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SELECTED PROBLEMS OF PRODUCTION PROCESS IN A BARN WITH ROBOTS

Summary

This two-year study analysed production performance in a barn with about 300 cows, equipped with milking robots, robotic feed pushers and barn cleaners. Cell count quality and chemical composition of milk as well as inputs and working conditions of personnel were analysed. Both primiparous and older cows up to the 7th lactation easily adapted themselves to the new technology. High milk production was achieved. In 2014, the average yield was 10,700 kg and in 2015 – 11,300 kg of milk. Chemical composition of milk was typical for the Holstein Friesians. In 2014, only 5.3% of these cows showed subclinical, and 2.1% – clinical signs of mastitis, which suggests a very good quality of the milk produced at the barn, measured by somatic cell count. In 2015, these signs were found in 4.8% and 1.5% of cows, respectively. The frequency of milking varied by yield and lactation stage. Cows were milked 3 times per day on average. Each robot conducted 150-160 milkings per day, which is a very high utilization rate. The work of personnel consisted mainly in control activities and was very efficient. Labour input was less than 3 minutes per cow per day.
***Key words**: barn, milking robot, robotic feed pushers, barn cleaners robot, milk, somatic cell count (SCC), working conditions, labour input*

WYBRANE PROBLEMY PROCESU PRODUKCJI W OBORZE Z ROBOTAMI

Streszczenie

Przeprowadzono dwuletnie badania efektywności produkcji obory na około 300 krów, w której zastosowano roboty udojowe, roboty podgarniające paszę i czyszczące podłogę. Analizowano jakość cytologiczną i skład chemiczny mleka, wydajność krów, a także nakłady i warunki pracy obsługi. Stwierdzono, że zarówno krowy pierwiastki, jak i starsze – do 7. laktacji – łatwo przystosowywały się do nowej technologii. Uzyskano wysoką wydajność produkcji mleka. W 2014 roku średnia wydajność wyniosła 10,7 tys. kg, a w 2015 roku 11,3 tys. kg mleka. Skład chemiczny mleka był typowy dla rasy holsztyńsko-fryzyjskiej. W 2014 roku stwierdzono u 5,3% krów w stadzie podkliniczne stany zapalne wymion, a 2,1% – kliniczne stany zapalne wymion, co wskazuje na bardzo dobrą jakość cytologiczną mleka produkowanego w tej oborze. W 2015 roku stwierdzono, że stany zapalne wymion występowały odpowiednio u 4,8 i 1,5% krów. Krotność doju była zróżnicowana w zależności od poziomu wydajności i stadium laktacji. Krowy były dojone średnio trzykrotnie na dobę. Jeden robot wykonywał 150-160 dojów na dobę, co wskazuje na dobre jego wykorzystanie. Praca obsługi polegała głównie na czynnościach kontrolnych i była bardzo wydajna. Nakłady pracy wynosiły poniżej 3 minut na krowę i dzień.
***Słowa kluczowe**: obora, robot udojowy, robot podgarniający paszę, robot czyszczący podłogę, mleko, liczba komórek somatycznych (LKS), warunki pracy, nakłady pracy*

1. Introduction

Various technology systems are used in cow milk production [2]. Particular solutions affect the behaviour and health of animals [15] as well as working conditions and labour input [14]. In recent times, robots have been used to automate work at the barn. Currently, eight companies manufacture milking robots, with Lely being the first to implement them in practice [10]. There are also robots which prepare and distribute TMR, push the feed in the feed fence, and clean barn floors. The number of robots used in barn has been constantly growing, although with different adoption rates across countries. Interestingly, in Germany, since 2012 more milking robots are sold than traditional milking parlours [11]. Szlachta [17] argues that the milking robots currently in use serve to satisfy human needs in terms of working conditions and work efficiency rather than the needs of animals.

In Poland, three DeLaval milking robots started operating at two barns in 2008. Over the next years, Lely and GEA also launched the sale and service of milking robots. By the end of 2015, about 200 milking robots have been used throughout Poland.

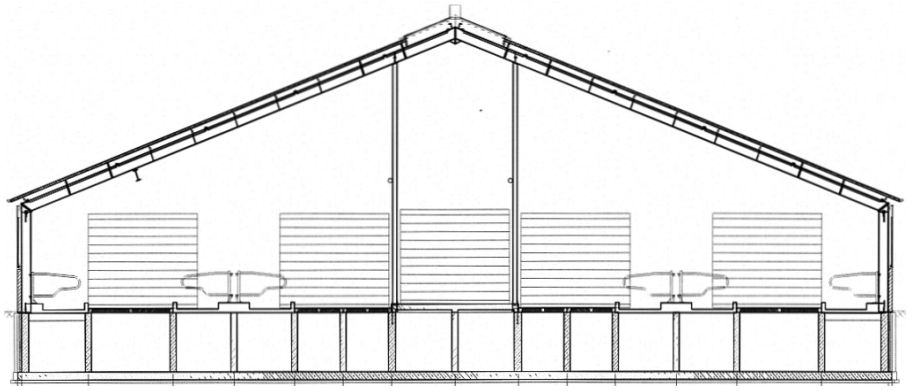
In addition, several years ago robots which prepare and distribute TMR, push the feed at the feed fence, and clean barn floors were also introduced.

Robots change the nature of work at dairy farms and require new skills from personnel. Both in Poland and in other countries there have been isolated cases of abandoning the use of milking robots and turning back to milking parlours. Therefore, it seemed advisable to conduct research at a barn equipped with both milking robots, feed pushers and barn cleaners, in which good production results were achieved. Robots are considered as significantly relieving humans from hard, arduous work, and increasing cow comfort.

The purpose of this study was to analyse production results, milk quality and working conditions, as well as emerging problems related to robotization.

2. Materials and methods

The study was conducted at a new barn situated in Kujawsko-Pomorskie Province of Poland, put to use at the end of 2013. The barn for about 300 cows is designed for animals throughout the full production cycle. Table 1 shows herd organization and housing conditions for particular production stages. Table 2 presents the equipment and machinery for particular activities at the barn. Figures 1 and 2 show the projection and cross section of the building.



Source: own work / Źródło: opracowanie własne

Fig. 1. Half-section of the barn. A manure pit is located under the building
Rys. 1. Przekrój pośredni obory. Pod budynkiem znajduje się zbiornik na gnojowicę

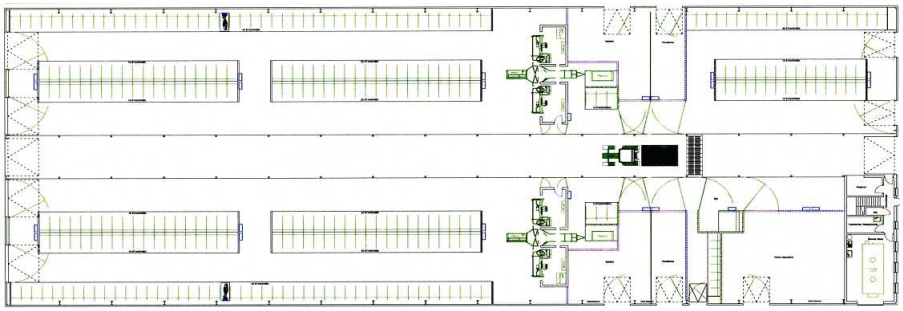


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Fig. 2. Functional layout of the barn, with division into sections
Rys. 2. Układ funkcjonalny obory z podziałem na poszczególne sekcje

Table 1. Herd organization and cow housing conditions
Tab. 1. Organizacja stada i system utrzymania krów

Cow group	Number of stalls	Parameters of housing
In lactation	123 x 2 = 246	a) resting area – bedded cubicles with dimensions: 2.5 x 1.2 and 2.75 x 1.2 (Figure 3, 4) b) walking area – slatted floor (Figure 5, 6) c) feeding area – feeding fence (Figure 7) and feeding stations (Figure 8) d) milking area – milking robot
Dry cows	50	paragraphs (a) and (b) as above, c) feeding alley
Close-up and fresh cows	variable 5-10	a) resting and walking area – group pens with solid floor and shallow bedding b) robotic milking c) feeding fence
In-treatment	variable	like for close-up and fresh cows

Source: own work / Źródło: opracowanie własne

Table 2. Equipment of the barn
Tab. 2. Wyposażenie obory w urządzenia

Activity	Equipment and machinery
Milking	4 milking robots Lely Astronaut A4
Feeding and drinking: – PMR feeding – pushing at the feed fence – feeding concentrate feed – drinking	 3 times per day, feeder wagon Sgariboldi with one horizontal auger - 14m^3 robot Lely Juno 100 – pushing 10 times per day – 4 feeding stations with protection gate (Figure 8), – milking stations drinking tank (Figure 5)
Cleaning – animals – claws – floor	 – cow brushes, Lely Walkway baths – Lely Discovery cleaning robots (Figure 6) – 4 slurry mixers at the corners of the building, switched on once per day for 30 minutes
Climate control	– automatic roll up - unroll of wall curtains based on wind direction and speed, precipitation and air temperature; – automated lighting Lely L 4C

The data input for analysis was based on the outcomes of milk productivity control carried out by A8 method and the on-farm data from the IT system, as well as information from the farm owner.

Source: own work / Źródło: opracowanie własne

Source: own work / Źródło: opracowanie własne

Fig. 3. A comfortable resting cubicle ensuring clean cow hair
Rys. 3. Wygodny boks legowiskowy zapewniający czystość powłok ciała krów

Source: own work / Źródło: opracowanie własne

Fig. 4. Slatted floor and resting cubicles with bedding
Rys. 4. Podłoga szczelinowa oraz boksy legowiskowe ścielone

Source: own work / Źródło: opracowanie własne

Fig. 5. Comfortable trough drinking station
Rys. 5. Wygodne poidło korytowe

Source: own work / Źródło: opracowanie własne

Fig. 6. Slatted floor cleaner
Rys. 6. Robot czyszczący podłogę szczelinową

Source: own work / Źródło: opracowanie własne

Fig. 7. Comfortable feed alley
Rys. 7. Wygodne stanowisko pobierania paszy

Source: own work / Źródło: opracowanie własne

Fig. 8. Feeding station with protection gate which ensures feed intake
Rys. 8. Stacja paszowa z obejmą zapewniającą pobieranie paszy

3. Results and discussion

The barn started to be populated in October 2013. Some cows originated from the owner's old free stall barn in which animals were kept on deep bedding and milked in a herringbone parlour. The remaining cows were purchased. In December 2013, 200 cows were housed in the barn (Table 3), of which 78 cows from the owner's own rearing, in the second to the seventh lactation. The remaining 122 cows were primiparous cows from the owner's own rearing, and purchased from the Netherlands and Poland. All animals were black-and-white Holstein Friesians (HF).

Over the two years, the herd age structure was changing. This concerns in particular the animals in the first and second lactations. The changes consisted mainly in a decreasing share of primiparous cows from 61% in 2013 to 43.3% in 2014, to 26.7% at end-2015. In comparison – the average share of primiparous cows in the Polish livestock was about 30% (PFHB and PM 2014 and 2015) [13]. In the herd under analysis, the typical national value was achieved after two years. Cows in the second lactation constituted an unusually large percentage. This is due to populating the farm with a large number of primiparous cows.

Table 3. Changes in age structure of cows in the herd in 2013-2015

Tab. 3. Zmiany struktury wiekowej krów w stadzie w latach 2013-2015

Lactation	Number of cows at year-end			Percentage of cows at year-end		
	2013	2014	2015	2013	2014	2015
1	122	112	70	61.0	43.3	26.7
2	35	99	121	17.5	38.4	46.1
3	22	23	48	11.0	8.9	18.3
4	10	16	13	5.0	6.2	5.0
5	8	3	7	4.0	1.2	2.7
6	2	3	2	1.0	1.2	0.8
7	1	1	1	0.5	0.4	0.4
8	0	1	0	0	0.4	0
Total	200	258	262	100.0	100	100

Source: own work / Źródło: opracowanie własne

The patterns of barn population resulted in a high percentage share of third-lactation cows at end-2015. This fact will have further effect on the herd age structure over the coming years. Nevertheless, such periodic fluctuations of cows in particular lactations have no direct influence on the organization of work at the barn.

Proper and good housing conditions in the new barn are supported by production results of cows in the fifth and later lactations. Old cows adapted themselves well to the housing and milking conditions that were new to them.

The proper herd structure with a split into in-lactation and dry cows is important for the optimum utilization of the machinery, equipment and stalls, as well as good organization of work and regular milk production. This can be achieved by properly designed structure of stalls in individual sectors of the barn. In Poland, the average calving interval is about 14 months (PFHB and PM 2014 and 2015). That is why 85% of the stalls should be allocated to milking cows and 15% – to dry cows. Such structure has been incorporated in the barn design (Table 1). However, the actual share of lactating and dry cows was varying widely (Table 4).

Until September 2014, there were 10 up to 13 dry cows, whereas the number of resting cubicles in that sector was 50 (Table 2). At the turn of 2015, the number of dry cows increased to 54-57. Bringing a large number of fresh cows into the farm at the same time resulted in heavy fluctuations of the number of dry cows. This led to difficulties with efficient utilization of stands in sectors. Two years into using the barn, no optimum ratio of lactating-to-dry cows was achieved. Sick cows (Table 4) were kept in a separate section of the barn (Table 1) which is a proper and necessary practice.

Annual milking output is considered as a key performance indicator of milking robots. The lower limit of profitability in Germany and Switzerland is taken to be 500,000 kg [3, 5, 6]. Bonsels and Sschmitz [1] argue that the minimum value is 600,000 kg per year. In the light of the figures provided above, the utilization rate of milking robots at the farm was very high (Table 4). Milking output depends on the number of milkings and milk yield of cows in a unit of time. In practice, about 160 to 180 milkings per day can be achieved [1, 20, 21, 22]. In addition, cow productivity is utilized well with average of three milkings per day. Therefore, the optimum number of lactating cows per robot should be about 60. At the farm studied here, there were 61.5 lying cubicles per milking robot (Table 1). In the period under study, the number of cows per robot varied from 48.5 in January 2015 to 59.5 in July 2014 (Table 4). An increase in the number of cows per robot leads to reduced milking frequency, and consequently to lower productivity. This relates in particular to high-yielding cows – in excess of 10,000 per standard lactation. Studies carried out by the authors [21] found that increasing the number of cows to 80 resulted in milking frequency reduced to 2 milkings per day.

Individual variation of milkings per day by daily yield and lactation stage is one advantage of the robot. At the considered barn, the robot performed about 6.4 milkings per hour and 154 per day. These figures suggest a potential for increasing the number of milking frequency. Incomplete utilization of robots resulted from too small number of cows per milking station – 54 cows instead of the 61.5 possible with the barn design (Table 1).

The average milking frequency was 2.84 per cow per day, which is an optimum value. Individual indicators varied between 1.6 and 4.4 times per day. This is a sign of proper control of milking frequency depending on cow biological parameters, i.e. daily yield and lactation stage. The number of milkings per day varied between primiparous and multiparous cows. More primiparous cows gave milk up to and including 2 times per day (25%) and from 2.1 to 3 times per day (55%) than multiparous cows did, for which these percentages were 14.4% and 40.6%, respectively (Table 5). On the other hand, more multiparous cows were milked 3.1 to 4 or more times per day than primiparous cows did (Table 5).

The variation between primiparous and multiparous was due to different milk yields. In both cow groups, daily milk yield was increasing with increased milking frequency. This is a sign of proper setting of milking frequency by the personnel. Good robot performance was achieved due to high average milk yield per cow (Table 4). There is a significant reserve of housing in sectors for lactating cows from the current 216 (Table 5) to 246 stalls possible (Table 1).

Table 4. Changes in size of cow groups depending on their physiological status and daily milk production on the farm
Tab. 4. Zmiany proporcji krów w zależności od ich stanu fizjologicznego oraz dobowej produkcji mleka fermy

Year, month	Number of cows				Percentage	Daily milk production:	
	in lactation	Dry	Sick	Total	of dry cows	Average per cow, kg	From farm - thousand kg
2014							
1	213	13	4	230	5.7	32.4	7.4
2	234	12	3	249	4.8	31.7	7.4
5	235	10	2	247	4.0	31.5	7.4
7	238	12	4	254	3.9	31.7	7.6
9	229	42	1	272	15.4	30.6	7.0
11	209	54	3	266	20.3	34.4	7.1
2015							
1	194	57	8	259	23.0	35.7	6.9
3	215	39	11	265	14.7	36.6	7.9
5	225	28	10	263	10.6	36.6	8.2
7	228	23	0	251	9.2	34.2	7.8
9	209	39	8	256	15.2	34.1	7.1
11	229	29	14	272	10.7	34.5	7.9

Source: own work / Źródło: opracowanie własne

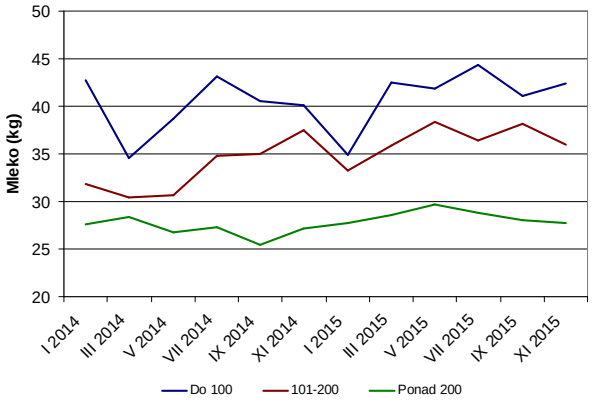
Table 5. Distribution of cow herd by milking frequency
Tab. 5. Rozkład stada krów pod względem częstotliwości doju

Milking frequency per day	Number of cows			Percentage of cows			Average daily milk production, kg	
	primiparous	multiparous	total	primiparous	multiparous	total	primiparous	multiparous
≤ 2	14	23	37	25.0	14.4	17.1	24.7	25.6
2.1 - 3	31	65	96	55.3	40.6	44.4	31.0	39.5
3.1 - 4	10	61	71	17.9	38.1	32.9	36.4	45.0
≤ 4.1	1	11	12	1.8	6.9	5.6	46.8	49.6
Total	56	160	216	100	100	100	30.7	40.3

Source: own work / Źródło: opracowanie własne

Stable distribution of production throughout the year and throughout lactation are favourable production features. Daily milk production at the farm was relatively evenly distributed during the two years of monitoring (Table 4). The lowest production was in January 2014 and 2015 – slightly more than 7,000 kg per day and the highest production was in May 2015 – 8,200 kg.

Cows in lactation are allocated to two production groups (Table 1), and the animals in each of these groups are at different lactation stages. Daily production of milk depends to a large extent on the lactation stage (Figure 9).



Source: own work / Źródło: opracowanie własne

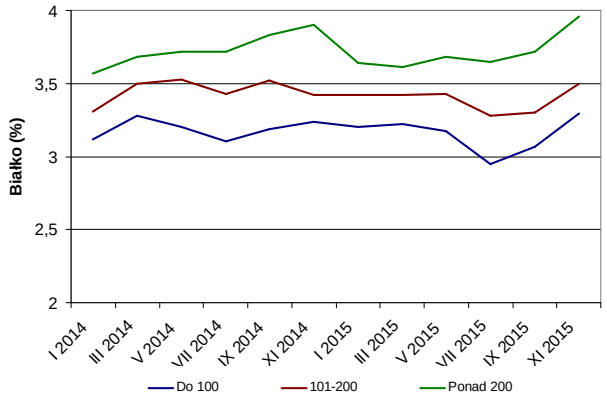
Fig. 9. Daily milk production in particular lactation stages in 2014-2015
Rys. 9. Dobowa wydajność mleka w fazach laktacji w latach 2014-2015

The whole herd receives the same basic ration fed as PMR. At the farm, this ration is calculated for the production of 26-27 kg of milk per day. This corresponds to the average yield 200 days in lactation (Figure 9), which remained relatively stable throughout the whole two-year period of study. To encourage milking, all cows are offered tasty mix of concentrated feed at the milking robot. The quantity of feed depends on current milk yield. Highest-yielding cows receive an additional ration of concentrated feed at the feeding station. The quantity of additional feed depends on current milk yield. Milk protein content indicates the level at which balance is achieved between energy intake and milk yield. For Holstein Friesians, the state of balance is achieved when milk protein is from 3.2 to 3.6%, underfeeding is when protein is below 3.2% and overfeeding – more than 3.6% [23].

In the studied herd, energy balance was found to occur in cows on the middle stage of lactation from day 100 to day 200 (Figure 10).

The cows at the beginning of lactation were on the border value or with a small deficiency. On the final stage, they were slightly or even significantly overfed. The basic ration designed for 26-27 kg of milk plus the in-milking feed can be therefore considered to be not completely effective in preventing slight overfeeding at the end of lactation. On the other hand, feeding with concentrated feed during milking and at the feeder not always prevented energy deficiency in cows at their peak of lactation. However, the scale of under- and overfeeding was small.

Milk at the processing plant has to meet certain hygienic requirements. Somatic cell count (SCC) is the primary criterion for hygienic quality.



Source: own work / Źródło: opracowanie własne

Fig. 10. Milk protein content in lactation phases over 2014-2015
Rys. 10. Zawartość białka mleku fazach laktacji w latach 2014-2015

SCC is a good indicator of udder health [7, 9]. In Poland, like in many countries, cell count of 400,000 dcm^{-3} is set as the regulatory upper limit for milk suitable for consumption. Table 6 presents the quality of milk measured by somatic cell count for individual samples in 2014 and 2015.

Table 6. Cell count quality of milk from cows from the herd in 2014-2015
Tab. 6. Jakość cytologiczna mleka krów w stadzie w latach 2014-2015

SCC thousand dm^{-3}	Number of samples per year		Percentage of samples per year	
	2014	2015	2014	2015
≤ 400	1213	1156	92.6	93.7
401-1000	69	59	5.3	4.8
≥1000	28	18	2.1	1.5
Total	1310	1233	100	100

Source: own work / Źródło: opracowanie własne

In 2014, SCC was less than 400,000 dcm^{-3} in 92.6% of individual milk samples. The percentage of samples indicating subclinical infection (SCC between 400,000 and 1,000,000 dcm^{-3}) was 5.3%. The percentage of cows with clinical signs of infection (SCC more than 1,000,000 dcm^{-3}) was 2.1%. In 2015, the quality of milk measured by somatic cell count improved.

The percentage of milk from healthy udders rose to 93.7%, accompanied by the percentage with subclinical and clinical signs falling to 4.8% and 1.5%, respectively. The results indicate very good quality of milk expressed as somatic cell count [9, 12, 16]. Such high cell count quality of milk compared to traditional solutions [8] resulted from very good housing conditions (bedded lying cubicles, clean floor cleaned with a robot (Figure 4), and robotic milking. In his studies conducted at 28 barns, Veauthier [18] found that switching from a milking parlour to robotic milking brought no improvement in hygienic quality of milk. SCC remained on a stable level, and microbial count even increased.

We would like to note another aspect of determining SCC in milk. German institutions based in Theunen [4] developed the rules for objective assessment of cow comfort. The percentage of cows in lactation with SCC less than 400,000 dcm^{-3} is one of the basic indicators The results (Table 6) point out to high level of comfort provided to cows in the barn studied here.

An animal husbandry specialist and two barn workers were employed full-time and one feeding worker - part-time. The duties of workers included the robot control and stall grooming, maintenance of the feeding alley, cleaning the places inaccessible to the cleaning robot, collecting straggling cows for milking, giving water to calves, and other activities. One worker is at the farm from 5:00 am to 01:00 pm, and the other from 07:00 pm to 02:00 am. Total labour input is about 3 minutes per cow per day. It is much less than in traditional barns with full automation of all work [14]. This barn outclasses the current traditional barns in terms of labour input, but primarily by quality of operations, i.e. proper milking, regular feed pushing in the feeding alley and clean floor. All this provides high comfort to cows and good working conditions to people. What should be noted is the change of the scope of activities performed by the team, but most of all the new skills which they should possess while working in a robotic farm. In particular, they are required to operate herd management software, analyse the results obtained from the IT system.

Relief from many arduous physical activities allows the workers to focus on control and management. In particular, due to a limited direct contact with animals, e.g. at milking, personnel is required to increase the scope of animal monitoring. These are all new tasks for which additional knowledge is required.

4. Conclusions

The analysis of barn performance shows that robots for milking, feed pushing and floor cleaning increased comfort both for cows and personnel. Cow comfort and welfare were accompanied by high production indicators, namely:

- the herd reached high performance of more than 10,000 kg of milk per cow per year, with regular lactation pattern,
- chemical composition of milk, typical of PHF cows, indicated balanced feeding both in terms of energy and protein,
- quality of milk expressed as somatic cell count was very high,
- average milking frequency was approx. 3 times per day.

The indicators of high comfort for the personnel tending to the herd are the following:

- the nature of activities, mainly monitoring and tidying up,
- low labour input of less than 3 minutes per cow per day.

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