



Robotic milking and milk quality: effects on bacterial counts, somatic cell counts, freezing point and free fatty acids

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Paper received June 26, 2003; accepted September 22, 2003

ABSTRACT

Changes in milk quality after the introduction of automatic milking systems (AM-systems) on dairy farms in The Netherlands, Germany and Denmark were examined and the data were compared with milk quality results of farms with conventional milking technology. After introduction, a small, but significant increase in total bacterial count, somatic cell count, freezing point and free fatty acids was observed. The highest levels for total plate count and cell count are found in the first six months after introduction. After this period the milk quality slightly improves to a more stable level.

Risk factors related with milk quality concern general farm characteristics, animal health, AM-system, cleaning and cooling, housing, management skills of the farmer and the hygiene on the farm. Total plate count was significantly related to milk yield of the herd, cleaning of the area around the AM-system and the overall hygiene on the farm. Bulk milk somatic cell count appeared to be significantly related to milk yield of the herd and the number of milkings before replacement of the liners. An increased milking frequency is not the only explanation of increased free fatty acid levels. Technical factors related to free fatty acids mainly concerned the air inlet in the teat cups, bubbling (excessive air inlet) and a too long post run time of the milk pump. However, several questions regarding the causes of increased free fatty acid levels remained unclear.

Key-words: Milk quality, Plate count, Somatic cell count, Free fatty acids, Automatic milking system

Introduction

Since the introduction on the first commercial Dutch dairy farms in 1992, automatic milking has been adopted in general as a realistic alternative for conventional milking. Systems have gradually been improved and farmers have become more familiar with the potentials and limitations of automatic milking systems (AM-systems). Milk quality is a very important aspect

of milk production. Automatic milking is a fully automated process, in which visual control of the milk is not possible as with conventional milking. Therefore, milk quality needs to be managed in another way. Several sources of information such as conductivity, temperature and color of the milk, yield and machine on time figures are integrated and inform the farmer on the status of the milk and cows. However, previous research has shown that the milk quality of farms with an

automatic milking system was significantly lower both when compared to the milk quality of the period before the introduction of the AM-system and when compared with the quality of conventional milking parlors (Billon, 2002; Klungel *et al.*, 2000; Justesen and Rasmussen, 2000; Pomies and Bony, 2000; Van der Vorst and Hogeveen, 2000).

In the EU project Automatic Milking (Meijering *et al.*, 2002), within work package 4 "Milk quality and automatic milking", much attention is paid to milk quality and automatic milking. In order to obtain more information regarding automatic milking and milk quality within this research, milk quality results from three countries were analyzed. Secondly the technical and management factors affecting the milk quality on farms with an AM-system were identified and quantified in an epidemiological study. In the final phase the issue of free fatty acids (FFA) will be studied more in depth. This paper describes the main results of the research on milk quality within the EU project.

Material and methods

Study 1 - Milk quality of farms with an AM-system in comparison with conventional milking

All farms in Denmark, Germany and The Netherlands, using an AM-system (AM-farms) between February 2001 and October 2001 were selected. The farms were divided in groups (AM-groups) as presented below, based on the installation dates of the AM-system:

- 1) Before January 1, 1998 (AM1)
- 2) January 1, 1998 - March 31, 1999 (AM2)
- 3) April 1, 1999 - June 30, 2000 (AM3)
- 4) July 1, 2000 - December, 2000 (AM4)

In total 99 Danish, 33 German and 262 Dutch farms were included in the study.

For the period of January 1997 until December 2000, for every selected farm, bulk milk quality data were collected. The collected milk quality parameters were: Total plate count (TPC), bulk milk somatic cell count (BMSCC), freezing point (FP) and free fatty acids (FFA). Total Plate Count is mainly a measure for the bacteria pre-

sent in the milk, BMSCC is a measure for the inflammatory cells in the udders of the cows, FP provides an indication on the amount of water in the milk and FFA is a measure of damage to the fat globules. FFA data were not available for Denmark and Germany.

Furthermore, two control groups were used. For the Netherlands, one group of 295 farms, milking two times a day (C2), was randomly selected. The second control group consisted of all farms (n=40) milking three times a day (C3) with a conventional milking parlor. Data of such control groups for Denmark and Germany were not available. Therefore, it was chosen to present the national averages of all dairy farms in these countries as a reference to the outcomes of the AM farms.

Study 2 - Identification and quantification affecting milk quality on AM-farms

The second study aimed to identify possible risk factors that affect milk quality on farms with AM-systems. A preliminary study was started in 2001 in the Netherlands to identify the risk factors on a larger scale (Van der Vorst & Ouweltjes, 2003). In that study 124 AM-farms were visited. The farms were analyzed for risk factors focusing on four milk quality parameters: TPC, BMSCC, FP and FFA. For study 2, out of these 124 farms, a selection was made based on the bulk milk quality performance during month 7 through 18 after introduction. The milk quality performance levels used resulted in the following groups:

- Total plate count (TPC) (x1000 CFU/ml)
 - TPC low < 8, TPC medium 8-14, TPC high >14
- Bulk milk somatic cell count (BMSCC) (x1000 cells/ml)
 - BMSCC low <170, BMSCC medium 170-265, BMSCC high >265
- Free fatty acids (FFA) (mMol/100 g fat)
 - FFA low <0.55, FFA medium 0.55-0.78, FFA high >0.78

The freezing point was omitted, because the preliminary study showed a clear explanation for the involved risk factors. Using the above criteria,

28 farms were selected for this study. Automatic milking was introduced on these farms between November 1996 and December 1999.

Milk quality data over the period January 1997 to November 2002 were provided by the national Milk Control Station. For studying the possible risk factors on the farms six sources were used; a questionnaire, a scoring list on management items, the periodic test report of the AM-system, milk recording data, a hygiene check list and available data from the AM management program (Van der Vorst et al, 2003). For the final analysis farms were classified for TPC, BMSCC and FFA in the classes as described, based on their milk quality during the 12 months before the farm was visited. All farms were visited once.

Results and discussion

Study 1 - Milk quality of farms with an AM-system in comparison with conventional milking

Before introduction of the AM-system all groups of farms had similar milk quality, independent of the date of installation of the AM-system. The only exception was that the Dutch conventional farms that milked three times daily had a

higher level of FFA in the milk than all other Dutch farms.

After the introduction of the AM-system significant differences were found. The results (predicted means and recalculated geometric means) are presented in Table 1. The average figures of conventional farms (two and three times milking per day) are presented in Table 1 as a reference to the AM-farms. For all three countries and for most milk quality parameters (TPC, BMSCC, FP, FFA) the milk quality was slightly negatively affected after introduction of the AM-system in comparison to the period before. One exception was seen for the BMSCC in Germany, where no significant difference was found between before and after introduction. Before introduction of the AM-system the TPC was comparable to conventional farms in Denmark and The Netherlands. For Germany a lower TPC was found before the introduction of the AM-system than the national average.

Both in Denmark and Germany the BMSCC of the AM-farms before introduction seemed to be slightly higher than the national average BMSCC. Furthermore, the FP increased significantly after introduction of the AM-system both in Germany and The Netherlands by 0.005 °C. The FFA-levels

Table 1. Predicted Log means (PM) and recalculated geometric means (GM) before versus after introduction of the AM system, with figures of conventional farms as reference (Van der Vorst et al, 2002)

Country	Group	N. of farms	TPC Cfu/ml		BMSCC Cells/ml		FP °C	FFA Meq/100 g fat	
			PM	GM	PM	GM	PM	PM	GM
DK	C2*	All	-	9,000	-	246,000	-	-	-
	Before	99	2.080 ^x	8,000	5.558 ^x	259,000	-	-	-
	After	99	2.633 ^y	14,000	5.633 ^y	279,000	-	-	-
D	C2*	All	-	21,000	-	181,000	-	-	-
	Before	33	2.835 ^x	17,000	5.302 ^x	201,000	-0.521 ^x	-	-
	After	33	3.033 ^y	21,000	5.313 ^x	203,000	-0.516 ^y	-	-
NL	C2*	295	1.995	7,000	5.169	176,000	-0.521	-0.8142	0.44
	C3*	40	2.016	8,000	5.214	184,000	-0.522	-0.5870	0.56
	Before	262	2.006 ^x	7,000	5.138 ^x	170,000	-0.522 ^x	-0.9310 ^x	0.39
	After	262	2.559 ^y	13,000	5.320 ^y	204,000	-0.517 ^y	-0.5569 ^y	0.57

* sections not included in model / x and y = averages with different superscripts within each column and country differ significantly ($p < 0,05$)

in The Netherlands show an increase from 0.39 to 0.57 meq/100 g fat after introduction.

For all countries the variation in the levels of TPC, BMSCC, FP and FFA could generally be explained by similar variables. Differences between the AM-brands explained 32% percent of the variation in TPC, 30% was explained by installation period and 22% by farm effect. Regarding BMSCC, 56% of the variation could be explained by the farm differences. For the FP 62% could be explained by differences in AM-brand and the last parameter, FFA, was mainly influenced by the interaction of time and the farm (58%) but also for 26% by differences in brand. Therefore, farm and time differences and the make of AM-system seem to play a great role in the variation of the outcomes of milk quality results.

Course of TPC

No significant differences were found in the average TPC between the different AM-groups (AM1-AM4) after introduction of the AM-system for all countries. However, differences in tendencies can be seen. To illustrate this, the course of TPC for the Dutch dairy farms milking with an AM system is presented in Figure 1. As a reference

the mean values of the conventional farms, C2 and C3, are also given. All TPC levels for the AM groups are higher than the reference values of the conventional farms. During the first 45 days after introduction in all groups a quick increase of TPC is noted. After this time the TPC seems to stabilize for all four groups. The same result can be found on Danish and German farms.

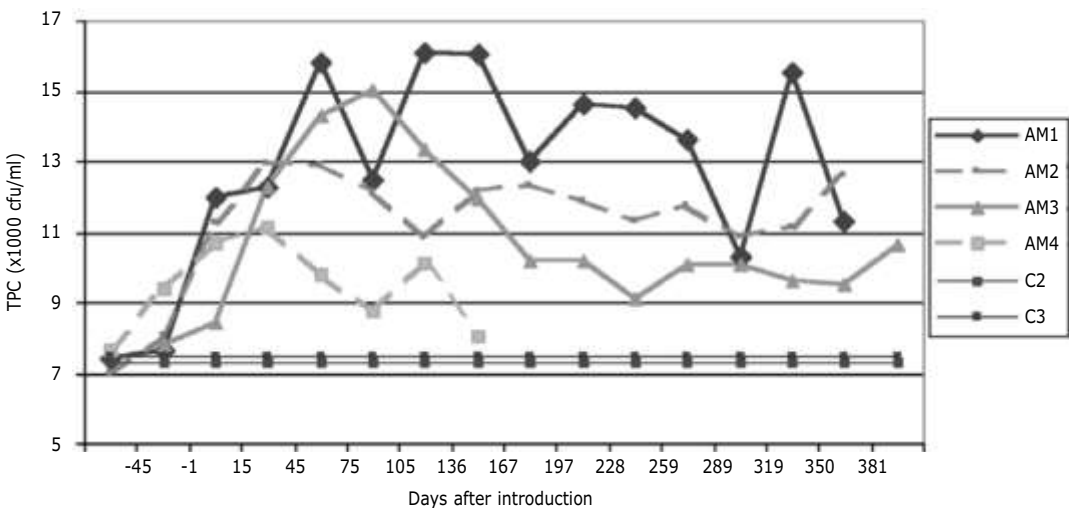
Course of BMSCC

Regarding the course of BMSCC after introduction again similar patterns were found for all three countries. During and just after introduction BMSCC increased slightly. However, after some time the BMSCC decreased in all countries to the same level as the conventional farms. The strongest decrease was found in Denmark (see Figure 2) where the AM3 group (largest number of farms) already reached the conventional level in about 110 days after introduction of the AM system.

Courses of FP and FFA

Regarding the course of FP, an increase was seen immediately after introduction of the AM-system and the level remained substantially higher. Little fluctuation was found after introduction. Regarding FFA the increase is less impulsive

Figure 1. Course of TPC after introduction of the AM-system on Dutch farms (Van der Vorst *et al.*, 2002)



after introduction. However it appears to rise slowly (Figure 3).

After 6 months the FFA-level of the AM2 and AM3 group was significantly higher than on the conventional farms that milk twice daily (C2). No difference was found when comparing with the C3 group during 1,5 years after introduction. The sig-

nificant difference with the C2 group, on the other hand, was still found at the end of year 2 after introduction of the AM system. As mentioned before, it is known that the milking frequency has an increasing effect on FFA (Klei et al, 1997). However, on the AM-farms it appears as if the FFA keeps increasing, although average milking frequency is less than 3 milkings per day.

Figure 2. Course of BMSCC after introduction of the AM-system on Danish farms (Van der Vorst et al, 2002)

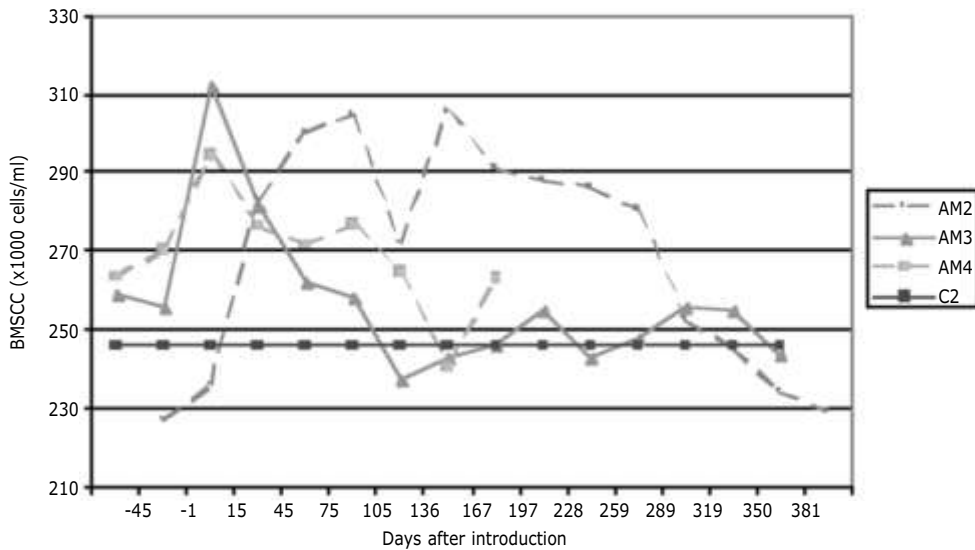
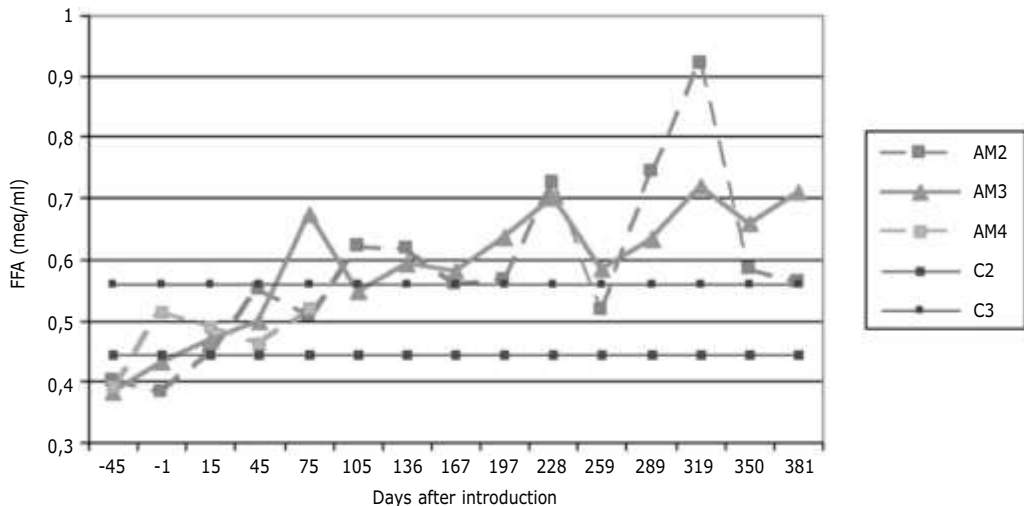


Figure 3. Course of FFA of four groups of Dutch AM-farms after introduction of the AM system (Van der Vorst et al, 2002)



As shown before, the introduction of the AM-system has a slight negative effect on the milk quality (Billon, 2001; Klungel *et al.*, 2000; Justesen and Rasmussen, 2000; Pomies and Bony, 2000; Van der Vorst and Hogeveen, 2000, Rasmussen *et al.*, 2002). However, in this study no significant differences were found between the different groups of farms (AM1-AM4) according to their date of installation in contradiction to earlier results where difference were shown between the AM1 and AM2 group (Van der Vorst and Hogeveen, 2000). In comparison to that study, study 1 had more data available over a longer period before and after introduction of the AM-system. As can be seen in Figure 1 and 2 TPC and BMSCC increase directly after introduction and then stabilize after some time. The point of stabilization for the four groups is around the same level for TPC, BMSCC, FP and FFA. Therefore, the longer the period after introduction is taken into account, the fewer differences will be found between the overall averages of the different groups.

The increases of the four milk quality parameters after introduction of the AM-system are relatively small, especially when compared with the European penalty limits. Besides substantial farm effects, for several milk quality parameters most variation could also be explained by differences over time and between brands. Farm effects are mainly based on management, time effects on changes over time such as seasonal effects and the brand effects are mainly based on the technique. Most probably interactions between these factors play an important role in affecting milk quality.

Study 2 - Identification and quantification affecting milk quality on AM-farms

The analysis of the data of the 28 farms in this study showed that size of milk quota and numbers of cows milked were not related to milk quality. The results showed a significant relationship between the production level after introduction with TPC and BMSCC. Both were lower for higher yielding herds. The results largely agree with those of the Dutch study on 124 farms in the Netherlands (Van der Vorst & Ouweltjes, 2003). Free Fatty Acid level was not significantly related

to production level, but on average herds with higher yielding cows, had higher FFA levels in the bulk milk.

Mastitis incidence was on average estimated at 22%, with a range from 0 to 71%. The estimated incidence was not related to milk quality. The farmers were asked about their opinion on conductivity as a tool to control mastitis. Only 2 farmers considered it useless, most farmers (25) regarded it as necessary. Five of them judged it as very useful. There was no significant difference in milk quality between farmers with different judgments. Half of the farmers used synthetic rubber liners, the other half used silicon liners. The type of liner used was not related to milk quality. Earlier replacement of liners tended to relate to a lower BMSCC. On average TPC and FFA levels were also lower with earlier replacement, but these relationships were not significant. The maximum interval between main cleaning cycles of the milking unit varied from 8 to 15 hours. The length of this interval seemed not to be related to milk quality. Most farmers spent more time between the cows and on management programs, and less time on cleaning and other activities around milking. This however, was not related to milk quality. On average the farmers reported to have more than 2 hours of labour time saved each day, with a range from 0 to 8 hours. The amount of saved labour was not related to milk quality.

Hygiene appeared to be important for TPC as well as for BMSCC. Both milk quality parameters showed increased values on farms with a poor overall hygiene. The TPC value was related to hygiene in the clean part of the AM-system and the waiting area. Also the overall impression of the farm was related to TPC. The relationship with hygiene is logical because with a poor hygiene, the chance for bacterial growth and the chance of contamination of milk increase. However, a direct relationship between hygiene on the farm and TPC is difficult to prove under experimental conditions (Slaghuis *et al.*, 1991). It was also found that TPC and BMSCC are lower on higher producing farms. It may be that these

farms have better overall management, resulting in a good milk production, animal health and hygiene (De Koning et al, 2002).

It was remarkable that on average farmers replace their teat cup liners (rubber as well as silicon) much too late. Rubber liners were replaced after on average 4636 milkings, silicon liners after 9579 milkings. The analyses showed that a high number of milkings is a risk for increased BMSCC. A technical factor that was also found to be important for BMSCC was the level of air inlet in the teat cups. However, there was an unexpected relationship between air inlet and BMSCC. The results showed a higher air inlet on farms with low BMSCC. Perhaps a higher air inlet might cause less teat washing in the liner.

There are big differences among and within farms in milk quality. Some farms have excellent milk quality results after introduction of the AM-system, some have a decreased milk quality, while others show incidental peaks in for example bacterial plate count.

Free fatty acids

With increasing milking frequencies, besides an increase in yield, a small decrease in fat and protein content, increases in the free fatty acids levels have been reported (Ipema and Schuiling, 1992, Jellema (1986), Klei et al, 1997). Lipolysis results from the enzymatic hydrolysis of milk fat, causing an accumulation of free fatty acids (FFA) which are responsible for the rancid flavor of milk. The milk fat present in milk fat globules is protected against the action of the endogenous milk lipoprotein lipase enzyme (mLPL) by the milk fat globule membrane. If this membrane is disrupted by e.g. agitation, fatty acids can be splitted up from the triglycerides. Another aspect of lipolysis is spontaneous lipolysis which results from the action of intrinsic mLPL and takes place when milk is cooled after milking. The milk fat globule is not disrupted, but some factors present in milk may favor the interaction of mLPL with the triglycerides resulting in a higher degree of FFA.

Several treatments are used to study lipolysis of milk fat by mLPL. Treatments that cause acti-

vation include agitation, homogenization, temperature changes and the addition of blood serum or heparin to milk. Milk from individual cows differs in the susceptibility to these treatments (Jellema, 1975, 1986). The mechanisms of the treatments that promote lipolysis are not clearly understood. In most cases the action of mLPL on cold stored milk fat does not depend on the amount of mLPL that is present in milk (Cartier and Chilliard, 1990). Activators might be related to blood serum components, as addition of blood serum to raw milk may increase the level of free fatty acids (Jellema, 1975, 1986). Inhibitors have been determined as proteose pepton component 3 fraction (Cartier *et al.*, 1990). Effects of feeding regimes of cows have been found for poor quality feed (Jellema, 1975), but literature is dated and feeding regimes have been changed.

In study 2, extra attention was paid to the FFA issue. The study showed both technical and management factors influencing FFA. It appeared that a regular check of the attention lists and check of the cleaning system was related to a lower FFA value. This may indicate a better overall management of the farmers who do this regularly. Farms that had more alerts from the cooling system had a higher FFA value than other farms. Unfortunately, the type of alert was not registered. Especially cows in late lactation seemed to be a risk. Their milk is more susceptible to lipolysis than milk from cows in early lactation (Jellema, 1986). A calving pattern spread evenly around the year may decrease the risk of a rise in FFA in a certain period because of the herd being in late lactation. If cows are in late lactation it is important that their milking frequency is not too high.

The technical factors related to FFA, mainly concerned air inlet in the system, bubbling (excessive air inlet) of the milk and a too long post run time of the milk pump, which increases the lipolysis. An interesting aspect is that air inlet in the teat cup seemed to have a positive effect on BMSCC and a negative effect on FFA levels. A remarkable result was that FFA seemed to be related with the number of feeding places and the accessibility of the water trough. The more places at the feeding fence and the better the accessibili-

ty of the water troughs, the lower the FFA. The exact relationships are unknown, but it may be related to some stress on the cows. It might be that stress induces the susceptibility of the milk to lipolysis, but more research is needed.

Conclusions

Milk quality, to a certain extent, is negatively affected when milking with an automatic milking system. The highest levels for TPC and BMSCC are found in the first six months after introduction. After this period the milk quality slightly improves and all farms more or less stabilize their levels. However, the stable level is still a little above the average of conventional farms. Differences between farms are seen both in averages and in variation. Possible risk factors related with milk quality concerned several general farm characteristics, animal health, AM-system, cleaning and cooling, housing, management of the farmer and the hygiene on the farm. An increased milking frequency is not the only explanation of increased FFA levels. Especially cows in late lactation seemed to be a risk. Technical factors related to FFA mainly concerned the air inlet in the teat cups, bubbling (excessive air inlet) and a too long post run time of the milk pump.

The studies are performed within the EU Project Implications of the introduction of automatic milking on dairy farms (QLK5 2000-31006) as part of the EU-Program Quality of Life and Management of Living resources.

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