot v_{11} \cdot \bar{v}_9 \cdot \bar{v}_{10} \cdot \bar{v}_{12}) \cdot E_6 \cdot \bar{R}_a \cdot t_{15} \cdot \bar{s}. \quad (20)$$

Based on this algorithm, the electrical diagram of the second circuit for the command and control of the milk cooling process is developed.

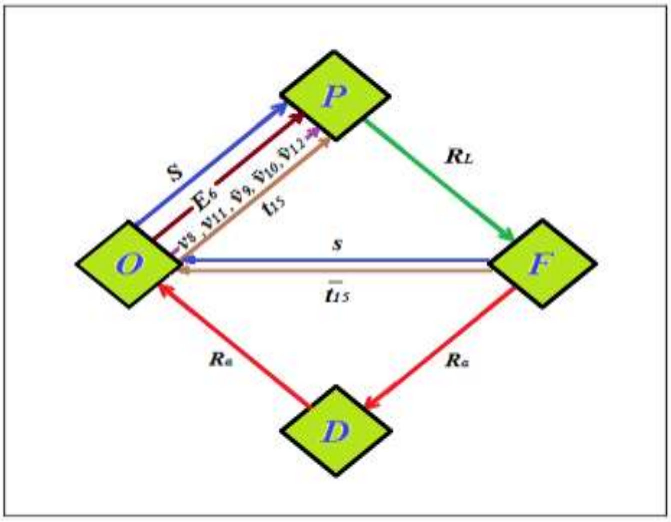

Fig. 10. Automatic graph of the milk cooling regime with AFI

The electrical energy consumed at the milk collection point by the ecological refrigeration plant in the processes of pumping and cooling the intermediate refrigerant (AFI), masticating and cooling the milk, pumping into and out of the milk cooling tank is converted into mechanical or thermal energy by driving the AFI pump, the fan, the valves, the artificial chiller, the masticator and the milk pump, and some of it is converted into energy losses.

The energy flow analysis is based on the energy balance equation:

$$\sum W = \sum W_c + \sum W_p, \quad (21)$$

where W - input energy; W_c - energy consumed; W_p - energy losses.

The calculations of the components of the energy balance equation are performed based on the nominal parameters of the electrical equipment of the ecological milk cooling plant and of the auxiliary ones at the collection point.

The proposed ecological plant has a low annual electricity consumption compared to the existing refrigeration plants at PCL, due to seasonal operating regimes.

For comparison, Table 1 shows the nominal parameters of the classic JAPY tech-700 type PCL installation and the calculated parameters of the electrical equipment for the development of the ecological installation with low electricity consumption.

Table 1. Nominal parameters of electrical equipment of IFFA and ecological installation

Name of the electrical equipment	IFFA type JAPY tech -700		Ecological installation with low electricity consumption	
	Rated power P_1, kW	Return	Rated power P_1, kW	Return
Compressor motor	3.0	0.78	3,0	0.78
Pump AFI Type GRS 15/6 (1.2-3.0 m^3/h)	0.093	0.86	0.093	0.86
Fan (with motor АЛ12-4У)	-	-	0.180	0.8
Milk chewer	0.08	0,65	0.08	0.65
Control panel	0.02	0,9	0.02	0.9
Milk pump	1.0	0,85	1.0	0.85

The analysis of the obtained data for each mode of operation of the ecological installation proposed for implementation at the milk collection points allows establishing the necessary electricity consumption for the entire cooling process of 700 liters of milk, which are presented in Table 2.

Table 2 Calculated electricity consumption in the process of cooling 700 l of milk

Cooling regime	Estimated electricity consumption for cooling 2.2 m3 of AFI (kWh)	Estimated electricity consumption for milk cooling (kWh)	Estimated electricity consumption for the entire cooling process of 700 liters of milk (kWh)
with FN	1.8	0.4	2.2
with FC	11.5	0.4	11.9
with FA	14.0	0.4	14.4

According to the data obtained from PCL administrators in the north of the republic, the average electricity consumption for cooling 1000 liters of milk with a classic refrigeration installation with direct cooling with freon is 21 kWh.

Comparing with the data obtained for the operation regimes of the ecological refrigeration plant proposed for implementation, we have:

- in the cooling process with natural cold, electricity consumption is reduced by 6.5 times;
- in the combined cold cooling process, electricity consumption is reduced by 1.2 times;
- and in the artificial cold cooling process the difference in consumption can be neglected, the basic advantage of the ecological installation in this case is that the AFI can be cooled at night using the differentiated electricity tariffs, this would provide a financial saving of 40%.

Analysis of statistical data on atmospheric air temperatures for seven months of 2017, 2018, 2019, 2020 and 2021 determined that the average duration of use of natural cold is 39% of the period of one year and that of use of combined cold is 5 %. Based on these data, it was established that the annual electricity consumption will be reduced by 34 percent on average.

4. Researching the ecological plant for cooling milk with low electricity consumption at the collection points as an object of direction

It includes:

- contributions to the modernization of milk cooling facilities for PCL in the country;
- the study of the technical-economic efficiency in the milk cooling process with the use of the ecological installation with low electricity consumption at the collection points;
- milk pre-cooling in the process of mobile collection from domestic producers;
- the feasibility study regarding the implementation of the On-Grid photovoltaic system at PCL GȚ "Harabari Andrei Victor".

In order to justify the applicability of calculation methodology and mathematical models, the experimental sample of the ecological milk cooling plant with low electricity consumption with two cooling stages, AFI cooling and milk cooling, using natural and artificial cold, was developed. The experimental refrigeration installation was developed at the PCL GȚ "Harabari Andrei Victor", which consists of two parts, the part outside the PCL intended for the seasonal cooling of AFI with natural cold (Fig. 11a) and the inner part, intended for both the cooling of the AFI and the cooling milk (Fig. 11b). For the development of the experimental installation, modern high-quality, wear-resistant materials that meet the requirements of the working environment for cooling systems were used. The technical parameters of the installation are presented in Table 3.

Table 3 Technical parameters of the experimental milk cooling plant with low electricity consumption

Installed power of the IFFA	kW	3.0
The volume of the milk cooling container	l	700
Pump power Typ GRS 15/6 de AFI 3.0 m^3/h;1.9 m^3/h;1.2 m^3/h	kW	0.093; 0.060; 0.040
Fan motor power	kW	0.180
The volume of the cold accumulator	m^3	2.2
Radiator dimensions	m	$L_z = 0.656$; $L_h = 0.686$; $L = 0.091$
Radiator volume	l	7.5
Hose d32	m	18
Valves d32	buc	5
Form hose connector T	buc	5

In Fig. 11a shows the external part of the ecological experimental plant with low electricity consumption that is intended for cooling AFI (water or brine), consisting of a heat exchanger, motor fan, temperature sensor and connection hoses with AFT.

This part of the installation is used only during the cold period of the year when the ambient temperature is below +6°C.

The part of the installation inside the PCL is shown in Fig. 11b and consists of the following basic components - IFFA, AFI pump, cold accumulator and capacitive heat exchanger for milk cooling.

The experimental installation was used during 2021 at the GȚ "Harabari Andrei Victor" milk collection point in Dondușeni district, Corbu village, the monthly electricity consumption data for milk cooling and the volume of milk collected and cooled at PCL are presented in Appendix 5 of the thesis.

a b

Fig. 11 Experimental refrigeration plant, combined with artificial and natural cold
a – section of the refrigeration plant outside the PCL
b- section of the refrigeration plant inside the PCL

In order to establish the actual specific electricity consumption for cooling 1000 liters of milk, the variable parameters that influence the cooling duration of the intermediate refrigerant and the milk were monitored during the period 21-27.11.2021, the AFI subjected to cooling had on the first day of evaluation initial temperature of +14°C, the data obtained are shown in Table 4.

Table 4. Real electricity consumption at PCL during the cold period of the year

Monitoring period	21.11.2021	22.11.2021	23.11.2021	24.11.2021	25.11.2021	26.11.2021	27.11.2021
Ambient temperature, °C	-1	+3	+2	0	-2	+1	-4
The initial temperature of the AFI, °C	+14	+10	+10	+9	+8	+10	+8
Cooling time of AFI to final temperature of +4°C	4.25	5.0	4.75	3.75	3.5	4.0	3.33
The volume of milk collected and cooled in two shifts, thousands of liters	0.52	0.49	0.53	0.51	0.5	0.53	0.48
The initial temperature of the milk in shift I, after chewing with the milk of shift II from the previous day, °C	+13	+15	+14	+13	+12	+14	+11
The initial temperature of the milk in shift II, °C	+18	+20	+20	+19	+18	+19	+17
Milk cooling time of two shifts	1.5	1.4	1.5	1.5	1.4	1.5	1.4
Daily electricity consumption, kWh	1.5	1.7	1.7	1.4	1.3	1.5	1.3
Specific electricity consumption, kWh/1000l	2.9	3.5	3.2	2.7	2.6	2.8	2.7

The practical data obtained during seven consecutive days with ambient temperatures between -4°C and +3°C show that the specific electricity consumption for cooling one thousand liters of collected milk is between 2.6 - 3.5 kWh, which confirms the correctness of the analytical calculations from chapter 3 where the specific electricity consumption of 3.12 kWh was obtained for the entire cooling process of 1000 liters of milk at the ambient temperature of +2^{0}C.

The results of the assessment during 2021 of the energy indices at PCL administered by GȚ "Harabari Andrei Victor" are indicated in Table 5.

The energy indices obtained based on the experimental data indicate a reduction of electricity consumption (EE) in the cold period by 6.4 times, and in the transitional period between seasons by 1.2 times.

Table 5. Results of the evaluation of the energy indices of the experimental refrigeration plant

Milk cooling regimes depending on the time of the year	Experimental indications						Calculated indices	
	Ambient temperature surrounding ^{0}C	Initial temperature of milk ^{0}C	The temperature of the cold milk ^{0}C	Duration of operation, h	The powe, kW	The consumed energy, kWh	Volume of chilled milk, liters	Specific electricity consumption, kWh/1000l
The process of cooling milk with natural cold (in the cold period)	0 +2	19	6	7.6	0.29	2.2	700	3.15
The process of cooling milk with artificial cold (in the cold period)	0 +2	19	6	4.7	3.0	14.1	700	20.1
Milk cooling process with combined cold (in the transitional period)	+4 +6	25	6	3.7	3.3	12.2	700	17.4
The process of cooling milk with artificial cold (in the warm period)	25	29	6	4.8	3.0	14.4	700	20.6

The technical-economic efficiency study regarding the implementation of natural cold at the studied PCL established that the investment recovery period for reusing the existing IF in the ecological milk cooling facility with low electricity consumption is 2 years and 7 months.

During the 2020 year at the PCL GȚ "Harabari Andrei Victor" after the mobile collection of milk from home producers were carried out periodic measurements of the temperature of the milk at the time of storage in the tank of the refrigerating installation in the PCL, it was determined that the average temperature of the milk at the time storage in the cold storage facility in PCL in the months of November-April is +19.4^{o}C, which reduces the risk of spoilage of the milk during collection, and in the warm period, in the months of May-October, the average temperature of the milk is +27^{o}C, a period that requires precooling solutions during collection. Pre-cooling of milk with ice was proposed as a solution in the thesis.

The experimental trials regarding the pre-cooling of milk in the mobile collection process by PCL GȚ "Harabari Andrei Victor" using ice boxes in the mobile vessel during 15.07-19.07.2021 demonstrated that the use of the ratio of milk/ice 6.5/100 kg, it allows to reduce the temperature of the milk within the limits of +18 ... +20^{o}C, but also to reduce the electricity consumption by the PCL IF by 42%.

The process of obtaining ice provides for additional costs, regarding the procurement of the ice machine and electricity consumption. In the thesis, a feasibility study was carried out that provides for obtaining electricity from renewable sources. It has been determined that the implementation of a 3 kW On-Grid photovoltaic system at PCL with an annual productivity of 5265 kWh would fully cover the electricity needs of PCL including the production of ice for pre-cooling. The payback of the investment that includes the photovoltaic system and the ice machine would take 6.5 years.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

- As a result of the analysis of the current state regarding the use of natural and artificial cold in the milk cooling process and the identification of solutions to increase the energy efficiency of refrigeration facilities for milk collection points in the Republic of Moldova, the possible ways to reduce energy consumption were pointed out electrical at PCL in the country. Priority was given to the reuse of the existing refrigeration facilities at the milk collection points in the Republic of Moldova in ecological facilities with an intermediate refrigerant and a cold accumulator, which have a number of advantages, the most important of which are: increased reliability of the cooling system due to the accumulation and the storage of natural or artificial cold in the thermally insulated cold accumulator; reduced service and maintenance expenses; increased energy efficiency in the cold period of the year; the possibility of using the differentiated tariff for electricity, by cooling the intermediate refrigerant at night, when the tariff is reduced by 40 percent; reducing environmental pollution during the cold period of the year by excluding from the cooling process the refrigeration plant with artificial cold that operates on the basis of freon; reduced consumption of materials for reuse.
- The development of mathematical models and calculation methods for the technological and constructive parameters of the milk cooling plant with natural and artificial cold facilitates its construction at the optimal level of the parameters. The improvement of the calculation method and the justification of the constructive characteristics of the installation allow to adjust the dimensions of the radiator, fan and pump according to the storage capacity of the thermally insulated cold accumulator. The mathematical models developed for the cooling process of intermediate refrigerant and milk establish the technological parameters milk-intermediate refrigerant and intermediate refrigerant-air.
- Based on the results based on the mathematical model of the milk cooling process in a capacitive cooler with an intermediate refrigerant (water) developed in this study, it was established that the ratio of the volume of AFI in the thermally insulated cold accumulator and the volume of chilled milk for the type of the proposed installation is of C_{IFC}=3.1, and of those based on the mathematical model of the AFI cooling process, it was established that the required volume of air with a temperature of +2ºC to cool the intermediate refrigerant from +14ºC to +4ºC has the equivalent coefficient of C_{AFN}=34.25. Calculations made using the mathematical model developed for the pre-cooling process of milk during mobile collection from home producers showed that the amount of ice related to the amount of milk required to be pre-cooled from the temperature of +27ºC to the temperature of +20ºC is 6.5%.
- As a result of the realization of the energy, operating and control regimes of the ecological milk cooling plant, the technical-economic and control parameters for the process of operating the plant were established. Thus, the electrical power of the experimental facility at the milk collection point managed by GȚ "Harabari Andrei Victor" in the case of cooling with natural cold is 0.3 kW, being 10 times lower in relation to the power of the facility with artificial cold. Theoretical calculations derived that the specific electricity consumption for cooling 1000 liters of milk with the ecological milk cooling plant with increased energy efficiency in the cold period of the year when the air temperatures are below +2ºC is up to 3.2 kWh, compared to 20.9 kWh when using typical refrigeration installations.

- The automatic graphs and operating algorithms developed for each individual operating mode allow the installation of the electrical scheme for the automation of the entire cooling process, switching from one mode to another depending on the temperature of the environment, the temperature of the intermediate refrigerant and the temperature of the milk, ensuring its cooling until at the required storage temperature.
- The implementation of the experimental installation with natural and artificial cold at the studied milk collection point showed a reduction of the annual electricity consumption in the milk cooling process by about 27%. The experimental data obtained during 7 consecutive days with ambient temperatures between -4ºC and +3ºC showed us that the specific electricity consumption for cooling 1000 liters of collected milk is between 2.6 - 3.5 kWh, which confirms the correctness of the theoretical calculations based on the mathematical models and calculation methods developed in the paper.
- Based on the use of the statistical data of the State Hydrometeorological Service regarding atmospheric air temperatures for the months of October-April of the years 2017-2021, it was established that the duration of use of the refrigerating installation operating in natural cold cooling mode is between 130-174 days for the north of the RM.
- It has been established that the reuse of typical installations in ecological installations with natural and artificial cold with the accumulation of cold in heat-insulated accumulators is easy to achieve due to the simple construction and foresee relatively small investments, which have a payback period of up to 3 years.
- It was established that, in the case of using the optimal technological parameters for the pre-cooling of milk with ice in the process of mobile collection from domestic producers, the ice/milk ratio is 6.5/100 kg. Thus, the experimental use of ice boxes in the mobile vessel during the days of 15.07.2021-19.07.2021 demonstrated that the pre-cooling of milk significantly reduces the risk of its alteration, reducing in a short time the temperature of the milk from that after milking to the temperature of + 18 ... +20ºC.
- It was determined that the implementation of a 3 kW On-Grid photovoltaic system at PCL with an annual productivity of 5265 kWh would fully cover the electricity needs of PCL including for the production of ice for pre-cooling. The recovery period of such investments is estimated at 6.5 years.

Based on the results of the scientific research carried out in the thesis, it is recommended:

- The use of calculation methodology and mathematical models in the reuse of typical refrigeration installations in refrigeration installations with low electricity consumption at milk collection points in the country. This will facilitate the implementation of natural and artificial cold in the cooling process and storage of the intermediate refrigerant in thermally insulated cold accumulators.
- Use of ice for pre-cooling milk during the mobile collection process at each collection point in the country. This measure will help reduce the risk of obtaining quantities of milk that do not meet the standard acidity requirements.
- In order to reduce the costs of bills for the electricity consumed to obtain ice and milk cooling, it is effective to implement, at the milk collection points, renewable energy installations such as photovoltaic panels with an On-Grid operating system and bidirectional metering.
- The introduction in the curriculum of the Technical University of Moldova of subjects related to natural and artificial cold for milk cooling in the curriculum of the lecture course "Technologies for the renovation of agricultural machinery.

BIBLIOGRAFIE

1. IRENA and FAO. 2021. *Renewable energy for agri-food systems* – Towards the Sustainable Development Goals and the Paris agreement. Abu Dhabi and Rome. 89 p. ISBN: 978-92-9260-341-8 [IRENA] and 978-92-5-135235-9 [FAO] https://doi.org/10.4060/cb7433en.

2. DAICU A., et al. *Combined automated installation deployment for milk cooling.* In: Journal of Engineering Science, vol. XXVII 3, Chișinău UTM, 2020 pp. 65-75, ISSN 2587-3474.

3. BHAT, R., et. al. *Global Dairy Sector: Trends, Prospects, and Challenges.* In: Sustainability 2022, (14) (accesat 15.10.2022) Disponibil: https://doi.org/10.3390/su14074193.

4. KOZLOVTSEV, A., KOROVIN, G. *Natural cold milk cooling system* In: IOP Conf. Series: Materials Science and Engineering 666 (2019) 012070, 6 p. IOP Publishing doi:10.1088/1757-899X/666/1/012070.

5. AGUSTRIYANTO, R., MOCHNI E., S. *Dynamic Study and PI Control of Milk Cooling Process.* In: International Journal on Advance Science, Engineering and Information Technology. Vol.12 (2022) No. 5, pp. 1836-1843. ISSN: 2088-5334.

6. SHANNAQ, R., AUCKAILI, A., FARID, M. *Cooling of milk on dairy farms: an application of a novel ice encapsulated storage system in New Zealand.* In: Food Engineering Innovations Across the Food Supply Chain 2022, pp. 207-228. (accesat 28.08.2022). Disponibil: https://doi.org/10.1016/B978-0-12-821292-9.00006-6.

7. DAICU, A. *Argumentarea regimurilor de funcționare și a parametrilor constructivi - tehnologici ai instalației ecologice automatizate cu frig natural și artificial pentru răcirea laptelui.* Teza de doct. în științe inginerești Chișinău, 2020. 155 p. (accesat 13.06.2021) Disponibil: http://www.cnaa.md/files/theses/2021/56597/anatolei_daicu_thesis.pdf.

8. ВОЛКОНОВИЧ Л., et al., *Применение холода для охлаждения молока и хранения плодоовощной продукции.* Chișinău, Moldova, Tipografia "Prit-Caro", 2019, 228 p. ISBN 978-9975-56-625-4.

9. SEGERS, O. *Modeling Milk Cooling Within A Dairy Farm To Minimize Electricity Costs.* In: BSc Thesis Electrical Engineering 2022. 16 p. (accesat 15.09.2022). Disponibil: http://essay.utwente.nl/92249/1/Segers_BA_EEMCS.pdf.

10. SHINE, Ph., UPTON, J., SEFEEDPARI, P., MURPHY, M. D. *Energy Consumption on Dairy Farms: A Review of Monitoring, Prediction Modelling, and Analyses.* In: Energies 2020,13, 1288; doi:10.3390/en13051288

11. COSSU, M., et al. *Evaluation of the Energy Utilization Index in Sheep Milk Cooling Systems.* In: Energies 2020(13,2127), 16 p. doi:10.3390/en13092127, ISSN 1996-1073.

12. DAICU, A., et al. *Contribuții la elaborarea mijloacelor tehnice de automatizare a proceselor de conservare a alimentelor cu utilizarea frigului natural.* Chișinău. In: Ştiinţa agricolă, nr. 2. CE UASM, 2019, pp. 95-102. ISSN 1857-0003 /ISSNe 2587-3202.

13. ЯРУТИЧ, В. *Исследование состояния процессов охлаждения молока.*Минск, Перспективная техника и технологии в АПК pp. 232-235. УДК. 637.117.

LISTA PUBLICAȚIILOR AUTORULUI LA TEMA TEZEI

Articole în reviste științifice

1. URSATII, Nicolai, VOLCONOVICI, Augustin, CHIRSANOVA, Alla et al. *Contribuții la îmbunătățirea parametrilor tehnico-economici ai instalațiilor frigorifice din punctele de colectare a laptelui.* In: Ştiinţa Agricolă. 2021, Nr. 1, pp. 97-103. ISSN 1857-0003.
https://www.doaj.org/article/9efaa585c15e49098932481b993eed23

2. Tudor AMBROS, **Nicolai URSATII**. *Some Aspects of Micro-HPP Utilization in the Republic of Moldova.* In: Problemele Energeticii Regionale. 2015, Nr. 3(29), pp. 100-105. ISSN 1857-0070.
https://www.doaj.org/article/ab801ff299234a9984360e32f169e5d4

3. Victor POPESCU, **Nicolai URSATII**, Mihail MELENCIUC, Onorin VOLCONOVICI, Tatiana BALAN, Maria ALII. *Studiul privind reducerea consumului de energie electrică în procesul de păstrare a produselor agroalimentare.* In:Intellectus 1/2023, pp. 184-189. ISSN 1810-7087.
https://www.agepi.gov.md/ro/intellectus/intellectus-1-2023

4. Victor POPESCU, Vitali VIȘANU, **Nicolai URSATII**, Anatol CECAN, Tatiana TODIRAȘ. *Sistem electric cu fiabilitate sporită pentru întreprinderile specializate în deshidratarea produselor agricole.* In:Intellectus 1/2023, pp. 198-203. ISSN 1810-7087.
https://www.agepi.gov.md/ro/intellectus/intellectus-1-2023

5. AMBROS, Tudor, BURDUNIUC, Marcel, **URSATII, Nicolai**. *Fluxes and Dispersion Reactances of the Asyncronous Machine of the Asyncronous Machine*. In: Buletinul AGIR, Nr. 3, România 2012, pp. 335-340 ISSN 2247-3548.
https://www.buletinulagir.agir.ro/articol.php?id=1404

6. AMBROS, Tudor, **URSATII, Nicolai**, BURDUNIUC, Marcel. *Study on synchronous generator with smooth air gap*. In: Buletinul AGIR, Nr. 4, România 2011, pp. 7-10. ISSN 2247- 3548.
https://www.buletinulagir.agir.ro/articol.php?id=1036

Articole în lucrările conferințelor și altor manifestări științifice

1. СЛИПЕНКИ, В., КИРСАНОВА, А., **УРСАТИЙ, Н.** et al. *Передовой зарубежный и отечественный опыт развития технологий и линий первичной обработки молока на фермах.* In: Lucrări ştiinţifice UASM, 2022, V. 55. Materialele Simpozionului Ştiinţific Internaţional "Reglementarea utilizării resurselor naturale: realizări și perspective", pp. 365-367. ISBN 978-9975-64-271-2.
https://agris.fao.org/agris-search/search.do?recordID=MD2022100153

2. URSATII, N. *Contributii la perfecționarea mașinilor electrice cu magneți permanenți pentru implimentare în agricultura modernă.* In: Lucrări ştiinţifice UASM, 2022, V. 55. Materialele Simpozionului Ştiinţific Internaţional "Reglementarea utilizării resurselor naturale: realizări și perspective", pp. 368-371. ISBN 978-9975-64-271-2.
https://agris.fao.org/agris-search/search.do?recordID=MD2022100151

3. ВОЛКОНОВИЧ, А., СКРИПНИК, Е., **УРСАТИЙ, Н.** et al. *Особенности, цели и задачи исследований автоматизировнных технологических линий обработки молока как объектов управления.* In: Lucrări ştiinţifice UASM, 2022, V. 55. Materialele Simpozionului Ştiinţific Internaţional "Reglementarea utilizării resurselor naturale: realizări și perspective", pp. 372-376. ISBN 978-9975- 64-271-2.
https://agris.fao.org/agris-search/search.do?recordID=MD2022100152

4. СЛИПЕНКИ, В., КИРСАНОВА. А., **УРСАТИЙ, Н.** et al. *Анализ процесса учета, транспортировки, очистки и охлаждения молока на фермах.* In: Lucrări ştiinţifice UASM, 2022, V. 55. Materialele Simpozionului Ştiinţific Internaţional "Reglementarea utilizării resurselor naturale: realizări și perspective", pp. 381-385. ISBN 978-9975-64-271-2.
https://agris.fao.org/agris-search/search.do?recordID=MD2022100149

5. URSATII, N. *Metodologia de măsurare a rezistenței izolației instalațiilor electrice folosite în domeniul agroindustrial.* In: Lucrări ştiinţifice UASM, 2022, V. 55. Materialele Simpozionului Ştiinţific Internaţional "Reglementarea utilizării resurselor naturale: realizări şi perspective", pp. 386-396. ISBN 978- 9975-64-271-2.
https://agris.fao.org/agris-search/search.do?recordID=MD2022100148

6. ВОЛКОНОВИЧ, А., ВОЛКОНОВИЧ, О., **УРСАТИЙ, Н.** et al. *Аналитический обзор и анализ тенденций развития автоматизированных технологических процессов и технических средств линий обработки молока на фермах.* In: Lucrări ştiinţifice UASM, 2022, V. 55. Materialele Simpozionului Ştiinţific Internaţional "Reglementarea utilizării resurselor naturale: realizări şi perspective", pp. 398-401. ISBN 978-9975-64-271-2.
https://agris.fao.org/agris-search/search.do?recordID=MD2022100345

7. URSATII, Nicolai, VOLCONOVICI, Ina. *Măsuri pentru sporirea eficienței energetice a instalațiilor frigorifice agroalimentare.* In: Tezele celei de-a 75-a conferinţă ştiinţifică a studenţilor, masteranzilor şi doctoranzilor, Chișinău, 2022, pp. 137. ISBN 978-9975-64- 336-8.
http://repository.utm.md/handle/5014/22527

8. URSATII, Nicolai, VOLCONOVICI, Onorin. *Clasificarea instalațiilor frigorifice din punctele de colectare a laptelui gestionate de SA "Inlac".* In: Tezele celei de-a 75-a conferinţă ştiinţifică a studenţilor, masteranzilor şi doctoranzilor, Chișinău, 2022, pp. 138. ISBN 978-9975-64-336-8.
http://repository.utm.md/handle/5014/22528

9. URSATII, Nicolai, VOLCONOVICI, Onorin. *Analiza consumului de energie electrică la punctele de colectare a laptelui din nordul Republicii Moldova.* In: Tezele celei de-a 75- a conferinţă ştiinţifică a studenţilor, masteranzilor şi doctoranzilor, Chișinău, 2022, pp. 139. ISBN 978-9975-64-336-8.
http://repository.utm.md/handle/5014/22529

10. URSATII, Nicolai, SLIPENCHI, Victorin. *Soluții de prerăcire a laptelui în procesul de colectare de la producătorii casnici.* In: Tezele celei de-a 75-a conferinţă ştiinţifică a studenţilor, masteranzilor şi doctoranzilor, Chișinău, 2022, pp. 140. ISBN 978-9975-64- 336-8.
http://repository.utm.md/handle/5014/22530

11. VOLCONOVICI, Ina, **URSATII, Nicolai.** *Metodologia de cercetare a instalațiilor de răcire a laptelui cu utilizarea frigului natural și artificial.* In: Tezele celei de-a 74-a conferinţă ştiinţifică a studenţilor, 20 mai 2021. Chișinău, 2021, pp. 147. ISBN 978- 9975-64-320-7.
https://ibn.idsi.md/ro/vizualizare_articol/145127

12. URSATII, Nicolai. *Soluții de reducere a consumului de energie electrică a instalației frigorifice de răcire a laptelui.* In: Tezele celei de-a 74-a conferinţă ştiinţifică a studenţilor, 20 mai 2021. Chișinău, 2021, pp. 149. ISBN 978-9975-64-320-7.
https://ibn.idsi.md/ro/vizualizare_articol/145129

13. VOLCONOVICI, Ina, **URSATII, Nicolai.** *Modelul monitoringului biotehnologic de producere și prelucrare primară a laptelui cu utilizarea frigului natural și artificial la ferma didactică a UASM.* In: Tezele celei de-a 74-a conferinţă ştiinţifică a studenţilor, 20 mai 2021. Chișinău, 2021, pp. 151-152. ISBN 978-9975-64-320-7.
https://ibn.idsi.md/ro/vizualizare_articol/145132

14. URSATII, Nicolai. *Studiul materialelor folosite la construcția mașinilor electrice.* In: Tezele celei de-a 74-a conferinţă ştiinţifică a studenţilor, 20 mai 2021. Chișinău, 2021, pp. 153. ISBN 978-9975-64-320-7.
https://ibn.idsi.md/ro/vizualizare_articol/145135

15. URSATII, Nicolai, VOLCONOVICI, Ina. *Argumentarea parametrilor constructivitehnologici ai motoarelor de acționare a compresoarelor depozitelor frigorifice de păstrare a fructelor.* In: Tezele celei de-a 73-a conferinţă ştiinţifică a studenţilor, 20 mai 2020. Chișinău, 2020, p. 106. ISBN 978-9975-64-313-9.
https://ibn.idsi.md/ro/vizualizare_articol/147981

16. URSATII, Nicolai, VOLCONOVICI, Ina. *Caracteristicile electromagnetice în generatorul sincron axial cu magneți permanenți.* In: Tezele celei de-a 73-a conferinţă ştiinţifică a studenţilor, 20 mai 2020. Chișinău, 2020, p. 113. ISBN 978-9975-64-313-9.
https://ibn.idsi.md/ro/vizualizare_articol/147989

17. URSATII, Nicolai, BURDUNIUC, Marcel. *Optimizarea construcţiei maşinii sincrone cu magneţi permanenţi.* In: Conferința Tehnico-Științifică a Colaboratorilor, Doctoranzilor și Studenților, Universitatea Tehnică a Moldovei, 8 – 10 decembrie, 2011. Chișinău, 2012, vol. 1, pp. 272-273. ISBN 978-9975-45-208-3.
http://repository.utm.md/handle/5014/3299

18. . **URSATII, Nicolai.** *Coeficientul de umplere a spauţiului înfăşurării statorice a maşinii sincrone fără crestături.* In: Conferința Tehnico-Științifică a Colaboratorilor, Doctoranzilor și Studenților, Universitatea Tehnică a Moldovei, 17 – 19 noiembrie, 2010. Chișinău, 2011, vol. 1, pp. 357-358. ISBN 978-9975-45-065-2. ISBN 978-9975-45-158-1.
http://repository.utm.md/handle/5014/3836

19. URSATII, Nicolai. *Influenţa geometriei magnetului permanent asupra curbei inducţiei magnetice din întrefer.* In: Conferința Tehnico-Științifică a Colaboratorilor, Doctoranzilor și Studenților, Universitatea Tehnică a Moldovei, 17 – 19 noiembrie, 2010. Chișinău, 2011, vol. 1, pp. 359-361. ISBN 978-9975-45-065-2. ISBN 978-9975-45-158-1.
http://repository.utm.md/handle/5014/3837

20. . **URSATII, Nicolai.** *Studiul caracteristicilor electromagnetice al mașinii sincrone cu magneți permanenți.* In: Conferința Tehnico-Științifică a Colaboratorilor, Doctoranzilor și Studenților, Universitatea Tehnică a Moldovei, 10-12 decembrie 2009. Chișinău, 2010, ISBN 978-9975-45-141-3.
http://repository.utm.md/handle/5014/22537

21. MORARU, Victor, **URSATII, Nicolai.** *Model de calcul al factorilor de emisii al gazelor cu efect de sera la diferite puncte de consum a energiei.* In: Conferința Tehnico-Științifică a Colaboratorilor, Doctoranzilor și Studenților, Universitatea Tehnică a Moldovei, 10-12 decembrie 2009. Chișinău, 2010, ISBN 978-9975-45-141-3.
http://repository.utm.md/handle/5014/22536

22. URSATII, Nicolai. *Studiul asupra câmpului magnetic al generatorului sincron cu magneți permanenți.* In: Conferința Tehnico-Științifică a Colaboratorilor, Doctoranzilor și Studenților, Universitatea Tehnică a Moldovei, 15-17 noiembrie 2007. Chișinău, 2008, ISBN 978-9975-45-068-3.
http://repository.utm.md/handle/5014/22538

23. AMBROS, Tudor, **URSATII, Nicolai.** *Armature's reaction in synchronous devices with smooth magnetic gap.* In: Conference on Electrical and Power Engineering: Proc. EPE 2010, 28-30 octombrie 2010, Iași, România, 2010, V. 2, p. 150-152. ISBN 978-606-13- 0079-2; 978-606-13-0078-5.
https://ibn.idsi.md/ro/vizualizare_articol/163389

ADNOTARE

URSATII Nicolai. Tema „Sporirea eficienței energetice a instalației cu frig natural și artificial la punctele de colectare a laptelui”, Chişinău, 2023**.**

Structura tezei: introducere, patru capitole, unul de analiză și trei de bază, concluzii generale și recomandări, bibliografie cu 116 titluri, 118 pagini de text de bază, 9 anexe, 23 tabele, 234 de formule, 78 de figuri. Rezultatele cercetărilor sunt publicate în 29 de lucrări științifice.

Cuvinte-cheie: eficiență energetică, frig natural, punct de colectare a laptelui, consum redus de energie electrică, model matematic, instalație frigorifică, surse regenerabile.

Scopul tezei. Creșterea eficienței energetice a instalației cu frig natural și artificial la punctele de colectare a laptelui din Republica Moldova.

Obiectivele cercetării: analiza stadiului actual în privința utilizării frigului natural și artificial în procesul de răcire a laptelui și identificarea soluțiilor de sporire a eficienței energetice a instalațiilor frigorifice pentru punctele de colectare a laptelui din Republica Moldova; dezvoltarea modelelor matematice și metodelor de calcul al parametrilor tehnologici și constructivi ai instalației cu frig natural și artificial pentru răcirea laptelui; concretizarea regimurilor energetice, de funcționare și de control ale instalației ecologice de răcire a laptelui; implementarea instalației experimentale cu frig natural și artificial la un punct de colectare a laptelui din țară; stabilirea parametrilor tehnologici optimali pentru prerăcirea și răcirea laptelui la punctele de colectare.

Noutatea și originalitatea științifică constă în: demonstrarea oportunității utilizării frigului natural în procesul de răcirea a laptelui pentru condiții concrete, specifice Regiunii de Dezvoltare Nord a țării; formularea unor recomandări noi cu privire la prerăcirea laptelui în procesul de colectare mobilă de la producătorii casnici, bazate pe utilizarea boxelor cu gheață.

Problema științifică soluționată. Efectele utilizării frigului natural și concretizării regimurilor energetice de funcționare și control asupra eficienței energetice al instalațiilor frigorifice utilizate la punctele de colectare a laptelui.

Semnificația teoretică se referă la dezvoltarea modelelor matematice și metodelor de calcul ale parametrilor tehnologici și constructivi ai instalației cu frig natural și artificial pentru punctele de colectare a laptelui din Republica Moldova.

Valoarea aplicativă constă în posibilitatea utilizării tehnologiei propuse la punctele de colectare a laptelui pentru reducerea consumului de energie electrică și a emisiilor nocive în mediul înconjurător, datorită excluderii din procesul de răcire în perioada rece a anului a instalației cu freon.

Implementarea rezultatelor ştiinţifice. Rezultatele obținute în acest studiu au fost implementate în perioada anilor 2020-2022 în proiectul științific nr. 20.80009.5107.04 - „Adaptarea tehnologiilor durabile și ecologice de producere a fructelor sub aspect cantitativ și calitativ în funcție de integritatea sistemei de cultură și schimbărilor climatice” și la elaborarea instalației experimentale la PCL din s. Corbu r. Dondușeni.

ANNOTATION

URSATII Nicolai. Title "Increasing the energy efficiency of the installation with natural and artificial cold at the milk collection points", Chisinau, 2023.

The thesis consists of: introduction, four chapters, one analytical and three basic, general conclusions and recommendations, bibliography with 116 titles, 118 pages of basic text, 9 annexes, 23 tables, 234 formulas, 78 figures. The research results are published in 29 scientific papers.

Key words: energetic efficiency, natural cold, milk collection point, low electricity consumption, mathematical model, refrigeration plant, renewable sources.

The aim of the paper. Increasing the energy efficiency of the plant with natural and artificial cold at milk collection points in the Republic of Moldova.

The objectives: analysis of the current state regarding the use of natural and artificial cold in the milk cooling process and the identification of solutions to increase the energy efficiency of refrigeration facilities for milk collection points in the Republic of Moldova; development of mathematical models and methods for calculating the technological and constructive parameters of the plant with natural and artificial cold for cooling milk; concretization of the energy, operation and control regimes of the ecological milk cooling facility; implementation of the experimental facility with natural and artificial cold at a milk collection point in the country; establishing the optimal technological parameters for the pre-cooling and cooling of milk at the collection points.

The scientific novelty and originality consists in: demonstrating the opportunity of using natural cold in the milk cooling process for specific conditions, specific to the Northern Development Region of the country; formulation of new recommendations regarding pre-cooling of milk in the mobile collection process from home producers, based on the use of ice boxes.

The scientific problem solved. The effects of the use of natural cold and the concretization of energy regimes of operation and control on the energy efficiency of refrigeration facilities used at milk collection points.

The theoretical significance refers to the development of mathematical models and calculation methods of the technological and constructive parameters of the installation with natural and artificial cold for the milk collection points in the Republic of Moldova.

Application value consists in the possibility of using the proposed technology at milk collection points to reduce electricity consumption and harmful emissions in the environment, due to the exclusion of the freon installation from the cooling process during the cold period of the year.

Implementation of scientific results. The results obtained in this study were implemented during the years 2020-2022 in the scientific project no. 20.80009.5107.04 - "Adaptation of sustainable and ecological technologies of fruit production in quantitative and qualitative aspects depending on the integrity of the culture system and climate change" and to the development of the experimental facility at the MCP in Corbu village, Donduseni district.

АННОТАЦИЯ

УРСАТИЙ Николай. Тема «Повышение энергоэффективности установки с естественным и искусственным холодом на пунктах сбора молока», Кишинев, 2023 г.

Структура диссертации: введение, четыре главы, одна аналитическая и три основные, общие выводы и рекомендации, библиография из 116 наименований, 118 страниц основного текста, 9 приложений, 23 таблиц, 234 формул, 78 рисунка. Результаты исследований опубликованы в 29 научных работах.

Ключевые слова: энергоэффективности, естественный холод, пункт сбора молока, снижение потребления электроэнергии, математическая модель, холодильная установка, возобновляемые источники.

Цель диссертации. Увеличение энергоэффективности установки с естественным и искусственным холодом на пунктах сбора молока из Республике Молдова.

Задачи исследования: анализ современного состояния использования естественного и искусственного холода в процессе охлаждения молока и определение решений по повышению энергоэффективности холодильных установок пунктов приема молока в Республике Молдова; разработка математических моделей и методов расчета технологических и конструктивных параметров установки с естественным и искусственным холодом для охлаждения молока; конкретизация энергетических, рабочих и управляющих режимов установки экологического охлаждения молока; внедрение экспериментальной установки с естественным и искусственным холодом на пункте сбора молока в стране; установление оптимальных технологических параметров предварительного охлаждения и охлаждения молока в пунктах сбора.

Научная новизна и оригинальность заключается в: демонстрации возможности использования естественного холода в процессе охлаждения молока для конкретных условий, характерных для северного региона освоения страны; разработка новых рекомендаций по предварительному охлаждению молока в процессе мобильного сбора от домашних производителей, основанных на использовании ледогенераторов.

Решаемая научная задача. Влияние использования природного холода и конкретизации энергетических режимов работы и управления на энергетическую эффективность холодильных установок, используемых в пунктах приема молока.

Теоретическая значимость связана с разработкой математических моделей и методов расчета технологических и конструктивных параметров установки с естественным и искусственным холодом для молокоприемных пунктов Республики Молдова.

Ценность применения заключается в возможности использования предлагаемой технологии в пунктах приема молока для снижения потребления электроэнергии и вредных выбросов в окружающую среду, за счет исключения фреоновой установки из процесса охлаждения в холодный период года.

Внедрение научных результатов. Результаты, полученные в этом исследовании, были реализованы в течение 2020-2022 годов в научном проекте №. 20.80009.5107.04 - «Адаптация устойчивых и экологических технологий производства плодов в количественном и качественном аспектах в зависимости от целостности системы культуры и изменения климата» и в разработке экспериментальной установки в пункту приема молока в селе Корбу, Дондюшанского района.

NICOLAI URSATII

INCREASING THE ENERGY EFFICIENCY OF NATURAL AND ARTIFICIAL COLD FACILITIES AT MILK COLLECTION POINTS

255.01 - technologies and technical means for agriculture and rural development

Doctor of engineering science dissertation summary

Approved for printing: 21.08.2023 Paper format 60x84 1/16
Offset paper. Digital print. Print run of 50 copies
Pattern sheets: 2.0 Order no. 21-08/23

SRL „EL CAMINO”
Chișinău, str. Calea Orheiului 75A of. 12
tel. +37379641445