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EFFECT OF CHANGING THE COW MILKING SYSTEM ON DAILY YIELD AND CYTOLOGICAL QUALITY OF MILK

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Abstract. The aim of the study was to analyse the effect of changing the milking system (from a milking parlour to automatic milking) on daily yield of cows and cytological quality of their milk. GLM and FREQ procedures of the SAS package were used in the statistical calculations. The change in the milking system caused a short-term decrease in daily yield and an increase in milk somatic cell count (SCC). In the long term (12 months), daily yield increased ($P \leq 0.01$) from 27.7 kg milk for cows milked in the milking parlour to 31.1 kg milk for cows milked automatically. The change in the milking system from the milking parlour to automatic milking had a positive effect on milk somatic cell count as the natural logarithm of SCC decreased from 12.44 to 11.97. The proportion of milk samples with low SCC (<100,000 cells/ml and from 101,000 to 200,000 cells $\cdot$ ml^{-1}) increased by 2.84 and 7.52%, respectively, whereas the proportion of milk samples with high SCC (>400,000 cells $\cdot$ ml^{-1}) decreased by 5.68%.

Key words: cows, milk, milking system, somatic cells

INTRODUCTION

Cow houses are now being upgraded to improve living conditions and milk collection technique, which plays a primary role in its hygienic quality [Skrzypek 2002, Sawa 2004]. For over 20 years in the world and for over 6 years in Poland, owners of dairy farms have been offered milking machines with full automation of the milking process [Czarnociński and Lipiński 2005, Głowicka-Wołoszyn et al.

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2010, Winnicki et al. 2010]. Robotic milkers perform all the milking operations instead of humans. They are constantly improved and enriched with new functions. The use of a milking robot with computer-based herd management will save two-thirds of the time during the year compared to conventional machine milking. The benefit of using milking robots is that they increase the frequency of milk letdown (2.5–3 milkings per day) and shorten the interval between milkings, which increases the cows' milk yield [Głowicka-Wołoszyn et al. 2010]. Automatic milking systems (AMS) enable the cytological quality of milk and thus the udder health of the cows to be accurately and continuously monitored [Gaworski and Kupczyk 1996, Romaniuk 1996, Llach et al. 2004, Głowicka-Wołoszyn et al. 2010].

Robotic milking systems meet most of the natural needs of the cows because they are free to choose their milking times and the waiting time before milking is reduced [Głowicka-Wołoszyn et al. 2010]. However, any change, including that improving milking conditions, can be a stress factor to the cows, as confirmed by Siegford and Jacobs [2010], who also reported that cows quickly adjust to the AMS. Over 80% of the herd was milking voluntarily within a week of introducing the cows to the robotic milkers, over 90% after 2 weeks, and over 97% after 2 months (with cows milked 2.5 times per day on average). Even Black-and-White stress may lead to a noticeable decline in daily milk production during the first weeks (months) and a deterioration in hygienic parameters of the milk.

Because many cow houses make a switch to automatic milking, attention should be given to the transition period by monitoring the quantity and quality of milk collected during the period preceding the switch and that which immediately follows.

The aim of the study was to analyse the effect of changing the milking system from a milking parlour to automatic milking on daily yield of cows and cytological quality of their milk, taking into account the age of cows and the stage of lactation.

MATERIAL AND METHODS

Analyses were performed based on milk recording results (A4 method) of a high-yielding (average of 8500 kg milk per lactation) herd of Polish Holstein-Friesian cattle of Black-and-White variety (50 cows on average), which was kept in a loose-housing system in an individual farm. The cows were initially milked in a herringbone milking parlour and later using a milking robot. The adjustment period, during which cows were adapted to enter the robot was two weeks long. The analyses disregarded 4 cows that failed to adapt to the robotic milking system during that period.

The cows' response to the change in the milking system was evaluated by analysing daily milk yield and somatic cell count (SCC) in the first, second and

third test-day records before and after the change in the milking system. Analysis was also made of the effect of changing the milking system on daily yield and cytological quality of milk in the long term (12 months preceding and following the change), taking into account factors such as age of cows (first, second, third and higher lactations) and stage of lactation ($\leq$100, 101–200, 201–300, >300 days). Analysis of variance was used in the statistical calculations and significant differences between the means were analysed with the Scheffe test [SAS 2013].

The χ^2 test of independence [SAS 2013] was used to analyse the proportion of milk samples with different SCC levels (<100,000 cells $\cdot$ ml^{-1}, 101,000–200,000 cells $\cdot$ ml^{-1}, 201,000–400,000 cells $\cdot$ ml^{-1}, >400,000 cells $\cdot$ ml^{-1}) depending on the milking system.

For SCC, data were log transformed to the natural logarithm of milk somatic cell count (LnSCC).

RESULTS AND DISCUSSION

The cows responded to the change in the milking system by reducing their milk yield, as evidenced by the first test-day records before and after the change – the difference ($P \leq 0.01$) between these milkings was 2 kg (Table 1). In the second and third test-day records after the transition, milk yield increased to exceed the level from before the change. A similar response was observed by Reinemann et al. [2001], who showed that during the first week of automatic milking cows produced 5 kg less milk per day compared to those milked in a milking parlour. These differences did not occur in the weeks that followed. According to some authors, daily milk production of robotically milked cows was in between the yield of cows milked twice and three times [Kruip et al. 2002].

The presence of stress associated with a change in the milking system was confirmed by Wenzel et al. [2003], who reported more frequent step behaviour, a significant increase in heart rate between 1 and 5 minutes of milking, and considerably higher cortisol levels of cows milked in the automatic milking system, compared to cows milked in the milking parlour.

A study performed to evaluate the differences in behavioural and physiological stress response of cows milked by AMS and those milked in a milking parlour showed that the automatically milked cows had slightly lower maximum plasma concentrations of adrenalin and noradrenalin during milking. No such differences were observed for the concentration of oxytocin, although higher oxytocin concentrations persisted longer in the blood of cows milked automatically. Based on these findings and the small differences between them, it can be stated that as far as the welfare of the cows during milking is concerned, automatic milking and parlour milking are equally acceptable [Hopster et al. 2002].

Table 1. Daily yield and cytological quality of milk before and after the change in the milking system

Tabela 1. Dobowa wydajność i jakość cytologiczna mleka przed i po zmianie sposobu doju krów

Milking system System doju		N	Daily yield, kg Wydajność dobowa, kg		LnSCC LNLKS	
			LSM	SE	LSM	SE
Milking parlour Hala udojowa	third milking before the change III dój przed zmianą	44	27.4	12.4	12.33	1.23
	second milking before the change II dój przed zmianą	45	28.5	11.9	12.39	1.25
	first milking before the change I dój przed zmianą	46	27.8^{A}	12.1	12.09^{a}	1.19
Milking robot Robot	first milking after the change I dój po zmianie	45	25.8^{A}	13.5	12.32^{a}	1.18
	second milking after the change II dój po zmianie	46	27.9	12.5	12.27	1.20
	third milking after the change III dój po zmianie	45	28.8	12.7	12.05	1.21

^{A} – Means within columns followed by the same letters differ significantly at $P \leq 0.01$.
^{a} – Means within columns followed by the same letters differ significantly at $P \leq 0.05$.
^{A} – Średnie w kolumnach oznaczone tymi samymi literami różnią się istotnie przy $P \leq 0{,}01$.
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As regards somatic cell count, it increased in milk from the first test-day yield after the automation of milking. LnSCC increased from 12.09 (last test-day yield in the milking parlour) to 12.32 (first test-day yield in the AMS) (Table 1). Over the next two test-day yields, a positive tendency for lower milk SCC was noted.

Kruip et al. [2002] found milk SCC to increase significantly after the introduction of automatic milking. This number increased particularly during the first three months of milking (from 246,000 to 302,000 cells $\cdot$ ml^{-1} of milk on average). Also other authors [Rasmussen et al. 2001 a, Rasmussen et al. 2001 b] reported milk SCC to increase after the switch to the milking robot, attributing this to the higher degree of milk bacterial contamination compared to milk from the parlour.

The data in Table 2 show that the change in the milking system had a favourable effect on daily yield and cytological quality of milk obtained within 12 months of introducing the milking robot, compared to the mean value of these traits during 12 months preceding the change. Daily yield was found to increase ($P \leq 0.01$) from 27.7 kg milk for cows milked in the milking parlour to 31.1 kg milk for cows milked automatically. This probably resulted from increased milking frequency. Many authors [Głowicka-Wołoszyn et al. 2010, Kozłowska et al. 2013] showed milking frequency to increase to 2.5–3 times per day when milking robots were used. High-tech milking systems have an effect on milk secretion and

letdown. Hogeveen and Ouweltjes [2003] reported that the average milking interval was 9.2 hours (2.6 milkings per day) and had an effect on milk flow rate (milk letdown and ejection) and production level. Results of a study on the efficiency of milk production and health status of cows depending on milking frequency indicate that the switch from twice daily to thrice daily milking may increase lactational milk yield from 5% to 25% while significantly improving the cows' udder health [Kuczaj 2010].

Table 2. Daily yield and cytological quality of milk during 12 months preceding and following the change in the milking system

Tabela 2. Wydajność dobowa i jakość cytologiczna mleka w okresie 12 miesięcy poprzedzających zmianę i w ciągu 12 miesięcy po zmianie systemu doju

Milking system System doju	N	Daily yield, kg Wydajność dobowa, kg		LnSCC LNLKS	
		LSM	SE	LSM	SE
Milking parlour total Hala udojowa ogółem	523	27.7[A]	12.3	12.44[A]	1.22
Milking robot total Robot ogółem	511	31.1[A]	12.8	11.97[A]	1.34

[A] – Means within columns followed by the same letters differ significantly at $P \leq 0.01$.
[A] – Średnie w kolumnach oznaczone tymi samymi literami różnią się istotnie przy $P \leq 0{,}01$.

Transitioning the cows from milking parlour to robotic milking also had a positive long-term effect on milk somatic cell count, an important determinant of udder health. Natural log somatic cell count decreased from 12.44 (average for 12 months of parlour milking) to 11.97 (average for 12 months of automatic milking) (Table 2). It is difficult to determine the effect of robotic milking on udder health because more frequent milking offers less time for invading bacteria to multiply in the udder whereas short milking intervals are insufficient for the teat tissue to recover after milking [Rasmussen et al. 2001 a].

Regardless of the cows' age (lactation number) and stage of lactation, the milk yield of robotically milked cows was superior ($P \leq 0.01$) to that of the parlour milked cows (Table 3 and 4). The highest increase in daily milk yield (by 4.4 kg) was characteristic of third and higher lactation cows, i.e. when their milk production level reached a peak. It was concluded from the study that primiparous and multiparous cows respond to increased milking frequency with different milk yields; better results were generally obtained by primiparous cows, although some authors reported the superiority of multiparous cows [Kuczaj 2010].

In terms of the stage of lactation, the milk yield of robotically milk cows increased by 6.9% to 13.9% compared to parlour milked cows (Table 4). The highest increase (13.9%) was noted in late lactation cows. This is probably the result of the higher milk yield, which persisted until the end of lactation and was asso-

Table 3. Effect of changing the milking system on daily yield and quality of milk with regard to lactation number

Tabela 3. Wpływ zmiany systemu doju na wydajność dobową i jakość mleka z uwzględnieniem kolejnych laktacji

Milking system System doju	Lactation number Numer laktacji	N	Daily yield, kg Wydajność dobowa, kg		LnSCC LNLKS	
			LSM	SE	LSM	SE
Milking parlour Hala udojowa	1	175	25.9^{A}	7.7	12.35^{A}	1.08
	2	185	28.4^{B}	8.9	12.34^{B}	1.11
	≥ 3	163	25.5^{C}	9.1	12.98^{C}	1.13
Milking robot Robot	1	221	28.8^{A}	8.9	11.72^{A}	1.08
	2	164	31.7^{B}	7.9	11.89^{B}	1.08
	≥ 3	126	29.9^{C}	9.3	12.12^{C}	1.10

$^{A, B, C}$ – Means within columns followed by the same letters differ significantly at $P \leq 0.01$.
$^{A, B, C}$ – Średnie w kolumnach oznaczone tymi samymi literami różnią się istotnie przy $P \leq 0{,}01$.

Table 4. Effect of changing the milking system on daily yield and quality of milk with regard to stage of lactation

Tabela 4. Wpływ zmiany systemu doju na wydajność dobową i jakość mleka z uwzględnieniem okresu laktacji

Milking system System doju	Lactation period (days) Okres laktacji (dni)	N	Daily yield, kg Wydajność dobowa, kg		LnSCC LNLKS	
			LSM	SE	LSM	SE
Milking parlour Hala udojowa	≤ 100	140	33.2^{A}	8.8	12.18^{A}	1.44
	101–200	145	31.1^{B}	7.7	12.55^{B}	1.45
	201–300	121	24.1^{C}	7.9	12.65^{C}	1.41
	> 300	117	17.2^{D}	7.7	13.33^{D}	1.22
Milking robot Robot	≤ 100	127	35.5^{A}	9.0	11.65^{A}	1.23
	101–200	116	34.4^{B}	8.1	11.89^{B}	1.34
	201–300	145	26.1^{C}	6.8	12.11^{C}	1.33
	> 300	123	19.6^{D}	6.8	12.68^{D}	1.23

$^{A, B, C...}$ – Means within columns followed by the same letters differ significantly at $P \leq 0.01$.
$^{A, B, C...}$ – Średnie w kolumnach oznaczone tymi samymi literami różnią się istotnie przy $P \leq 0{,}01$.

ciated with more complete milkout of the more frequently milked cows. It was established that increasing milking frequency (as in the automatic milking system) already during the first weeks of lactation elevates whole lactation milk yield by an average of 8% [Capuco et al. 2001].

Our study revealed that after the introduction of automatic milking, the cytological quality of milk improved regardless of the cows' age (lactation number). LnSCC decreased the most (by 0.86) in oldest (≥3 lactation) cows.

It was also found that improvement in the cytological quality of milk as a result of changing the milking system concerned all stages of lactation. LnSCC ranged from 12.18 (≤100 days) to 13.33 (>300 days) in the group of parlour milked cows, and from 11.65 (≤100 days) to 12.68 (>300 days) in the group of automatically milked cows. Dahl et al. [2004] report that in addition to improving milk production efficiency, an increase in the milking frequency of early lactation cows influences the mammary gland capacity to resist infection.

Table 5. Effect of changing the milking system on the proportion of milk samples with different SCC levels

Tabela 5. Wpływ zmiany systemu doju na udział próbek mleka z określonym poziomem komórek somatycznych

Milking system System doju	N	Proportion of milk samples (%) with different SCC levels, thous. · ml^{-1} Udział próbek mleka (%) z określonym poziomem komórek somatycznych, tys. · ml^{-1} ($\chi 2 = 74.16^{x}$)			
		≤ 100	101–200	201–400	> 400
Milking parlour Hala udojowa	523	22.33	21.45	35.90	20.32
Milking robot Robot	511	25.17	28.97	31.22	14.64

^{x} – Significance at P ≤ 0.05.
^{x} – Istotność przy P ≤ 0,05.

Analysis of the results in Table 5 suggests that after changing the milking system, the proportion of milk samples with low SCC (<100,000 cells · ml^{-1} and from 101,000 to 200,000 cells · ml^{-1}) increased by 2.84% and 7.52%, respectively, while the proportion of milk samples with high SCC (>400,000 cells · ml^{-1}) decreased from 20.32% (milking parlour) to 14.64% (automatic milking). Olechnowicz et al. [2006] found that the proportion of milk samples with SCC exceeding 400,000 cells/ml was 8.7% for parlour milk and increased to 25.4% within the first three months of automatic milking. However, it decreased to 11% after introducing a milk quality monitoring programme (animal sorting, checking and analysing the reasons for reduced milk quality) and to less than 9% over the next 9 months of milking. Also the results of some foreign studies [Klungel et al. 2000, Rasmussen et al. 2001 a] showed the somatic cell count in bulk milk to increase after the cows were subjected to robotic milking. A study performed in a herd milked concurrently in the milking parlour and in the automatic milking system [Berglund et al. 2002] showed that quarter milk contained fewer somatic cells when the cows were milked automatically.

CONCLUSIONS

The change in the milking system from the milking parlour to automatic milking caused a statistically significant increase in daily milk yield of the cows and improved the quality of milk in terms of somatic cell count. However, one must consider that a change in milking technology is stressful to the cows and may cause them to respond by a short-term decline in milk yield or a deterioration in the cytological quality of milk.

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WPŁYW ZMIANY SYSTEMU DOJU NA WYDAJNOŚĆ DOBOWĄ KRÓW I JAKOŚĆ CYTOLOGICZNĄ MLEKA

Streszczenie. Celem pracy była analiza wpływu zmiany systemu doju (z hali udojowej na robota udojowego) na wydajność dobową krów i jakość cytologiczną mleka. W obliczeniach statystycznych wykorzystano procedury GLM i FREQ z pakietu SAS. Stwierdzono, że zmiana systemu doju spowodowała krótkotrwały spadek wydajności dobowej i wzrost liczby komórek somatycznych w mleku. Biorąc pod uwagę dłuższy (12 miesięczny) okres wykazano wzrost ($P \leq 0{,}01$) wydajności dobowej – z 27,7 kg mleka u krów dojonych w hali udojowej do 31,1 kg mleka przy doju robotem. Zmiana systemu doju z hali udojowej na dój automatyczny miała pozytywny wpływ na liczbę komórek somatycznych w mleku (wartość logarytmu naturalnego liczby komórek somatycznych uległa obniżeniu z 12,44 do 11,97). Udział próbek mleka z niskim poziomem komórek somatycznych (do 100 tys. $\cdot$ ml^{-1} i od 101 do 200 tys. $\cdot$ ml^{-1}) wzrósł – odpowiednio o 2,84 i 7,52%, natomiast udział próbek mleka z wysokim poziomem komórek somatycznych (powyżej 400 tys. $\cdot$ ml^{-1} mleka) uległ obniżeniu o 5,68%.

Słowa kluczowe: mleko, komórki somatyczne, krowy, system doju

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