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AUTOMATIC MILKING SYSTEMS AND MILK QUALITY IN THREE EUROPEAN COUNTRIES

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Abstract

In the study presented in this paper, recent milk quality data of farms with an AM-system were analyzed based on four consecutive groups (based on date of installation) and compared to conventional farms. Data of 99 Danish farms, 33 German and 262 Dutch farms were included and analyzed for possible relations and elapses regarding the milk quality from January 1997 until January 2001. Data of Dutch farms that milked twice (n=295) or three times a day (n=40) in conventional milking parlors during the same period, were used as controls. A slight deterioration of the milk quality can be found in all three countries for the period after introduction of the milking system compared to before introduction and compared to conventional farms. Nevertheless, the milk quality of AM-systems is good and levels are still far below the European penalty limits.

Introduction

Automatic milking (AM) has evolved rapidly after the introduction on the first commercial Dutch dairy farms in 1992. AM is widely accepted and works satisfactory, however, it does not go without significant amendments of the farm management and its related farm figures.
An AM-system is in use for 24 hours per day, needs adjusted cleaning and cooling procedures, complicates visual control and the milking frequency varies from cow to cow and from day to day.
One of the aspects affected by AM is milk quality. The quality of milk is a very important aspect of milk production. Milk payment systems and consumer acceptance are, to a great extent, based on it. Automatic milking is a fully automated process. Visual control of the milk is not possible as during conventional milking. Therefore, the milk quality needs to be managed in a different manner. Several devices such as sensors for conductivity, color and temperature of the milk, yield measurement and machine on time figures are integrated and inform the farmer on the status of the milk and cows. However, previous research has elucidated that the milk quality of farms with an automatic milking system was significantly lower when compared to the milk quality of the period before the introduction of the AM-system and compared to the milk quality of farms with conventional milking parlors (Billon, 2001; Klungel *et al*, 2000; Justesen and Rasmussen, 2000; Pomies and Bony, 2000; Van der Vorst and Hogeveen, 2000). All studies showed an increase of the total plate count (TPC). Results on bulk milk somatic cell count (BMSCC) were not always consistent. The study of Van der Vorst and Hogeveen (2000), shows

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a significant increase of TPC, as well as the free fatty acids (FFA), the bulk milk somatic cell count (BMSCC) and the freezing point (FP) after the introduction of the AM-system. Similar effects are found by Justesen and Rasmussen (2000).
Due to experience with automatic milking built up over the past years, it may be expected that adjustments made by the dairy and robot industry and the farmer, resulted in a better overall milk quality.

To evaluate the most recent situation, the development of the milk quality on farms with an AM-system in three countries and with different dates of installation over the past years was evaluated within the current EU project Automatic Milking (See Meijering *et al.*, 2002).

Material and Methods

Selected farms
All farms using an AM-system between February 2001 and October 2001 were selected in Denmark, Germany and The Netherlands. These countries were involved in the EU project and were chosen based on the considerable number of farms with an AM system present at the start of this study (January, 2001). The farm addresses were collected with help of all suppliers of automatic milking systems and the dairy industry. For Denmark, Germany and Holland respectively, 110, 65 and 325 addresses were received. The groups of Danish and Dutch farms were reasonable complete. For Germany it was estimated that only half of the total number of farms was collected. Consecutively, after receiving the consent from involved farmers, the milk quality data were collected by means of available databanks (Denmark) or with help of regional (Germany) and national (The Netherlands) milk control stations. In total 99 Danish, 33 German and 262 Dutch farms were included for this study, representing approximately 90%, 25% and 80% of the total population of AM farms in the selected countries.

In the study of Van der Vorst and Hogeveen (2000) different 'generations' were used. To be able to compare the outcomes found in this study, with earlier results, similar grouping was used. Instead of 'generations' the term 'groups' will be used throughout this paper. The groups are presented below, based on their installation dates:
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)

The fourth group of farms were farms that recently switched to AM. These farms are still in a transition status and not much data of the period after the introduction of the AM-system were available. Therefore, these results should be interpreted with care. Furthermore, no farms introduced an AM-system in Denmark before 1998. Regarding the German data only one farm introduced its AM system before 1998. This is therefore not a representative group. Both AM1 groups for Denmark and Germany will for this reason not be presented in the results of model [2] (differentiated between AM1…AM4, however the one specific German farm is included in the

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overall statistical analysis of model [1] (comparison before vs. after introduction). The models are described below.
Furthermore, two control groups were used. 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 comparable control groups for Denmark and Germany were difficult to collect. 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.

Data collection
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: TPC, BMSCC, FP and FFA. The TPC is mainly a measure for the bacteria present in the milk, the BMSCC a measure for the inflammatory cells in the udders of the cows, the FP provides an indication on the amount of water in the milk and the FFA is a measure on damage to the fat globules (air inlet, freezing, milking frequency, etc.). Per country, the sampling frequencies and determination methods differ. Table 1 provides a summary of these differences.

Table 1 Available milk quality data and frequency of sampling per country involved

	The Netherlands	Determination*	Denmark	Determination*	Germany	Determination*
TPC	Every 2 wks	BC 8000	Every wk	BC 8000	Every 2 wks	BC-8000 or BC-FC
BMSCC	Every 4 wks	Fossomatic	Every wk	Fossomatic	Every wk	Fossomatic
FFA	Every 6 mnths	Titration	-		-	
FP	Every 6 mnths	Cryoscopic	-		Every 2-4 wks	Cryoscopic

*BC 8000/BC-FC=Bactoscan 8000 and Bactoscan FC = fluorescence method; Fossomatic = fluoro-opto-electronic method; Titration = titration according to provisional Dutch standards (NEN 6854, 1988); Cryoscopic = cryoscopic determination with 22 seconds constant plateau-time (ISO 5784, 1986)

More differences than explained in table 1 have to be noted. In Denmark and Germany the milk is collected every day or every second day. This depends on the different dairies (Knappstein, 2001; Rasmussen, 2001). In The Netherlands the milk is collected every 3 days. The time of storing and cooling the milk before determining the milk quality will have influence on its outcomes, especially on the TPC, since the flora differ. Furthermore, during the data collection period the determination procedure for TPC (Bactoscan) in Germany changed from BC-8000 to BC-FC. Conversion factors between the two methods have been established and used in Germany to provide analogous results (Suhren *et al*., 2000). However, this change in methods over time makes it very difficult to compare the TPC of Germany with Denmark and The Netherlands. Denmark and The Netherlands both use BC-8000 which makes their results comparable, however the difference in milk collecting interval should still be taken into account. Furthermore, due to the conversion characteristics for Bactocounts into colony forming units (cfu), in Germany the TPC below 10.000 cfu/ml is not differentiated. In this study it is assumed that the somatic cell count figures are reasonably comparable between the countries (Van den Bijgaart, 2001). Regarding the freezing point (FP) determinations in The Netherlands and

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Germany have a constant difference. The freezing point of Germany is consistently 0,005 degrees Celsius lower than the Dutch (Buchberger, 1994; Van den Bijgaart, 2001; Slaghuis, 2001). Therefore, 0,005 °C was added to all German individual freezing point determinations to make all figures comparable.

Data Analysis
Before analyses, all data were checked for unlikely values. To approximate a normal distribution, TPC, BMSCC and FFA were transformed with a natural logarithm. This transformation prevents extreme high or low levels to have a big effect on the averages presented. For FP the absolute values were used.
Due to the difference in determination procedures of several milk quality parameters, the effects on milk quality are evaluated for every country separately. Two major comparisons were made: 1) a general comparison of the milk quality before versus after the introduction of the AM-system and 2) a more detailed comparison of the period after introduction of the AM-system based on the date of installation. Four groups are compared to evaluate the milk quality over time. As a reference these four AM groups are compared to conventional farming systems. The comparisons will be referred to as model [1] and model [2]. The results of both models were corrected for farm, make and time effects.

<u>Results</u>

Before introduction of the AM-system all 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 then all other Dutch farms.
After the introduction of the installation significant differences were found. The results (predicted means and recalculated geometric means) from model [1] are presented in Table 2. The average of conventional farms are also presented as a reference however are not statistically tested in model [1] (this is done in model [2], see table 4).
For all three countries and all milk quality parameters (TPC, BMSCC, FP, FFA) the milk quality was slightly negatively affected after introduction of the AM-system in comparison to before. One exception was seen for the BMSCC in Germany. Here no significant difference was found between before and after introduction.
Before introduction of the AM-system the TPC was comparable in Denmark and The Netherlands to conventional farms. For Germany a lower TPC was found before the introduction of the AM-system than the national average, however this could not be statistically analyzed.
Both in Denmark and in Germany the BMSCC of the AM-farms before introduction seemed to be slightly higher than the average national BMSCC. Unfortunately, no data were available to analyze this difference.
Furthermore, the FP increased significantly after introduction of the AM-system both in Germany and The Netherlands by 0,005 ^{o}C. The FFA in The Netherlands shows an increase from 0,39 to 0,57 meq/100 g fat after introduction.

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Table 2 Predicted and recalculated geometric means before versus after the introduction of the AM system (model [1]), with figures of conventional farms as reference.

Country	Group	No. 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

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

The European limit for TPC (100.000 cfu/ml) and BMSCC (400.000 cells/ml) are laid down in legislation (Council Directive 92/46/EEC). The German penalty limit for FP is 0,515°C. The Dutch limit is 0,505°C. The Dutch limit for FFA is 1,0 meq/100 g fat. From the figures it can be concluded that, the milk quality in all three countries slightly deteriorates after the introduction of the AM-system. Analogue to this is the percentage of milk deliveries exceeding the European or National penalty limits after the introduction of the AM-system in comparison to before introduction as is presented in table 3.

Table 3 Percentage (%) of samples of bulk tank milk exceeding penalty limits before versus after the introduction of the AM-system, with figures of conventional farms as reference.

Country	Group	TPC Cfu/ml	BMSCC Cells/ml	FP °C	FFA Meq/100 g fat
		>100.000	>400.000	>-0,505	>1,0
DK	Before	0,8%	9,1%	-	-
	After	2,5%	11,1%	-	-
D	Before	2,9%	6,0%	1,1%	-
	After	7,7%	9,3%	2,8%	-
NL	Before	0,8%	2,4%	0,4%	1,6%
	After	2,8%	5,5%	1,4%	7,3%

For all countries the variation in the levels of TPC, BMSCC, FP and FFA could be generally explained by similar variables. A 32% percent of the variation in TPC could be explained by differences between make of the AM-system, 30% by year and 22% by farm effect. Regarding BMSCC, 56% of the variation could be explained by the farm differences. For the FP 62% could

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be explained by differences in make and the last parameter, FFA, was mainly influenced by the interaction of time and the farm (58%) but also for 26% by differences in make. 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.
Table 4 provides more insight into the course of the milk quality after the introduction of the AM-system depending on the installation time (model [2]).

Table 4 Predicted and geometric mean of every milk quality parameter after introduction (AM1…AM4) of the AM system in comparison to conventional farms

Country	Group	No. 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	-	-	-
	AM2	23	2,707[a]	15.000	5,624 [a]	277.000	-	-	-
	AM3	44	2,868 [a]	18.000	5,657 [a]	286.000	-	-	-
	AM4	32	2,677 [a]	15.000	5,745 [a]	312.000	-	-	-
D	C2*	All	-	21.000	-	181.000	-	-	-
	AM2	12	2,930 [a]	19.000	5,286 [a]	198.000	-0,516 [a]	-	-
	AM3	18	3,140 [a]	23.000	5,383 [a]	218.000	-0,515 [a]	-	-
	AM4	2	2,690 [a]	15.000	5,306 [a]	202.000	-0,515 [a]	-	-
NL	C2*	295	1,995[a]	7.000	5,169[a]	176.000	-0,521[a]	-0,8142[bd]	0,44
	C3*	40	2,016[a]	8.000	5,214[a]	184.000	-0,522[a]	-0,5870[ac]	0,56
	AM1	27	2,733[b]	15.000	5,264[ab]	193.000	-0,519[a]	-0,5576[ab]	0,57
	AM2	56	2,531[b]	13.000	5,250[a]	191.000	-0,519[a]	-0,5706[ab]	0,57
	AM3	122	2,690[b]	15.000	5,382[b]	217.000	-0,519[a]	-0,6405[ab]	0,53
	AM4	57	2,625[b]	14.000	5,401[b]	222.000	-0,518[a]	-0,8355[cd]	0,43

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

The averages after introduction of farms with different installation dates (groups AM1…AM4) showed no differences for the Danish and German dairy farms for all four quality parameters. The same can be said of the Dutch farms regarding TPC and FP. Looking at the Dutch BMSCC significant higher levels can be found for the AM3 and AM4 farms than AM2 and the conventional farms. The BMSCC of AM1 and AM2 shows no difference with the conventional farms. No significant difference is seen between the FP of the conventional farms and of the AM farms. However, the FP appears to be slightly higher for AM farms (as corresponding with model [1]). Furthermore, the Dutch AM4 group shows a significant lower FFA than AM1-AM3. The FFA levels of the conventional farms are equal to the levels of all AM groups. However, as with FP, the FFA appears to show a tendency to be higher for AM1…AM3 in comparison to the conventional farms that milk twice daily (as can be noted too by the averages).

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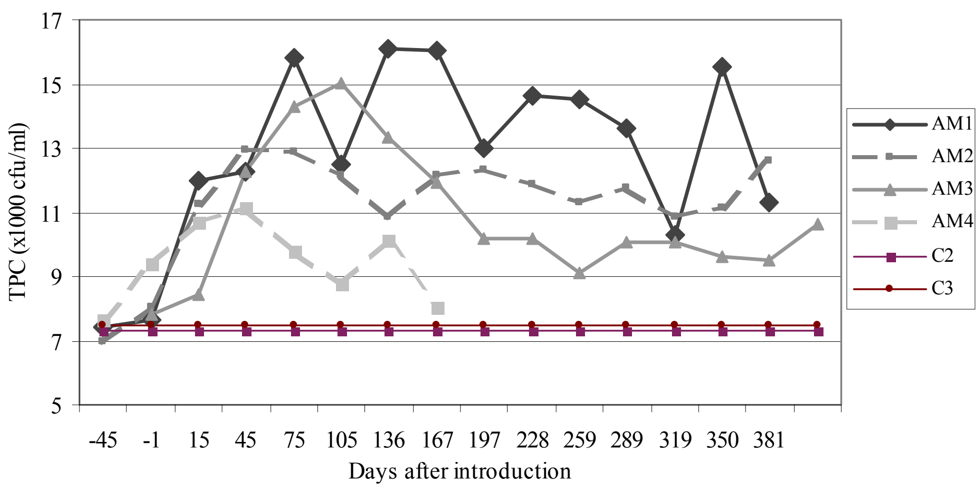
Course of TPC

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. Looking at the period after the first 6 months (180 days) it seems that the Dutch farms that switched more recently to AM (AM2 and AM3) perform better than AM1. This can not be said for the Danish and German farms. No difference was found there.

Figure 1 Course of TPC after introduction of the AM-system on Dutch farms



Course of BMSCC

Regarding the course of BMSCC after introduction similar patterns were found for all three countries as for TPC; during and just after introduction the BMSCC increased slightly. However, after some time the BMSCC decreased in all countries to a comparable level of 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 after about 110 days after introduction of the AM system.

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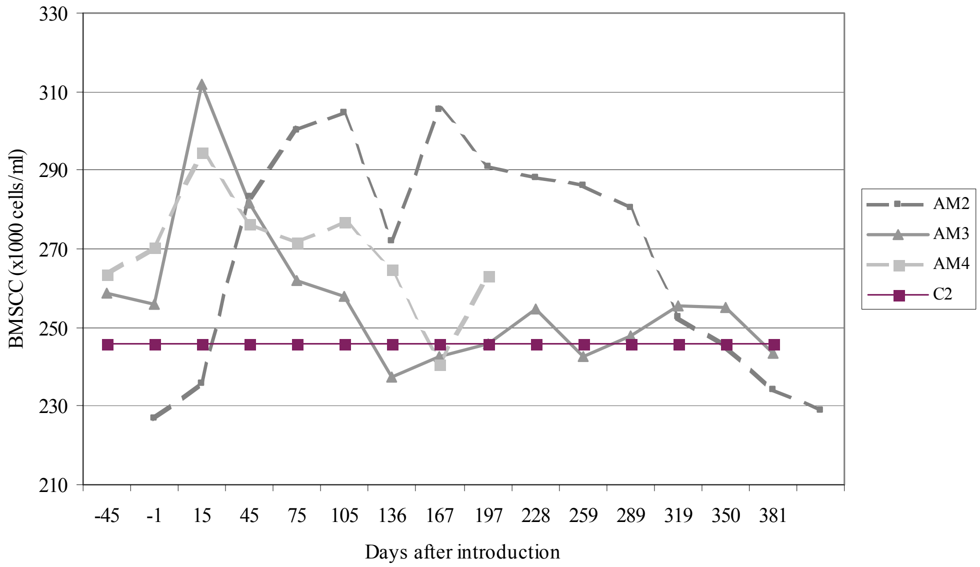

Figure 2 Course of BMSCC after introduction of the AM-system on Danish farms

Courses of FP and FFA

Regarding the course of FP, the increase was seen immediately after introduction of the AM-system and stays higher than conventional levels. Little fluctuation was found after introduction. Regarding FFA the increase is less impulsive after introduction. It appears to rise slowly. More study is necessary on this parameter to study the causes of the increase and to evaluate whether the increase is ongoing, and where it reaches its top level equilibrium.

Individual farm figures

The courses shown in figures 1 and 2 represent the averages of all farms analyzed. Naturally, individual farm figures often agree with the averages however also very much variation is seen. For all quality parameters in all countries the variation in average milk quality increases after introduction in comparison to all the years before introduction. This indicates farm differences. As already explained above three out the four parameters (except FP) were to a great extent influenced by farm effects. Figure 3 shows the course of TPC of a German farm before and after introduction. Besides an increase in TPC an increase in variation was seen after the introduction of the system.

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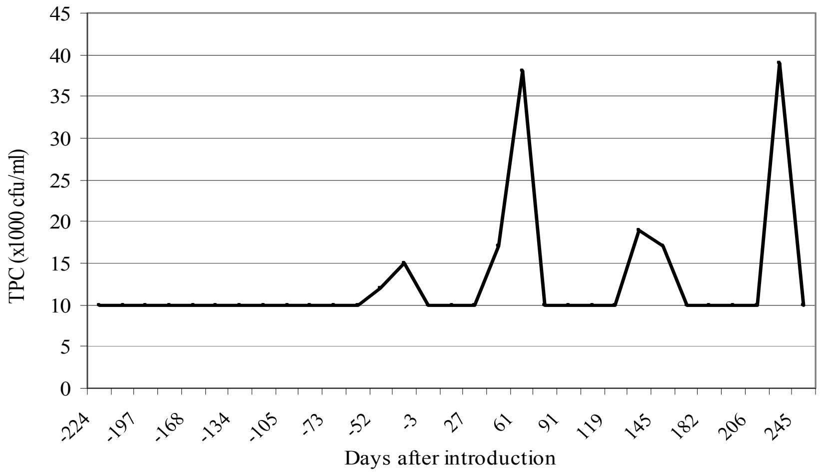

Figure 3 Course of TPC of one German farm before and after introduction of the AM system.

Discussion

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). However, in the present 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, the present study had more data available over a longer period before and after introduction of the AM-system (max. 4 years). As can be seen in figure 1 and 2 the TPC and BMSCC increased directly after introduction and then stabilize after some time. This point of stabilization is for the four groups around the same level of 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. Looking at the milk quality of farms with different dates of installation the main differences were found in the first 6 months. Analyses will be continued taking these questions into account.

Due to the differences in determination procedures, comparisons between countries could not be made for TPC. It appears that the TPC is highest for Germany but this may be dedicated to the determination procedure and conversion methods from bactocounts to colony forming units. Furthermore, it should be taken into account that only 25% of all German farms with an AM-system are included in this study. Regarding the BMSCC reasonable comparisons can be made since all three countries use the fluoro-opto-electronic method. Conclusions can be drawn that the BMSCC is highest in Denmark both for conventional farming and for AM farms (246.000 and 279.000 cells/ml respectively). However, farmers milking with an AM-system in Denmark

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have to participate in a self-monitoring program (Justesen and Rasmussen, 2000). After the initial increase of BMSCC recently after introduction of the AM-system, an evident decline can be seen after several months (see figure 2). Furthermore, it appears that the later the switch to automatic milking was made the quicker the recovery of the BMSCC to the level of before introduction. Therefore, the self-monitoring program seems to be effective for these farms. The German and Dutch BMSCC levels both lay around 203.000 cells per ml after the introduction of the AM system. However, for the Dutch farms this means a significant increase of 30.000 cells per ml in comparison to before introduction while the German farms showed no significant difference. Regarding the significant higher levels of BMSCC for the Dutch AM3 and AM4 may also be explained by the change in the Dutch penalty system for BMSCC at the beginning of 2000. From that time on the penalties were based on the geometric averages of three months compared to the absolute values before 2000. Regarding the freezing point, it can be concluded that both for Germany and The Netherlands the increase is comparable after introduction of the AM-system (0,005^{o}C). More water gets into the milk.

The average increases of the four milk quality parameters after the introduction of the AM-system are relatively small, especially when compared with the European penalty limits. It should not be taken for granted that the milk quality improves with AM milking as was once assumed when the first AM-systems were introduced. For example, Automatic milking does not necessarily mean an improved BMSCC, as was expected, following an increased milking frequency (Harmon, 1994; Hogeveen *et al*, 2000) and individual teat cluster detachment. Apparently, more factors play a role. The variation of BMSCC could be explained for 56% by farm differences. A wide range of factors fall within this denominator. Besides farm effects, for several milk quality parameters most variation could also be explained by differences over time and between makes. Farm effects are mainly based on management, time effects on changes over time such as seasonal effects and the make effects are mainly based on the technique. Most probably interaction between these large variance components plays an important role in affecting the milk quality.

Besides an increase of the mean levels after the introduction of the AM-system, also an increase in variation within and between farms is found. This is also illustrated by table 3. The number of penalty points increase visibly after introduction. The variation implicates that improvement is possible.

Possible causes and related effects are described by Van der Vorst and Hogeveen (2000) and De Koning, *et al.,* (2002) and are under current investigation by the Research Institute for Animal Husbandry in The Netherlands. This study is performed in order to gain more insight into the causes and effects. It was initiated by a workshop identifying all potential risk factors of AM on milk quality. In total 128 farms milking at least 12 months with an AM-system were visited and detailed information was collected. Around 400 factors were evaluated and will be linked to milk quality data from 1997 until the end of 2001. The information collected covered: general farm information, education of farmer and family, milk quality, hygiene of barn and AM-system,

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cooling of milk, animal health, feeding, housing, grazing strategies, and management and decision-making aspects concerning the AM-system.

At the time of writing this paper (January, 2002) the first descriptive statistics had started. These will be further analyzed to draw sensible conclusions on the relation between management and/or technical aspects of farming with an AM-system and the milk quality on those particular farms by spring, 2002.

Conclusion

Milk quality is to a certain extent negatively affected when milking with an automatic milking system in Denmark, Germany and The Netherlands. The highest levels are found in the first six month after introduction. After this period the milk quality slightly improves and all farms more or less stabilize their levels (with exception of FFA). 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. This, together with the knowledge that the milk quality improves about 6 months after introduction implicates that improvements are possible. First the risk factors have to be identified. This study is still ongoing.

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