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THE EFFECTS OF MILKING AUTOMATION ON A FAMILY FARM

Summary

Analysis of consequences after changes in the system of maintenance and milking on a family farm has been carried out. In a conventional cowshed a herd of 30 cows was tethered, with littered cubicles and a pipeline milking system. In December 2014 the herd was taken to a modern, newly built shed. This shed was designed so as to use a free stall cow maintenance system and was equipped with 85 stands in cubicles with litter and cavity floor at corridors. A single-station robot, Astronaut A4, manufactured by Lely was used for milking. Daily labour inputs in a conventional shed amounted to 14.5 minutes per 1 cow, whereas in a modern shed they have decreased fivefold and amounted to 2.8 minutes per 1 cow. The working conditions of service, as well as environmental conditions of cows have also improved. After relocation of cattle to a new shed a rapid increase in the milk yield has been noted, both in the first year, as well in the following years. The year-to-year increase in productivity was over 2 thousand kg per head. Cytological quality of milk has improved and the number of cows with subclinical and clinical inflammation of the udder has decreased.
***Key words**: milking robot, free stall maintenance system, effects of automation*

EFEKTY ROBOTYZACJI DOJU W GOSPODARSTWIE RODZINNYM

Streszczenie

Przeprowadzono analizę następstw po zmianie systemu utrzymania i doju krów w gospodarstwie rodzinnym. W oborze konwencjonalnej stado 30 krów utrzymywane było na uwięzi, z legowiskami ścielonymi i dojem do rurociągu. W grudniu 2014 r. stado przeprowadzono do nowoczesnej, nowo wybudowanej obory. Obora ta zaprojektowana w celu zastosowania systemu wolnostanowiskowego utrzymania krów była wyposażona w 85 stanowisk w boksach legowiskowych ze ściółką i podłogę szczelinową na korytarzach. Do doju krów zastosowano jednostanowiskowy robot Astronaut A4 firmy Lely. Dobowe nakłady pracy w oborze konwencjonalnej wynosiły 14,5 minut na 1 krowę, a w oborze nowoczesnej zmniejszyły się pięciokrotnie i wynosiły 2,8 minuty na 1 krowę. Poprawiły się również warunki pracy obsługi oraz warunki bytowania krów. Po przejściu zwierząt do nowej obory nastąpiło skokowe zwiększenie wydajności mleka, zarówno w pierwszym roku, jak i w latach następnych. Wzrost wydajności rok do roku wyniósł ponad 2 tys. kg od sztuki. Poprawiła się jakość cytologiczna mleka oraz zmniejszyła się liczba krów z podklinicznymi i klinicznymi stanami zapalnymi wymienia.
***Słowa kluczowe**: robot udojowy, wolnostanowiskowy system utrzymania, efekty robotyzacji*

1. Introduction

Automation of works includes more and more fields of human activity, also including agricultural production. In 2017 25 years passed from activation of the world's first cow milking robot. This major breakthrough was made by workers of Lely company [11].

At present milking robots are manufactured by eight companies [12] and are sold all over the world. The greatest number of milking robots is used in the countries of Western Europe. Two examples may confirm the scale of use of milking robots. In Germany since 2012 the sales of milking robots has been greater than the sales of milking parlours [14]. Milking robots in Bavaria are used in 1700 sheds, where 20% of the total number of cows in herds counting more than 50 cows is kept [4].

In Poland first three milking robots manufactured by DeLaval commenced operation in two sheds in 2008. The first robot manufactured by Lely was mounted in a shed in 2010. A milking robot as relatively new equipment has still been continuously improved.

The aim of our own research was to analyse and evaluate the effects of use of a milking robot in a shed, on a family farm. The subject of analysis concerned the influence of use of a robot on labour inputs and organisation, as well as productivity in the cows.

2. Material and methods

While selecting a test object two criteria were applied: maintenance system and milking system before modernisation and size of herd.

A stanchion-tied system for maintenance of cows has still been dominating in Poland [1, 21], in which milking is carried out with the use of pipeline milking machine [13].

The largest group of cows under control of milk performance consists of herds from 20 to 49 cows. In 2016 there were 10,935 of such herds in sheds [15]. Such herds were maintained in specialist farms, which are characterised by a natural tendency of increasing the number of cows in a shed. Size of a herd, for which the use of a single-station milking robot is justified amounts to 55-65 cows.

A facility conforming to the above-mentioned assumptions has been found in Kujawsko-Pomorskie Voivodeship. The basic characteristics of the old and a new shed have been presented in Table 1.

Cows were kept in the old cowshed until December 20th, 2014, and they have been kept in the new shed since the middle of December 2014 until present.

Table 1. Basic characteristics of cow housing, feeding, and milking systems used in the studied barns
Tab. 1. Rozwiązania technologiczne i wyposażenie techniczne w starej i nowej oborze

Specification	Solution used in the barn	
	C – conventional	**M – modern**
Number of stands	30	85
Maintenance of cows at the stage of: – lactation – drying-out – periparturient	 – tethering with litter – tethering with litter – tethering with litter	 – in cubicles (Fig. 2) – in cubicles – pen with litter
Milking system	Pipeline milking machine	Single-station robot manufactured by Lely, Astronaut A4
Feeding	TMR fed once a day Manual gathering up	PMR fed once a day (Fig. 1) Manual gathering up
Removal of excreta	– shallow litter – bucket	– cavity floor – robot for removal of excreta in a shed with cavity floor manufactured by Lely Discovery 509 (Fig. 3) – mobile slurry mixer

Source: own work / Źródło: opracowanie własne

The scope of research included the following elements for functioning of the farm:
1) labour inputs in the old and in the new shed,
2) comfort of living conditions for cows in the new shed,
3) reaction of cows to the change of shed in a short period of time – 6 months and up to 6 months after settlement in the new shed,
4) comparison of herd performance in the last two years in the old shed and in the first two years in the new shed,
5) cytological quality of milk in the old and in the new shed,
6) operating characteristics of a milking robot.

Numerical material for calculation of basic values of descriptive statistics covered data from control of performance (Resulting reports no. 1 and 2) carried out using A4 method by PFHBiPM from years 2013-2016.

3. Results and discussion

In the middle of December a herd of 30 cows moved to live in a new shed, whereas calves and young cows remained in the old building. Table 2 presents age structure dynamics of cows in the new shed.

Table 2. Cowherd structure in January in the years 2015-2017 acc. to lactation number in sheds: C - conventional, M - modern
Tab. 2. Struktura stada krów styczniu w latach 2015-2017 wg numeru laktacji w oborach: C – stara, M – nowa

Lactation no.	No. of cows in a shed				Percentage of cows in a shed			
	C	M			C	M		
	2014	2015	2016	2017	2014	2015	2016	2017
1.	18	16	25	27	58,1	53,4	56,8	46,6
2.	7	7	9	15	29,6	23,3	20,5	25,9
3.	6	6	4	9	19,3	20,0	9,1	15,5
4.	-	1	6	2	-	3,3	13,6	3,4
5.	-	-	-	5	-	-	-	8,6
Total	31	30	44	58	100	100	100	100

Source: own work / Źródło: opracowanie własne

In 2015 the number of cows was increased by 14 pieces, and in 2016 by further 14 pieces. The herd was complemented with own pieces and partly by purchased animals. Due to extended reproduction in a shed, pieces constituting approx. 50% of the herd were dominant in the analysed period, namely substantially more than in domestic stock population – 23.5% [15]. After two years of exploitation of the new shed areas in cubicles were settled by cows only in 68 per cent. Free spaces were used by in-calf heifers.

In accordance with the assumptions of the owner of the farm the original purpose of robotisation of milking process envisaged improvement of conditions and reduction of labour inputs. Table 3 presents size and structure of labour inputs in the old and in the new shed. Due to the fact that farmers handle the cattle it is difficult to separate labour inputs for cows themselves, therefore the specific values are given for the entire herd including cows and youth. Despite double increase in the number of animals in a herd, total labour inputs of humans in the new shed have decreased 2.5 times, and 5 times when calculating per head.

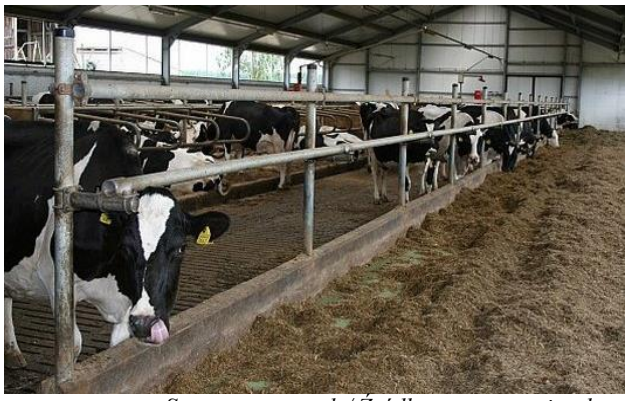
The character of work related to milking has also changed. At present it is mainly a control function. At the same time change in the system of removal of excreta and transition to a slurry system resulted in drastic reduction in labour inputs. Simplified feeding in the new shed – a drive-through feed table also caused decrease in the labour inputs for handling of animals. Simultaneously, the labour input structure has changed to specific activities. Hence it may be stated that robotisation of milking and change in the maintenance system have drastically reduced labour inputs and have changed its structure for the better.

Table 3. Size and structure of labour inputs in the old C (conventional) and new M (modern) shed (for herd of cows - without calves)
Tab. 3. Wielkość i struktura nakładów pracy w starej (C) i nowej(M) oborze (dla stada bydła – bez cieląt)

Activity	Total working hours in a shed minutes		Structure of working time in a shed, %	
	C	M	C	M
1. Milking of cows	180	30	41.4	18.2
2. Feeding: – basic ration – nutritive	 90 45	 120 -	 31.0	 72.7 -
3. Handling of natural fertilisers	120	15	27.6	9.1
Total	435	165	100	100
Per head with offspring	14.5	2.8	-	-

Source: own work / Źródło: opracowanie własne

Comfort of living conditions for cows has improved significantly in the new shed in comparison to the old one. A change in the maintenance system resulted in the fact that animals are free to move along the corridors and to eat for the entire day and night (Fig. 1), and are provided with comfortable, littered cubicles (Fig. 2).



Source: own work / Źródło: opracowanie własne

Fig. 1. Feed table with one-side access
Rys. 1. Stół paszowy z jednostronnym dostępem

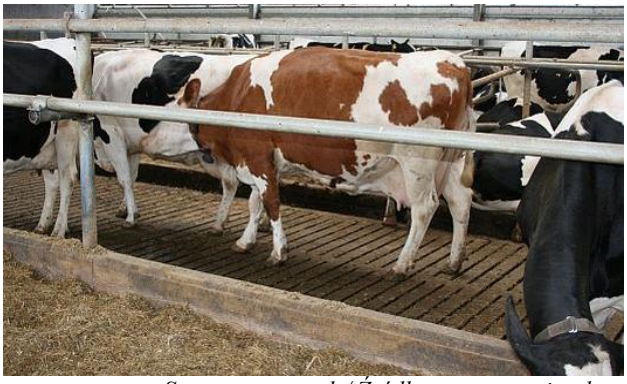
Source: own work / Źródło: opracowanie własne

Fig. 2. Three-row layout of littered cubicles with cavity floor at the corridor
Rys. 2. Trzyrzędowy układ boksów legowiskowych ścielonych z podłogą szczelinową na korytarzu

In a periparturient period cows live in a group pen with littered full. Use of robots cleaning corridors (Fig. 3) has a positive impact on cleanliness of hooves and legs and improves tidiness in cubicles, and at the same time cleanliness of body shells of cows (Fig. 4).

Source: own work / Źródło: opracowanie własne

Fig. 3. A robot manufactured by Lely cleaning cavity floor
Rys. 3. Robot firmy Lely czyszczący podłogę szczelinową



Source: own work / Źródło: opracowanie własne

Fig. 4. Clean cows in the new shed
Rys. 4. Czyste krowy w nowej oborze

Operation of a milking robot is characterised by a series of indicators. The number of performed milking cycles and amount of fresh milk in a specific period are specified most often. The values of both these indicators are variable in time, which may be stated when comparing them for different herds, as well as within the herd. The both depend on a human, as well as on animals.

The basic performance indicators of operation of a milking robot in the tested shed are presented in Table 4. It contains data summarised in monthly intervals for 1 day in the middle of each month, for the subsequent 10 months. The original factors influencing the work efficiency of a robot include: number of milked cows and their productivity. The level of cow productivity changes in the course of lactation, thus Table 4 presents an average lactation day of a herd in a relevant month. The number of milked cows amounted from 46 to 54 pieces. The maximum use of a robot takes place with a fixed number of milked cows, which occurs in a situation of even distribution of calving within a year. In the tested farm extended reproduction took place, and the distribution of calving was in the course of adapting to robot milking.

A milking robot is expensive equipment and therefore when planning its purchase certain factors should be taken into account, which influence profitability of its use in a specific shed. Commonly adopted measure of effectiveness of robot operation refers to the amount of fresh milk in a specific time. It usually refers to day and year. Many authors from Western European countries provide the value of 500 thousand kg of fresh milk as a lower limit of profitability within a year, namely approx. 1400 kg per day and per one robot station [5, 7, 8]. Whereas Bonsels and Schmitz [2] provide 600 thousand kg per year as minimum (ca. 1650 kg per day).

In order to use genetic production capabilities of cows, the average amount of herd milking should amount to more than 3 times per day. In the tested shed cows were milked on the average 3.1 times per day, and the amount of milk obtained in the course of one milking cycle was optimum. These two factors decided on the amount of milk obtained during a day and within a year and on positive assessment of operation of a milking robot.

The shed after two years of use was settled in 70%. The so-called "free time" gives an indication of the existing reserve, namely the time when the robot was not used by cows. It amounted to ca. 7.7 hours (32%) in a twenty-four hour period. The manufacturer of the robot – Lely company informs that for optimum use of a robot the sufficient time reserve amounts to 10-15%. The existing reserve points out the purpose of increasing number of cows at the stage of lactation by 6-7 pieces.

Table 4. Basic values of indicators of operation of a milking robot and cow productivity
Tab. 4. Podstawowe wartości wskaźników pracy robota udojowego oraz produkcyjności krów

Year 2017 month	Number of		Amount of fresh milk		Average cow lactation day	Average number of milking cycles for 1 cow	Average daily from cow		
	milked cows	milking cycles performed	from cow per 1 milking	from herd per day			milk production	content of %	
								fat	protein
03	53	175	11.2	1968	138	3.3	37.1	3.87	3.37
04	49	162	11.2	1818	160	3.3	37.1	3.75	3.30
05	51	179	11.6	2079	172	3.5	40.8	3.70	3.27
06	54	167	11.8	1972	192	3.1	36.5	3.76	3.18
07	54	162	11.2	1809	217	3.0	33.5	3.55	3.15
08	54	162	10.7	1728	236	3.0	32.0	3.51	3.11
09	50	145	10.3	1497	240	2.9	29.9	3.70	3.18
10	46	147	10.0	1476	256	3.2	32.1	3.80	3.37
11	50	150	10.8	1627	240	3.0	32.5	3.89	3.42
12	52	161	11.2	1804	218	3.1	34.7	3.99	3.35

Source: own work / Źródło: opracowanie własne

The least amount of milk – 1476 kg per day was milked in October 2017. Then the herd was composed of only 46 cows, on the average on 256th day of lactation (9th month), with average daily milk production in the amount of 32.1 kg. Whereas the highest daily production – 2079 kg was obtained in May 2017 - from 51 cows on 172nd day of lactation (6th month) – on the average 40.8 kg of milk daily. The daily yield of milk from a cow was quite close related to the day of lactation, which is a physiological pattern. The content of fat and protein in milk used to change. It was associated with individual properties of cows and stage of lactation. Whereas use of a milking robot has no impact on the content of fat and protein in milk.

The average number of milking cycles performed by a robot in a twenty-four hour period changed from 145 to 179. It depended on the number of cows and amounts of milking cycles. Amounts of milking cycles are established by a human depending on daily yield of cow's milk. Lely Company recommends such frequency, so as to obtain from 8 to 12 kg of milk per milking. In the analysed shed this value changed from 10 to 11.8 kg (Table 4). It demonstrates correct adjustment of time intervals between the next milking cycles.

Cows were milked for the entire twenty-four hour period. The number of milking cycles performed amounted from 2 to 9 times per hour, however without any clear pattern. The timetable of the number of milking cycles in a 6-hour day ranges are presented in Table 5, based on the example of three days selected at random.

The differences regarding the number of milking cycles between times of day were insignificant, which demonstrates that cows accept milking during the entire day.

Table 5. Timetable of milking cycles in six-hour day ranges
Tab. 5. Rozkład dojów w sześciogodzinnych przedziałach doby

Time of day	Amount of observations in a day			Percent of observations in a day		
	1	2	3	1	2	3
0-6	31	31	32	23	22	23
6-12	38	42	37	28	32	26
12-18	32	33	35	24	23	25
18-24	34	33	36	25	23	26
Total	135	139	140	100	100	100

Source: own work / Źródło: opracowanie własne

The advantage for cows of milking using a robot consists in the capability of adjusting individual and variable numbers of milking cycles. As has already been pointed put, daily milk yield is a guide in determining the number of milking cycles. The example presented in Table 6 illustrates how this principle is put into practice.

Table 6. Herd distribution in terms of amount of milk obtained per one milking cycle
Tab. 6. Rozkład stada pod względem ilości mleka uzyskanego na jeden dój

Amount of milk per 1 milking cycle	Total of cows	
	Number	%
Up to 8	4	8.2
8.1-10	9	18.4
10.1-12	25	51.0
12.1-14	8	16.3
≥14.1	3	6.1
Total	49	100

Source: own work / Źródło: opracowanie własne

Below 8 kg of milk within one milking cycle was obtained from 4 cows. Due to the facts that these cows waited for drying off, such amount demonstrates correct designation of the number of milking cycles. The highest number of cows – 51% of the herd provided 10.1 up to 12 kg of milk. A similar number of cows provided from 8.1 to 10 kg and from 12.1 to 14 kg. Only three cows gave more than 14 kg per milking cycle. In two cases these were the cows at the end of lactation period, prepared for drying process.

Enhanced frequency of milking, above standard frequency – twice per day results in the increase in daily milk yield. Nevertheless the size of increase depends on the output level of yield.

The frequency distribution is presented in Table 7.

Seven cows were milked twice per day. These cows were at the final stage of lactation. Over half of the herd – 57% of cows, was milked more than three times. Two cows out of seven were milked over 5 times per day. These cows were at the second lactation with milk yield of 56.9 and 59.2.

The presented data point out that a milking robot may be included in the equipment from the group of the so-called precision farming. It offers an opportunity to adjust the number of milking cycles, which stimulates milk pro-

duction to the level of conditioning animals with genetic assumptions and environmental conditions created by man. At the same time animals have great comfort.

Table 7. Frequency distribution of milking of cows in a herd
Tab. 7. Rozkład częstotliwości doju krów w stadzie

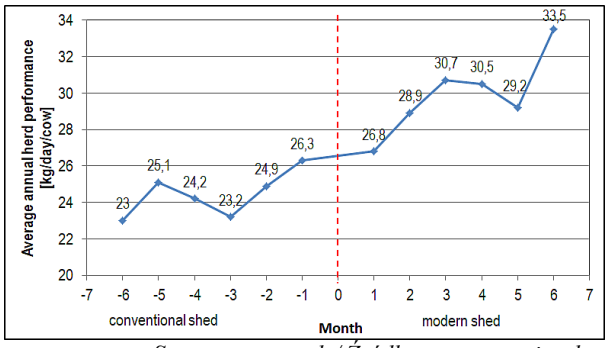
Number of milking cycles per day	Total of cows	
	number	%
Up to 2	7	14.3
2.1-3	14	28.6
3.1-4	18	36.7
4.1-5	8	16.3
≥5	2	4.1
Total	49	100

Source: own work / Źródło: opracowanie własne

In the conditions of conventional sheds with milking in a parlour, fourfold milking leads to fatigue of animals as a result of reducing the time of lying and taking food [6]. Leopold [10] cites American data on fourfold milking, pointing out the increase in milk yield and at the same time on the risks for animal welfare and difficulties with organisation of work in a shed. Milking using a robot has no such disadvantages, cows do not have to wait with a group in a waiting room and there is no deterioration of comfort for animals. It is also not necessary to milk all the cows in a herd four times. In the analysed shed such a situation regarded only approx. 20% of the herd.

Change in the maintenance system and milking process also had a positive impact on the milk yield, both in the short and long term (Fig. 5).

Within the last six months in the old shed (from June until November 2014) average daily yield within a month amounted to from 23 to 26.3 kg per head (Fig. 5). Whereas in the new shed in the first month (January 2015) amounted to 26.8 kg and increased in increments to 33.5 kg in June 2015.

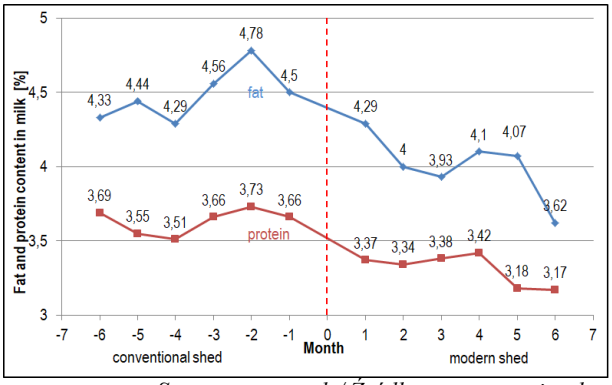


Source: own work / Źródło: opracowanie własne

Fig. 5. Average daily milk yield in a herd
Rys. 5. Średnia dobowa wydajność mleka w stadzie

Due to the fact that cows were fed using the same feed, both in the old, as well as in the new shed, increase in the milk yield may be attributed to the change in the maintenance and milking system. In particular an incentive to eat feed was multiple gathering up of feed on a feed table, individual dosing of nutritive feed and increase in the number of milking cycles.

Reaction of cows to change in the milking system from a conventional one to automatic is diversified very individually [20]. According to our own research, after a month from the change of shed insignificant growth in the milk yield took place (Fig. 5). After moving to a new shed a decrease in the content of fat and protein in milk occurred (Fig. 6). Protein content in the milk from animals kept in the old shed amounted from 3.51 to 3.73%, whereas in the new shed from 3.17 to 3.42%.



Source: own work / Źródło: opracowanie własne

Fig. 6. Fat and protein content in milk in the transitional period
Rys. 6. Zawartość tłuszczu i białka w mleku w okresie przejściowym

Fat content in milk, in the corresponding periods, amounted from 4.29 to 4.78% for the old and from 3.62 to 4.29% for the new shed. A drop in the content of fat and protein in milk was a natural physiological reaction to the increase in the mild yield.

Average annual yields of the herd are presented in Table 8. In the staring year 2005 the herd performance amounted to 5639 kg and was one thousand kilograms lower than the national average. It increased in the following years, so that in 2015 and 2016 it was higher by 2-2.5 thousand kg than the national average. The content of fat and protein in milk decreased, which, as had been pointed out earlier, is a normal physiological reaction. Whereas the amount of kg of fat and protein from milk obtained in the new shed has grown substantially in comparison to the old facility.

Table 8. Average annual herd performance
Tab. 8. Przeciętne roczne wydajności stada

Year	Number of cows	Average annual herd performance					National average of milk kg
		kg			%		
		milk	fat	protein	fat	protein	
2005	26.8	5639	237	182	4.2	3.23	6664
2013	26.4	8314	353	293	4.25	3.52	8293
2014	29.8	8388	366	301	4.36	3.59	8458
2015	38.4	10428	405	339	3.88	3.25	8643
2016	53.1	11362	427	373	3.76	3.28	8647

Source: own work / Źródło: opracowanie własne

One of the basic hygiene quality indicators of milk is the somatic cell count (SCC). The SCC value gives an indication of the health status of the udder. Inflammation of the udder (mastitis) is a polietiologic disease, and a factor present at a minimum level decides about its occurrence. The SCC value is specified as cytological quality of milk.

In the course of milking using a robot certain favourable circumstances occur that prevent inflammation of the udder, and in particular "over-milking" is eliminated and milling hygiene regime is strictly followed. However in practice, the advantages of milking using a robot are not always confirmed [5, 16, 17, 19].

In the tested shed SCC was analysed over the last two years in the old shed (2013 and 2014) and over the two first years in the new shed (2015 and 2016), in terms of:

– average SCC value for a herd on herd performance days (Table 9),
– distribution of individual SCC values in grades (Fig. 7).

Table 9. Content of SCC in bulk tank milk in the period until and after introduction of a milking robot

Tab. 9. Zawartość LKS w mleku zbiorczym w okresie do i po wprowadzeniu robota udojowego

SCC assessment (thousand ml)	No. of area	
	until	after
<150 very good	0	2
151-250 good	3	8
251-399 satisfactory	10	10
400-500 poor	2	2
>501 very poor	7	0
Total	22	22

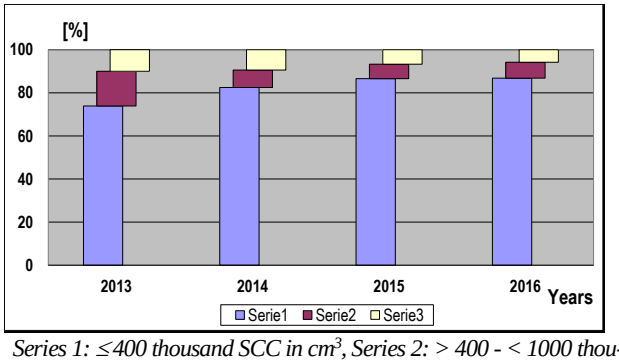
Source: own work / Źródło: opracowanie własne

In both analyses limit values used in the works of PFHBiPM were applied for division to quality grades [3].

Milk in the grade specified as "very good" has never been obtained in the old shed. Whereas obtaining milk in the grade "poor" (2 cases) and "very poor" (7 cases) has been noted.

Milk obtained using a milking robot is milk with significantly higher hygiene quality. Milk graded as "Very good" was obtained in two cases and graded as "good" in eight cases. Whereas there was no "very poor" milk, and "poor" one occurred only twice. Thus it may be stated that a change of milking method to a milking robot and free stall maintenance system had a very good impact on cytological quality of milk.

Distribution of individual SCC values is presented in Fig. 7.



Series 1: ≤400 thousand SCC in cm^3, Series 2: > 400 - < 1000 thousand SCC in cm^3, Series 3: ≥1000 thousand SCC in cm^3

Source: own work / Źródło: opracowanie własne

Fig. 7. SCC distribution in years until (2013-2014) and after introduction of a milking robot (2015-2016)

Rys. 7. Rozkład LKS w latach 2013-2014 i po wprowadzeniu robota udojowego (2015-2016)

In 2013 in the course of milk tests in the old shed it was stated that only 73.9% of samples conformed to the requirements for milk in a collection point, and 10% of samples indicated a clinical form of inflammation of the udder. In 2014 all quality grades improved. After transition of cows to the new shed further improvement of cytological quality of milk took place, and in particular percentage decline in samples from cows with clinical form of mastitis. When comparing the obtained results for the new shed with literature data [9, 18] it may be stated that cows in the new shed demonstrate a good level of healthiness of the udder.

4. Conclusion

Transition of cows from the shed with a stanchion-tied maintenance system and a pipeline milking system to the new building with cubicle maintenance system and milking using a milking robot resulted in:

– major improvement of working conditions and security,
– dramatic increase in work productivity,
– clear improvement of comfort of living for cows,
– immediate clear increase in the milk yield,
– improvement of cytological quality of milk.

Milking using a milking robot conforms to the requirements of the physiology of milk extraction and hygiene for obtaining milk, thus it may be included in the equipment conforming to the requirements of precision farming.

5. References

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