



# Investigation of the entry process of high yielding cows to the milking parlour with the optimization of their relocation

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**Abstract.** The expediency of the development of scientifically grounded effective technological methods of automatic milking, parameters and modes of equipment, the implementation of individual production processes consist in ensuring maximum detection of productivity of cows, further increase of their productivity and attractiveness of the work for the staff. In view of the increased requirements for the physiology of systems that directly contact with the living organism, the research aimed finding new technical and technological solutions and effective regimes for their application in production conditions with maximum consideration of the physiological characteristics of high yielding cows should be considered relevant. The purpose of the paper was to study the entry process of high yielding cows to the milking parlour with the optimization of their relocation. It has been established that when cows are driven to milking mechanically, the operator is fully focused on the process, while he is not distracted and does not pay attention to other kinds of work. This allows achieving a high throughput of the milking plant, providing a proper preparation of high yielding cows to automatic milking and high intensity of milk let-down – 2.08 kg/min on the average. According to the results of the research, the gentle technological mode of operation of a mechanical driver has been substantiated, the use of which provides the milk yield of 1.92 kg/min, the duration of one individual milking at a level of 6.04 min, and promotes a rapid and calm entry of cows for milking.

**Key Words:** bovine, driving, ethology, behavior, indicators of milk let-down.

**Introduction.** Dairy cattle breeding are one of the leading sectors of livestock and the improvement of the conservation technology, increasing the useful life and maintenance of high milk productivity of cows when introducing high-tech domestic and foreign milking equipment are considered to be a key factor of its successful development in Ukraine.

At the same time, modern livestock breeding advances its specific requirements to scientific and technological progress, because, in this area of equipment, as a rule, it directly contacts with living organisms. Therefore, newly-created machines and automation systems of production processes should provide on farms and complexes the conditions that have a positive effect on the cow health and contribute to the growth of their milk productivity (Lucenko et al 2006; Morozov 2004; Paliy 2014).

Automatic milking possesses a leading place in dairy cattle breeding and it is also the most labor-intensive and complex (Edwards et al 2014; Paliy & Paliy 2019). The milking plant is in direct contact with the animal, and the technical parameters of the equipment affect not only on the efficiency of production, but also its health status.

In recent years, an urgent need arisen to determine effective technological methods of automatic milking stands in the forefront of competition for the production of

high-quality products and increasing the productive life-span of high yielding cows on dairy farms and industrial complexes (Stelwagen 2001; Vtoryj & Vtoryj 2018).

It has been established that the complexity of the milking process is caused by the fact that it involves a lot of technological components, in particular, in man-machine-animal system (Paliy 2016; Solov'ev & Kartashev 2001). The quality of the implementation of the individual elements of the milking process for each of these components and their interaction affect the intensity of the milk let-down reflex, the completeness of milking, and the productivity in general during the lactation, the quality of milk and the physiological state of the mammary gland. This circumstance is associated with the fact that if the milking machine modes do not meet the physiological needs of the cows, they are not able to fully realize the existing genetic potential of milk productivity (Osipenko et al 2018).

The expediency of the development of scientifically grounded effective technological methods of automatic milking, parameters and modes of equipment, the implementation of individual production processes consists in ensuring maximum detection of productivity of cows, further increase of their productivity and attractiveness of the work for the staff (Fenenko et al 2002; Hupfauer et al 1966; Paliy 2017).

However, it should be noted that increasing milk production is necessary with simultaneous growth of labor productivity and reduction of energy expenditures for the implementation of the milking process because in modern conditions the technological and economic aspects which form the reliable and efficient use of equipment, as well as animal treatment on dairy farms are the main and determining factors (Chernuha & Jemcev 2018; Legoshin & Gudenko 2001; Paliy et al 2018).

Milking systems directly influence the milk let-down of cows, their productivity and terms of economic use. The interaction of animal body, milking plant and operators determines the efficiency of application of technological scheme and automatic milking equipment. The stimulation of an unconditional reflex of milk let-down, the rate of milk yielding and the cow health depend on the strict adherence to the technology of automatic milking (Erdman & Varner 1995; Hart et al 2013; Paliy et al 2019; Tucker et al 2009). Therefore, consideration of certain perspectives of experimental substantiation and improvement of certain parameters of technological methods of automatic milking and their introduction on farms and industrial complexes form an actual task, the solution of which is of considerable interest for the science and practice of automatic milking of high yielding cows and the reserve for increasing the reliability of milking mechanization facilities, productivity and terms of use of cows which will help to increase the efficiency of dairy cattle in general.

**Material and Method.** The purpose of the scientific and economic experiments was to study the entry process of high yielding cows to the milking parlour with the optimization of their relocation.

To achieve this goal, the following tasks were performed:

- determination of the time required for driving high yielding cows to the parlour in manual and mechanized modes;
- specifying the indicators of milk let-down and investigation the behavior of high yielding cows by various techniques of their driving to the milking parlour;
- optimization of the method of mechanical driving of high yielding cows to the milking parlour.

To determine the optimal system for driving high yielding cows to the milking parlour, the study was carried out on technological groups of Ukrainian black-and-white milk dairy breed cows, on two farms, with 200 individuals in each unit. The groups were formed on the basis of selection of cows-analogues, taking into account the amount of lactation (I-II), live weight (430-550 kg) and productivity (6,500-7,300 kg of milk during the previous lactation).

For substantiation and determination of the optimum technological mode of mechanized driving of high yielding cows to the milking parlour, the study was carried out on eight technological groups (n=455), 40-71 individuals in each group, by the period method. The technological groups were formed taking into account the live weight

(450–550 kg) and the productivity of animals (7,000–7,500 kg of milk during the previous lactation).

The scheme of the first stage of our scientific and economic research is presented in Table 1.

Table 1

The scheme of the first stage of research for determination of the optimal system of driving of high yielding cows to the milking parlour

Group	Preparatory period (7 days)	Experimental period (60 days)
	<i>System of driving of cows to the milking parlour</i>	
I (control)	Accepted at the enterprise	Accepted at the enterprise
II (experimental)	Accepted at the enterprise	Periodical (manual)
III (experimental)	Accepted at the enterprise	Continuous (mechanized)

According to the experimental scheme, during the preparatory period the cows in groups I, II and III were driven by the operator to the milking parlour continuously, as they arrive to the panel stall of milking machines in manual mode, as it is accepted on other dairy farms.

During the experimental period the cows in group I were driven similarly to the preparatory period.

The cows in group II were driven to the milking parlour by the operators manually periodically after the cycle of milking of each subgroup and its exit from the panel stall.

The cows in group III were coming in for milking by means of mechanized driving, controlled by the pipe-line milking operator from the trench of the milking plant.

The scheme of the second stage of our scientific and economic research is presented in Table 2.

Table 2

The scheme of the second stage of research for substantiation and determination of optimal technological mode of driving mechanism

Preparatory period (7 days)	Experimental period (30 days)
<i>Technological mode of the mechanical driver (sec)</i>	
Accepted at the enterprise	10
Accepted at the enterprise	11–15
Accepted at the enterprise	16–25
Accepted at the enterprise	26–35

According to the scheme, during the preparatory period, the cows were driven for milking by the mechanical driver, the operation mode of which varied from 10 to 30 sec.

In the beginning of the first stage of the experimental period, the technological groups of cows were driven for milking by the mechanical driver, the operation mode of which was 10 sec, at the second stage – 11–15 sec.

The working mode of the mechanical driver at the third stage was 16–25 sec and on the fourth 26–35 sec, respectively.

**Results and Discussion.** The determination of the basic theses for the improvement of modern dairy cattle breeding lies on the concept of the industry development, which is based on the objectives of transforming livestock production into a competitive industry. The issue of directing the development of its technical and technological support is closely linked to its functional abilities to realize the genetic potential of biological production facilities with high nutrition of a proper quality.

Driving the animals to the milking parlour is one of the main operations performed by a driving operator, the performance of which affects not only the productivity of the milking plant but also the indicators of milk let-down; this gave grounds for monitoring the work of the driving operator and the pipe-line milking operator for costing time required to perform driving of high yielding cows in manual and mechanized variants (Table 3).

Table 3

The costs of working time with various methods of driving of a group of cows to the milking parlour, ( $X \pm S_{\bar{x}}$ ), n=6

Number of cows at the milking stall, individuals	Time expenditures for prodding of a group of cows to the milking parlour (min)			
	Manual		Mechanized	
	By a pipe-line milking operator	By the driver	By a pipe-line milking operator	By the driver
8	1.47±0.41	8.06±0.18	0	5.15±0.28

It has been established with the manual driving of cows from the milking pen to the panel stall for 8 heads the operator spends on average 8.06 min, that is, 1 min per 1 head, which is 56.5% more compared to the time spent by the operator with the application of mechanical driving. The participation of the pipe-line milking operator in the driving of the cows and closing of the hatches is not excluded, and these costs are 1.47 min per 8 cows, i.e. 0.18 min per a cow.

The total labor costs for manual driving of the cows are 9.53 min, which is 85.0% more than for mechanized one, which, in turn, allows the operator to spend 0.64 min per one cow on average. The pipe-line milking operator does not participate in the process of driving, which allows him to focus only on the process of preparing cows for milking. With a manual driving of the cows, the pipe-line milking operator is distracted from the main technological process, which negatively affects the quality of preparation of cows for milking and the process of milking in general; as a result, it reduces the productivity of the plant.

The data obtained indicate that on the industrial complexes with the automation of the technological process of automatic milking of high yielding cows it is necessary to use the equipment for mechanized driving them to the milking parlour, which allows the milking operator to concentrate on qualitative work with the animals, increases the throughput of the milking plant.

On automated milking plants with mechanical driving, the pipe-line milking operator participates only in driving of the first lactation heifers in the process of training them to enter the panel stall of the milking plant.

The studies on the detection of the behavior of high-yielding cows of Ukrainian black-and-white dairy breed during the entry to the milking parlour with mechanical and manual driving have established that the time of their stay in the milking pen depends on the amount of the one-time milk yield and the manifestation of the milk let-down reflex.

Thus, with a mechanical driving of the cows and milking them at the plant "Parallel", with the one-time milk yield of 14.8 kg, 39 cows remained in the milking pen for 15.5 min with an average intensity of milk let-down of 2.12 kg/min. It took 0.40 min per one cow while her staying in the milking pen. At the same time, with the one-time milk yield of 11.3 kg, the animals spent in the milking pen 0.84 min per a cow on the average, with an average milk let-down intensity of 1.87 kg/min.

With the value of one time milk yield of 13.6 kg, 56 cows were waiting for milking in the milking pen for 40.2 min. The average intensity of milk let-down was observed at the level of 2.06 kg/min. Thus, one cow spent 0.72 min in the milking pen. With the one-time milk yield of 15.3 kg, the cows spent in the milking pen 0.78 min/head on the average, with an approximate milk let-down intensity of 2.27 kg/min.

With the manual method of milking on the traditional milking plant of the "Herringbone" type, 57 animals spent in the milking pen 0.35 min/head. At the same time, the value of a one-time milk yield was 13.7 kg, and the intensity of milk let-down was 2.21 kg/min. Along with this, with the amount of one-time milk yield of 10.8 kg, 65 animals spent in the milking pen 0.78 min/cow on the average.

With the amount of a one-time milk yield of 12.2 kg, 47 cows were waiting for milking in the milking pen for 45.6 min. An average intensity of milk let-down was observed at 1.74 kg/min. It was spent 0.97 min/cow. Along with this, with the size of a group of cows of 31 heads and the amount of one-time milk yield of 13.1 kg, the animals spent 0.82 min/head in the milking pen.

The results of the research indicate the dependence of the amount of milk yield and the intensity of milk let-down on the time of animals staying in the milking pen, both with a mechanical and manual driving of the cows to the milking parlour at the plants of "Parallel" and "Herringbone" types.

Negative factors that arise during the aggressive interaction of cows between themselves cause stress accompanied by a metabolic disorder and a decrease of milk yields (Abitov et al 2018). It is stress that is responsible for the loss of milk yields and the lack of young animals. The combination of stress-factors does not provide a good state of animal health.

Stresses may be of a various origin, and all of them cause similar changes in the body of the animal. If the intensity of stress is insignificant, the body is able to adapt but when the stress factor exceeds the compensatory capacity of the body, the animal is ill, and in some cases it leads to its death. According to statistics, up to 80% of stresses in animals are linked with feeding and treatment, and only 20% are attributed to other factors (Dangles et al 2018).

In the context of automatic milking, the behavior of high-yielding cows while waiting for the milking in the milking pen is of particular importance because this factor affects both the manifestation of the milk let-down reflex and the completeness of milking.

The observations proved that while waiting in the milking pen in groups of 33–72 animals, 26.4–33.3% of them are staying calm, 13.9–24.2% are butting, 1.4–3.0% are in heat, 6.0–12.8% are moving actively and 33.5–47.2% are being milked and leaving the milking machines, with the milking at the plant of the "Parallel" type.

If the operator activates a mechanical driver from the trench of the milking parlour, then the behavior in these is as follows: 19.4–33.3% are moving, 19.9–26.4% are standing, 6.9–12.1% are fighting and 33.5–47.3% of the animals are milked and leaving the milking machines. The results obtained testify to the calm behavior of cows during their stay in the milking pen with mechanical driving, since 19.9–26.4% of the animals, respectively there were staying calm.

At the moment of its starting, the mechanical driver produces a certain sound (bell, etc.) that reflexively disposes the animals to milking, and the operator only monitors their movement across the area under the control of the mechanical driver.

During the milking of cows at the plant of the "Herringbone" type with a manual driving 25.0–34.5% are calmly standing and waiting for milking in the milking pen, and with driving – 16.9–18.2% are calm and 8.5–14.3% of the animals, respectively, are fighting. These data indicate a fairly calm behavior of cows before milking.

The response of high yielding cows to driving, both mechanical and manual, changes their behavior: 19.4–33.3% and 27.3–40.4% of the animals, respectively, move.

It should be noted that, with the manual method of driving, the cows are more responsive to the cry of the driving operators – they start moving.

Costs of the operator's time for driving cows to milking with the use of mechanical driver are quite low – 0.64 min/head, due to this he has enough time to identify the cows in heat, to organize the removal of problem animals, etc., whereas with driving the cows in manual mode the operator spends 1.0 min/head, and the pipe-line milking operator has to help him, spending 0.18 min/head.

Thus, with a mechanical driving of the cows for milking, the operator is fully focused on the technological process; he is not distracted and does not pay attention to

other kinds of work. This allows achieving a high throughput capacity of the milking plant, providing a proper preparation of high yielding cows for automatic milking and a high intensity of the milk let-down – 2.08 kg/min on the average.

At the next stage of research, the experimental substantiation of mechanical driver modes was performed on cows of Ukrainian black and white dairy breed at the milking plant "Parallel" 2×14. The milking pen of this plant with an area of 162 m<sup>2</sup> (9×18) is designed to move the technological group of cows of 80 heads. The mechanical 9 m long driver moves at a speed of 1 m/sec.

In the course of the studies conducted the technological mode of the mechanical driver and the process of moving the group of cows of 80 individuals to milking have been determined, as shown schematically in Figure 1.

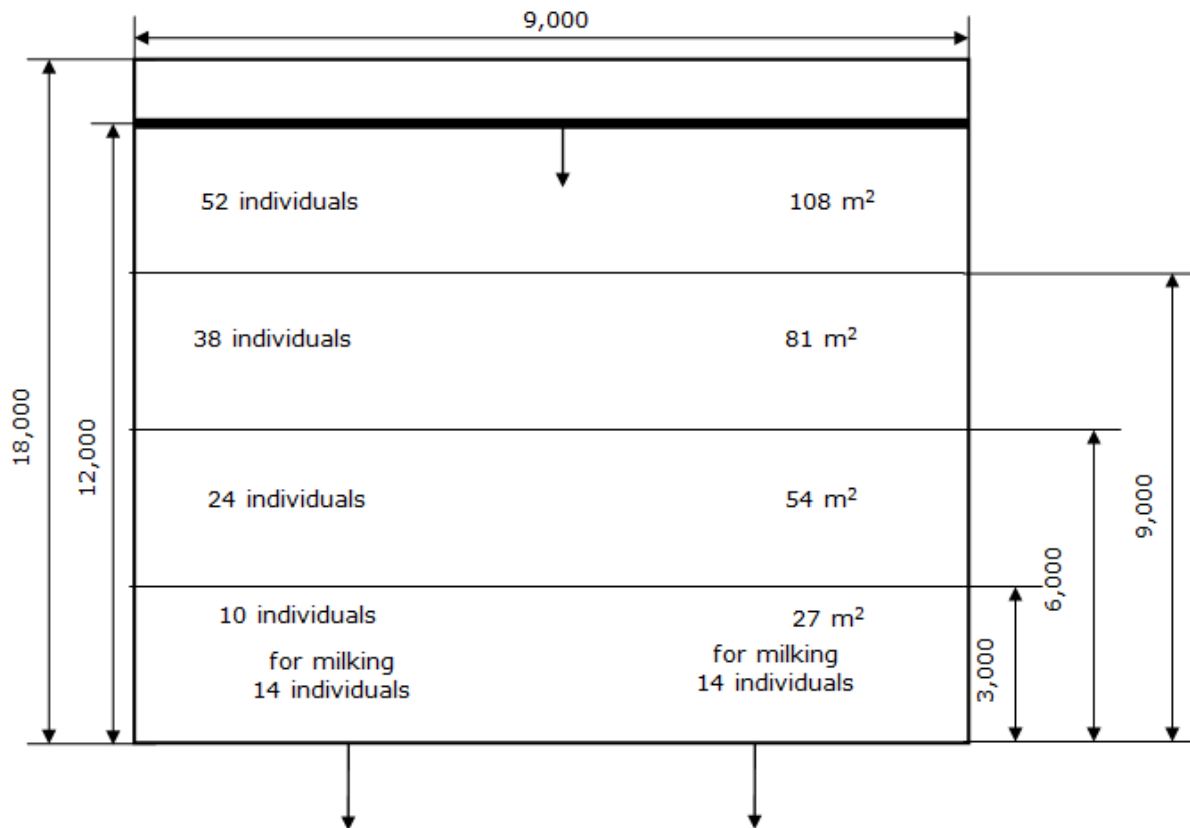


Figure 1. The scheme of the movement of the group (80 individuals) from the milking pen to the milking parlour: 52 individuals, 38 individuals, 24 individuals, 10 individuals are the groups of cows waiting in the milking pen; 108 m<sup>2</sup>, 81 m<sup>2</sup>, 54 m<sup>2</sup>, 27 m<sup>2</sup> – the area of the milking pen remained for the expectation of the group of cows during the relocation of the mechanical driver.

In the research conducted, several technological modes of starting the mechanical driver from the trench of the milking parlour by 10, 11–15, 16–25 and 26–35 sec were substantiated. During this experiment, the animal behavior indicators, their response to the driving, the average one-time milk yield, the intensity of the milk let-down and the duration of milking were determined.

The principle of work of a mechanical driver is in its movement on special rails. An electric device (bell, etc.) is installed on the driver, which, when the driver is started, warns about the cows' readiness for entering the milking parlour.

A new technological group of cows comes after a mechanical driver when it moves forward. This ensures the continuity of the flow of the animals and the support of their distribution into groups.

After the driving of a technological group of the cows to the milking parlour is done, the mechanical driver goes up with the help of a pneumatic mechanism and moves over a new technological group of the cows, returns to its original position, and then goes down at the end of the milking pen. Thus, when it begins a new cycle of motion, all the cows are in front of him.

During the preparatory period, the technological groups of the cows were directed to milking and milked according to the technology accepted on the farm.

The observations during the experimental period found that with the mechanical driving with duration of 10 sec in the group of 40–71 heads: 48.2–56.7% of the total number of the cows was standing calmly, 9.5–11.3% was fighting and 33.3–40.7% was moving.

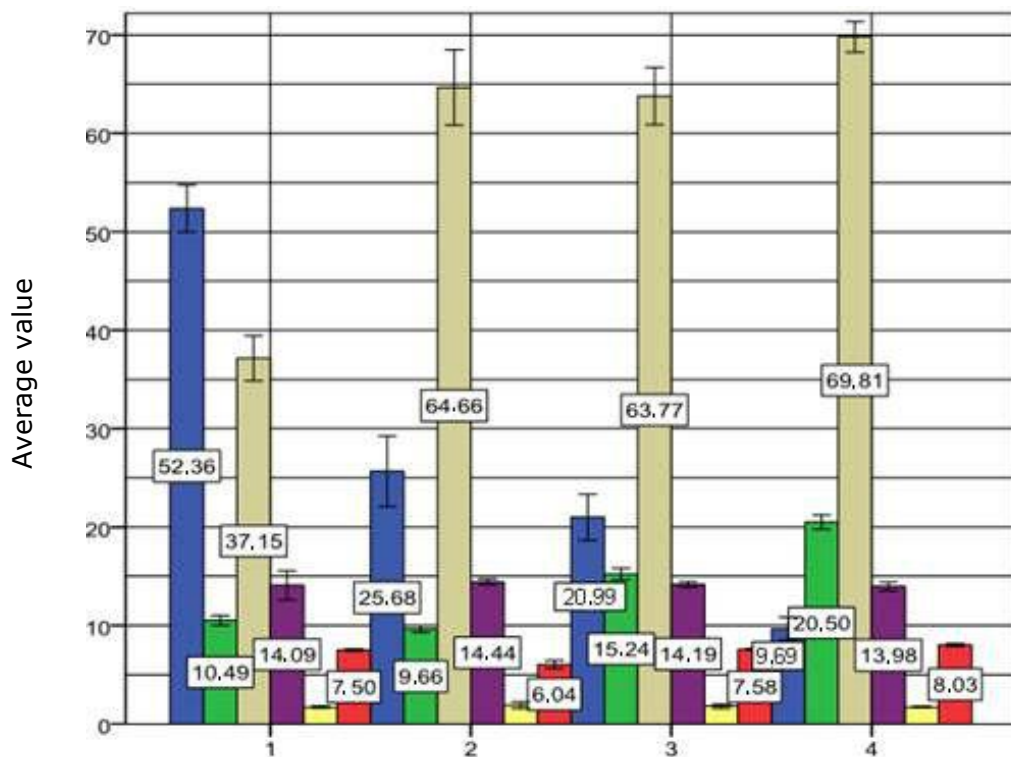
With the driving of the cows with the mechanical driver for 11–15 sec in the group 40–71 heads: 21.4–34.5% of the animals were standing calmly, 9.2–10.3% – were fighting and 55.2–69.2% of their total was moving.

Due to the application of this mode of the driver, the cows had the time for movement without pushing.

With the driving of cows with a mechanical driver for 16–25 sec in the group of 40–71 cows: 17.5–26.2% of the animals were standing calmly, 14.1–16.7% was fighting and 57.1–67.6% of their total was moving.

It was established that when the cows were driven with a mechanical driver for 26–35 sec in the group of 40–71 cows: 7.5–11.9% were standing calmly, 19.7–22.2% was fighting and 66.7–72.5% of the total was moving.

Thus, the data obtained indicate a calmer and more comfortable behavior of the high yielding cows when they enter the milking parlour driven with a mechanical driver for 11–15 sec and the group size is 40–71 individuals, compared to the 10 sec driving (Figure 2).



The mode of the mechanical driver  
 ■ – not moving (% individuals); ■ – fighting (% individuals); ■ – moving (% individuals); ■ – milk yield, kg; ■ – milk let-down intensity, kg/min; ■ – duration of milking, min.

Figure 2. The cows' response to various modes of the mechanical driver: mode 1 – 10 sec, mode 2 – 11–15 sec, mode 3 – 16–25 sec, mode 4 – 26–35 sec.

It should be emphasized that for the driving modes for 16–25 and 26–35 sec the animals are moving more actively, but a significant number of them behaves aggressively (fight), which negatively affects the indicators of the milk let-down. Thus, with regard to the driving mode of the cows for 11–15 sec, the average one-time milk yield for these driving modes decreases by almost 1.7–3.2%, the intensity of the milk let-down also decreases, by 6.2–10.9%, respectively, and the duration of milking, on the contrary, increases by 25.5–32.9%. Compared to the driving mode for 11–15 sec, with the driving mode for 10 sec, the intensity of the milk let-down decreases by 10.9%, and the duration of milking, on the contrary, increases by 24.2%.

Consequently, the results of the studies conducted indicate that due to the decrease in the intensity of the milk let-down in high yielding cows, the duration of milking is also increasing which has direct negative productive effects.

According to the results of the research conducted, the part-load mode of operation of the mechanical driver was substantiated, the application of which provides:

- milk let-down at the level of 1.92 kg/min;
- duration of milking of one head at the level of 6.04 min;
- proper preparation of cows for automatic milking – quick and calm entry to milking plants;
- compact movement of the technological group and the calm behavior of the animals.

Along with this, the use of the improved mode of the mechanical driver made it possible to obtain an economic effect of 2.10 UAH (0.079 USD) per 1 head due to the power saving, which amounted to 4,778.04 kW/h in the control version, against 3,893.83 kW/h – in the experimental one.

Based on the results of the studies conducted, it can be stated that increasing the efficiency of dairy cattle breeding in Ukraine is possible through the complex implementation of new technological, organizational and technical solutions and techniques.

**Discussions.** During milking of high yielding cows in milking parlours, pipe-line milking operators are provided with assistants whose duties include: driving the cows from the section to the milking plant and driving them back to the section after milking, monitoring the location of the animals at the milking plant, cleaning the milking pen and participating in veterinary measures (Curtis 2000; Paliy 2012; Skorkin 2005).

However, the use of a mechanized driving of the cows for milking allows increasing a throughput capacity of the milking plant and eliminates the milking habit alteration (Osterman & Redbo 2001; Petrusha & Semencov 2011).

According to some literature sources (Tuvaev & Sedunov 1992; T'enen & Semkov 2013; Vedishhev 2006), the cost of labor per cow is within the range of from 0.80 to 1.09 min. In this case, the standard throughput capacity and efficiency of the plants is achieved. Our research not only confirms this assertion, but also proves the need for technical solutions to increase the efficiency of milking plants.

Adjusting the duration of staying of cows in the milking pen is almost impossible, because it depends on how much time they spend in the milking parlour. But with the rational use of mechanized equipment of driving it is possible to reduce the time of relocation of cows from the milking pen to the milking parlour, with a direct positive effect on milk yield and animal behavior (Hillerton et al 2002; O'Driscoll et al 2011; Paliy et al 2015).

It should be noted that the presented optimal mode of operation of the mechanical driver gives an opportunity not only to improve the milk yields of high-yielding cows, but also to obtain an economic effect at the expense of energy savings, which at present is a very important factor in the efficiency of production.

The prospect of further research is to substantiate, develop and implement innovative technical and technological solutions for the servicing of high yielding cows at all the stages of their keeping and treatment in order to maximally approach the significant production factors to the physiological needs of the animals, which, of course, will have both a theoretical and practical value.



**Conclusions.** It has been found that the total labor costs for manual driving of cows are 9.53 min, which is 85.0% more compared to the mechanical one; this, in turn, allows the operator to spend on the average 0.64 min per/cow.

It has been proved that the use of adaptive, scientifically grounded techniques and cow driving modes in the milking parlour contributes to reducing the duration of milking, increasing the intensity of the milk let-down and increasing the efficiency of dairy cattle breeding.

It has been established that the introduction of an optimized mode of mechanical driver for 11–15 sec with the size of the a technological group of 40–71 individuals provides compact movement of the animals, calm behavior, increase in the intensity of the milk let-down by 6.2–10.9% compared to the driving of cows for 10 sec, 16–25 sec and 26–35 sec, reducing the duration of one-head milking by 24.2, 25.5 and 32.9%, respectively, and the increase in labour productivity of milking operators – up to 85.0%, compared to manual driving of the cows for milking.

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