ТЕХНОЛОГІЯ ВИРОБНИЦТВА І ПЕРЕРОБКИ ПРОДУКЦІЇ ТВАРИННИЦТВА

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Ergonomic and economic indicators of milk production using different cow milking technologies

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The purpose of this work was to study the effect of changing the way of keeping and milking equipment on ergonomic and economic indicators. The research was carried out at «Ostriykivske» LLC, Bilotserkivskyi district, Kyiv region, where the milking herd was transferred from a capital-type room with tethered housing and milking into the milk pipeline to an easy-to-assemble room with loose housing and milking in the milking hall at the «Carousel» plant. The material for the research was lactating cows of the Ukrainian black-spotted dairy breed of II and III lactations. In order to accurately determine the duration of the technological operations of the milking process through the milk pipe and at the «Carousel» milking plant, it was filmed during the morning milking of cows. The change in the method of keeping (from tethered to loose housing) and the milking option (in the stall to the milk pipeline to the milking hall) had a significant impact on the time spent when performing the technological operations of one cow milking. The total time spent by machine milking operators in the slope decreased by 31.35 seconds. When moving the animals to the milking parlor, the duration of such operations as washing, wiping and massaging of the udder decreased by 4.8 s, milking of the first trickles of milk – by 0.6 s, and putting milking cups on the udders – by 1.3 s. The duration of preparatory and final milking operations decreased by 7.2 seconds, and other operations related to milking decreased by 58.2 seconds. At the same time, the complex indicator of the ergonomics of the milking installation when transferring cows to the milking parlor increased significantly (by 0.60) and met the requirements of the standard. The total labor costs when the conditions of keeping and milking were changed decreased by 52.96 man hours/year per cow. Labor costs for the following types of work decreased most significantly: milking and primary processing of milk; cleaning of stalls and manure passages; making litter and operating costs: 22.00; 19.40; 2.60 and 6.60 man hours/year per cow, respectively. Electricity consumption per cow per year increased by 22 kWh, and water for the milking process increased by 560 liters.

Key words: dairy cows, ergonomics of milking, change of housing conditions, milking facilities, consumption of energy resources.

Problem statement and analysis of recent research. The development of animal husbandry in general and dairy cattle breeding in particular under modern conditions is based on intensive technologies with a high level of mechanization and automation of production processes [1, 2]. The process of technical re-equipment of animal husbandry today acquires a completely new meaning. In recent years, the trend of transition from the tethered way of keeping cows to the loose housing one, which is also accompanied by a change in milking equipment, has been quite clearly outlined. In such cases, significant reserves lie in the formation of a complex approach, which takes into account all the nuances and peculiarities of mechanized technologies. Here it is extremely important to ensure the clear implementation of technological techniques aimed at stimulating delicate natural biological processes, interwoven with thin threads of interrelationships of the elements of the triune system: «man-

machine-animal». Any little thing here can become a factor that determines the final effect of a long and multifaceted process [3, 4, 5].

Today, the technical modernization of dairy livestock enterprises is considered as a priority direction, which ensures the receipt of profit due to the effective use of innovative technological solutions, which are based on multivariate methods of programming, organization and management of processes. Innovative development of dairy farming depends on intensive technologies with a high level of mechanization and automation of production processes. Intensification allows you to use the advantages of large-scale production. Such an approach can be implemented by exporting modern technologies from Western countries, where the share of profit obtained from the use of innovations in the field of technical support for production is steadily growing, or at the expense of domestic competitive developments [6, 7, 8].

In the current situation, one of the most important conditions for the development of animal husbandry is the effective use of innovations in technical support. Investments in the mechanization and automation of technological processes provide the possibility of implementing an intensive type of extended reproduction and sustainable development of the industry [9, 10]. The process of technical re-equipment of animal husbandry today acquires a completely new meaning. In recent years, the trend of transition from the creation of equipment to support existing technologies to the creation of innovative technological solutions based on new machines and equipment has been quite clearly outlined [11, 12, 13]. Modern technology makes it possible to radically change approaches to the implementation of many technological processes [14, 15, 16]. The development of technical support is aimed at creating universal machines that allow combining various previously incompatible processes and elements of technology, increasing the reliability and improving the operational characteristics of equipment, reducing the metal capacity and energy consumption of machines, the use of automation and computerization tools that ensure the improvement of the work efficiency of service personnel and level of welfare and comfort for animals [17, 18, 19].

Modern information technologies make it possible to implement production management taking into account human psychology, ergonomics, physiology and ethology of animals, features and capabilities of technology. It is necessary to ensure the introduction of technological methods aimed at stimulating the natural biological processes of the animal's body, which are implemented according to a peculiar catalytic mechanism, which involves a subtle, signaling effect on a complexly determined system [20].

Automation and robotization of the milking process require high demands on the physiological state of lactating animals. Modern technologies of milk production on an industrial basis represent a complex process of interaction between the animal, milking system and service personnel. During operation, the milking system comes into close contact with the animal and actively affects one of the main organs – the mammary gland. Uncontrolled use of milking systems, incorrect milking technology and long-term milking cause severe diseases and stress in animals. The issue of interaction between the cow and the modern milking system during milking is topical and of considerable scientific interest.

Therefore, the **purpose of this work** was to study the effect of changing the method of keeping and milking equipment on the ergonomic and economic indicators of milk production.

Materials and methods of research. The research was carried out at «Ostriykivske» LLC, Bilotserkivskyi district, Kyiv region. At the farm, over a period of one and a half years, the milking herd transferred from capital-type premises with tethered maintenance to an easy-to-assemble room with loose housing maintenance. The milking equipment was also changed: milking on the UDM-200 unit was replaced by milking in the milking hall on the «Carousel» unit with 32 milking places. The material for the research was lactating cows of the Ukrainian black-spotted dairy breed of II and III lactations.

The time spent on performing technological operations for one-time milking of one cow on different types of milking machines and a complex indicator of the ergonomics of milking machines were carried out according to the method of Shablia V. [21]. In order to accurately determine the duration of technological operations, the milking process in the cowshed in the milk pipeline and on the «Carousel» installation was filmed using a Canon EOS M50 digital device (made in Japan). Filming was done during the morning milking of cows.

The costs of natural and energy resources for the milking process before and after changing the milking equipment were determined according to the technical characteristics provided by the manufacturers. Ergonomic indicators when performing standing work were determined according to the methodology of Lutsenko M. [22].

Research materials processed by the method of variation stratification based on the calculation of the arithmetic mean (M), the root mean square error (m) and the reliability of the difference between the compared indicators (P). To show the

probability in the tables, the notation P>0.95 is used; P>0.99; P>0.999, which are respectively marked with asterisks (*;**;***) in the paper.

Research results and discussion. An important condition for the efficient production of livestock products, along with satisfying the animal's needs, is the creation of conditions to ensure high productivity of farm workers, which mainly affects the productivity of their work. At dairy farms, this is achieved by taking into account factors that directly affect work capacity: production fatigue, deterioration of health, injuries, impact of machines and equipment on the body, workplace and posture, pace and rhythm of work, physical effort, and microclimate [12].

For different milking technologies, different technological equipment used at farms, which significantly affects the working conditions and results of the staff. During milking with portable devices in the milk pipeline, operators perform the following basic tasks: they go to each cow of their group, carry milking devices, equipment and water for cleaning of stalls, animals, udders and performing other hygienic procedures. At the same time, they have to sit next to each cow while preparing, connecting and disconnecting the devices and observing the milking process. In addition, they perform work related to the rationing of feeding, tying and untying cows and driving them to a walking area or gym. The milker's workplace is located along the entire length of the cowshed, which necessitates significant transitions on a slippery and uneven surface with an increased degree of labor difficulty and fatigue. During transitions, it is often necessary to step over the manure conveyor tray, to push cows away, to be in an uncomfortable position between cows during milking, with an increased effort to perform work movements at different speeds with frequent body position changes [4, 11].

The workplace of the operator of the «Carousel» installation is located in the middle of the platform of the milking installation. Here there is an opportunity for convenient placement of devices, inventory and other means in relation to the employee. The worker is below the level of the cow and does not need to bend during the preparatory and final milking operations. The site on which the operator stands meets the requirements for area, safety, spatial parameters (dimensional, free and layout), the ability to perform basic and auxiliary operations in a rational working position, as well as free movement of the operator along the optimal trajectory. The working posture of the operator has the following characteristics: straight body, uniform support, absence of extreme positions in the joints of the upper limbs. During the work, it is possible to change the posture and pace of movements. The reach zone is within the optimal and easy range. It is also possible to change the workplace during the work, which contributes to better operator's efficiency by reducing fatigue [8].

It was established that the change in milking conditions had a positive effect on the duration of the body of machine milking operators in an uncomfortable position (Table 1).

The duration of the machine milking operator's stay in the bent position of the body (at an angle) during milking of cows in the milking hall at the «Carousel» plant decreased by 31.35 s per cow compared to milking at the UDM-200 plant. It should also be noted that after transfer to the milking parlor, machine-milking operators do not need to tilt their torsos at an angle greater than 40 °.

After transferring the animals to milking in the milking hall, the duration of preparatory operations before milking (Table 2), such as washing, wiping and massaging of the udder, decreased by 4.8 seconds; milking of the first teats of milk – by 0.6 s, and putting milking cups on the udders – by 1.3 s.

Operations not related to milking had significantly decreased after the change of milking conditions and time spent on. Thus, during milking on the UDM-200 unit, the machine-milking operator performed actions related to the introduction of bedding material into the rest areas, cleaning of the rest areas, and transfer of milking machines, their connection and shutdown.

Table 1 – **Duration of stay of the machine milking operator in an uncomfortable position when using different types of milking installations, per cow** (n=50), (M±m).

Type of milking setting	Uncomfortable body position		
	torso at an angle		together
	20 – 40°	40 – 90°	
UDM-200	3.35±0.08	55.20±2.75	58.55±1.96
«Carousel»	22.40±0.33***	-	22.40±0.45***

Note. *** – P≥0.999 – compared to the indicators before the change in milking conditions.

Table 2 – **Time spent (in seconds) to perform technological operations for one-time milking of one cow on milking installations of different types** (n=50), (M±m).

Technological operations, c	Type of milking installation	
	UDM-200	«Carousel»
milking of the first milk trickles	5.3±0.2	4.7±0.2*
washing, wiping and massage of udder	17.3±2.2	12.5±2.0
putting on milking cups	6.3±0.4	5.0±0.3*
preparatory operations, together	28.9±2.7	22.2±1.8*
final operations, together	4.5±0.3	4.0±0.1
other operations, related to milking	72.3±6.5	14.1±1.8***

Notes: * – P≥0.95; *** – P≥0.999 – compared to indicators before the change in milking conditions.

For milking options in milking parlors, operators only perform operations to clean the milking areas from dirt using a hose with pressurized water supply.

To evaluate the complex indicator of the ergonomics of various milking installations before and after transferring the animals to milking conditions in the milking parlors, we used data from the evaluation of their construction, noise, dustiness of the air, physical exertion, the operator's working posture, the frequency of his working movements, etc. (Table 3). It was established that during milking in stalls on the UDM-200 milking unit, the ergonomics index was at a low level and was only 0.40 against 1.00 according to the requirements of the standard. Such low values of the level of ergonomics of the stall milking installation are caused by the lack of control systems for the milking process, the performance of the final milking operations and the irrational working posture of the operator in relation to the animal. The change in milking conditions (on the «Carousel» unit) significantly affected the ergonomics index of the milking unit (1.00). This is due to the rational placement of the operator and animals, the optimal number of cows served by one operator, and the reduced physical workload of the operators (compared to milking on the UDM-200).

The change in options for keeping and milking cows also affected labor costs per head per year (Table 4). Thus, there was a decrease in labor costs for all main types of work, except for zoo-veterinary activities (remained at the same level) and work related to animal training (they were absent before the change in the conditions of keeping and milking cows in tethered keeping). Labor costs for the following types of work decreased most significantly: milking and primary processing of milk; cleaning of stalls and manure passages; making litter and operating costs: 22.00; 19.40; 2.60 and 6.60 man hours/year per cow, respectively. The total labor costs for the performance of work related to keeping cows decreased by 2.34 times.

Table 3 – **A complex indicator of the ergonomics of milking installations**

Indicator	Type of milking installation	
	“UDM-200”	«Carousel»
the number of cows served, heads	200	400
load on onemachine milking operator, heads	200	200
Availability in the design:		
- systems for preparing cows for milking	-	+
- milking process control systems	-	+
- machines for removing milking machines	-	+
noise	1.0	1.0
dustiness	1.0	1.0
physical activity	0.0	1.0
ergonomics of technological maintenance	0.0	1.0
working posture	0.0	1.0
complex indicator of ergonomics	0.40	1.0

Table 4 – **Labor costs for the performance of manual labor for cow milking technologies on various types of installations (person-hours/year per cow).**

Type of work	Type of milking unit	
	«UDM»-200	«Carousel»
Feed distribution	12,86	7,30
Milking and primary processing of milk	40,00	18,00
Driving animals for milking	-	3,20
Cleaning of stalls, manure passages, milking platform	24,80	5,40
Adding of litter	4,40	1,80
Operating expenses	7,90	1,30
Carrying out zoo-veterinary measures	2,60	2,60
Total	92,56	39,60

Thus, the change in the type and design of milking units affected the quality of the technological process. When using a stall milking machine located on the territory of the premises for keeping cows, the operator spends 2.8-6.7 seconds more physical labor per cow compared to milking in the milking hall. According to the set of ergonomic indicators, stall milking installations are the most imperfect.

The process of milking cows with all preparatory and final operations, as well as natural and energy resources that are consumed during operation, is of great importance in increasing the level of production of dairy products and improving its quality along with feeding and keeping animals. It has been established that changes in milking conditions affected the electricity consumption per cow per year (Table 5). Thus, when transferring cows for milking in the milking hall of the «Carousel» installation, electricity consumption per cow per year increased by 22 kWh. The rate of water consumption for the milking process depends on the following factors: the length of the milk pipeline and the number of milking places, the distance between the milking parlor and the milk cooler tank, the area of the platform for waiting for milking and the angle of the floor towards the sewage drains. Due to the change of milking equipment from «UDM-200» to «Carousel» water consumption per cow per year was increased by 560 liters.

Conclusions. 1. The change in the method of keeping (from tethered to loose housing one) and the milking option (in the milk pipeline to the milking parlor) significantly affected the time spent on the technological operations of milking one cow. The total time spent by machine milking operators in the slope decreased by 31.35 seconds. The duration of preparatory and final operations before milking decreased by 7.2 s, and other operations related to milking – by 58.2 s. At the same time, the complex indicator of the ergonomics of the milking unit when cows transferred to the milking parlor increased (by 0.60) and met the requirements of the standards. The total labor costs when the conditions of keeping and milking were changed decreased by 52.96 man hours/year per cow. Electricity consumption per cow per year increased by 22 kWh, and water for the milking process increased by 560 liters.

Table 5 – **Costs of natural and energy resources for the milking process before and after changing the milking equipment.**

Type of milking plant	Water consumption per cow per year, l	Electricity consumption per cow per year, kWh
"UDM"-200	1190	52
«Carousel» × 32	1750	74

2. Thus, milking cows in the milking parlor on the «Carousel» plant significantly improves the ergonomics of the process: it increases the efficiency of the «man-machine-animal» system, ensures work safety, and creates conditions for the development of a person's personality in the work process.

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Ергономічні та економічні показники виробництва молока за різних технологій доїння корів

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Метою цієї роботи було вивчити вплив зміни способу утримання та доїльного обладнання на ергономічні та економічні показники. Дослідження проводили у ТОВ «Острійківське» Білоцерківського району Київської області, де дійне стадо було переведене із приміщення капітального типу з прив'язним утриманням та доїнням у молокопровід в легкозбірне приміщення із безприв'язним утриманням та доїнням у доїльному залі на установці «Карусель». Матеріалом для досліджень були лактуючі корови української чорно-рябої молочної породи II та III лактацій. Для точного визначення тривалості виконання технологічних операцій процесу доїння молокопроводом та на доїльній установці «Карусель» її фільмували упродовж ранкових доїнь корів. Зміна способу утримання (із прив'язного на безприв'язний) та варіанту доїння (в стійлі у молокопровід на доїльний зал) суттєво вплинула на затрати часу при виконанні технологічних операцій доїння однієї корови. Загальний час перебування операторів машинного доїння у нахилі знизився на 31,35 с. При переведенні тварин до доїльного залу тривалість таких операцій як обмивання, витирання і масажу вимені зменшилась на 4,8 с, здоювання перших цівок молока – на 0,6 с, а надягання доїльних стаканів на дійки – на 1,3 с. Тривалість підготовчих та заключних операцій доїнням знизилась на 7,2 с, а інші операції, котрі пов'язані з доїнням – на 58,2 с. При цьому комплексний показник ергономічності доїльної установки при переведенні корів до доїльної зали значно збільшився (на 0,60) та відповідав вимогам стандарту. Загальні затрати праці при зміні умов утримання і доїння знизились на 52,96 люд·год/рік на корову. Найбільш суттєво знизились затрати праці за наступними видами робіт: доїння і первинна обробка молока; чищення стійл і гнойових проходів; внесення підстилки та експлуатаційні затрати: на 22,00; 19,40; 2,60 і 6,60 люд. год/рік на корову, відповідно. Витрати електроенергії у розрахунку на 1 корову в рік збільшились на 22 кВт/год, а води для здійснення процесу доїння – на 560 л.

Ключові слова: молочні корови, ергономіка доїння, зміна умов утримання, доїльні установки, витрати енергетичних ресурсів.

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