Optimal cleaning of equipment for automatic milking

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Frequency of system cleaning

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Abstract

In several European countries there is a demand that milk producers with automatic milking systems (AMS) must clean the milking system three times a day. Cleaning an AMS reduces possible milking time as well as consuming considerable amounts of hot water and detergents. Therefore, it is important to acquire greater knowledge during practical conditions to better understand the consequences of less frequent cleaning.

This study was carried out on 13 Dutch and 9 Swedish farms during a period of 4 month. All AMS brands were included in the study, the two investigated treatments were cleaning with 8 and 12 hours intervals. Milk quality was analysed for total bacterial count (TBC), coliform count (CC), psychrotrophic count (PC) and thermoduric count (TC). The AM-systems were tested before and after each period of cleaning with one of the two cleaning frequencies. If necessary the systems were adjusted to the demands set by the manufacturer. To ensure that milk cooling and cleaning have been done correctly during the sampling period, in the Swedish farms the temperature was monitored in the milk pipe and in the bulk tank.

In both countries the difference for TBC was significant for the two different cleaning frequencies, even though the difference is small. In the Netherlands also a significant difference was obtained for the other groups of bacteria. In some farms, probably depending on type of AM-system and on management, the TBC is low in all cases, with no difference between two and three times cleaning per day.

Depending on the payment system for milk quality, the number of coliform bacteria when two system cleanings per day are performed can be above the level for first quality milk. It is suggested that the less frequent change of filters could attribute to this.

When AM-systems have a sanitary design, are optimised for cleaning, are well maintained and controlled, a good milk quality can be achieved with two system cleanings per day. This will reduce consumption of water, energy and chemicals and will increase the milking capacity. But defects in the construction or in the procedures will show sooner and will have a larger effect on milk quality.

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1. Introduction

Automatic milking is a continuous process throughout the day. Every hold-up in this process should be avoided, in order not to disrupt cow traffic and to reduce throughput (Ipema, 1997). On the other hand, the hygienic quality of the milk should not be decreased.
Starting with a clean and disinfected system and milking the first cows, it will take some time for bacteria to adapt to the environment. Depending on the type of bacteria, the temperature of the milk and other factors adaptation time will vary. It is important to clean and disinfect the machine before bacteria have adapted. Earlier research, with simulated AM-systems and with first generation AM-systems has shown that after eight hours bacterial growth is increasing (Verhey, 1992; Ordolff et al, 1992; Frost et al 1999). Based on these results it became a demand in several European countries that milk producers with AM-systems must perform a system cleaning 3 times per day.

Bacterial growth however is not only depending on cleaning frequency, but also on how well milk residues in the system are flushed away during the milking of the next cow. In this regard the construction in general, and in particular the inner surface, the slope towards the receiver and the absence of 'dead ends' are important, as is the remaining volume in the receiver and in the delivery line (Schuiling, 1995; IDF 1996; Verstappen et al, 1999). A sanitary construction will also increase the efficiency of cleaning (Vorst, et al, 2002). It is known that some farmers do clean the AM-system only twice a day, often with good results for milk quality.

At first it was decided to compare 2, 3 and 4 cleaning per day, but in the light of the current knowledge 4 cleanings per day would be an overkill and will influence the capacity of the AM-system in a unnecessary large extend. A system cleaning every 10 hours (2,5 cleaning per day) is considered as a good time lap between cleanings, regarding adaptation time of bacteria. This frequency is not investigated. The reasons are the probable disturbance of cow routine when having different cleaning times every other day, practical problems with software-settings in some systems and the inconvenience in working time if the milk filter should be removed before cleaning.

The aim of this study was to investigate the effect of cleaning frequency (two and three system cleanings per day) on the milk quality on farms in the Netherlands and Sweden.

2. Material and Methods

2.1 Test on Dutch commercial farms

The effect of the cleaning frequency, 2 versus 3 system cleanings per day, was studied on commercial farms. The farms were selected on their milk quality in the past six month (average TBC<= 15 without large fluctuations) and on the willingness to participate in the project under the project conditions. During 9 weeks the system was cleaned 2 times/day and during 9 weeks 3 times per day. The order of the cleaning frequency was set at random. During both periods of 9 weeks the bulk milk quality was analysed: total bacterial count (TBC) each collection of bulk milk, coliform count (CC), thermoduric count (TC) and psychrotrophic count (PC) once per two weeks. Also the freezing point of the milk was measured once every two weeks. The frequency of bulk milk collection was every 3 days or 3 times/week (2, 2 and 3 days), depending on regional systems.
Samples for bacteriological quality were taken by the lorry driver who is collecting the milk and is approved for taking and handling samples. The samples were put on ice, transported to the MCS Nederland (Milk Control Station the Netherlands) and analysed within 24 hours after sampling. Milk collected on Saturdays was not sampled, due to the impossibility to analyse the samples within 24 hours. TBC was analysed using the Bactoscan 8000, CC conform NEN 6874, TC conform NEN 6807 and PC conform ISO 6730.

On each farm the system cleaning was analysed and the hygienic condition of the AM-system was checked at the start of the project, at change-over of the frequency and at the end of the project. These check consisted of measuring the volumes, concentration and temperatures of the cleaning fluids, the efficiency of the post rinse during one cleaning. For this test a procedure was developed, see appendix 1. The hygienic condition of the installation was tested by visual checking of known weak points in the installation (f.i. liners) and ATP-measurements of the housing of the inline milk filter. The choice for ATP-measurements in the housing of the inline filter is based on the fact that this place is easily assessed in all AM-systems and is one of the weak points in the system due to minimal turbulence and low flow rate during cleaning. To collect a sample, the swab is brought inside the tube 10 cm deep and a sample is collected by making a spiral motion upwards, using 10 spins and covering 5 cm of tube length.

2.1.1 Statistical analysis

The collected data was evaluated by an analysis of variance using GenStat. In the fixed part of the model brand, treatment, period and interactions between these were tested. No significant interactions were obtained. The random part of the model were farm within brand and residuals. The random components were assumed to be normal distributed. For TBC, TC and PC log transformation was used to meet the demands.

2.2 Test on Swedish commercial farms

The study was carried out on 9 farms during a period of 8 weeks per cleaning frequency - 2 versus 3 system cleanings per day. In the Swedish study 3 different brands were included - AM systems from Fullwood, Lely and DeLaval. The order of the cleaning frequency was set at random. The cleaning systems on the farms were checked before the milk sampling started. Criteria for the selected farms were low total bacterial count in delivered milk without large fluctuations and on the willingness to participate in the project under the project conditions. The bulk milk was analysed for total bacterial count (TBC; Bactoscan 8000), coliform count (CC; NMKL Method no 44, 5th ed. 2001), psychrotrophic count (PC; IDF 101A:1991and thermoduric count (TC; Standard Methods for the examination of dairy products" 15th ed. 1985). The sampling frequency was for TBC every bulk milk collection (every second day) and for CC, PC and TC once every week. Also the freezing point of the milk was measured once every treatment to make sure that the freezing point was within the normal range. The milk samples were taken and handled, by the lorry driver who was collecting the milk, in the same way as milk samples used for the quality control as the basis for the payment to the farmer. The samples were analysed by Steins in Sweden. Before analyses, all data was checked and corrected for outliers.

To ensure that milk cooling and cleaning have been done correctly, the milk temperature was measured in the milk pipe and in the bulk tank. The temperatures were measured with thermistors and logged with Tiny-Tag loggers. One of the thermistors was placed at the end of the pipe just before the tank inlet. The other thermistor measuring the tank temperature was placed close to the tanks own sensor. Both thermistors were mounted and insulated for good heat conduction and to avoid external disturbances.

On each farm the system cleaning was analysed and the hygienic condition of the AM-system was checked at the start of the project. During cleaning, conductivity measurements were made to check for detergent residues in the last water of the rinse cycles and to check the proper strength of the cleaning solution. Temperature and water flow was measured and logged throughout the cleaning cycle. Also the hygienic condition of the installation was tested by visual checking.

2.2.1 Statistical analysis

The collected data was evaluated by an analysis of variance using the Mixed Model of SAS. In the fixed part of the model brand, treatment, period and interactions between these were tested. No significant interactions were obtained.
The random part of the model were farm within brand and residuals. The random components were assumed to be normal distributed. For thermoduric and psychrotrophic bacteria log transformation was used to meet the demands.

3. Results

3.1 Results of test on Dutch commercial farms

Thirteen farms participated in the project. On these farms the system cleaning was checked before the start of the experiment: in six cases the system cleaning had to be adjusted to improve the concentration of the cleaning fluid (3 x), to raise the water quantity for the after rinse (2 x) or for the pre rinse (1 x). Problems with the water quantity do often occur when the quantity is based on filling time and the pressure in the water supply is below normal values.
At the change-over of frequency and at the end of the experiment these checks of the system cleaning and of the hygienic condition of the installation were repeated. No defects or problems were found then.

In case a raise in TBC occurred (TBC > 50) the farmer was informed, questioned about the cause of the problem and in case no explanation could be found, the farm was visited and the installation was checked. In seven cases the TBC in the bulk milk showed raised values. The cause of the problems was variable; a broken valve in the cleaning system, insufficient hot water (2 x), faulty attachment of teat cups to the cleaning jetter(s), blockage in the cleaning system, an alarm which was not handled properly and one unknown cause. In some cases the cause was hard to find, so elevated TBC was found in consecutive samples.

For the analysis the bacterial counts are log 10 transformed, in order to create a normal distribution. The results in table 1 are transformed again to numbers of cfu/ml.

Table 1. Effect of cleaning frequency on milk quality

Frequency Quality parameter	2 times/day	3 times/day	significance
TBC (10^3 cfu/ml)	13	10	<0.001
Coliform bacteria (cfu/ml)	173	13	<0.001
Thermoduric bacteria (cfu/ml)	877	320	<0.001
Psychrotrofic bacteria (cfu/ml)	1047	522	<0.001
Freezing point (^{o}C)	-0,520	-0,519	0.003

For all bacterial groups there is a significant difference between two and three cleanings per day. The difference for TBC is however small and in average for both frequencies far below the penalty limit (100*10^3 cfu/ml). 8 results on 4 farms showed TBC over 100; the cases were equally divided over both cleaning frequencies.
As expected, the freezing point of the milk was slightly higher when more system cleanings are performed.

On five farms, using four types of AM-systems, there was no difference in the average log TBC between 2 and 3 times cleaning per day (see table 2 and figure 1), indicating that also with a lower cleaning frequency it is possible to have the same milk quality. The influence of the farm and type of AM-system is small for coliform bacteria (see figure 2), compared to TBC and to TC and PC (figure 3 and 4).
As can be seen from the causes of hygienic problems, it is important to have a proper installation check, a good maintenance of the AM-system and a keen operator.

Table 2. Average log TBC per farm with 2 or 3 system cleanings/day

No of cleanings/day	2	2	3	3
farm / AMS code	avg log TBC	min/max log TBC	avg log TBC	min/max log TBC
A / a	3.82	3.5 / 4.5	3.67	3.0 / 4.2
B / a	3.79	3.3 / 4.4	3.83	3.3 / 4.3
C / b	4.27	3.8 / 5.1	4.20	3.9 / 5.4
D / c	3.99	3.0 / 4.6	3.89	3.6 / 4.5
E / d	4.12	4.0 / 4.7	4.06	3.6 / 4.7
F / d	4.10	3.9 / 4.6	3.96	3.6 / 4.3
G / b	3.90	3.3 / 4.4	3.90	3.6 / 4.5
H / a	4.21	3.8 / 4.6	4.27	3.9 / 5.0
I / c	5.65	4.0 / 5.1	4.15	3.9 / 5.5
J / e	3.73	3.3 / 4.3	3.74	3.5 / 4.3
K / b	4.56	4.0 / 5.0	4.45	4.0 / 5.1
L / c	4.17	3.9 / 4.4	4.13	3.8 / 4.8
M / d	4.22	4.1 / 4.4	3.92	3.6 / 4.1

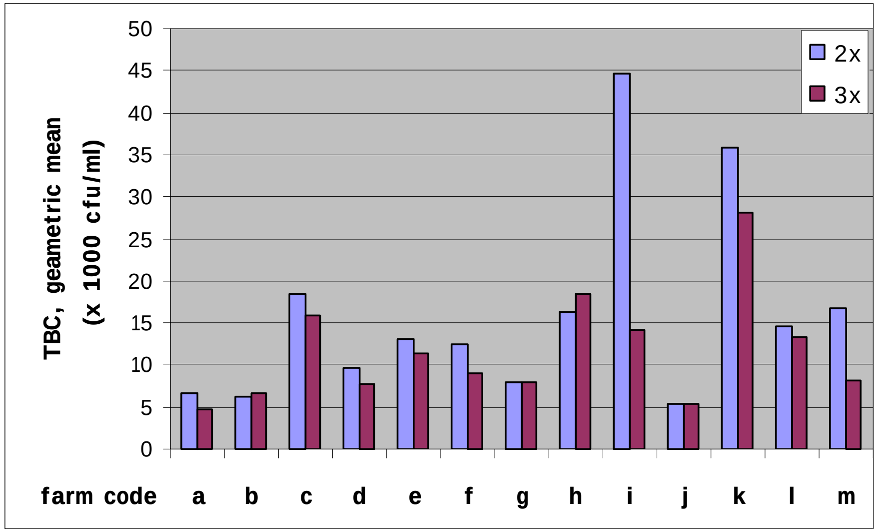

Figure 1. Geometric mean of TBC per farm and per cleaning frequency

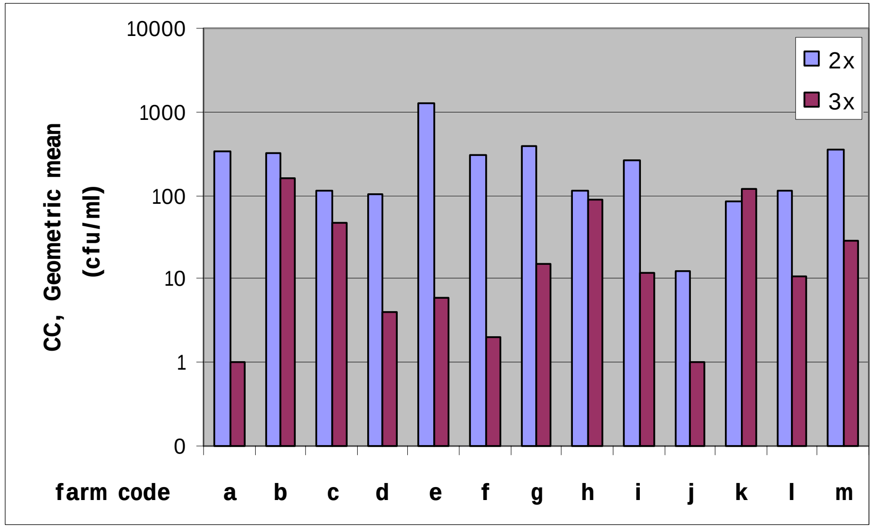

Figure 2. Geometric mean of CC per farm and per cleaning frequency

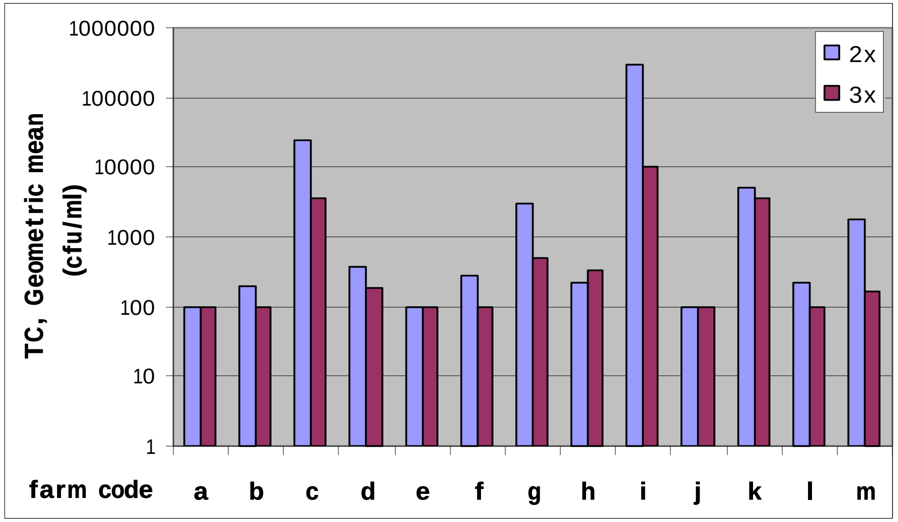

Figure 3. Geometric mean of TC per farm and per cleaning frequency

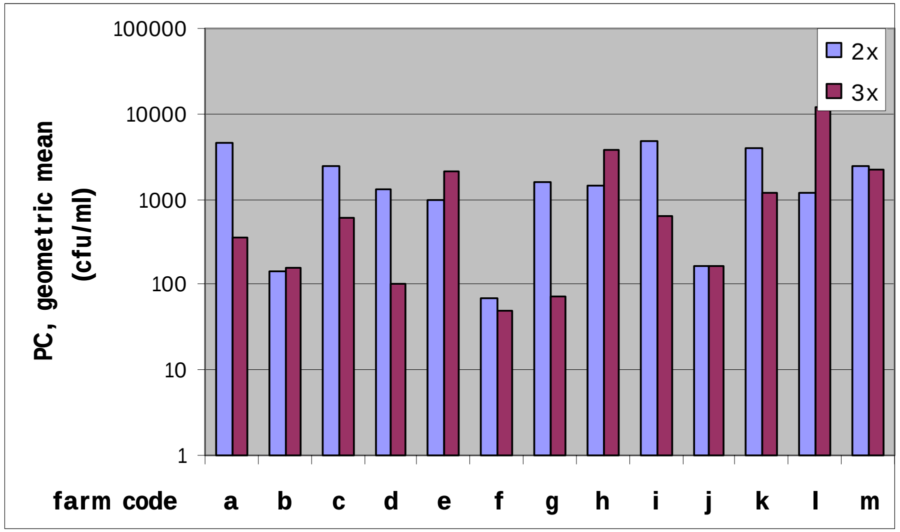

Figure 4. Geometric mean of PC per farm and per cleaning frequency

3.2 Results of test on Swedish commercial farms

The farmer was informed if a raise in TBC occurred from the farm´s normal level and questioned about the cause of the problem. In most cases the cause of the problems could be explained by the farmer. One farm switched back to 3 systems cleaning per day after a couple of weeks due to problems with high TBC. Later it could be established that the water temperature was too low during cleaning. When the starting time of the heater was adjusted so that a sufficient cleaning temperature was reached before start, the TBC decreased to much lower values (Fig. 5). Other cause of the problems were: faulty attachment of teat cups to the cleaning jetter(s), problems with water supply, no detergent left, power failure and temporary cooling problems.

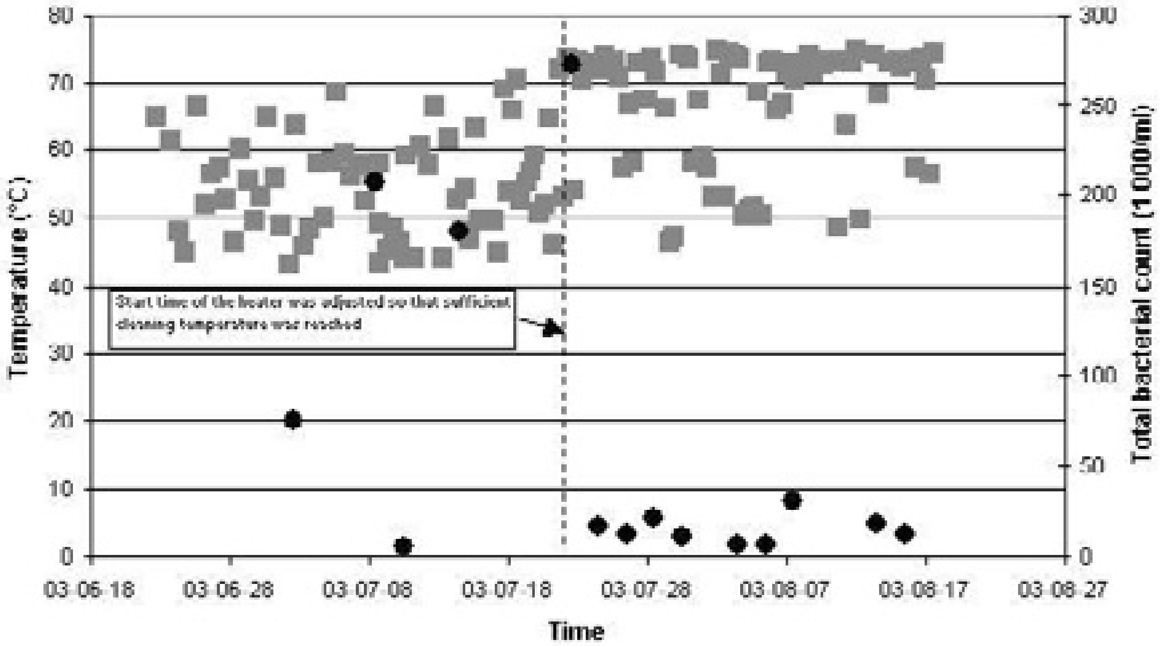

Figure 5. Maximum cleaning temperature (^{o}C) measured in the milk pipe (■) and TBC (1 000/ml) in the bulk tank during the same period (•).

For the analysis the bacterial counts are log 10 transformed, in order to create a normal distribution. The results in table 3 are transformed again to numbers of cfu/ml.

Table 3. Effect of cleaning frequency on milk quality – arithmetic mean TBC, coliform bacteria, thermoduric bacteria and psychrotrophic bacteria

Frequency Quality parameter	2 times/day	3 times/day	significance
TBC (10^3 cfu/ml)	14	9	<0.05
Coliform bacteria (cfu/ml)	50	33	No
Thermoduric bacteria (cfu/ml)	1 549	1 047	No
Psychrotrofic bacteria (cfu/ml)	1 047	661	No

The average TBC, CC, TC and PC for each cleaning frequency are presented in table 3. The difference for TBC was significant with different cleaning frequencies but no significant difference was obtained for the other groups of bacteria. No samples collected on any farm exceeded 100 *10^3 cfu/ml in TBC. Cleaning the system twice a day resulted in a TBC of log 4.15 compared to log 3.98 when cleaning the system three times a day. The bulk tank milk contained an acceptable average level of CC irrespective of farm and cleaning frequency. However, the variation between farms and cleaning frequency was high with the lowest value of 0 and the highest value of log 3.9. With a limit for TC of 200 cfu/ml, all farms regardless of cleaning frequency exceeded that limit for almost all of the milk samples (mean between log 3.02 - log 3.19). Average TBC per Swedish farm is presented in table 4. In table 5 a defined limit is set for all groups of bacteria for a better overview of each farm´s sanitary status.

Table 4. Average log TBC and maximum and minimum values per Swedish farm with 2 or 3 system cleanings/day

No of cleanings/day		2		3	
Farm code	Brand	avg log TBC	Min/Max values	avg log TBC	Min/Max values
1	2	4.12	4 / 25	3.83	3 / 11
2	2	*	* / *	4.09	3 / 31
3	3	3.89	3 / 33	3.59	3 / 8
4	1	4.00	3 / 45	3.63	3 / 14
5	2	4.45	3 / 57	4.23	3 / 54
6	3	3.87	4 / 15	3.71	3 / 12
7	3	3.90	3 / 32	3.83	3 / 18
8	1	3.89	3 / 23	3.96	3 / 32
9	1	4.39	11 / 41	4.32	3 / 84

Table 5. Percent of samples exceeding a defined limit on quality parameters

No of cleanings/day	% of samples >30 000 TBC per ml		% of samples >1 000 coliform bacteria per ml		% of samples >200 thermoduric bacteria per ml		% of samples >5 000 psychrotrophic bacteria per ml	
	Cleaning frequency		Cleaning frequency		Cleaning frequency		Cleaning frequency	
farm code	2	3	2	3	2	3	2	3
1	0	0	0	14	100	100	40	0
2	*	3	*	0	*	100	*	9
3	4	0	0	0	100	33	18	0
4	9	0	0	0	100	100	0	0
5	56	8	0	0	100	100	17	17
6	0	0	17	0	100	80	0	0
7	4	0	0	0	100	56	0	0
8	0	3	0	11	100	100	12	0
9	33	9	25	17	100	100	67	50

On one farm the first milk entering the tank after tank cleaning was not cooled below 4 ^{o}C within 3 hours several times, which can clearly be seen in Figure 6. TBC in the milk increased during a period of time and exceeded this farm´s normal TBC.

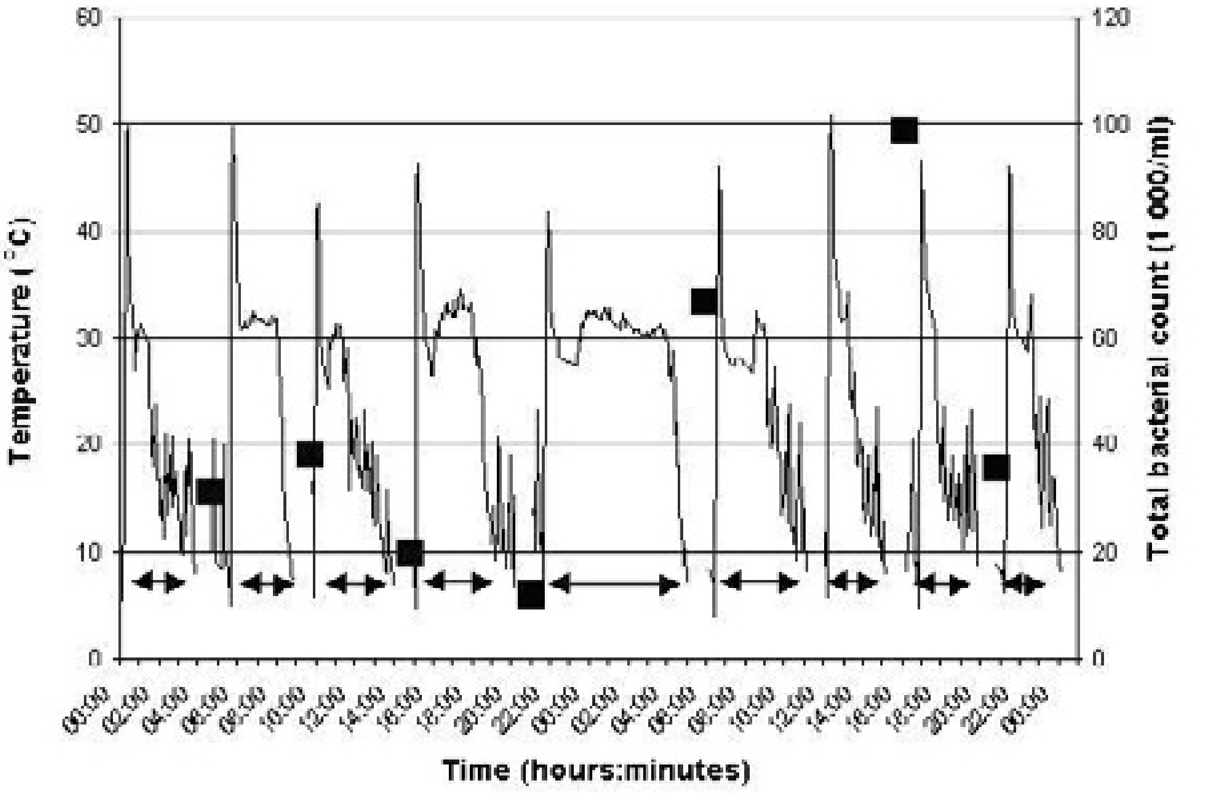

Figure 6. Temperature (°C) measured in the bulk tank at one of the farms that had temporary cooling problems. Temperatures measured from collection of milk and cleaning of the bulk tank until the storage temperature is reached (data from July 9 to July 25). TBC (10^3 cfu/ml) in delivered milk during the same period (■).

During the initial check of the farms, the cleaning cycle was measured on all farms to make sure that the last cleaning water had a sufficiently high temperature (Fig 7). In the study, all farms obtained a sufficiently high temperature in the last cleaning water. Conductivity measurements were made on the cleaning solutions and the final rinse water on all farms. There was a sufficient concentration of detergent in the cleaning solution and there were no detergent residues in the final rinse water for all the farms.

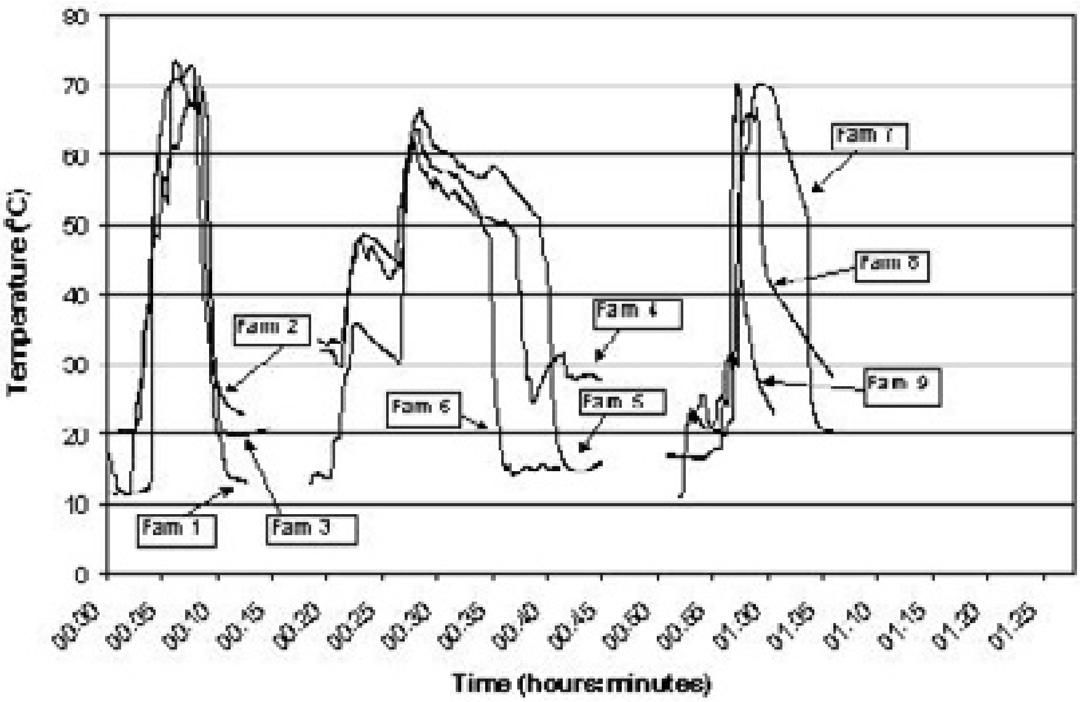

Figure 7. Measured temperature (^oC) during the cleaning cycle for all nine farms.

4. Discussion and recommendations

Both in the Netherlands and in Sweden an significant increase in TBC occurred comparing 2 system cleanings per day with 3 system cleanings. The average increase in TBC is small however, in all cases the mean TBC is far below the level for reduced payment. None of the farms in the Netherlands or in Sweden reached the level for reduced payment (100*10^3 cfu/ml), occasionally this limit is passed in some samples for both 2 and 3 times cleaning. The maximum level of TBC on the studied Swedish farms is exceeding the Swedish class limit of extra payment (30 000 cfu/ml) for one or both cleaning frequencies in 7 of 9 farms. For 2 of the 7 farms, 12-56 % of the collected milk samples were exceeding 30 000 cfu/ml compared to the other 5 farms that only occasionally exceeded that level.
Influence of farm management and brand of the AM-system can be observed. When the cleaning of the AM-system is tuned well and constructed in a sanitary way, the maintenance of the system and the control of the cleaning is performed well, the TBC will be low as well with 3 times cleaning as with 2 times cleaning per day. When the circumstances are less optimal, TBC will vary more and will be raised in average. In these cases the cleaning frequency will have a larger influence, because the system will be more susceptible for shortcomings.

In the Netherlands a significant raise in CC, TC and PC was found at a lower cleaning frequency, where in Sweden no significant differences were found. The level of CC indicates pre-milking hygiene and equipment cleanliness (Knappstein et al., 2002; Reinemann, 2002). CC between 100 and 1000 are an indication of poor milking hygiene and values exceeding 1 000 cfu/ml indicate that bacterial growth is occurring on milking equipment (Reinemann, 2002). In the Netherlands 11 out of 13 farms had an average CC less than 100 when 3 times cleaning and only 2 out of 13 farms when 2 times cleaning. In the Swedish study the CC in most samples in the bulk milk were below 1 000 cfu/ml and 2 out of 9 Swedish farms were not exceeding 100 cfu/ml at all during the data collection period. In countries were CC is part of the payment for quality, penalties for inferior quality will occur. Possibly the longer period between change of filters contributes to the increase in coliform bacteria, assuming that these bacteria will be present in the collected material (dirt) on the filter, multiply and will be partly washed away with the milk passing the filter.
A general problem with AMS irrespective of brand is that the filter change is often not done automatically. The optimal way in filter change is that the operator removes the filter before the start of the cleaning to avoid a decrease in activity of the sanitizer and inserting a new filter after cleaning. The consequence is that the operator has to visit the AMS twice in the right time in each cleaning, with is specially demanding for the farmer at a higher cleaning frequency.
Replacing the old filter by a new one before cleaning is the second best option, cleaning with a dirty filter should be avoided at all times.

TC is another bulk milk test that can be of diagnostic value. TC exceeding 200 cfu/ml indicate poor cleaning of the equipment (Knappstein et al., 2002; Reinemann, 2002). Also a suboptimal teat cleaning could contribute to an elevated TC. All the investigated Dutch and Swedish farms exceeded the above recommended limit. Since the Swedish farms and especially the 2 farms with high TBC have not been investigated further, the reason can not be fully explained. However, there can be two possible explanations. One is that for the 2 farms with high levels of bacteria, all investigated groups of bacteria were high, and therefore it can be a lack in the cleanliness of the environment as well as the cows and the milking equipment. The other is that the milk samples from these farms were transported for a longer time than milk samples from other farms before analysis.

It has also been noticed in this study that recording the temperature in the cooling and the cleaning procedure might be a useful tool in the management system, as an early warning parameter for bacterial problems.

When the AM-system is well constructed from a sanitary view, the cleaning system is optimised and there is a good control of the cleaning by the AM-system and by the operator, it is possible to produce a good quality milk with 2 times cleaning/day. The advantage of 2 times cleaning is less waste of water, energy and detergents and a higher milking capacity.

Defects in the construction or in the cleaning procedure will however show earlier, and will have a larger effect on milk quality. Cleaning 3 times per day is of course a more profound way of cleaning, with less risk for raised bacterial growth. In order to minimise the effect on capacity of the AM-system, it is also possible with 3 times cleaning to choose cleaning times during ‘slow milking hours’. Due to the large differences in cleaning time (Schuiling et al, 2001), the influence of the cleaning frequency on the capacity of AM-systems is depending on brand. In some cases cleaning time can be reduced by optimising the cleaning procedure.

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Appendix

Appendix 1. Method to check the system cleaning

In this test the quantity of water used by the cleaning is checked by collecting the water flowing out of the system during the cleaning cycle.
Conductivity measurements are used to check for the amount of milk or cleaning agent in the last water of the rinse cycles and to check the proper strength of the cleaning solution. Calculations are made of the amount of milk in the last water of the pre-rinse, based of the conductivity of the water and the milk on the farm. The same method is used for the calculation of the percentage of cleaning solution in the last water of the after rinse cycle.
Note. It can be very handy and useful to have a technician of the AMS-company to assist and to tell were the water outlets are.

Materials needed:

Weighing unit (at least 30 kg)	to measure the amount of water
Conductivity meter	
ATP-meter	
10 buckets (plastic)	to collect the water flowing out of the system (in case of low outlet take also low buckets or beholders)
Stopwatch	To measure time needed for the different cycles
Thermometer	
Tubes (different diameters)	To redirect outlets of the AMS to buckets
Laboratory tubes and glasses	To collect samples
Fenolphthaleïne	To test for residues of the cleaning agent (be sure to use an alkaline agent)
Pipette and titration balloon	
Measuring glass (500 ml)	To make a accurate dilution of 0.5% cleaning agent for testing conductivity

Checklist

		Start time	End time	Unit 1	Unit 2
Water					
Conductivity (mS)					
0,5 % Cleaning agent					
Conductivity (mS)					
Melk					
Conductivity (mS)					
System cleaning	**Pre rinse**				
	Water quantity				
	Start temperature				
	End temperature				
	Conductivity last water (mS)				
	>> calculate % of milk				
	Cleaning cycle				
	Water quantity				
	Start temperature				
	End temperature				
	Conductivity cleaning solution (mS)				
	After rinse				
	Water quantity				
	Conductivity last water (mS)				
	>> calculate % of cleaning solution				
	Phenolftaleine-test				
Unit flush					
	Water quantity				
	Conductivity last water (mS)				
	>> calculate % of milk				
Cluster flush					
	Water quantity				
	Conductivity last water (mS)				
	>> calculate % of milk				