MILK LEAKAGE FROM THE UDDER OF COWS ON DAIRY FARMS WITH AUTOMATIC AND CONVENTIONAL MILKING SYSTEM

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Abstract. The occurrence of milk leakage (ML) on farms equipped with automatic and conventional milking system was examined. The frequency of ML was higher in AMS (7.3%) compared to CMS (1.9%). A statistically significant relationship was detected between ML and the position of the cow in the resting and feeding area (P=0.006). Relationship between ML and the average and maximum milking speed was statistically unreliable. Significant relationship between milk yield and leakage was not observed, whereas the trait was statistically relevant only in cows milked in the parlour on the Farm C (P=0.049). Some linkage was found between ML and the age of a cow – older cows (≥4 parities) had higher probability of ML. The average somatic cell count score differed between cows with (3.03) and without (2.62) ML (P=0.064). The research indicated that despite the relatively low occurrence and repetitiveness of recorded ML during the observation period, ML may be a problematic issue in older cows.

Keywords: milk leakage, automatic milking system, conventional milking system, dairy cow, somatic cell count score, milking speed, milk yield, lactation number

Abbreviation Key: AMS - automated milking system, CMS - conventional milking system, ML - milk leakage, SCC - somatic cell count, SCS - somatic cell count score

Introduction. With regard to the introduction of new milking technologies, dairy farms have encountered problems that have previously not appeared. One such phenomenon is leakage of milk (ML) from the udder, the incidence of which is associated with continuous AMS-based visual and auditory stimuli, which stimulate the release of oxytocin and hence milk secretion, leading to ML (Jacobs and Siegford, 2012).

Milking process in a milking parlour and usage of a milking robot differs by the frequency and intervals between milkings, milking equipment adjustments and attaching technique of teat cups (Hovinen and Pyörälä, 2011). Milking times are usually fixed in conventional milking, while AMS allows the cows to freely go to the milking unit on their own schedule, making intervals between milkings irregular (Bach and Busto, 2005; Løvendahl and Chagunda, 2011).

So far, there is published only one research article, where Persson Waller et al. (2003) compared the incidence of ML on AMS and CMS farms (Siegford and Jacobs, 2012). Milk leaking, or dripping or flowing from cow's udder usually takes place between milkings (Persson Waller et al., 2003) and it is associated with the increased incidence of udder diseases (clinical mastitis) (Jørstad et al., 1989; Schukken et al., 1990; Barkema et al., 1999; Waage et al., 2001; Hovinen and Pyörälä, 2011). ML, while lactating cow is in lying position, makes the animal susceptible to the infections caused by *Escherichia coli*, as an open teat canal is susceptible to the pathogen in feces (Schukken et al., 1991). Mastitis in dairy farming, in turn, causes substantial economic loss by reducing milk production and milk quality and increasing costs of veterinary services, labour, and herd reproduction (Luttinen and Juga, 1997).

ML can occur when the teat canal closing mechanism is damaged, i.e., when the tip of the teat has been damaged (Jørstad et al., 1989). The passage of the teat canal may also be affected by the anatomy. Wide (Jørstad et al., 1989) and short (Lacy-Hulbert and Hillerton, 1995) teat canals are associated with an increased risk of mastitis incidence. ML can also occur when the intra-udder pressure exceeds the resistance of closing mechanism of the teat canal (Persson Waller et al., 2003).

Although the heritability of ML is estimated to be around 0.10 (Steine, 1988; Juga et al., 1996; Luttinen and Juga, 1997), this trait has been regularly recorded in Norway, Sweden and Finland (Luttinen and Juga, 1997), whereas, for the first time it was recorded already in 1978 by using three classes – 'no', 'little,' or 'much leakage' (Ruane et al., 1997).

The first AMS was installed in the Netherlands in 1992, and by 2009 there were already more than 8000 AMS worldwide (Svennersten-Sjaunja and Pettersson, 2008; de Koning, 2010). Most of the AMS are situated in Northern Europe (90%) and Canada (9%) (De Koning, 2010). The popularity of AMS is also constantly increasing among Estonian dairy farmers. The objective of this investigation was to conduct an initial study of the occurrence of ML on AMS and CMS farms, evaluate the relationship with other traits, provide an overview of the problem on the basis of the literature and consider the need for further research.

Materials and methods. Animals and farms. Data were collected from three farms with uninsulated free-stall cowsheds. Farm C was an experimental farm of the Estonian University of Life Sciences, whereas Farm A and Farm B were randomly selected commercial farms.

AMS was applied in one section of the Farm C and in Farm A cowshed (DeLaval VMS and Lely Astronaut A3, respectively). The other section of the Farm C and Farm B used CMS (DeLaval Endurance 1x8 parallel milking parlour and DeLaval P2100 2x10 parallel milking parlour, respectively). On the Farm B with CMS the lactating cows were milked three times a day and in one section of the Farm C twice a day.

Most cows under observation were Estonian Holsteins (Farm A – 222, Farm B – 530, Farm C with AMS – 65 and CMS – 87), less from the Estonian Red breed (Farm A – 21, Farm B – 367, Farm C with AMS – 5 and CMS – 17), from the Estonian Native breed (Farm C with CMS – 8) and some beef cows (Farm A – 4).

Milking performance. All farms were involved in the performance testing test-day milking program of Estonian Animal Recording Centre (EARC). To characterize dairy cows performance during study period (March 2012 – April 2013), the data from EARC database were used. According to this, average milk yield on the Farm A was 30.5 kg, Farm B 34.6 kg, Farm C with CMS unit 26.5 kg, and 28.5 kg in cows visiting milking device voluntarily on the Farm C (Table 1).

Table 1. **Descriptive statistics of dairy cows performance traits on farms during study period according to EARC records** (mean value ± standard deviation)

Variables	Farm A	Farm B	Farm C	
			AMS	CMS
No. of individual cows	240	889	82	133
No. of test-day samples	2311	7907	800	921
Parity	2.9 (1.5)	2.4 (1.5)	2.7 (1.3)	2.0 (1.2)
Lactation month	6.8 (4.0)	6.4 (3.8)	6.8 (3.9)	6.8 (4.0)
Days in milk, day	191.7 (122.0)	180.2 (116.3)	192.4 (118.3)	190.5 (121.9)
Daily milk yield on test-day, kg cow^{-1}	30.5 (9.9)	34.6 (12.3)	28.5 (9.3)	26.5 (9.1)
Fat content, %	4.0 (0.7)	3.9 (0.9)	4.3 (0.7)	4.1 (0.9)
Protein content, %	3.5 (0.4)	3.5 (0.4)	3.6 (0.4)	3.5 (0.4)
Somatic cell count, $x10^3$	274.9 (898.5)	303.6 (897.6)	165.9 (396.1)	164.6 (354.9)
Somatic cell count score	2.5 (1.7)	2.4 (1.8)	2.8 (1.8)	3.0 (1.9)
Urea	28.7 (7.5)	28.5 (8.1)	18.5 (4.8)	18.3 (6.0)

A total of 11,940 test-day milk samples were analysed during the study period March 2012 – April 2013 in the Milk Analysis Laboratory of EARC (Farm A - 2311, Farm B – 7907, and Farm C - 1722). The average fat content of milk (4.3%) during the study period was the highest in cows milked on the Farm C with AMS. However, milk with the lowest average fat content (3.9%) was obtained from Farm B. The average fat content of milk on the Farm C with CMS was 4.1% and that on the Farm A was 4.0%. The average protein content of milk on dairy farms under observation was quite similar ranging from 3.5 to 3.6%. The average milk SCC was the highest ($303.6*10^3$) in cows on the Farm B, the lowest ($164.6*10^3$) in cows milked on the Farm C with CMS. Regarding the cows from Farm A and Farm C with AMS, the respective figures were $274.9*10^3$ and $165.9*10^3$.

Feeding. All farms had loose housing uninsulated cowsheds, where cows feeding and rest area were connected. The cows were fed with a total mixed ration or a mix of silage *ad libitum*, whereby concentrates were fed individually, according to milk production, using the automatic feeding stations.

Culling. Mastitis was the main reason for culling cows on farms during the study period. In addition to mastitis, common causes of culling on the Farm A and B were leg diseases and reproduction problems. Other prevalent culling reasons on the Farm C were low milk production of cows in AMS unit, and metabolic diseases and other causes in CMS unit. Over the study period, the rarest culling causes were accidents as well as bad character and poor milkability of cows.

Data collection. To detect udder leaks in dairy cows, data were collected on farms by one person using visual observation. Cows were observed in 16 occasions, whereas four separate observations were conducted on each farm from March 2012 to April 2013. Visually detected ML was observed on an udder quarter basis. In addition, the strength of the leakage was assessed and the position of cow (lying or standing) was recorded when leak was detected. Leak strength was defined as milk dripping or flowing from one or more teats.

Regarding CMS farms, milk leakage data was collected visually from Farm B before noonday milking and from Farm C before the evening milking, whereas in AMS farms, milk dripping was observed after feeding. To record additional cow's records, a query was compiled in farm computer. Milk performance variables were collected after milkings from farm computers in digital form. The recorded data were: cow ID, lactation number, days in milk in the current parity, date of birth, milk yield before the observation, average and maximum milking speed (Table 2).

Table 2. **Explained variables recorded from the farms PC or EARC[1] databases for all cows with or without ML during the study period**

Trait	Explanation
Parity	1, 2, 3, ≥4
Stage of lactation	≤60, 61–150, >150 days
Days in lactation	Days in milk in the current parity
Milk yield	Milk yield (kg) at the milking before the observation
Somatic cell count[1]	The cow's average SCC measured at the monthly milk recording during the study period.
Somatic cell count score	SCS = $\log_2$ (SCC / 100 000) + 3
Milking speed	Average and maximum milk flow (kg min^{-1}) on the observation day measured by milking equipment

Statistical Analysis. The ML frequency in different AMS and CMS farms was compared with χ^2-test. This method was also used to compare the proportion of refused or failed milkings in cows with and without ML on the Farm A.

To study the relationships between ML and milk yield and milking speed at the observation day, average milk yield before ML observations, and average and maximum milking speed was modeled by the following general linear model (GLM) (SAS, 1999):

$$y_{ijklm} = \mu + PL_i + LNR_j + LStage_k + LNo_l + Cow_m + e_{ijklmn},$$

where y_{ijklm} is dependent variable, μ is model intercept, PL_i is ML effect (with or without leakage), LNR_j is parity effect (1st, 2nd, 3rd, ≥4th parity), $LStage_k$ is lactation stage effect (≤60, 61–150, >150 days), LNo_l is number of milkings in AMS effect (1–5), Cow_m is random effect of cow and e_{ijklmn} is random error. The models were fitted separately for studied farms and milking systems.

In order to achieve normal distribution of SCC, it was converted into somatic cell count score by formula SCS = $\log_2$ (SCC / 100000) + 3 and assessed by GLM (SAS, 1999):

$$SCS_{ijklmn} = \mu + PL_i + F_j + PL*F_{ij} + LNR_k + LStage_l + Cow_m + e_{ijklmn},$$

where SCS_{ijklm} is somatic cell count score, μ is model intercept, PL_i is effect of ML, F_j is farm effect, $PL*F_{ij}$ is ML and farm interaction, LNR_k is parity effect, $LStage_l$ is lactation stage effect, Cow_m is random effect and e_{ijklmn} is random error. Due to small number of leakages recorded in Farm C with AMS and CMS section, the farm was considered as one unit.

Probability of ML dependence on parity and stage was predicted by the logistic model (SAS, 1999):

$$\text{logit}(p_{ij}) = \mu + L_i + e_{ij},$$

where p_{ij} is probability of leakage (logit(p) = ln [p / (1 - p)]), μ is model intercept, L_i is parity or lactation stage effect and e_{ij} is random error.

Neither, the models that included both parity and the stage effect, nor those that took into account the effect of the repeated measurements of the same cows, were estimated due to minimum occurrence of ML.

Results And Discussion. Occurrence of milk leaks. During the conducted on-farm observations, the proportion of cows with ML varied between 0 and 8.6%. Previous studies have shown that the number of cows with teat leakage varied between farms to a large extent, ranging between 0 to 24% (Van de Geer et al., 1988; Schukken et al., 1990; Slettbakk et al., 1995; Juga et al., 1996; Luttinen and Juga, 1997).

Comparison of farms using AMS (Farm A) and CMS (Farm B) showed that the difference between the cows with ML was statistically significant (P<0.001). However, on the Farm C, where a robot milked about a one third of the cows and the other part was milked in the parlour, one per cent less cows with ML were detected in case the robot device was used (P=0.77) (data not present). Comparison between the robot-milked and the parlour-milked cows showed that the proportion of cows with ML was relatively higher on AMS compared to CMS farms (18/247 and 16/828, respectively) (Fig. 1). ML was observed more frequently on AMS farms, where it was detected in 7.3% of the cows. In contrast, only 1.9% of cows had ML on the farms using CMS (Fig. 1).

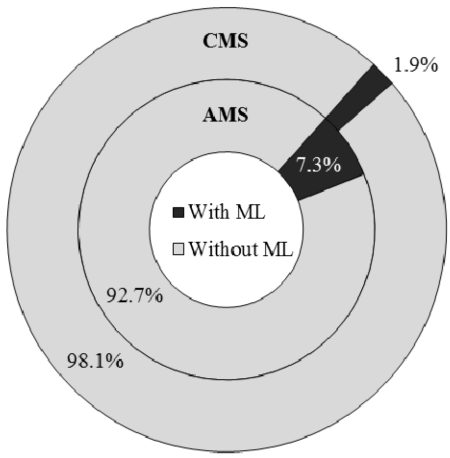

Fig. 1. **Percentage of cows with or without ML depending on the milking system** (P<0.001)

Furthermore, Persson Waller *et al*. (2003) have found that the risk of ML between milkings is higher in AMS than in CMS, where milking takes place at fixed times. Klaas et al. (2005) studied milk leakage risk factors on 15 commercial farms with CMS. They recorded 1.2–12.3% ML cases at the waiting area before milkings. In a widerange study of unspecified milking systems in Norway (30% of the cows are milked by AMS (Sletmoen and Børresen, 2013)), ML was not detected in 82% of the first-lactation cows, while 15% of the cows had moderate and 4% intensive ML (Sivertsen Storli and Heringstad, 2011).

The present study showed that ML usually occurred from one or two teats, which do not correspond to the results obtained by Persson Waller et al. (2003), who found that in many cases ML took place simultaneously from three or four teats. Leakage occurred most frequently from the rear quarters of udder, on both AMS and CMS farms (54% and 71%, respectively; P=0.521, Fig. 2), but the overall difference between percentage of leakage from rear and front quarters was not statistically significant (P=0.077). Similarly, Persson Waller et al. (2003) observed that occurrence of ML from the rear quarters was higher, however, they found the difference to be statistically significant (P<0.05). They observed that ML occurred both in lying and standing cows, which also corresponds with the results of the current work.

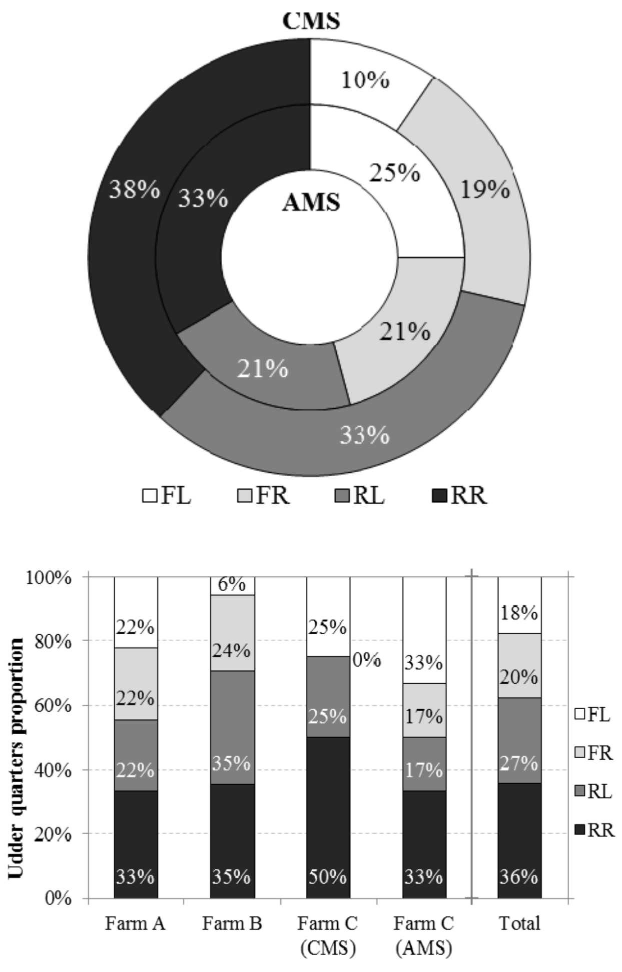

Fig. 2. **Distribution of ML by udder quarters on AMS and CMS farms** (FL – front left, FR – front right, RL – rear left, RR – rear right, P=0.521)

In AMS, udder quarters are usually milked individually, which reduces the risk of over-milking and has a positive impact on udder health (Berglund *et al*., 2002). Earlier studies have shown that problems related to attaching teat cups at milking may occur in about 15% of the cases (Mottram et al., 1995; Ipema *et al*., 1997). This may denote a failed or an incomplete milking of one or more quarters, which may increase the risk of ML. However, no differences were found between AMS and CMS regarding after-milking (Svennersten-Sjaunja *et al*., 2000) or residual milk (Hopster *et al*., 2002).

A total of 53% of cows with ML were in the standing position on CMS farms, while only 11% on AMS farms. The proportion of lying cows was 47% and 89%, respectively (Fig. 3). The position of dairy cows with ML on CMS and AMS farms was statistically significantly different (P=0.006).

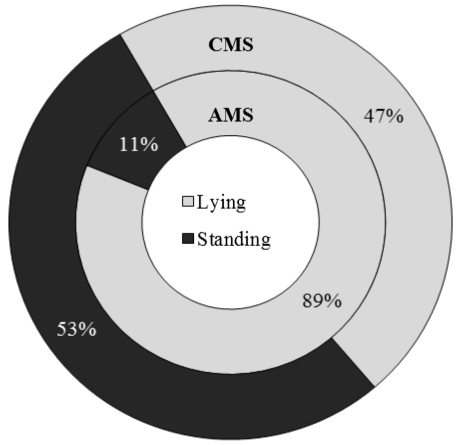

Fig. 3. **Position of cows at ML on AMS and CMS farms** (P=0.006)

Furthermore, Persson Waller *et al*. (2003) found, that in most cases when ML was observed, the cows were in the lying position (P<0.001), and the time that had elapsed since the previous milking, varied. Lying of the cows can be caused by social dominance. At the same time, longer intervals between milkings may lead to shorter lying periods before the next milking, the reason of which is, according to Österman and Redbo (2001), discomfort caused by the full udder during lying down. It was found that there were no big differences in the positions of animals between the farms. Österman and Redbo (2001) also reported that mastication or sleeping of cows did not affect the occurrence of ML, although Svennersten *et al*. (1990) found that irritation of the oral cavity increases the release of oxytocin. Persson Waller *et al*. (2003) explained the increase in the occurrence of ML from rear teats by higher pressure of the rear feet on the rear quarter of the udder. This also corresponds with the research findings, according to which the rear udder quarters have a higher risk of udder diseases and mastitis (Adkinson *et al*., 1993; Lancelot *et al*., 1997).

Excessive ML was detected more frequently on AMS farms compared to CMS farms. Particularly excessive ML was observed by 9% more frequently on AMS farms compared to CMS farms, (21% and 12% of all registered cases, respectively, P=0.455).

Incomplete emptying of the udder may result in up to 60% lower milk yield per milking (Persson Waller *et al.*, 2003). Although the cows without ML on the Farm A had omitted or failed milking attempts 12% more frequently compared to those with ML (23%), the difference was not statistically significant (P=0.088) (data not presented). Persson Waller *et al*. (2003) recorded 32% of ML incidences in failed or incomplete milking cases on an AMS farm. Stefanowska et al. (2000) observed 60% of linked cases between interrupted or incomplete milkings and ML on an AMS farm, which was a significantly higher percentage compared to the current study. Furthermore, they noted that ML occurred not always in the quarter that had a milking problem. Moreover, the experimental simulation showed that in case of interrupted milking there was a higher occurrence of ML (Stefanowska *et al*., 2000). However, it has not been found that the oxytocin level would increase before a cow enters a robot milking unit, which indicates that ML is obviously not related to the acoustic or visual stimuli originating from AMS (Bruckmaier *et al*., 2001; Dzidic *et al*., 2004). Thus, it can be concluded that ML is caused not only by failed or omitted milking, but ML frequently occurs also among regularly milked cows, and may therefore be caused by different other factors.

Milk yield and ML. No relevant relationship was found between milk yield before the observations and ML on the farms (Fig. 4). The recorded milk yield per milking was only by 0.2 kg higher in the cows with ML on AMS Farm A. In contrast, milk production was by 0.4 kg higher in cows without ML on CMS Farm B. Likewise, Persson Waller *et al*. (2003) found no significant difference in milk yield between cows with or without ML (P=0.15), while Luttinen and Juga (1997) claimed, based on their findings, that there is no genetic relationship between milk yield and ML.

Higher milk yield was found in the cows with ML on the Farm C with CMS, whereas the difference in the milk yield between the cows with and without ML was statistically significant (P=0.049) in the parlour section of the cowshed. Klaas et al. (2005) have referred to the study of Wendt *et al*. (1994), which concluded that higher yield and easily milked cows have a higher risk of teat leaking.

Milking speed and leakage are genetically related (Larsgard, 2013), e.g. according to the study carried out in Norway almost 80% of cases (Sivertsen Storli and Heringstad, 2011). Thus, genes that have a positive impact on milking speed have a negative impact on milk leakage (Larsgard, 2013).

Both the average and maximum milking speed at observation day were slightly higher in the cows with ML compared to those without ML (Fig. 5). However, this difference was statistically significant only on the Farm B with CMS (average milking speed P=0.004, and maximum P=0.012).

Earlier studies with Finnish Ayrshire and Finnish Holstein-Friesian cattle have shown non-desirable phenotypic correlation 0.28 to 0.29 and genetic correlation 0.65 to 0.89 between subjectively rated milking speed and ML (Luttinen and Juga, 1997). It means that selection on higher milking speed may increase milk leakage.

Relationship between the frequency of ML and the age of cows was similar on all the farms, i.e. ML increased with the age of cows (Fig. 6). This trend was statistically significant on the Farm B with the largest numbers of animals.

Furthermore, dependence of ML on the lactation stage differed by farm (data not presented). While the frequency of leakage increased during lactation on AMS Farm A, and this tendency was close to being statistically significant (P=0.055), leakage rate decreased significantly during lactation on CMS Farm B (P<0.001). No significant relationships between ML and the lactation stage were found on the Farm C with AMS and CMS units.

Persson Waller et al. (2003) did not find a relationship between ML and stage of lactation and parity. This study, however, showed that ML occurred in cows with larger parity, while, similarly to the above, no relationship was detected between ML and lactation stage.

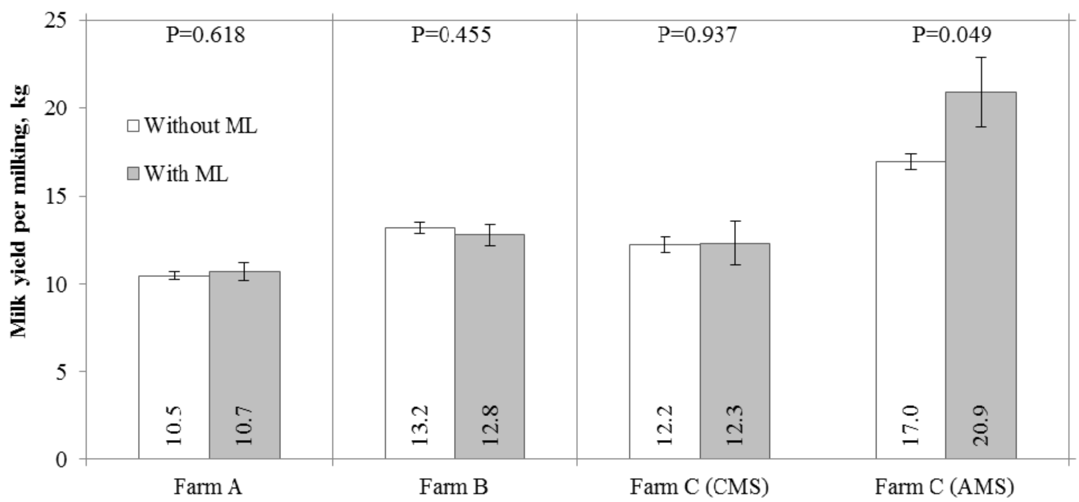

Fig. 4. **Estimated milk yield** (±standard error) **per milking before observation in cows with and without ML during study period** (P-value shows statistical significance of in-farm difference)

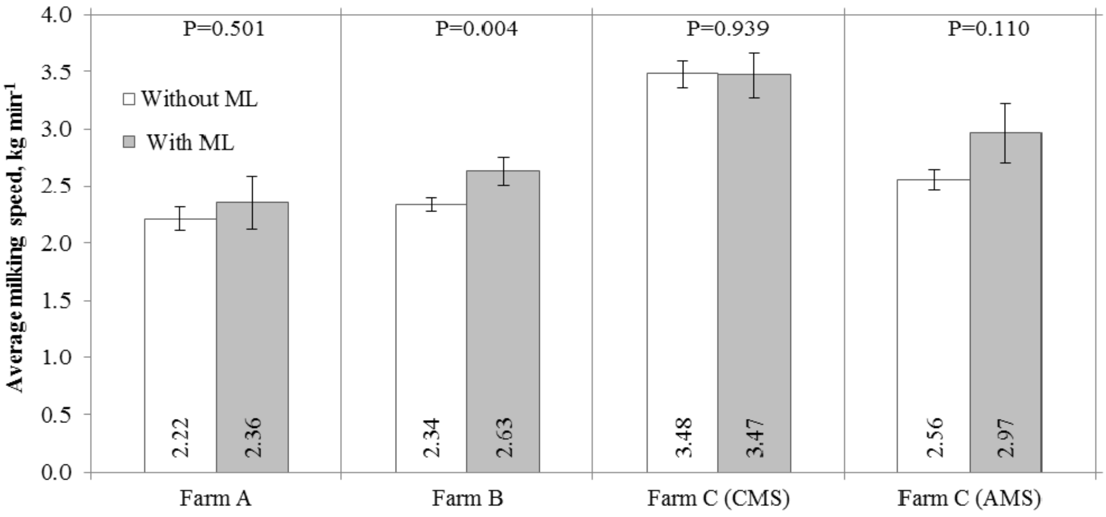

Fig. 5. **Estimated average milking speed** (±standard error) **in cows with or without ML** (P-value shows statistical significance of in-farm difference)

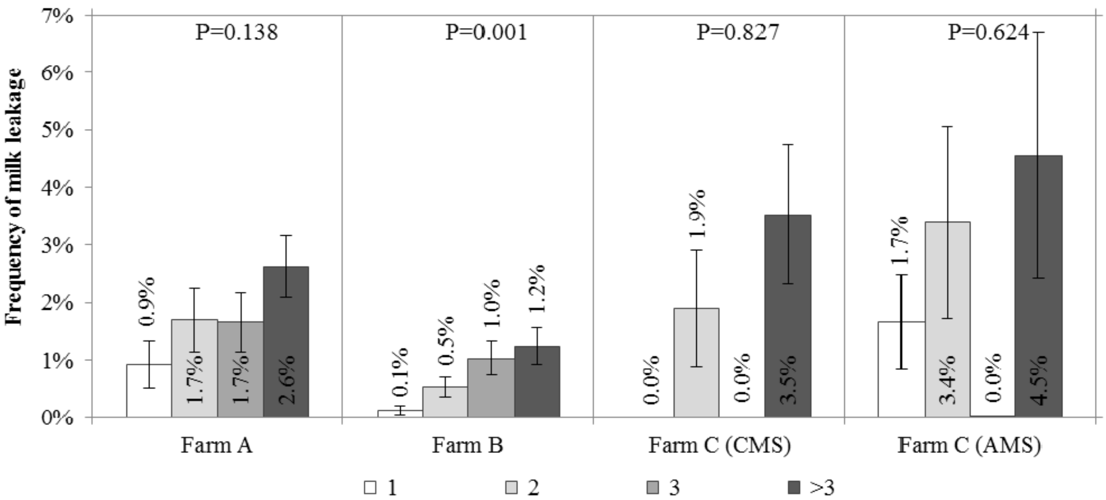

Fig. 6. **Estimated frequency of ML** (±standard error) **according to parity** (P-value shows the statistical significance of in-farm difference)

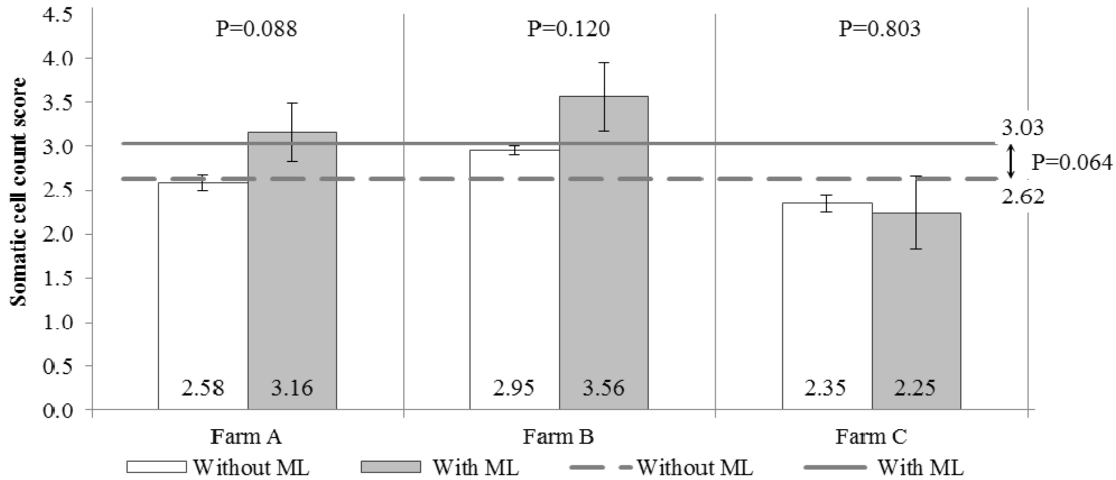

Fig. 7. **Estimated average SCS** (±standard error) **of test-day milking in cows with and without ML during study period** (horizontal lines indicate average of all the farms)

It appeared that the SCS of the cows with ML was higher than that of cows without ML (3.03 and 2.62, respectively; Fig. 7). Due to a very rare occurrence of ML this difference was not proven to be statistically significant (P=0.064), while the tendency was still found (P<0.10). At the same time it must be noted that in the cows with ML the standard error of SCS was significantly higher than that in the cows without ML. Similarly, Luttinen and Juga (1997) and Lund *et al*. (1994) have reported that cows with ML have higher SCS, whereas Persson Waller et al. (2003) noted a higher udder disease index (calculated on the basis of SCC) in the cows with ML (2.1) than in cows with no leaks detected (1.5), while similarly to this study, their results revealed no statistically significant difference (P=0.11).

Comparison of the farms (Fig. 7) may indicate certain trends between SCS and recorded ML, but as mentioned above, this difference was not statistically significant on all the farms. SCS in cows with ML was 3.16 on the Farm A with AMS, which was 0.58 points higher than that in the cows without ML. The tendency of difference was statistically significant (P<0.10). Although the difference in SCS was higher (0.61) on the Farm B with CMS than that on the Farm A, the results revealed no statistically significant difference. On the contrary, SCS was slightly lower in the cows with ML (0.10) on the Farm C where both milking systems were used (P=0.803).

Conclusions. In conclusion, it appeared that the risk of ML was higher on the farms using AMS compared to CMS farms using fixed milking times. ML occurred more frequently in the cows of AMS farms. In the parlour-milked cows, ML mostly occurred from rear udder quarters, while in the robot-milked cows ML was equally detected from both the front and rear udder quarters. In case of both milking systems, milk leakage was mostly observed when the cows were lying. Although ML occurred more frequently in older cows (≥4 parities), the difference between age groups or lactation stages was not statistically significant. Higher SCS was observed in the dairy cows with ML (P=0.064). The research demonstrated that despite the relatively low occurrence and repetitiveness of recorded ML during the observation period, ML may be a critical issue. It may become a problem along with the increase in the productive life of cows in the herd, as ML occurs more frequently in older cows.

In the future, the relationship between ML and the behaviour of cows as well as udder health and shape should be investigated. Taking into consideration the results and the variability of ML between herds, a more extensive study is needed covering a larger number of AMS and CMS farms, to identify the extent of the problem.

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