Acta Scientiarum
http://periodicos.uem.br/ojs
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v43i1.51336

Milk production process, quality and technological properties of milk for the use of various types of milking machines

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ABSTRACT. Studies have been carried out to evaluate the efficiency of using easy-assembled cow houses in modern milk production technologies for the use of high-productive milking plants of the type 'Parallel' and 'Carousel' with 32 machines each. It has been established that new types of premises not only provide comfortable conditions for the maintenance of highly productive cows, but also reduce the labor costs for their maintenance and, most importantly, allow the use of modern high-productive milking installations of the type 'Parallel' and 'Carousel'. It has been established that the technology of preparation of cows for milking and milking technology provides more complete display of the milk ejection reflex at the installation of the 'Parallel' type. The average intensity of cows' milk flows at this plant is 30% higher compared to those of the installation of 'Carousel' type, which is confirmed by the intensity of milk flow production at the first minute of milking, which is at the level of 2.97 against 1.85 kg $min.^{-1}$ per installation of 'Carousel' type. Milk obtained using a milking installation of the 'Parallel' type has higher values of the mass fraction of fat and protein that is associated with the genetic potential of animals. According to physical, chemical and technological properties, milk obtained from milking installations such as 'Parallel' and 'Carousel' is within the limits of the standards in force. Milk obtained from the use of milking equipment such as 'Carousel' has higher electrical conductivity at the level of 4.6 mS cm^{-3}, which is confirmed by a higher level of mastitis disease of cows. Due to bacterial contamination, reductase test and milk clot characteristic, milk obtained using a milk installation of 'Parallel' type also has higher quality indicators than the installation of 'Carousel' type. But according to the complex of indicators, milk obtained from various technologies of milking refers to the desired cheese-making class.

Keywords: dairy farms; milking installations; milk ejection; quality; technological properties of milk.

Received on December 10, 2019.
Accepted on June 25, 2020.

Introduction

During recent years in Ukraine powerful dairy farms for 500 and 1000 cows are created. The basis of their functioning is the innovative milk production technologies, in particular the keeping of animals in easy-assembled premises of a new type with a width of 32.5 m and milking with highly productive installations of the type 'Parallel' and 'Carousel' with 32 machines (Schewe & Stuart, 2015; Machulnyi, 2018**).**

Introduction of new technologies in dairy cattle breeding makes it possible to put into practice the production of new approaches to the maintenance and exploitation of animals, especially high-yielding ones, and to ensure the production of milk economically beneficial (Vaccaro, 1990)**.**

However, it is known that the technology of milk production is a complex biotechnical system of parameters, in which the conditions of animals maintenance, technical and technological links enter into direct interaction with the biological object - an animal (Gaworski, Leola, Sada, Kic, & Priekulis, 2016).

In the technology of milk production, the technology of keeping cows has a strong influence on the productivity of cows. Studies conducted in recent years (Dascălu et al., 2011; Cielava, Jonkus, & Paura, 2017) showed the availability of keeping high-yielding cows in easily assembled premises with a width of 32.5 m.

For such volumetric-planning and technological solutions the volume of premises per an animal is increased almost twice from 45.6 to 96.3 m^3. At the same time due to increase of the air movement from 0,16...0,27 to 0.5 m s^{-1}, the gas content of ammonia in rooms is reduced by 8-9 times and bacterial colonization in comparison with the norms is reduced by 18.7 times (Nardone, Ronchi, Lacetera, & Ranieri, 2010; Bozhydarnik & Krisanov, 2011; Bilchenko, 2011).

Studies also show that no machine or technological equipment that provides the milk production technology does not contact with the animal as close as a milking installation, in particular its main operating mechanism - the milking machine (Jacobs & Siegford, 2012). The design of the milking installation has a great influence on the milking process, in particular the realization of the milk ejection reflex at cows, and on the quality of milk and its technological properties (Vasseur et al., 2015).

Hovinen and Pyörälä (2011) and Toušová, Ducháček, Stádník, Ptáček, and Beran (2014), studying the influence of milking systems on the functional properties of cow's udder and the quality of milk, found that in order to increase the effectiveness of the manifestation of the genetic potential of cows and improve the quality of milk, it is advisable to use milking equipment that provides timely stimulation of the milk ejection reflex, full dry milking and rapid transportation & cooling of milk In their opinion, the most effective are the 'Westphalia Arge' and 'DeLaval' milking installations.

Milking installations of the 'Parallel' and 'Carousel' type, which are implemented in Ukraine, differ significantly from each other both by design and by milking technology, in particular, the technology of placement of cows, their preparation for milking and the control of the milking process (Borshch, Borshch, Kosior, Lastovska, & Pirova, 2019). At the same time, studies in the comparative aspect of assessing the quality of the milking process at these facilities were not carried out, which complicates the process of choosing one or another milking equipment for the acquisition of equipment for new farms.

In this regard, the purpose of our research was to study the conditions for the maintenance of high-yielding cows in the premises of a new type and to evaluate the efficiency of using milking installations of the 'Parallel' and 'Carousel' types according to the indicators of milk ejection, quality and technological properties of milk.

Material and methods

Assessment of maintenance conditions

This research was conducted from 2016 to 2018 at two farms with a population of 1000 cows each. The conditions for the maintenance of high-yielding cows in easy-assembled premises of a new type were assessed according to the microclimate indicators: temperature, relative humidity, gas content, bacterial air pollution and behavior of cows of various physiological groups (Vasseur et al., 2015).

For direct registration of temperature and relative humidity, daily and weekly thermographs model M-16 AH ('Gidrometpribor', Russia) were used; also model M-16 AC ('Gidrometpribor', Russia) with model M-21 AC ('Gidrometpribor', Russia) and psychrometer model MB-4M ('Gidrometpribor', Russia). The velocity of air in the premises was determined by cup anemometers model MC-13 ('Gidrometpribor', Russia), concentration of ammonia and hydrogen sulfide - by gas analyzer model UG-2 ('Analitpribor', Ukraine), carbon dioxide content - by chemical method (Borshch O.O. et al., 2018). Bacterial air insemination was determined using the device of the bacterial analysis 'Typhoon' model P-40 ('Termolab', Ukraine).

Evaluation of milk ejection at cows

Indicators of milk ejection and milk flow at cows with different types of milk installations were determined in two groups of cows-analogues that were in the 2-4 months of lactation, suitable for machine milking and had the same productivity and daily hopes.

The average intensity of milk flow was determined in kilograms per minute of milking using the Equation 1:

$$Q = \frac{\sum^{n}(q1+q2)}{\sum^{n}(t1+t2)} \quad (1)$$

where:

q1 is the value of machine milking, kg;

q_2 is the value of machine dry milking, kg;

t_1 is the duration of machine milking, min.;

t_2 is the duration of machine dry milking, min.

The assessment of the quality of milk indicators was carried out using the device 'Bentley 150 Combi' ('Bentley Instruments Inc.', USA).

Evaluation of the chemical composition of milk was performed by determining the percentage of fat mass, true protein, protein, lactose and solids skimmed milk residue by infrared spectroscopy at the device 'Bentley 150 Combi' ('Bentley Instruments Inc.', USA).

Common bacterial contamination of milk was investigated by the method based on the properties of mesophilic aerobic and facultative anaerobic microorganisms proliferate on dense nutrient agar ('Alfarus', Ukraine) at a temperature of 30 ± 1°C for 72 hours (DSTU IDF 100V:2003, 2005).

The number of growing bacterial clumps was counted in each petri dish.

The total number of bacteria in 1 cm^3 or 1 g of milk (X) was evaluated using the Equation 2:

$$X = n \cdot 10^m \quad (2)$$

where:
n is the quantity of clumps, counted in petri dish;
m is the quantity of tenfold dilutions.

The coli-titer of milk was determined by the method based on the properties of the bacteria of the colon bacillus group to ferment lactose in the medium of Kesler, resulting in the formation of acid and gas (GOST 9225-84, 2009).

Somatic cells in milk were studied using a viscometer «Somatos» model AMB-1-0,2 (Agroservis, Ukraine). 5 cm^3 of the 'Mastoprim' preparation solution and 10 cm^3 of experimental milk were poured into the vessel of the device. The number of somatic cells in milk was set at the time of the mixture outflow (GOST 23453-2014, 2015).

The thermal stability of milk was evaluated by the method based on the ability of ethyl alcohol to denature the milk proteins completely or partially and thereby break the stability of the colloidal system (DSTU 5073:2008, 2010).

Research results

Influence of new volumetric-planning and technological solutions of premises on the conditions for the maintenance of highly productive cows was estimated by the indicators of the microclimate and ethological indicators and compared with the traditional cows in Ukraine (Table 1, 2, 3).

Table 1. Indicators of microclimate in different types of premises in winter.

Indicator	Value of the indicators		
	Normative parameters for (VNTP-APK-01.05, 2005)	Traditional cow house	New type of a cow house (with width of 32,5 m)
Speed of air movement, m s^{-1}	0,3-0,4	0,16...0,27 ± 0,05	0,5 ± 0,09***
Lighting in the feeding area, lux	52,0	31,0 ± 2,70	49,0 ± 3,2**
Air gas pollution: Ammonia, mg m^{-3}	20,0	10,5 ± 0,50	1,3 ± 0,25**
Carbon dioxide, %	0,25	0,75 ± 0,05	0,05 ± 0,01**
Bacterial air pollution, thousands m^{-3}	Up to 70,0	493,6 ± 0,57	26,4 ± 2,5***

Note: **p > 0.99; ***p > 0.999.

Table 2. Indicators of microclimate in different types of premises in summer.

Indicator	Value of the indicators		
	Normative parameters for (VNTP-APK-01.05, 2005)	Traditional cow house	New type of a cow house (with width of 32,5 m)
Speed of air movement, m s^{-1}	0,3-0,4	0,26 ± 0,02	0,6 ± 0,04***
Lighting in the feeding area, lux	52,0	53,4 ± 1,13	63,1 ± 4,60**
Air gas pollution: Ammonia, mg m^{-3}	20,0	8,2 ± 0,70	0,9 ± 0,25**
Carbon dioxide, %	0,25	0,85 ± 0,07	0,08 ± 0,01**
Bacterial air pollution, thousands m^{-3}	Up to 70,0	523,4 ± 1,21	38,6 ± 0,09***

Note: **p > 0.99; ***p > 0.999.

It was established that new volumetric-planning and technological solutions of the premises provide comfortable conditions for the maintenance of highly productive cows.

The presence in the design of these rooms of the side curtains and the light-aeration crest increases the speed of air more than three times (0.5 vs. 0.16 m s^{-1} in winter and 0.26 vs. 0.6 m s^{-1} in summer) that positively affects the gas content of the premises and bacterial air pollution. The presence of ammonia in new cows houses is 8...9 times in comparison with traditional premises, and bacterial contamination, due to an increase in the volume of the premises up to 129.6 m^3 per head, decreases in winter period to a minimum level and is 2.8 thousand m^{-3} (p > 0.999). Similar data were obtained in the studies of Yilmaz et al (2016) in assessing the conditions for the maintenance of highly productive cows in easy assembled premises.

Table 3. Behavior of cows in different types of premises (n = 80).

Indicator	Indicator value			
	Type of cow house			
	New easy assembled		Traditional	
	Duration of the behavior act			
	min.	%	min.	%
Method of maintenance	Free-stall housing		Tie-up housing	
Lie without activity,	750,0	52,1	667,2	46,34
Some of them chewing cud	174,7	23,3	149,6	22,43
Stand without activity,	262,2	18,20	431,6	29,98
Some of them chewing cud	37,2	14,2	66,2	13,29
Move	123,0	8,6	-	-
Consume food	252,0	17,4	320,2	22,23
Consume water	19,8	1,4	13,8	0,95
Milking	33,0	2,3	7,2	0,5

Investigation of the behavior of cows in new premises showed that animals for a long time were in a quiescent state and had a rest. They lie without activity for 52.1% of the day, and at low temperatures this figure rises to 54%, while in the traditional cow house the rest reaches only 46.34%.

Positive fact is that cows in an easy-assembled house have the opportunity to move around, for which they spend 8.6% of the time.

It was established that new types of premises not only provide comfortable conditions for the maintenance of highly productive cows, but also reduce the labor costs for their maintenance and, most importantly, allow the use of modern high-productive milking installations of the type 'Parallel' and 'Carousel'.

The effectiveness of these installations usage was estimated by the indicators of the milk ejection reflex realization of thanks to the intensity of milk flow per minutes of milking, total milk yield and quality of milk (Table 4). The researches have established that the reflex of milk ejection at cows at the milking installation of the 'Parallel' type appears more fully than at the installation of 'Carousel' type.

Thus, the average intensity of milk flow at cows at the milking installation of the 'Parallel' type is 30% higher compared to the 'Carousel' type installation. The adequacy of the milk ejection reflex realization at cows at the installation of the 'Parallel' is evidenced by the intensity of milk flow at the first minute of milking, which is at the level of 2.97 against 1.85 kg min. ($p > 0.999$) at the installation of 'Carousel' type. At the same time, the maximum intensity of milk flow at the installation of the 'Carousel' type is observed at the second minute of milking, which indicates the inhibition of the milk ejection reflex (Figure 1).

Table 4. Indicators of milk flow at cows with different types of milking installations (n = 20, M ± m).

Indicators	Types of milking installations	
	'Parallel'	'Carousel'
Average intensity of the milk flow, kg min.	1,93 ± 0,25**	1,47 ± 0,12
Intensity of the milk flow, kg min.		
Per the first minute of milking	2,97 ± 0,10***	1,85 ± 0,02
Per the second minute of milking	2,49 ± 0,15**	2,35 ± 0,20
Per the third minute of milking	2,05 ± 0,05**	1,85 ± 0,03
Average milk yield, kg	12,10 ± 0,17**	11,5 ± 0,15
Total milking time, %	6,30 ± 0,15**	7,08 ± 0,10

Note: **p > 0.99, ***p > 0.999.

The obtained results coordinate with the research of Tullo et al (2019) and other scientists (Rafiq et al., 2016).

Simultaneously with the physiological assessment of the milking process, the quality of milk and its technological properties were investigated when using these types of milking installations.

According to the results of the research, it was established that when milking equipment such as 'Parallel' type is used, somewhat higher parameters of a mass fraction of fat and protein are observed in milk (Table 5).

Apparently, this is connected with the fact that at these farms cows have a high productivity at the level of 9-10 thousand kg per lactation, and in their rations there is a high percentage of concentrated feed, the feeding of which provides a high level of protein and fat in milk. A number of indicators of milk quality also depend on the technology of its production (McGuffey, 2017), and the genetic potential of animals.

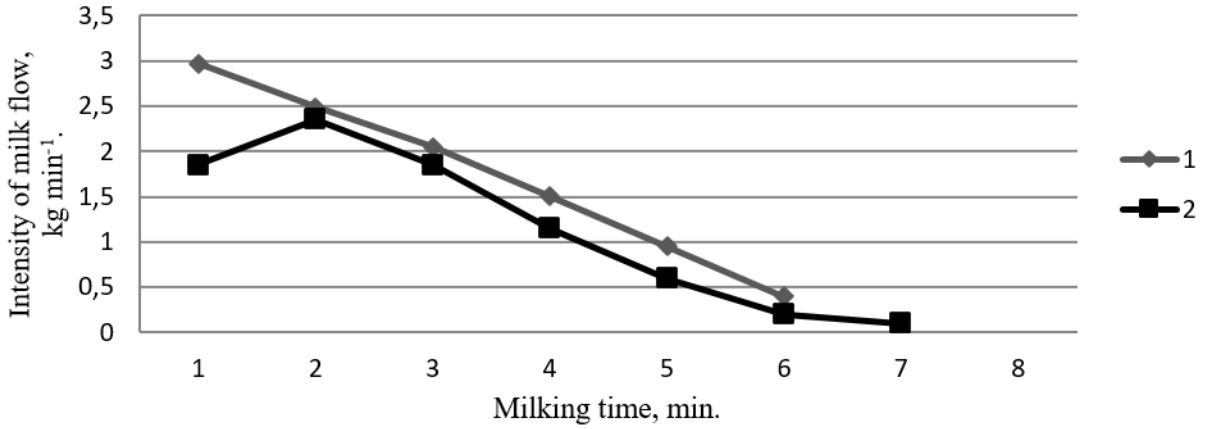

Figure 1. Intensity of the milk flow at the cows at different types of milking installations: 1-'Parallel', 2 -'Carousel'.

Table 5. Chemical composition of milk, obtained at different types of milking installations (n = 12, M ± m).

Indicator	Type of milking installation	
	'Parallel'	'Carousel'
Mass fraction of fat, %	4,15 ± 0,02	4,1 ± 0,01
Mass fraction of protein, %	3,12 ± 0,04	3,07 ± 0,03
Mass fraction of dry matters, %	12,83 ± 0,11	12,35 ± 0,07
SNF, %	8,68 ± 0,05	8,55 ± 0,03

It is known that in the process of production of dairy products among the physical and chemical properties of milk, titrated acidity, active acidity, density, heat resistance, and the like are the most important. Titrated acidity is a criterion for assessing of the quality of milk primary materials, namely its freshness and naturalness, and is characterized by a set of factors that depend on the period of the year, the stage of lactation, the state of animal health, the physiological state, dietary rations, etc. At the same time, in the production of dairy products, the index of active acidity is more important than titrated acidity. The number of indicators of the actual technological process depends on the pH amount. As an indicator of falsification, the cryoscopic temperature of milk freezing also has practical significance, so you can determine the degree of dilution of milk with water (Kondrasiy & Yakubchak, 2015; Borshch et al., 2018).

A comparative assessment of the physical-chemical and technological properties of milk testifies that milk at the use of the investigated types of milking installations fully meets the requirements of the current standard (DSTU 3662:2018, 2018), which indicates the absence of falsification. The cryoscopic temperature of freezing milk varies from -0.57 to -0.55°C, which is within the normal range. The active acidity of milk obtained from the use of milking installations of the 'Parallel' and 'Carousel' type is also within the normal range, while the titrated acidity of milk obtained at the milking installation of the 'Carousel' type has the lowest value (Table 6). In our opinion, this is due to the fact that the milk obtained of a milking device of the type 'Carousel' has an increased content of somatic cells, which indicates a higher level of mastitis in cows.

Table 6. Physical-chemical and technological indicators of milk, obtained at different types of milking installations (n = 12, M ± m).

Indicator	Type of the milking installations	
	'Parallel'	'Carousel'
Density, kg m^{-3}	1027, 5 ± 0,02	1028,1 ± 0,01
Titrated acidity, °T	18,5 ± 0,4	18,0 ± 0,3
Active acidity, pH	6,67 ± 0,01	6,68 ± 0,01
Conductivity, mS cm^{-1}	4,22 ± 0,03	6,41 ± 0,06
Freezing point, °C	-0,56 ± 0,01	-0,57 ± 0,01
Thermal stability according to the alcohol test, group	II (alcohol 75%)	III (alcohol 72%)

It is known that the indicator of somatic cells quantity is in the list of the main criteria of the primary milk quality and safety. Today, there are many different test methods that allow you to control the state of the udder and the suitability of the milking technology to the needs of the animal. The main one is the electrical conductivity of milk. The obtained results of researches testify that the higher electrical conductivity at the

level of 4.6 mS cm^{-3} has milk obtained by the use of a milking device of the type 'Carousel', which is confirmed by a higher level of cows' mastitis disease.

Investigation of the sanitary-and-hygienic parameters of milk showed that, due to bacterial contamination and reductase test, milk obtained with the use of the milking unit of the 'Parallel' type also has higher quality indicators than the installation of the 'Carousel' type (Table 7). This is obviously due to the better performance of pre-milking operations and better milking of cows on the 'Parallel' installation.

Table 7. Sanitary and hygienic indicators of milk obtained with different types of milking installations (n = 12, M ± m).

Indicator	Type of the milking installations	
	'Parallel'	'Carousel'
Purity, group	I	I
KMFAAM, thousands. KUO cm^{-3}	205,5 ± 9,67	314,0 ± 10,05
Reductase test, class	The highest (more than 3,5 hours)	I (3,5 hours)
Fermentation test, class	I	II
Rennet fermentation test, class	I	II

Suitability of milk for cheese was evaluated by the rate of milk turning under the action of the rennet enzyme and the fermentation test. Thus, according to the fermentation test, milk obtained in the milking parlor 'Parallel' was assigned class I, because the clot had a smooth surface, was elastic to the touch, without voids in the longitudinal section and floated in a transparent whey. And the milk obtained at the Carousel installation was assigned the II class, because the clot was soft to the touch, with single voids (1-10), torn, but not swollen. It has been established that according to the characteristic of the milk clot, milk that was got with the milking installation of the 'Parallel' type also has the advantage. But according to the complex of indicators, milk obtained by various technologies of milking refers to the desired cheese-making class (Gaworski, 2016).

Conclusion

1. New types of livestock premises with the width of 32.5 and the height of 10.5 m provide comfortable conditions for the maintenance of high-yielding cows and the possibility to use high-productive milking installations 'Parallel' and 'Carousel' with 32 machines each.

2. The milking technology of the cows at the installation of the 'Parallel' type is more physiological in relation to the animal, since it provides a high intensity of the milk flow at the first milking minute at the level of 2.97 against 1.85 kg min. at the installation of the 'Carousel' type.

3. Milking installation of the 'Parallel' type provides higher quality indicators of milk, its technological properties in comparison with the installation of the 'Carousel' type.

4. Trends in the growth of the requirements for the quality of milk cause the need to improve the processes for its obtaining and revise a number of scientific regulations for the production of high-quality products with the simultaneous transition to more strict regulations for determining of its quality indicators.

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