Ann. Anim. Sci., Vol. 11, No. 3 (2011) 433–441

EFFECT OF AUTOMATIC AND CONVENTIONAL MILKING ON SOMATIC CELL COUNT AND LACTATION TRAITS IN PRIMIPAROUS COWS

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Abstract

The aim of this study was to determine the effect of automatic milking on somatic cell count and lactation traits in Polish Holstein-Friesian cows. A total of 381 primiparous cows were analysed, including 220 in two barns with an automatic milking system (AMS) and 161 in three barns with a conventional milking system (CMS) which involved milking twice daily in milking parlours. A total of 4213 milk samples were collected to determine milk composition and somatic cell count (SCC). Milk yield over a standard lactation was significantly (P≤0.05) higher (by 741 kg) in primiparous cows milked automatically compared to conventionally milked cows, due to a higher milking frequency per day (2.43) and higher lactation persistency. Automatic milking, compared with conventional milking, contributed to a decrease in milk somatic cell counts. The percentage of healthy udders (SCC < 200 000 ml^{-1}) reached 75.70% in the AMS group and was significantly (P≤0.01) lower in the CMS group (50.09%). In the automatic milking system, incomplete milking was at a high level of 13.87%, thus indicating that more attention should be paid to the accurate detection of teat position and the attachment of milking cups as well the selection of cows for automatic milking based on behaviour and udder conformation.

Key words: automatic milking, cows, somatic cells, milking characteristics

Changes in cattle management conditions and nutritional regimes, but above all breeding work carried out for many years, have led to an enormous increase in milk yield, from 400–800 l per lactation in the aurochs – the ancestor of domestic cattle, to 7–12 000 l in the modern cow. As productivity levels and herd sizes continued to increase, there was a growing need for efficient milking machines to replace labour-intensive manual milking. Robot milking stalls were first introduced in the Netherlands in 1992. The first commercial robotic milking system was Lely Astronaut (Rasmussen et al., 2001). In Poland, the first milking robot was installed in 2008, and currently there are around 40 automatic milking systems in Polish dairy farms (Winnicki and Jugowar, 2010).

In automatic milking systems, milking frequency may increase to three times per day (Klungel et al., 2000). According to Hogeveen et al. (2001), a higher milking fre-

quency increases milk yield per cow, whereas such a relationship was not observed by Kruip et al. (2002). An increase in daily milk yield is followed by an increase in protein and fat concentrations, while the percentage content of protein and fat decreases due to the dilution effect, and freezing point tends to increase (Berglund et al., 2002).

A higher milking frequency may have both positive and negative effects on udder health (Klungel et al., 2000). One of the indicators of milk quality and udder health is somatic cell count (SCC) (Sawa and Piwczyński, 2003). SCC, which is a widely accepted and useful measure of mastitis, may be affected by various factors, including milking system and milking frequency per day. Shorter milking intervals support frequent flushing of the teat canal, thus preventing the growth of bacteria responsible for infections. In the voluntary milking system, short milking intervals adversely affect teat tissue regeneration. One AMS unit milks 50 to 60 cows, and every cow is treated in the same way in the cleaning programme which does not differentiate between clean and dirty udders, therefore the probability of bacterial transmission increases (Klungel et al., 2000). Most findings suggest that the introduction of AMS to replace CMS contributes to a higher incidence of mastitis (Hogeveen et al., 2001; Kruip et al. 2002; Rasmussen et al., 2002), although some authors do not share this opinion (Berglund et al., 2002). AMS is expected to benefit udder health and teat condition since it is based on individual quarter milking (Rasmussen et al., 2001).

In view of the inconclusive results of previous research into the use of milking robots, the objective of this study was to determine the effect of automatic and conventional milking on the udder health and lactation characteristics of primiparous Polish Holstein-Friesian cows.

Material and methods

The experimental material comprised 381 Polish Black-and-White Holstein-Friesian cows in their first lactation, kept in five barns located in the Province of Warmia and Mazury (NE Poland), within 50 km from the city of Olsztyn. Barn and herd characteristics are given in Table 1. In 2009–2010, once a month, bulk tank milk samples were collected at the end of the day. A total of 4213 milk samples were analysed. Protein and fat concentrations in milk were determined by indirect methods, using the Milko-Scan analyser. SCC was measured with the use of a Fossomatic cell counter. Each milk sample was mixed with a staining solution that stains the DNA in somatic cells. The stained sample was injected into a cuvette where the cells were excited by light. Somatic cells were visualized as light spots. The emitted spots were counted by means of a CCD light sensitive chip. In order to obtain the normal distribution of a variable, SCC was log-transformed according to the formula:

$$Y = L_n(x)$$

where:

x – SCC determined in milk samples.

Table 1. Characteristics of the experimental material

Item	Herd characteristics				
	AMS*		CMS*		
Herd	1	2	3	4	5
Form of ownership	private	private	university--owned	university--owned	private
Service standards	very high	medium	high	high	medium
Management conditions	very good	good	good	good	good
Number of cows per herd	245	165	200	250	280
Number of primiparous cows	177	43	48	55	57
Milking	VMS*	VMS*	twice daily in tandem parlour	twice daily in herringbone parlour	twice daily in rotary milking parlour
Housing system	free-stall barns	free-stall barns	free-stall barns	free-stall barns	free-stall barns
Feeding system	TMR*	TMR*	TMR*	TMR*	PMR*
Predominant diet components	maize silage, haylage, concentrate feed	maize silage, haylage, concentrate feed	haylage, concentrate feed	haylage grass silage, concentrate feed	maize and grass silage, concentrate feed

*AMS – Automatic Milking System; CMS – Conventional Milking System; VMS – Voluntary Milking System; TMR – Total Mixed Ration; PMR – Partially Mixed Ration.

SCC per ml of milk was used to determine udder health, using the udder disease score proposed by Sawa and Piwczyński (2005): SCC ≤ 200 000 – very good udder health; SCC 201 – 400 000 – increased risk of mastitis; SCC 401 – 500 000 – latent mastitis; SCC 501 – 1 000 000 – subclinical mastitis; SCC ≥ 1 000 000 – clinical mastitis.

Daily milk yield per cow in the first 100 days of lactation and over standard lactation was determined. The average number of milkings per day and the percentage of incomplete milking operations (milking of two or three udder quarters) were calculated using VMS Client software.

The data were processed statistically using Statistica 9.0 software. The effect of AMS and CMS on production traits was estimated by one-way ANOVA. The χ^2 test was applied to determine the number and percentage of cows with a different udder health status, subject to the milking system, milking frequency per day and the number of incomplete milking operations in the AMS:

$$\chi^2 = \sum [\frac{(fi - Fi)^2}{Fi}]$$

where:
fi – abundance obtained,
Fi – expected number.

Results

During the first 100 days of lactation, primiparous cows milked in conventional milking parlours produced more milk than cows milked automatically (Table 2). The noted difference (213 kg) resulted from a higher maximum milk yield in the former group. Milk yield over 305-day lactation was higher in AMS than in CMS, and the observed difference (741 kg) was significant (P≤0.05). Attention should be paid to differences in lactation persistency between the milking systems (Figure 1). Milk yield decreased in successive months of lactation at a significantly slower rate in AMS, compared with CMS. The difference in daily milk yield (kg), to the advantage of AMS, increased from the fourth month of lactation (+0.4 kg) to reach 4.8–4.9 kg in the last months of lactation (P≤0.01). The milk of AMS group cows had a significantly higher fat content and a lower milk content, in comparison with the milk of CMS group cows.

Table 2. The effect of the milking system on production traits and somatic cell count (SCC)

Item	Milking system				Statistical significance
	AMS*		CMS*		
	LSM	SD	LSM	SD	
Number of primiparous cows (head)	220		161		
Milking frequency per day	2540		1673		
Maximum daily yield (kg)	26.5	4.23	26.8	5.11	NS
Daily yield per 100 days of lactation (kg)	2331	671.8	2543	533.5	NS
Daily yield per 305 days of lactation (kg)	7231	986.4	6490	1121.3	x
Milk fat content (%)	4.08	0.65	3.97	1.06	xx
Milk protein content (%)	3.43	0.29	3.47	0.42	x
Somatic cell count (SCC) (L_n)	12.4	1.15	12.9	1.17	xx

NS – no significance; xx – P≤0.01; x – P≤0.05.
*AMS – Automatic Milking System; CMS – Conventional Milking System.

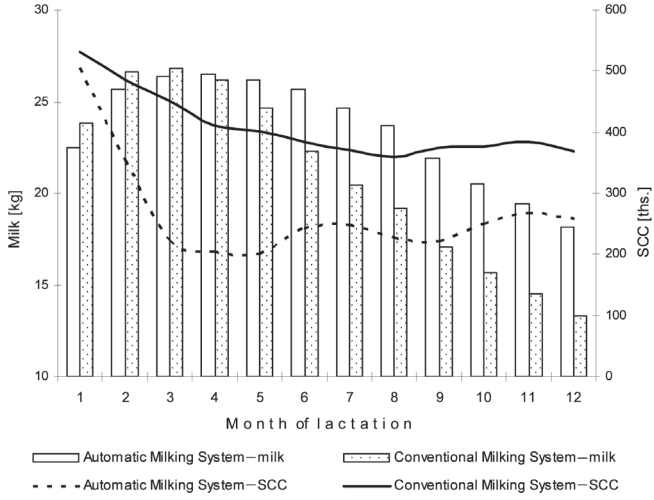

Figure 1. Daily milk yield and somatic cell count (SCC) in successive months of lactation

The average SCC per ml of milk was significantly lower in AMS than in CMS (Table 2). Similar average SCC values were recorded only in the first month of lactation, at 532 000 ml^{-1} in CMS and 504 000 ml^{-1} in AMS (Figure 1). In subsequent months, SCC decreased in milk samples collected from cows milked automatically, remaining at a stable level from the third month until the end of lactation (month 5–200 000 units, month 10–268 000 units). Over the lactation period, SCC decreased more slowly in the CMS group than in the AMS group.

The studied milking systems had a significant (P≤0.01) effect on udder health, as measured by SCC (Table 3). The percentage of healthy udders (SCC<200 000 ml^{-1}) reached 75.70% in the AMS group, and 50.09% in the CMS group. Symptoms of latent, subclinical and clinical infections (>400 000 cells per ml of milk) were observed in 12.68% milk samples in AMS and 29.59% milk samples in CMS.

Table 3. Udder health evaluation based on SCC

Udder health	Milking system				Statistical significance
	AMS*		CMS*		
	n	%	n	%	
Very good	1922	75.70	838	50.09	xx
Increased risk of mastitis	295	11.62	340	20.32	NS
Latent mastitis	57	2.26	73	4.36	NS
Subclinical mastitis	125	4.91	227	13.57	xx
Clinical mastitis	141	5.51	195	11.66	xx

NS – no significance; xx – P≤0.01.
*AMS – Automatic Milking System; CMS – Conventional Milking System.

In CMS, cows were milked twice daily, and in AMS the average milking frequency per day was 2.43 (Figure 2). The maximum milking frequency was noted in the third month of lactation (2.53). The number of milkings decreased gradually from the sixth month of lactation, reaching 2.30 in the last month.

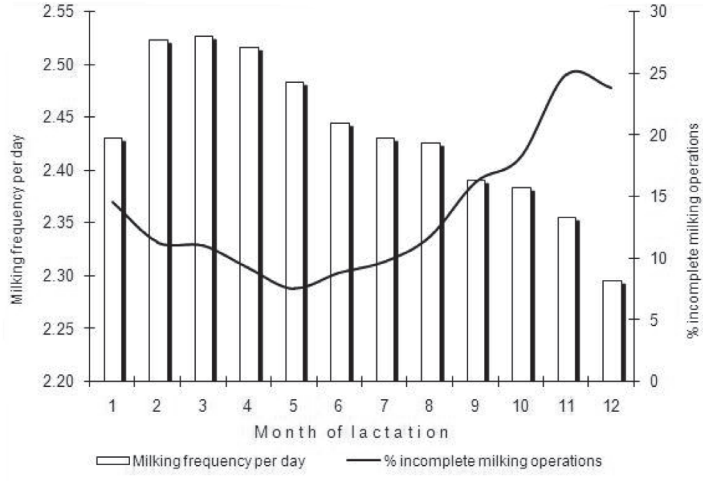

Figure 2. Milking characteristics in the automatic milking system

Over the experimental period, the average percentage of incomplete milking operations in AMS was 13.87% (Figure 2). Incomplete milking operations accounted for 14.56% and 7.51% (minimum) in the first and fifth month of lactation, respectively. The percentage of incomplete milking operations increased substantially at the last stage of lactation, to reach a maximum of 24.84% in month 11.

Discussion

The milk yield of primiparous cows over a standard lactation, observed in this study, is comparable with the milk yield of Holstein cows in their first 305-day lactation (6814 kg), in dairy herds participating in the official milk yield recording program (Ocena i hodowla..., 2010). The milk yield of primiparous cows of the active population over the first 100 days of lactation was 2505 kg in 2010, which corresponds to the milk yield of the CMS group in the present experiment. Lower milk production levels in the first months of lactation, a shift in the peak of the lactation curve and a higher milk performance of cows milked automatically point to high lactation persistency in this group of cows. Similar results were reported by Salvuo et al. (2005) for AMS-milked cows. Automatic milking allows increasing the number of daily milkings which, according to Hogeveen et al. (2001), increases the average milk yield from 5% to even 26% and has a beneficial influence on lactation persistency.

In our study, in the AMS group, the reason for lower productivity at the first stage of lactation (as compared with the second stage) could be the stress related to encouraging cows to attend for voluntary milking. The cow's motivation to be milked automatically is relatively weak (Halachmi et al., 2003). When a herd is switched to robotic milking, it takes cows several days to learn how to use the automated system. Cows that had been previously milked in milking parlours seem to adapt more easily. In most cases, 5% to 15% cows in a herd need three to four weeks to learn the AMS routine, while approximately 15% will not adapt to the robot (Lipiński, 2002).

In the present experiment, primiparous cows were characterized by the highest SCC in the first months of lactation. This could be a normal physiological process in the postpartum period, not necessarily indicating mastitis (Kruip et al., 2002). The reason for high SCC in the AMS group could be the cows' reluctance to be milked by a robot. Residual milk left in the udder can increase the risk of mastitis. In a study by Hovinen et al. (2009), the highest SCCs were recorded in the first and second month after the introduction of AMS.

Many authors reported an increase in SCC and bacterial counts in bulk milk samples after conversion to AMS (Hogeveen et al., 2001; Rasmussen et al., 2002). One of the reasons could be the stress experienced by cows trained to enter the milking stall voluntarily. In a study by Kruip et al. (2002), milk samples with SCC above 400 000 ml^{-1} accounted for 8.7% in CMS, their proportion increased to 25.4% in the first three months after the introduction of AMS, and decreased to 8.8% after the subsequent nine months. Also other authors (Berglund et al., 2002; Klungel

et al., 2000) observed no significant effect of AMS on an increase in SCC. In our experiment, AMS contributed to an increase in the number of healthy udders in the herd. According to Rasmussen et al. (2001), the above could be due to milking each quarter separately.

As the udder fills with milk, the pressure within the udder increases. The milk secretory process stops when the pressure inside the udder and inside capillaries becomes equal. Automated systems offer the possibility of frequent and voluntarily milking of high-yielding cows. The optimum milking frequency, aimed at increasing milk yield and maintaining udder health, is 2.5–3 times per day (Klungel et al., 2000; Hogeveen et al., 2001). As reported by Neijenhuis et al. (2008), the mean milking frequency in 150 Dutch farms with an average of 62 cows per farm was 2.3 times per day. In our study, the average milking frequency was higher, which could have a beneficial influence on milk production and udder health. Dahl et al. (2004) demonstrated that at the early stage of lactation SCC was lower in cows milked six times daily than in cows milked three times daily. In another study (Hogeveen et al., 2001), three times a day milking, compared with twice daily milking, contributed to a decrease in SCC and to a lower number of new infections. Köhn et al. (2007) noted a weak negative correlation between SCC and milking frequency in 10 farms with AMS.

In AMS, incomplete milking operations account for several to 15% (Kelton et al., 2001). Problems with the attachment of milking cups are most often due to system imperfections rather than cow behaviour during milking (Gygax et al., 2007). Incomplete emptying of the udder may lead to the inefficient use of the milking robot (Kelton et al., 2001), a decrease in milk yield due to milk leakage from stimulated teats (Gygax et al., 2007), and an increased risk of mastitis (Bach et al., 2004). Klaas et al. (2008) reported that after failed milking, cows visited the milking stall up to nine times per day. In a study by Głowicka-Wołoszyn et al. (2010), incomplete milking operations did not exceed 2%, but reached 11.7% in cows that visited the milking unit four times daily. The frequency of incomplete milking may increase in udder infections. As demonstrated by Rasmussen et al. (2007), the proportion of unsuccessful milkings increased from 5% to 30% one week before the occurrence of clinical mastitis. The relatively high percentage of incomplete milking, observed in our experiment, resulted from system imperfections regarding the detection of teat position and the attachment of milking cups, as well as from the restless temperament of some cows during milking. A considerable increase in the frequency of unsuccessful milking towards the end of lactation could be due to changes in the tissue geometry of mammary glands and a large number of primiparous cows whose udder conformation was unsuitable for automatic milking. The minimal distance between rear teats, supporting the attachment of milking cups, is 3 cm. In some cows, the distance between rear teats decreases after milking (Miller et al., 1995).

The results of this study show that automatic milking, compared with conventional milking, contributed to a decrease in SCC. AMS had a positive effect on lactation persistency and milking process consistency, leading to a significant increase in milk yield. The high proportion of incomplete milking operations in AMS indicates that more attention should be paid to the accurate detection of teat position and the

attachment of milking cups as well the selection of cows for automatic milking based on behaviour and udder conformation.

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Accepted for printing 1 VII 2011

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Wpływu doju automatycznego i konwencjonalnego na liczbę komórek somatycznych oraz cechy laktacji krów pierwiastek

STRESZCZENIE

Badano wpływ doju automatycznego na liczbę komórek somatycznych oraz cechy laktacji krów rasy polskiej holsztyńsko-fryzyjskiej. Łącznie uwzględniono 381 pierwiastek, z czego 220 pochodziło z 2 obór stosujących automatyczny system udoju (AMS) i 161 z 3 obór z udojem dwukrotnym w ciągu doby w halach udojowych (CMS). Pobrano 4213 prób mleka, w których określono jego skład i liczbę komórek somatycznych (SCC). Pierwiastki dojone automatycznie, dzięki większej liczbie udojów (2,43) w ciągu doby oraz lepszej wytrwałości laktacji uzyskały statystycznie ($P \leq 0,05$) o 741 kg mleka wyższą wydajność w laktacji standardowej, w porównaniu do dojonych tradycyjnie. Dój automatyczny, w porównaniu z dojem tradycyjnym obniżył w mleku liczbę komórek somatycznych. Udział wymion zdrowych (SCC<200 tys.·ml^{-1}) w grupie AMS wynosił 75,70%, natomiast w CMS był istotnie ($P \leq 0,01$) niższy i wynosił 50,09%. W oborach z automatycznym udojem stwierdzono 13,87% udojów niekompletnych, co wskazuje na potrzebę zwrócenia większej uwagi na działanie systemu rozpoznania strzyków i zakładania kubków udojowych oraz dobór krów do doju automatycznego z uwzględnieniem budowy wymienia i temperamentu.