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Report 28

Milk Quality and Automatic Milking; a risk inventory

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April 2003

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Preface

This is the report of a study on the relationship between milk quality and the concomitant farm characteristics on farms with an automatic milking system. The research was carried out by order of the Ministry of Agriculture, Nature Management and Fisheries, the Dutch Dairy Board (PZ) and all suppliers of automatic milking systems in order to identify the most important factors that increase the risk of reduced milk quality after the changeover to automatic milking.

We would like to thank the clients who made this research possible. We would also like to thank the Dutch Milk Control Station, the suppliers of automatic milking systems and the dairy industry for controlling and making the data available.

We would particularly like to thank the participating farmers for their time they put into answering questions and for making their data available. We hope this information will help (future) users of automatic milking systems to improve milk quality and/or to maintain high quality levels.

Kees de Koning

Project Manager Milking Research

Summary

This research provides an overview of the management and settings of the AM-system that are applied on farms after introduction. Such a sizeable study has not been done yet, and provides much new information and insights. Moreover, it is tried to gain more insights into the most important risk factors for reduced milk quality. This research indicates that finding clear causal relationships for milk quality after introduction is difficult.

Particularly management issues are hard to define. There is dependency on the reliability of the responses, and the perception and interpretation of the questions. Also the time of the interview may influence the results. For example, if there had been some setbacks in the week prior to the interview, the answers might be different from the ones provided, if things had gone successfully. Moreover, management is variable and a farmer is flexible. There are many changes on a farm and it proves to be difficult to discover which change has resulted in a particular improvement or deterioration. These are all issues that make analysis of such a study difficult.
It is likely that the above has influenced the results of this study. The frequency distributions demonstrate however a clear overview of the current situation on farms with an AM-system. Moreover, the relationships, as described in section 3.4, indicate the most important risk factors that are most likely to play a role. Different aspects have been discussed, if relevant.

It has been proved that almost all farmers are used to the system within 6 months; most cows adjusted already after 2 months. Over 50% of the farms combine grazing with automatic milking. It has also become clear that many farmers spend a considerable amount of time on the daily checking of the cows (teats, condition, signal lists and the overall appearance) and that most farmers think they know their cows well or even better after the introduction of the AM-system.

On average, twice a day farmers have to collect cows with a too large milking interval according to the settings. Mainly free cow traffic is applied and most farms have a milking frequency of 2,5. Moreover, it has become clear that not each farmer meets the KKM (Milk Quality Assurance Programme) standard to clean thrice a day. Also, a specific characteristic of the system, measurement of conductivity, does not prove to be always appreciated, but farmers do use it on a frequent basis, because, as they indicate themselves, a better alternative is lacking. As far as the number of failures is concerned, on most farms this occurs (only) approximately once a month, most of which can be fixed by the farmers themselves.

In general it can be stated that by far the most farmers are satisfied with the purchase of the system and they indicate that they can handle automatic milking well.

The levels of total bacterial count, somatic cell count, free fatty acids and freezing point are, on average, a bit higher than prior to the introduction of automatic milking. However, there are also farms on which these quality parameters have improved after introduction. In general, the increases are smaller if the values were already high before the introduction. Farms that had a relatively low total bacterial count run a higher risk of increasing this after introduction than farms that already had a relatively high total bacterial count before the introduction. The values for total bacterial count and somatic cell count before introduction are positively related to the values after introduction. This indicates that factors that play a role in conventional milking as to these parameters are still important after introduction. Management is thus an important factor here.

Particularly replacing the teat brushes and teat liners, and hygiene of the teat cups prove to be important for total bacterial count. Placing the system in a new facility results in a lower total bacterial count increase on average than placing the system in an existing facility. Replacing the teat liners also proves to be important for the somatic cell count, besides a not too high milk flow. As to the free fatty acids, the increased machine milking time and cleaning seem to play a role. The latter cannot be explained by the current knowledge on free fatty acids. The higher freezing point in automatic milking is related to the rinsing frequency and other aspects of cleaning.

Further relationships between housing and milk quality have not been found. Hygiene does not seem to be strongly related to the milk quality either, nor do factors with regard to cooling show clear relationships. As to this latter item, it might be that a structural influence cannot be discovered anymore, due to frequent maintenance and the current technique of the cooling tanks.

It seems that particularly the factors that play a role in conventional milking as to the milk quality do so in automatic milking as well.

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1 Introduction

The developments in the area of AM-systems have considerably increased lately. At the end of 2002, approximately 520 dairy farms in the Netherlands used such a system. The milk quality of the average Dutch dairy farm is good, including the milk from AM-system farms (Van der Vorst *et al,* 2002). This quality is, however, not similar to that of those farms with a conventional milking system. After introduction of an AM-system, the milk quality decreases, the extent of which has been listed several times (Hoefman, 1998; Rasmussen, 2000); also by the Research Institute for Animal Husbandry (PV) (Klungel *et al*, 1998; Van der Vorst and Hogeveen, 2000, Van der Vorst *et al*, 2002). The studies have shown that total bacterial count and free fatty acids increase after introduction. However, different results have been found as to somatic cell count and freezing point. A recent study by the PV has shown that all the above mentioned quality parameters slightly decrease after introduction (Van der Vorst *et al,* 2002). This study has shown that after introduction a rapid increase in total bacterial count, somatic cell count and freezing point can be observed. Free fatty acids also increase, but more gradually. After 6 to 12 months after introduction total bacterial count and somatic cell count improve again. On most farms, somatic cell count reaches a level similar to the farms with a conventional milking system (170,000 cells/ml) after one year. Total bacterial count is still higher after one year, however (13,000 compared to 8,000 bacteria/ml), but acceptable. Freezing point increases after introduction from on average - 0.522^{0}C to - 0.517^{0}C and remains at that level. The gradual increase in free fatty acids persists for a long time and reaches the level of farms that milk thrice a day in a milking parlour (on average 0.57 mmol/100 g of milk fat).
Particularly the bulk milk somatic cell count and the total bacterial count are internationally considered as important milk quality parameters. An increased freezing point and free fatty acids can also affect the quality image of milk. The free fatty acid level does not recover after some time, nor is there a clear balance.
There are great differences among and within the farms. Some farms continually supply first class milk, the quality of which has hardly changed after introduction, while other farms show a continuous decreased milk quality after introduction. Other farms show incidental peaks in, for example, total bacterial count. The underlying causes of which are not always clear, but yet show that improvements are possible.
The effects of automatic milking on the milk quality are known; the causes of the reduced milk quality, however, are not. They may be ascribed to two aspects: the farmer's management and the technique and software of the milking equipment. The extent to which each aspect contributes is not clear as yet.

To gain more insight into the causes of the reduced milk quality, possible causes have been listed in an observational study in combination with the milk quality data of the period before and after introduction of an AM-system.

By identifying the so-called risk factors that affect the milk quality on farms with an automatic milking system (AM-system), the milk quality may be improved.

2 Material and Methods

2.1 Workshop

Prior to the study a one-day workshop was organised in July 2001, the objective of which was to identify all possible risk factors that might affect the milk quality of the milk produced on farms with an AM-system.
For this workshop, those people were invited who were directly or indirectly involved with automatic milking. Present were representatives from: AM-industry, dairy industry, milk cooling industry, Ministry of Agriculture, Nature Management and Fisheries, Product Board for Dairy Products (PZ), Animal Health Service, Milk Control Station (MCS) (Holland), Nizo Food Research, consultants and farmers who milk with an AM-system.
Four quality parameters were considered: total bacterial count, somatic cell count, freezing point and free fatty acids. The people present first listed all possible risk factors for a particular quality parameter in different groups, after which these factors were discussed by a second group and subdivided as to priority. On the basis of the results of this workshop the research was set up further.

2.2 Selection of farms

The addresses of dairy farms with an AM-system were collected by means of KOM (Association for Quality Care Maintenance Milking Equipment). This list was checked for completeness by the AM-industry, suppliers of AM-systems and by the dairy industry, and completed if necessary. Next, the dairy industry asked the farmers for permission. Those farmers who did not wish to participate were removed from the list. From the resulting data set, farms that had used the AM-system for at least 12 months were selected. Farms that were known to still milk part of the herd in a milking parlour were not considered. The final result was 224 farms. The farms were asked to co-operate at the end of September 2001, and 124 farms were visited in the period of 1 October 2001 to early January 2002. Of the 100 farms that were not visited, 32 had indicated not to be willing to co-operate and 68 farms could not be visited during the time available. After finishing the visits, all farmers received a letter of thanks with information about the course of the study and an extended summary of the results.

2.3 Factors studied

The goal of this study was to relate the milk quality of farms having milked at least 12 months with automatic milking systems to demonstrable risk factors on those farms. The milk quality parameters that were considered are described below, as well as which factors were studied and in what way.

2.3.1 Milk quality data

The milk quality data covering the period January 1, 1997 to December 31, 2001 were provided by the MCS (Milk Control Station) for 3 groups of farms: the farms selected milking with an automatic milking system, a group of 295 farms that milk twice a day in a conventional milking parlour and a group of 40 farms that do so three times a day. The following quality parameters were considered: total bacterial count, somatic cell count, freezing point and free fatty acids (table 1).

Table 1 Milk quality parameters and frequency of control

Milk quality parameter	Freq./yr	Interval
Total bacterial count (TBC)	26	Every 2 weeks
Somatic cell count (SCC)	13	Every 4 weeks
Free fatty acids (FFA)	2	March/April & Sept/Oct
Freezing point (FP)	2	Every 6 months

The data on quality were then related to the farm factors collected. Total bacterial count and somatic cell count were observed in more detail, since these two parameters are internationally considered to be the most important measures of milk quality.

2.3.2 Studying possible accounting variables

For studying possible risk factors on the farms visited, the following 5 means were made use of:
1. Questionnaire
2. Milking machine test report
3. Milk recording system data
4. Hygiene check list
5. Data from the management program AM-system

These data were collected during farm visits, which were performed by two trainees from the Agricultural College at Dronten.

Ad 1. Questionnaire
Based on the results from the workshop (described under 2.1), a questionnaire was formulated, which was subdivided into 11 components:
- General farm data (number of AM-systems, date of introduction, number of cows, quota et cetera)
- General data (labour force, training, succession et cetera)
- Milk quality (control: how?, target level, approach to problems et cetera)
- Animal health (control: how?, curative and preventive approach, cow management et cetera)
- AM-system (orientation before purchase, settings, maintenance, use of data, failures et cetera)
- Cleaning of AM-system (frequency, cleaning AM-system and teats, lengths of tubes, volume of water heaters et cetera)
- Cooling (type, size, control, cleaning, failures et cetera)
- Housing (numbers, removing manure from floor, waiting room, scraping & bedding cubicles et cetera)
- The farmer (control: how and how often?, cow management, timetable for the day, spending leisure time, type of farmer et cetera)
- Feeding (roughage, supplementary feed, concentrates, where and how often, production groups, body condition et cetera)
- Other (cow traffic, grazing, non-lactating cows, replacement percentage, breeding)

The questionnaire consisted mainly of multiple-choice questions. If relevant, also open questions were asked. If found relevant, also questions were asked as to opinions and satisfaction about the AM-system and concomitant factors such as cow management, maintenance and repairs. Anonymity was assured, so that the questions would be answered as reliably as possible. Before the questionnaire was used, it was intensively discussed with co-workers of the Research Institute for Animal Husbandry and with one employer of the Dutch Dairy Board Products (PZ) and tested with 5 farmers.

Ad 2. Milking machine test report
The most recent periodic test report was used, from which the following 5 items were noted down (per AM-system):
- Air inlet teat cups
- Air leakage milk line
- Pulsation rate
- Pulsator ratio (a+b and c+d)
- Vacuum

Ad 3. Milk recording system data
If available, the following data were included from the two latest annual overviews of the milk recording system:
- Kg of milk
- % fat and protein
- Average age of herd
- Which breed
- Number of cows
- Average number of lactation days
- Calving interval (current)

Moreover, the following data were copied from the latest periodic milk recording data form:
- Kg of milk
- Number of cows

Ad 4. Hygiene checklist

Besides the questionnaire, also a brief inventory was done in the barn as to hygiene, presence or lack of particular aspects, construction of the barn and the bulk tank room. The list consisted of 4 items.

- Hygiene

  Hygiene was visually inspected for the components: AM-system, housing and climate in the facility. Three categories were used: good, moderate, and poor. The criteria were the following:

Component	**Criteria paid attention to**
First impression of the farm	Extent to which the farm is tidy and cleaned
First impression of the barn	Impression feeding walkway, humidity, cobwebs, manure
Impression of AMS	Manure on floor and walls, cleanliness equipment
Impression of the waiting area	Presence of dirt, old or fresh manure
Floor AMS	Presence of dirt, old or fresh manure
Teat cups	Presence of dirt, milk and manure
Robot arm	Presence of dirt, milk, manure or damage
Pre-milking device	Presence of dirt or manure, state of maintenance
Bulk tank room	Tidiness, cleanliness
Finishing AMS room	Room, clear organisation, tidiness
Feeding walkway	Remains of feed, dirt and odour
Floor facility	Presence of old or fresh manure
Storage bedding material	Outside or inside, whether or not in packages, whether or not humid
Water trough	Clarity of water, odour, sediment
Climate in barn	Volume of barn, air humidity, odour
Illumination in barn	Presence of badly lit parts
Ventilation	Fresh air influx

- Yes/no

  Here the presence or lack of particular aspects was checked, such as: farm clothing, hygiene corridor, manure scraper and windbreaking screens.
- Type

  Here the construction and type of the bulk tank and housing (sidewalls, floor, ridge) were noted down
- Other

  Here distances and locations were registered (distance from AM-system to tank, distance from main tank to first rinsing valve, place of the AM-system in the barn et cetera).

Ad 5. Data from management program of AM-system

From the management program of the AM-system the following data of the 24 hours prior to the visit were collected:

- number of milking per box
- hours of idle time per box
- time for cleaning per box
- number of refusals per box
- total milk yield per box
- average milk flow per box
- average milking interval of total herd

Not all farmers proved to have sufficient insight into the management programs to print out these values or the system was not able to do that at herd level. This resulted in a couple of lacking values in the dataset.

2.4 Data analysis

All data as described under 2.3.2 were entered into a database in Access by the trainees, of which they made two reports. The factors were studied further by the Research Institute for Animal Husbandry by the calculation program Excel and further analysed with the statistical program Genstat, 5th edition.

2.4.1 Representativeness of farms visited

Prior to the analysis of the data collected, the farms surveyed were checked for representativeness of an average farm with an AM-system as to the milk quality. To this end, the milk quality data of the 3 groups of farms were compared in time on the basis of the averages per periods of 30 days. Geometric averages were calculated for total bacterial count, somatic cell count and free fatty acids. In this way the peaks that can occur for these parameters have less influence on the averages and will show the average level at the farms in a most optimal way. For the freezing point the arithmetic average was used, because no extremely high or low values occurred for this parameter (normal distribution). The averages calculated give an impression of the development of the four milk quality parameters on farms with an AM-system compared with conventionally milking farms. Furthermore, the course of the four milk quality parameters were compared in time on the farms that were surveyed (n=124) and those that were not (n=100) (so, before and after introduction of the AM-system).

Besides the average values for the four quality parameters, also the number of penalty points was considered on the farms surveyed. To this end, the percentage of tank milk samples with penalty points was calculated for four 6-month periods before and after the introduction of the AM-system. This was done additionally because the penalty point system of the milk control station (MCS) was not similar over the years. For total bacterial count 1 penalty point was calculated with for a value of >100,000/ml and ≤250,000/ml and 2 penalty points for values of >250,000/ml. For somatic cell count a value of between 400,000 and 500,000 resulted in 1 penalty point and a somatic cell count of >500,000 resulted in 2 penalty points. For free fatty acids 2 penalty points were calculated for values of >1.00 mmol/100g of fat. For the freezing point values of >-0.505 °C resulted in 1 penalty point.

2.4.2 Descriptive statistics

Before starting the statistical analysis, all data collected were ordered. First, frequency tables, histograms, were made for a number of the farm factors studied to gain more insight into the way the farmer works with an AM-system. At each histogram the data collected are discussed.

2.4.3 Subdivision of groups

The averages were calculated from the MCS-data for the farms surveyed as to the milk quality parameters total bacterial count, somatic cell count, free fatty acids and freezing point for different comparable periods before and after introduction. Because the milk quality between seasons can differ, it is important that the periods before and after introduction concern the same seasons. In this study the following periods were considered:

- Annual periods: the last year before introduction together with the first year after introduction
- 6-month periods: from month 7 to month 1 before introduction and from month 6 to month 11 after introduction.

The 6-month periods cover the same season, before as well as after introduction. These periods were chosen besides the yearly periods, since the effect of the changes during the introduction of the AM-system might have less influence on the milk quality here and thus other factors might play a role.

For the analysis, the average values were calculated per farm before and after introduction (for the above mentioned periods) and with the differences (after minus before introduction) per farm. Thus, a reduction or increase in milk quality respectively.
Of the 124 farms surveyed, 4 farms were excluded from further analysis, because they also used a conventional milking parlour. One farm was excluded because no milk quality data were available, and 5 farms were removed because only milk quality data of the period after introduction were available. An analysis could yet be made for 114 farms of the change in milk quality in the first year after introduction compared to the last year before

introduction. A value for free fatty acids or freezing point could not be determined for all farms in the period between month 7 and month 1 before introduction or in the period between 6 and 11 months after introduction since the determination frequency was too low. The change in the free fatty acids for these periods was calculated for 95 farms and the change in freezing point for 75 farms.

2.4.4 Linear regression

With use of linear regression (Genstat, 5th ed.) it was calculated to what extent the values of the milk quality parameters before introduction were related to the values after introduction and to the size of the changes (degree of increase or decrease). To this end, a classification was made on the basis of the level of each parameter before introduction.

- Total bacterial count was subdivided into 5 classes: ≤5, >5-≤8, >8-≤12, >12-≤20 and >20
- Somatic cell count was subdivided into 4 classes: ≤150, >150-≤180, >180-≤210 and >210
- Free fatty acids was subdivided into 4 classes: ≤0.37, >0.037-≤0.42, >0.42-≤0.47 and >0.47
- Freezing point was subdivided into 4 classes: ≥-0.520, <-0.520-≥-0.522, <-0.522-≥-0.524 and <-0.524.

For analysis of the free fatty acids and freezing point, only those parameters were considered that concerned the entire year after and before introduction, for the level as well as the change, because for the 6-month periods too few data were available.

The data (variables) acquired by the questionnaire and the farm visits were classified for the purpose of linear regression analysis. Appendix 1 shows the classification that was used in the calculations. Through linear regression (Genstat, 5th ed.) it was studied which of these variables showed a relation with the milk quality parameters. The regressions were carried out per related cluster of variables (relation was assumed on the basis of the distribution of the questionnaire, see 2.3.2) as to the milk quality parameters after introduction (the first year as well as 6 months to 11 months after introduction) and the change in milk quality after introduction in these periods.
It was calculated which of the variables were significantly related to the milk quality parameters in a marginal (only the variable concerned was included in the model) and a conditional model (the variable was added to a model that already included all other possible variables from the cluster). Subsequentlyk, all models were constructed, in which only the significant variables were included and the nature of the relations between these variables and the quality parameters found were evaluated.

The results of these models are presented and discussed in sections 3.4 and 3.5.

3 Results and Discussion

3.1 Representativeness of milk quality on farms surveyed

Milk quality before introduction
Total bacterial count of farms that introduced automatic milking was on average not different before introduction from farms that milked in a conventional way. It could be noticed, however, that the total bacterial count gradually decreased from 1 January 1997 to 31 December 2001 for the conventionally milking farms. Total bacterial count was, on average, lowest in the period of April-June and the highest in October-December, which was caused by seasonal effects and by the determination method of the milk control station.

Also somatic cell count of farms that introduced automatic milking did not differ on average before introduction from farms that still milked in a conventional way. Conventionally milking farms showed a slightly increased tendency as to somatic cell count in the years 1997 to 2001. The tank milk somatic cell count was somewhat higher on farms that milked three times a day than on farms that did so twice a day, but this difference was not significant. Somatic cell count was, on average, highest in August and September and lowest in February and March.

For free fatty acids and freezing point there was less information available than for total bacterial count and somatic cell count due to the lower determination frequency. On average, before introduction free fatty acids of farms that started automatic milking were equal to farms that milked twice a day in a conventional way. Farms milking 3 times a day had a higher degree of free fatty acids. With regard to the freezing point, the farms now milking with an AM-system were not different before introduction from farms that milked twice or three times a day in a conventional way.

Course of milk quality
The course of milk quality before and after introduction of automatic milking is presented in Appendix 2 for the farms surveyed and not surveyed with an AM-system. This is based on the averages for both groups of farms per day in relation to the situation before introduction. The milk quality of the farms surveyed seems to be representative of the total group of farms that introduced automatic milking.
Total bacterial count considerably increased after introduction initially, but after ±100 days improvement could be seen. The level of approximately 10,000 bacteria/ml remained higher than before introduction, however. Also somatic cell count increased particularly the first 100 days after introduction, after which no clear change could be observed within the first 400 days. Free fatty acids kept rising gradually on average during the first 400 days after introduction from ± 0.40 to 0.60. Freezing point became higher particularly in the first 150 days after introduction, after which it remained at an increased but stable level. For an elaborate analysis of milk quality on farms with an AM-system one is referred to Van der Vorst et al., 2002.

Penalties
For the farms surveyed, the percentage of penalty points for the four milk quality parameters were calculated for four 6-month periods surrounding the introduction (see 2.4.1). The results are presented in table 2.

Table 2 Distribution of penalty points per milk quality parameter for 4 different periods before and after introduction

Parameter	Period	% without penalties	% w/ 1 point	% w/ 2 points
TBC	365-183 days before introduction	99.2	0.5	0.3
TBC	182-1 days before introduction	99.6	0.3	0.1
TBC	1-182 days after introduction	96.9	1.7	1.4
TBC	183-365 days after introduction	98.6	1.2	0.3
SCC	365-183 days before introduction	98.5	1.4	0.1
SCC	182-1 days before introduction	97.3	2.0	0.7
SCC	1-182 days after introduction	93.7	4.4	1.9
SCC	183-365 days after introduction	94.2	3.8	2.0
FFA	365-183 days before introduction	100	n.a.	0
FFA	182-1 days before introduction	100	n.a.	0
FFA	1-182 days after introduction	95.7	n.a.	4.3
FFA	183-365 days after introduction	91.4	n.a.	8.6
FP	365-183 days before introduction	100	0	n.a.
FP	182-1 days before introduction	100	0	n.a.
FP	1-182 days after introduction	99.2	0.8	n.a.
FP	183-365 days after introduction	100	0	n.a.

TBC=total bacterial count, SCC=somatic cell count, FFA=free fatty acids, FP=freezing point

The percentage of penalty points for total bacterial count was low before introduction. After introduction it was clearly increased initially, but was decreased again in the second 6 months after introduction. However, the percentage remained higher compared to the situation before introduction. Values of >250,000 per ml (two penalty points) occurred considerably less often in the second 6 months after introduction than in the first 6 months. For somatic cell count it can be seen that in the first 6 months before introduction the percentage of penalty points had already increased slightly. After introduction there was a further increase that did not differ much between the first and second 6 months. Penalty points due to too many free fatty acids frequently occurred, the increase continued in the second 6 months. Regarding freezing point, only in the first 6 months after introduction a small increase in the percentage of penalty points could be observed.

3.2 Descriptive statistics

The frequency distributions are presented below per component, as described in section 2.3.2. If relevant, graphs have been used, other information has been described. Not all questions were answered by all farms, because some information was unknown to the farmer or he/she was insecure (for example, the percentage of clinical mastitis) or because a particular question did not concern the farm in question. Numbers are presented if relevant.

3.2.1 Farm data

The largest group (48%) of farms introduced AM in 1999, 31% in 2000 and 15% in 1998. The other farms in the dataset introduced AM in 1996 or 1997 (6%). One farm had already introduced an AM-system before 1996.
In this study the different brands are presented in representative numbers. Of the 124 farms visited, the single-box system was the most frequent one.

Table 3 shows the general farm data of the 124 farms. The number of animals present was taken from the milk recording system. The production data were obtained from the farmer him/herself.

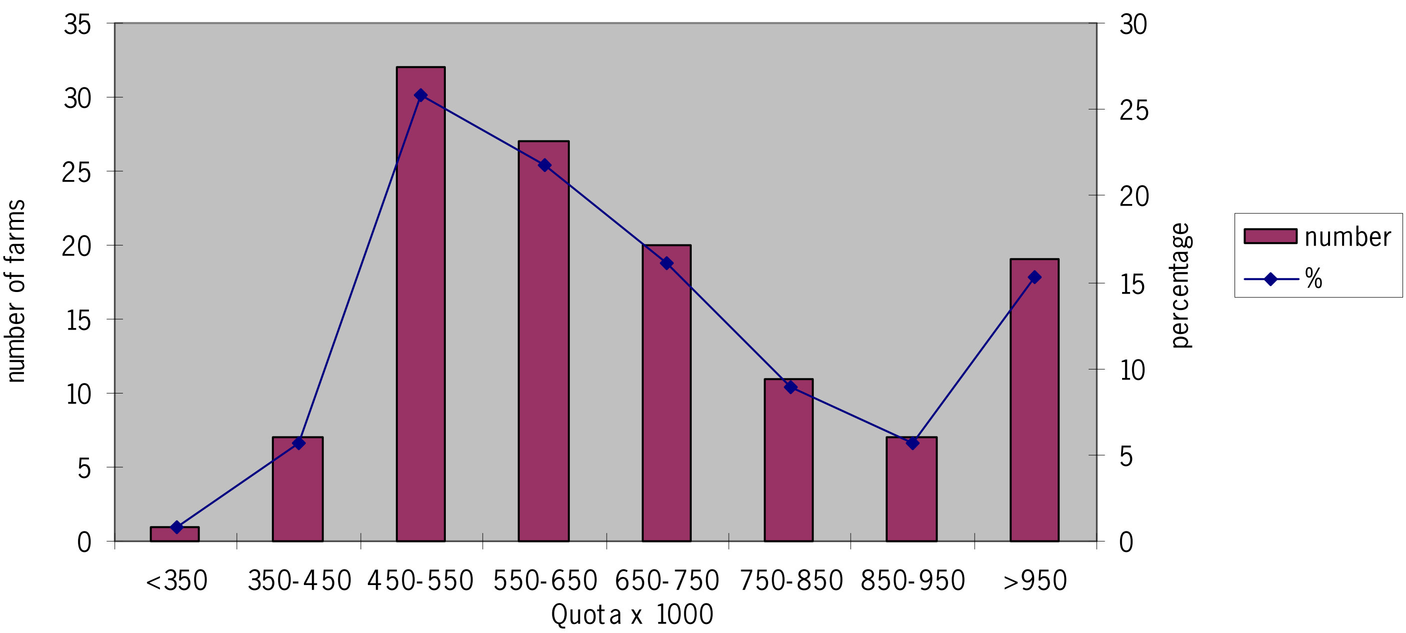
Table 3 Average farm data of 124 farms studied

Type	Number of systems	Number of boxes	Number of farms	Number of cows	Cows per box	Production per cow	Quota x 1000	Litres per box per yr x 1000*	Litres per box per day*
Single-box	1	1	79	58	58	8914	547	547	1499
	2	2	28	90	45	9121	976	488	1337
	3	3	1	137	46	9427	1600	533	1460
Multi-box	1	2	10	61	30.5	8856	618	309	846
	1	3	5	75	25	8607	801	267	732
	1	4	1	149	37.3	8597	1200	300	822

*These are numbers calculated from the farm quota as given by the farm manager. It is possible that farms with low productions per stall tend to expand in the future.

The average milk yield before introduction was equal to 8263 kg per cow (305-day production). After introduction this was equal to 8701 kg per cow, which is an average increase of over 5%. However, there was a great range in the production effects reported by the farmers; the largest reduction given was 1633 kg (16% reduction), the largest increase was 2250 kg (35%). Almost one-third of the farms did not have a production increase after introduction, over 19% had a production decrease even after introduction. On seven of these farms with reduced milk production, this was equal to or more than 500 litres. On 70% of the farms an increase in milk production could be observed, ranging from 1 to 35%.
Figure 1 shows the frequency distribution of the quota. It is clear that the farms that introduced the AM-system are primarily farms with a quota of between 450,000 and 750,000 litres. These are productions that are feasible with a single-box system, although a production of over 700 tons requires an enormous effort of the farmers' management capacities. Twenty of the 124 farms did not utilise their entire quota, the reason of which is not known.

Figure 1 Milk quota per farm (n=123)

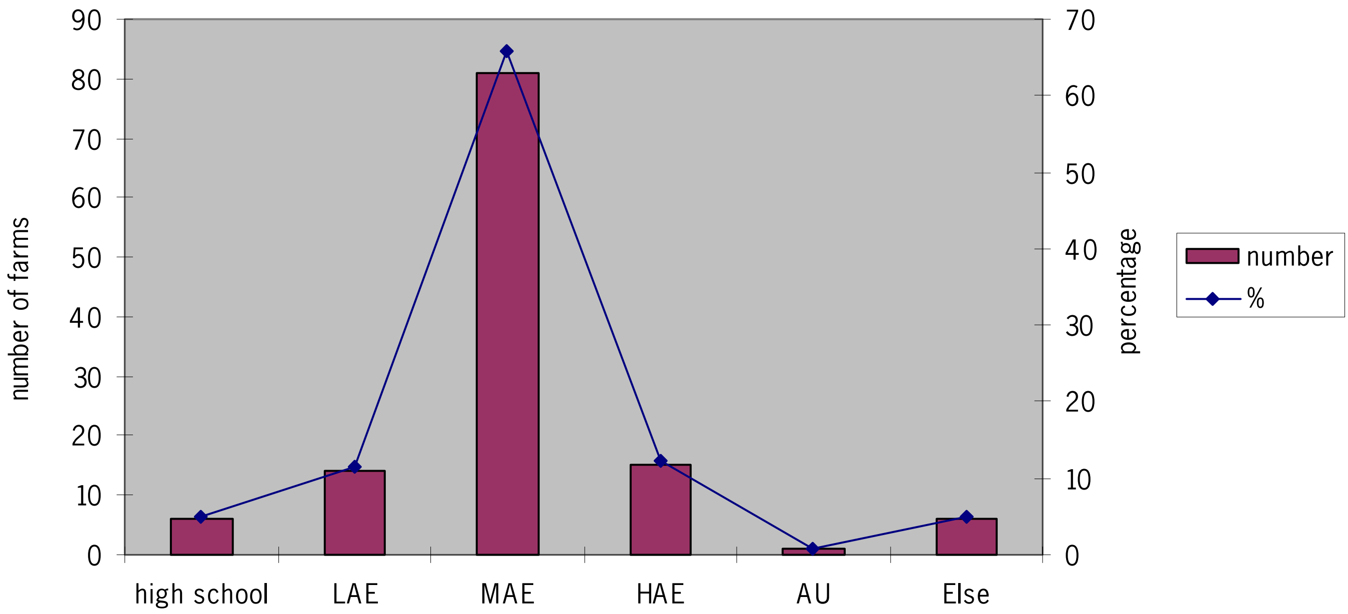


3.2.2 General information

In almost all cases (except for 3 farms) the male is involved in the farm in determining the farm management as well as in cattle control. In 26% of the cases also the female is involved in the management and in 17% of the cases also in cattle control. In cattle control it has been indicated that in 27% of the cases also another person than a relative is involved. These may be consultants, veterinarians, but also suppliers of AM-systems. Thirty percent of the farmers are sure to have a successor and over 50% do not know yet. Average age of the farmers who have indicated to have a successor is 50 years old. The group of farmers who do not know exactly to have a successor is on average 41 years old.

By far the highest degree of education of the male is intermediate agricultural education (IAE). Five percent of the men have followed another course than agricultural (see figure 2). Moreover, 65% of the farmers also participate in study groups.

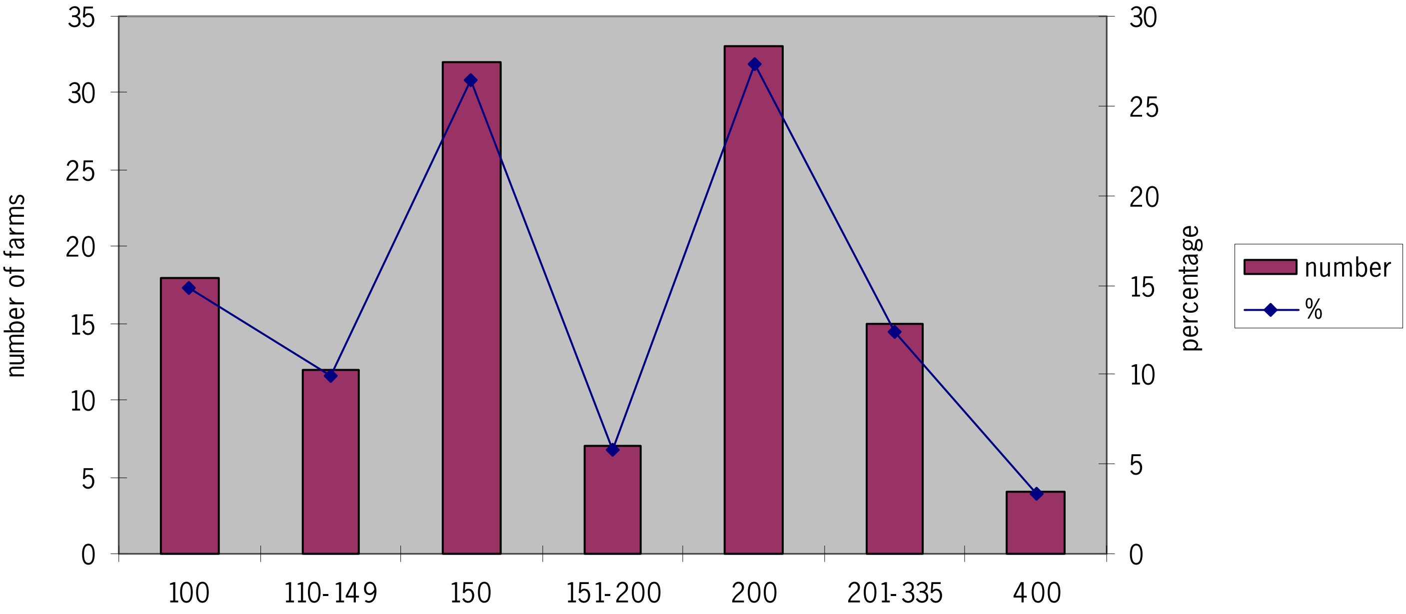
Figure 2 Highest degree of education of male (*AE=Lower, IAE=Intermediate or HAE=Higher Agricultural Education, AU=Agricultural University) (n=123)



3.2.3 Milk quality

Target values
To get an impression of the farmer's knowledge about his own milk quality data and the target levels he deals with, some questions were asked. A comparison of the values for total bacterial count, somatic cell count, free fatty acids and freezing point that were given by the farmers with the data of the milk control station indicates that the farmers have a clear picture of these parameters for their farms. Figure 3 indicates the frequency of the most-given values for somatic cell count, below which farmers want to remain. Over 84% of the farmers have indicated to strive after a value of 200,000 cells/ml or less, 61% of whom even after an average somatic cell count of less than 150,000 cells/ml. For information, a recent study (Van der Vorst *et al*, 2002) has shown that the average somatic cell count on AM-farms is equal to 204,000 cells/ml. For conventional farms this number is 176,000 cells/ml. It should be mentioned, however, that on most farms somatic cell count is equal to the normal level after about one year after introduction. Aiming at a somatic cell count below 150,000 cells/ml is yet very ambitious. Four farms deal with a target level of 400,000 cells/ml, which is equal to the penalty limit. Detailed study of the data on somatic cell count of these farms showed they have had an average geometrical somatic cell count of about 300,000 cells/ml since the introduction. Moreover, these farms regularly get a penalty point due to too high somatic cell counts, which makes some improvement necessary on these farms.
85% of the farmers have indicated they themselves are responsible for an adequate somatic cell count and 3% of the farmers hold the maintenance mechanic of the AM-system responsible. Twelve percent hold others responsible, which may be the veterinarian or other farm managers.
For total bacterial count 74% of the farmers have indicated to aim at a level of 10,000 bacteria/ml, 22% of whom want to reach a level of below these 10,000 bacteria. The highest target level mentioned is 20,000 bacteria/ml. As with somatic cell count the farmer holds himself responsible for total bacterial count (88% of the farms). Moreover, the maintenance mechanics of the cooling system and the AM-system are considered co-responsible.

Figure 3 Target values for somatic cell counts as given by the farmer (SCC x 1000) (n=122)



Activities and responsibilities by deterioration of milk quality
If there is an increase in total bacterial count, over 93% of the farmers check their cleaning system, whether or not in combination with the cooling system. If a high total bacterial count occurs, only 4% of the farmers call the cooling system or AM-system mechanic immediately, without checking for possible reasons themselves. Three percent of the farmers do nothing when there is an increase in total bacterial count and assume that this will reduce automatically.
As to the free fatty acids and the freezing point of the milk the responsibilities are considered somewhat differently. Only 59% of the farmers think they themselves are responsible and over 25% of them hold others responsible. Within this range the supplier of the AM-system is mentioned most frequently, but also cows are considered to be responsible (sensitive cows, late lactating cows and the like). The remaining 16% hold themselves responsible as well as others.
The perception of the responsibilities as to freezing point corresponds to that for the free fatty acids. In over 60% of the cases the farmer holds himself responsible for the values of the freezing point. In 20% of the cases he holds others responsible. As with free fatty acids, particularly the AM-system mechanic is mentioned. The other 20% of the farmers hold themselves responsible as well as others.

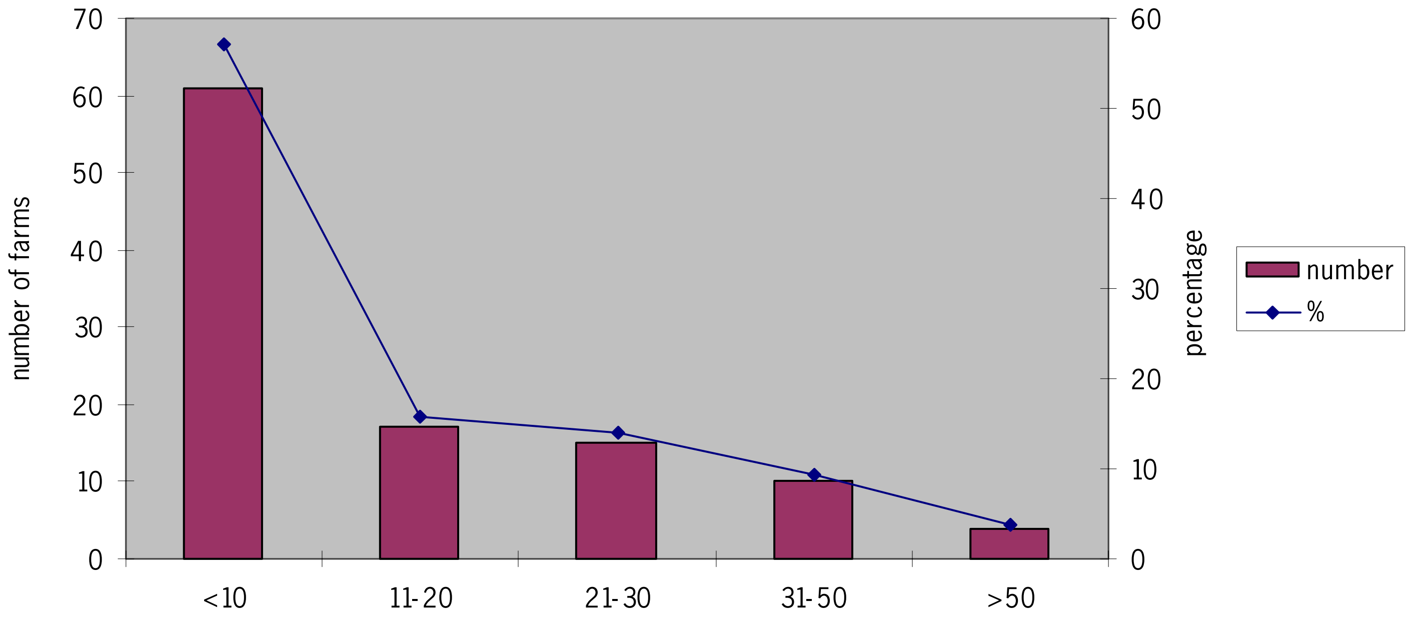
3.2.4 Animal health

For obtaining an impression of the animal health status at the farms visited we depended on the perception and interpretation of the farmer as to this subject matter. Because this differs much among farms and to be able to get an adequate impression concerning this subject, many questions were aimed at registration animal health and dealing with these data.

Type of registration
Six of the 124 farms do not participate in milk recording. 44% of the farms have their cows recorded every other 3 or 4 weeks and 51% of the farms every other 5 or 6 weeks. 95% of the farms with milk recording also use these data to follow the cow somatic cell count and to do something if necessary. Besides these data, 75% of the farms also use the bulk tank somatic cell count and/or conductivity results. 60% of the farms use the cow somatic cell count, bulk tank somatic cell count as well as the conductivity to follow the somatic cell count carefully. 16% of the farms do not use the conductivity to follow somatic cell count, although conductivity sensors were available. However, at a few farms measuring conductivity is only possible at udder level, which provides less information than at quarter level.

Mastitis
After that, the farmer was asked for the percentage of clinical mastitis incidences on the farm during the latest year. These values are presented in figure 4. 57% of the farmers have indicated a mastitis percentage of lower than 10%. Almost 30% of the farmers have indicated to have a percentage of between 10 and 30%. Almost 4% of the farms have a mastitis percentage of higher than 50%. The number of farms with a mastitis percentage lower than 10% seems fairly large, because research on common commercial farms by the Research Institute for Animal Husbandry has shown that in practice the percentage of clinical mastitis is approximately 25%, on average. It is known that farmers underestimate the real figure for mastitis. The data in figure 4 should therefore be interpreted with care.

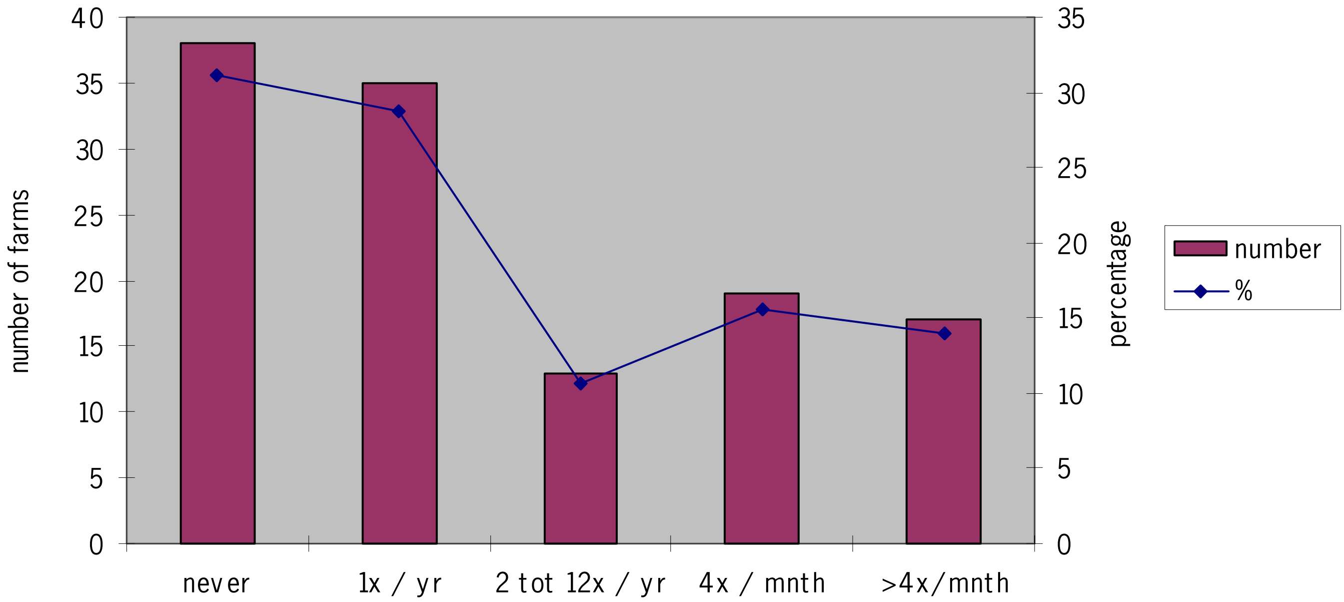
Figure 4 Average percentage of mastitis on farm as given by farmer (n=107)



48% of the farmers have indicated they milk clinically mastitic cows just as others in the AM-system and that they do not take extra measures with regard to the cow. So, over half of the farmers pay extra attention to mastitic cows. This mostly concerns extra stripping (by hand), milking more often, milking with a separate milking device and (partially) handmilking. 29% of the farmers have indicated to milk cows by hand once in a while, when they suppose the cow suffers from mastitis.
Only 16% of the farms have indicated to have a farm treatment plan for diseased animals. Even fewer, only 2%, have a mastitis planner. Moreover, these farms use this planner only if a problem has already risen, which is also a reason for interpreting figure 4 with care.

Teat condition
Figure 5 presents how often the teats are inspected after introduction of the AM-system. 38 of the 122 farms (2 missing values) have indicated to never inspect the teats (see figure 5). 35 farms inspect the teats once a year while 16 farms have indicated to inspect the teats every day. Interpretation of inspection of the teats plays a role here. One farmer will kneel down and inspect thoroughly all teats, while another will look superficially at the cows and udder (and thus the teats) while he/she is in the housing facility for other chores. Yet, it is difficult to interpret this item adequately. In general this is not a subject of much concern on the farms. Farmers do have an opinion on teat condition, however. In total on 54% of the farms teat condition has improved after introduction. Over half of the farms (n=38) have indicated that they do not inspect the teats seriously. 40% have indicated that teat condition has not changed and 2% have reported that this condition has decreased even. The other farms (n=5) do not have an opinion on this, since they never check the teats and thus do not know anything about it.

Figure 5 Frequency of teat inspection on farm (n=122)



Data from AM-system
Besides registration in for example standard overviews the farmer was also asked what he does with the information he can obtain from the management system of the AM-system.
Sixteen percent of the farmers mentioned they never check milk yield per cow, while 52% of the farmers do so daily and 33% check this even more often (maximum was 6 times a day (n=1)). Milking interval is never checked by 26% of the farmers, 16% do so once a day and 57% do so more often than once a day (maximum was 6 times a day (n=2)). On farms that said to never check the milking interval this does not seem to be related to the robot occupancy (cows/box). Only 7% of the farmers never check conductivity. The greater part (50%) check this once a day and 43% do so more often (maximum was 8 times a day (n=1)).
It seems that first conductivity, then milk yield and then milking interval are considered the most important outputs. Besides these 3 parameters, 33% of the farmers also check for other aspects, among which particularly intake of concentrates/feed and the cows' activity. If a farmer suspects a cow of suffering from mastitis, 45% of the farmers check the filter for flakes.

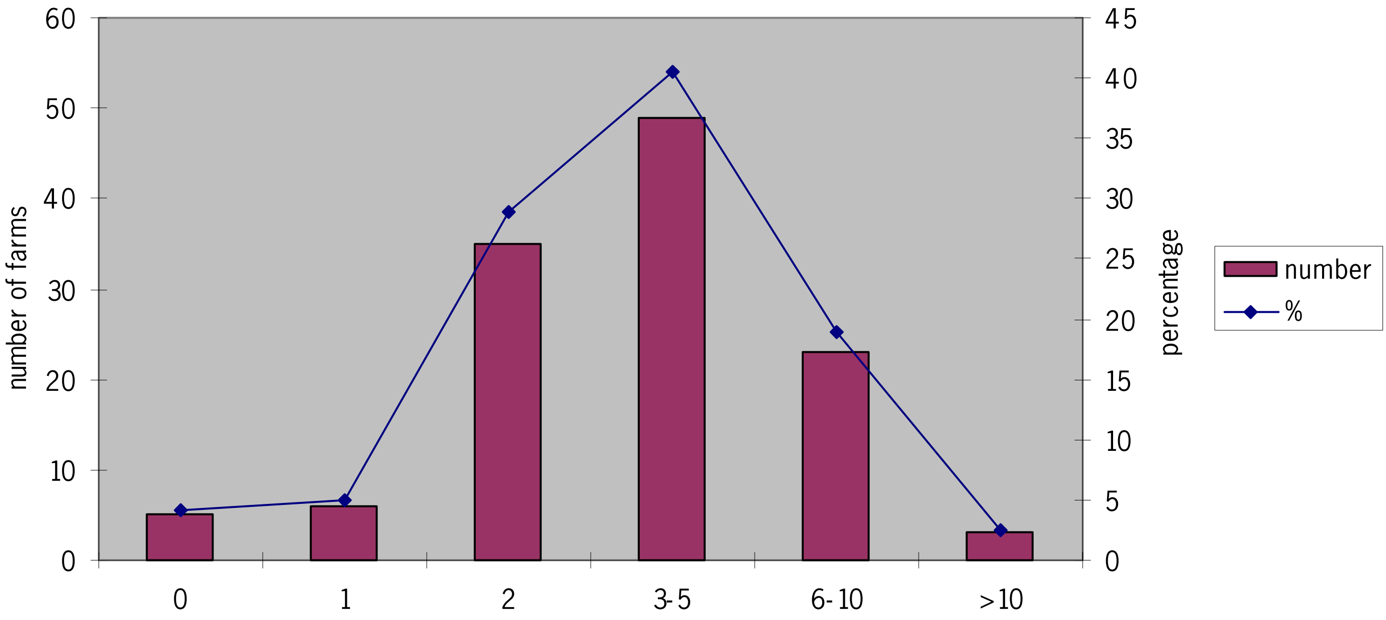
Alert lists and response of farmer
If a cow appears on the alert list, 65% of the farmers check immediately. This does not seem to be related to the number of times that a farmer checks the alert lists. 34% of the farmers have indicated that whether or not to check strongly depends on the cow's history. Some cows are well known and do not receive immediate attention. With early lactating cows farmers check immediately. Also the time of the day plays a role in whether or not checking immediately.

Conductivity
Figure 6 presents the number of cows that appear on the signal list daily, due to high values for conductivity. These marginal values have been indicated by the farmers themselves and differ among the various brands and are thus not comparable. This figure provides an indication of how many cows the average farmer with an AM-system is willing to check for conductivity daily. 4% of the farms have indicated to never have a cow on the signal list due to high conductivity values. The greater part of the farms (70%) have indicated to have between 2 and 5 cows on the lists every day, which is a number that can be handled. Three farmers check more than 10 cows with high conductivity every day. Related to the number of cows per farm, on average 6% of the cows appear on the list of high conductivity daily. For a herd of 60 cows this means slightly less than 4 cows a day.

14% of the farms have linked an alarm system to conductivity, so that they will be warned at an early stage. These are primarily farms that have relatively few cows on the signal lists due to conductivity.

Wrongful signals
The above shows that conductivity is a much-used output parameter of the AM-system. Figure 7 shows, however, that the operation of the system is not always appreciated well. Two farms (2%) have stated that none of the

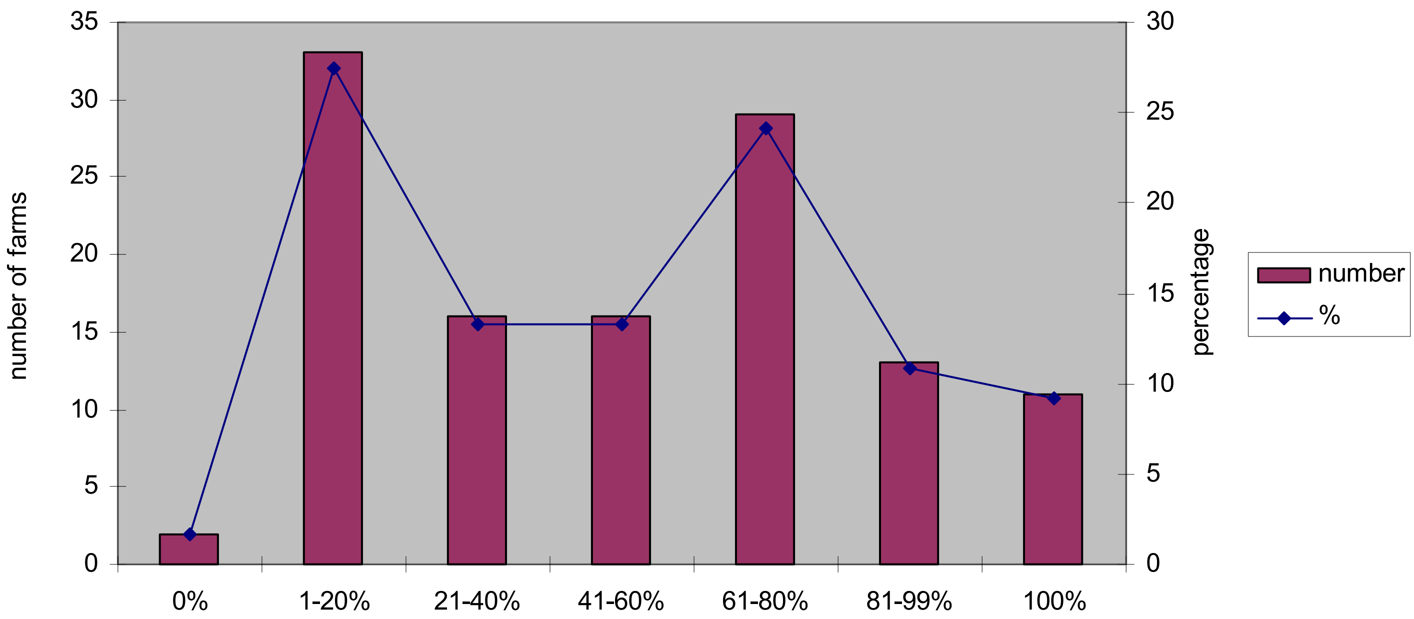
Figure 6 Average number of cows that appear daily on the signal lists for high conductivity levels. The high levels are predetermined by the farmer. (n=121)



conductivity signals are correct, while 11 farms (9%) find that all signals can be considered correct. 20% of the farms find that more than 80% of the signals are correct. This means that, according to the farmers, of each five cows that are on the list daily, one can be considered wrongful.

Most farmers have indicated, however, that it is mostly clear immediately which cows can be considered wrongful signals. The two most important reasons that have been indicated for wrongful signals are late lactating cows, whether or not in combination with low milk yield and a brief milking interval, and oestrous cows. Moreover, diseased animals, cows having suffered from mastitis and colostrum cows have been indicated as being the cause. The question is whether this can be considered wrongful signals; after all these cows suffer from something. Only four farms have indicated that wrongful signals can be blamed on the software of the AM-system. 26 farms (22%) have indicated that they do not know why these wrongful signals occur. Whether or not this is considered a shortcoming of the conductivity is not known.

Figure 7 Percentage of conductivity signals that are considered to be correct (n=120)

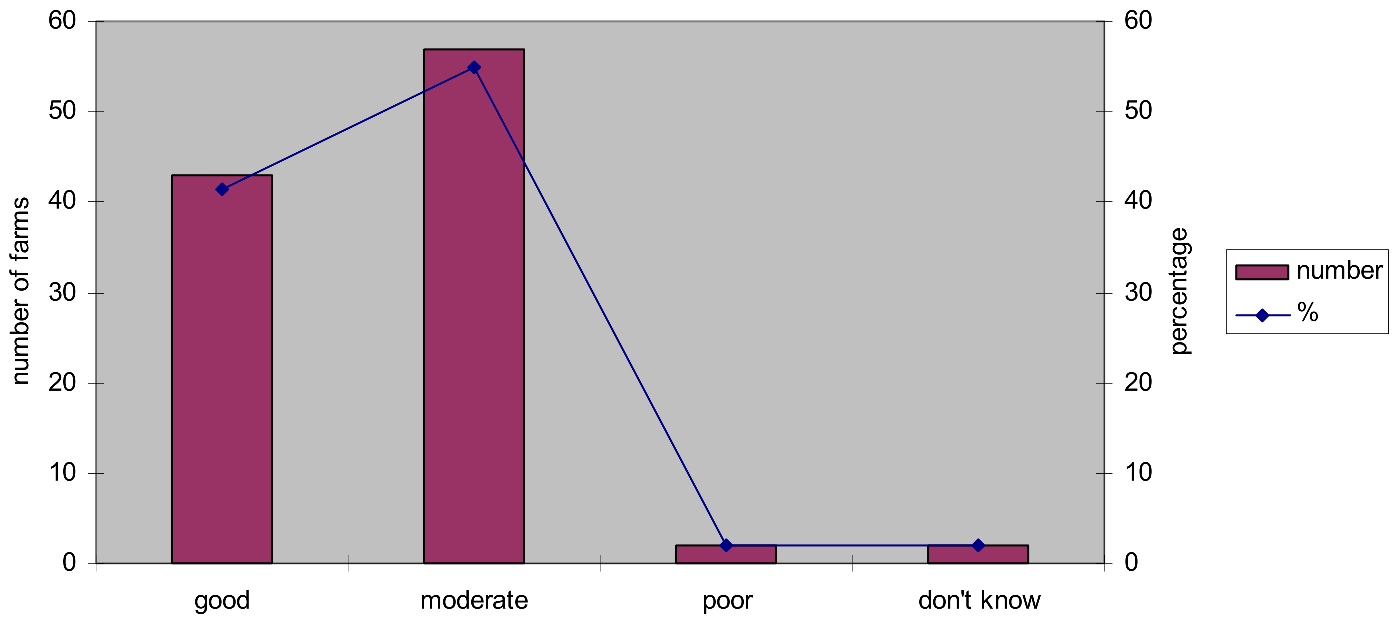


3.2.5 AM-system

Perception and orientation before introduction
Almost all farms (96%) had familiarised themselves with the AM-system prior to purchase by means of farm visits throughout the Netherlands. Eleven percent had (also) been on farms abroad. Besides farm visits, 26% of the farmers had also had themselves informed by means of courses and/or study groups in the Netherlands.
As far as the results as to the belief one had of the possibilities of the system prior to purchase are concerned, 43% of the farms have indicated that all or most of these expectations with respect to the system have been met. 47% have indicated that these expectations have only partly been met and slightly less than 10% have stated that these expectations have not been met at all.

Spraying
As to the use of the system, the greater majority applies spraying after milking (84%), which is, of course, also dependent on the possibilities of the system. Of those farms that apply spraying, 70% use an iodine solution and 16% a chlorine solution. The remaining farms use other products.
The farmers' satisfaction as to spraying is presented in figure 8. 55% of the farmers find that this happens moderately and 2% poorly. This often concerns the way in which the teats can be touched. 2% of the farmers do not have an opinion about the quality of spraying, because they never check it.

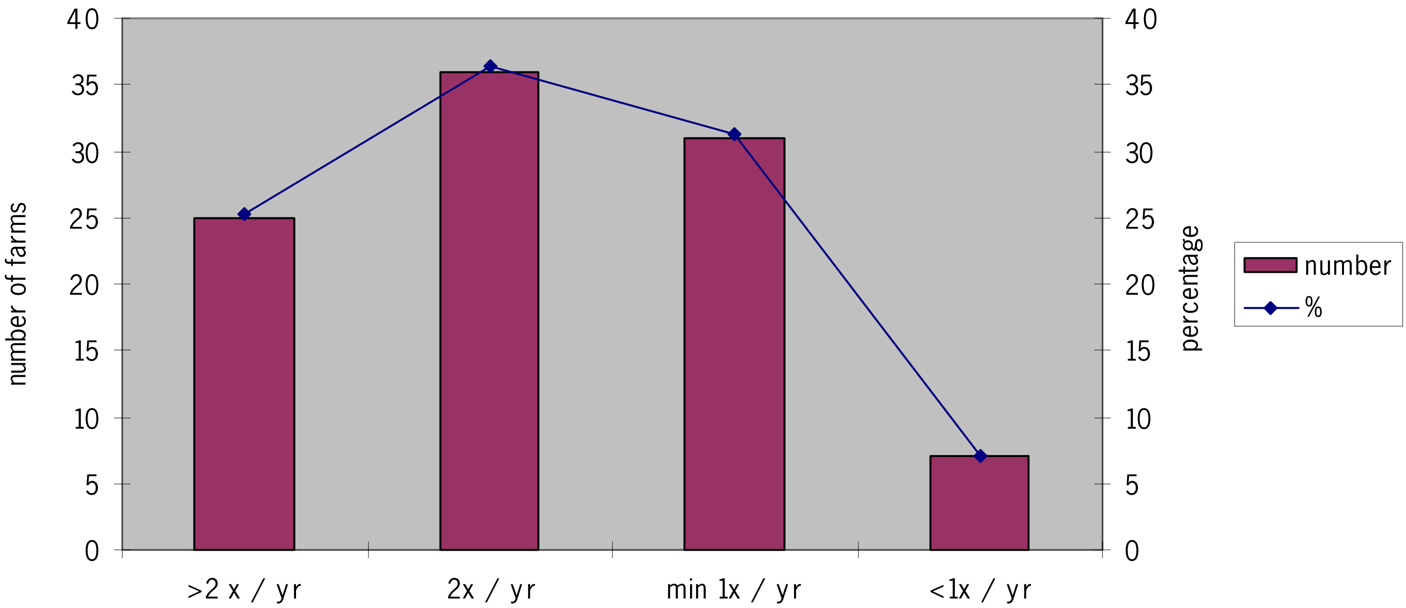
Figure 8 Satisfactory level of farmer regarding spraying of teats by AM-system (n=104)



Replacing teat liners and teat brushes/cups
As far as replacing teat liners is concerned, 74% of the farmers have indicated that they themselves determine the time at which this should happen. 24% of the farmers wait until the system indicates that they should be replaced and almost 3% of the farmers have the mechanic do this.
Figure 9 shows the data on the brands Lely Astronaut and Merling as to the frequency of replacing the teat brushes. These brands have been chosen because they are used most and they apply similar methods for cleaning the teats. It is difficult to make such a comparison for other brands. The largest group (64%) have indicated to replace the brushes at least 1 to 2 times a year. 24% do so more often than 2 times a year and 7% less often than once a year.

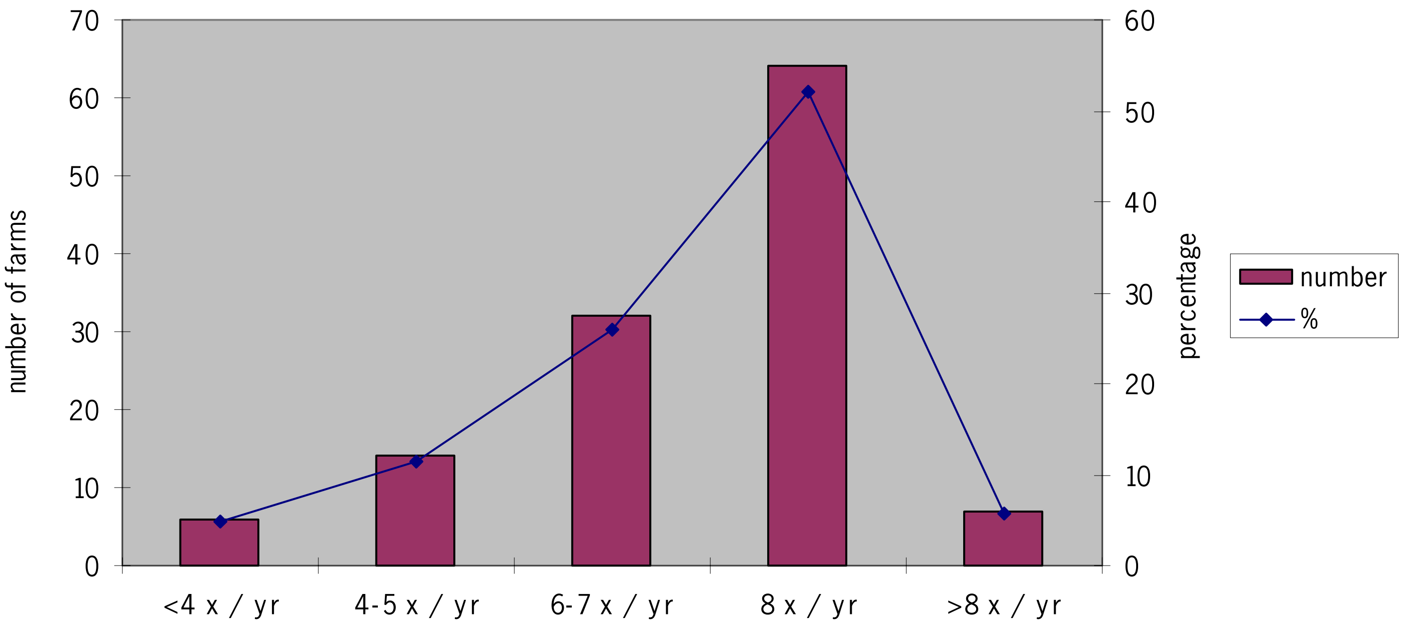
The frequency at which the teat brushes clean each teat varies from 1 to 3 times (ca. 15 sec. each time). 45% of the farms have settings at just once, 47% at two and 8% at three times. For the farms with different types of systems and at which teat cleaning is done by teat cups, the duration of cleaning varies, according to the farmers, from 7 to 12 seconds per teat.

Figure 9 Frequency of replacing the cleaning brushes for the teats



Maintenance and equipment measurements
How often the farmers have their AM-systems cleaned does not vary much. The largest group of farms have a maintenance contract of 6 to 8 times a year (78%), which can be seen in figure 10. 93% of the farmers have indicated to be satisfied with the mechanic. 92% of the farmers have indicated that the mechanics keep correct records. However, only 15% of the farmers read these records carefully and 40% leaves through the pages every now and then, while 45% never read it. This is probably caused by the fact that in 93% of the cases the mechanic always or mostly says if something has changed to the system.

Figure 10 Frequency of maintenance per year (n=123)

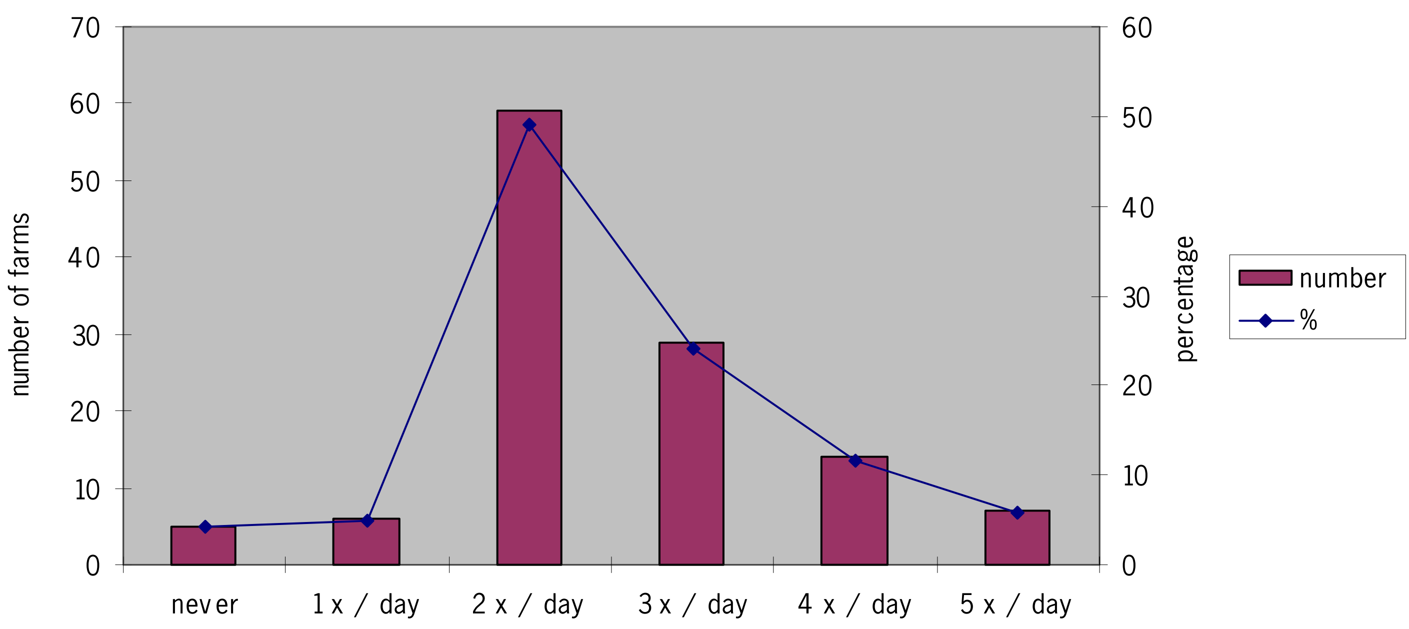


the Milk Quality assurance programme (KKM) dairy farms with an AM-system should have their milking system tested twice a year since early 2002. On farms on which this test is done more often than twice a year (21%), this is probably meant as a preventive measure or something else is the matter. It is also possible that farmers answered this question positively, if aspects that are usually checked at testing are checked at the same time as the periodic maintenance of the system. However, with an adequately working system checking twice a year should be sufficient.

Visits to the system
Depending on how the farmers have set the AM-system, a cow can be late and is fetched by the farmer to be milked. The greater part of the farmers (53%) allow 12 hours for their cows to be late. This, however, is dependent on the lactation stage, expected milk yield and the usual rhythm of the cow concerned. 14% have indicated that this can be longer than 12 hours with a maximum of 24 hours (3 farms). 15% of the farmers stated that they are not able to express this in hours and that they themselves make an estimation during the day. Figure 11 shows how often per day farms opt for fetching the cows that have to be milked and do not come by themselves (barn-period). Four farms have indicated to never fetch the cows. These are farms with an overcapacity of on average 25%. This overcapacity may be the reason for not fetching the cows, there is no need. Yet these farms check their list with milking intervals daily to keep an eye on it. Almost 50% of the farms fetch some cows twice a day to be taken to the AM-system for being milked. The maximum is 5 times a day, but only 7 farms do so.

The most important reason for fetching a cow is that they are late according to the settings in the AM-system. All farms mentioned this as a criterion. Moreover, the cows suspected of mastitis or other diseases are also fetched more often (by 57% mentioned as co-reason).

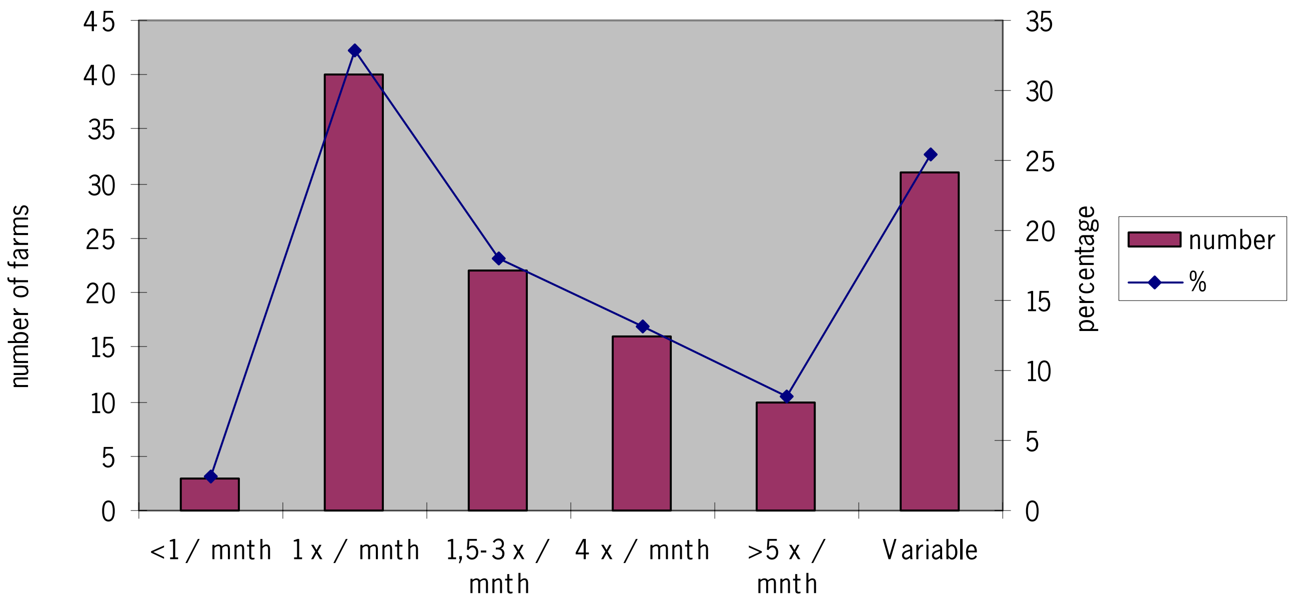
Figure 11 Frequency of fetching cows per day (n=120)



The farmers were asked for the busiest and quietest periods of the AM-system during the day. The quietest period is from midnight to 7 o'clock in the morning, after which the busiest period is started until in the afternoon. At about 6 to 7 p.m. a little peak in visits can be seen again. These later periods largely depend on feeding times or fetching of cows that are late.

Failure of the AM-system
Each farm experiences failure of the AM-system to a more or lesser degree, as is shown in figure 12. Of the farms that have responded to this question (n=122), 33 % have indicated to have failures once a month; 18% between 1.5 and 3 times a month. 13% have failures 4 times a month on average, while 8 % of the farms experience failure of the system more often than 5 times a month. One-quarter of the farms cannot indicate the frequency of the failures, due to the fact that this frequency is different from time to time. Sometimes there are periods with many failures (for example, in summer when there are many flies) or very few. Some farmers have indicated that particularly in the period just after introduction there were many failures, which occur far less often now.
55% of the farmers mostly solve the problem themselves. In all other cases it depends on the kind of failure whether they call the mechanic or try to solve the problem themselves.
According to the farmers failures are often caused by the same things. Often a dirty laser is mentioned as a reason for failure, as are broken tubes or tubes that have come loose or are leaking. A third reason for failure is cow traffic. A cow is often slow at entering or at exiting the system. As secondary reasons, the following are mentioned: failed connection, teat cups having come loose or entangled, a broken compressor and other technical reasons.

Figure 12 Number of failures that occur on the farms (n=122)



3.2.6 Cleaning

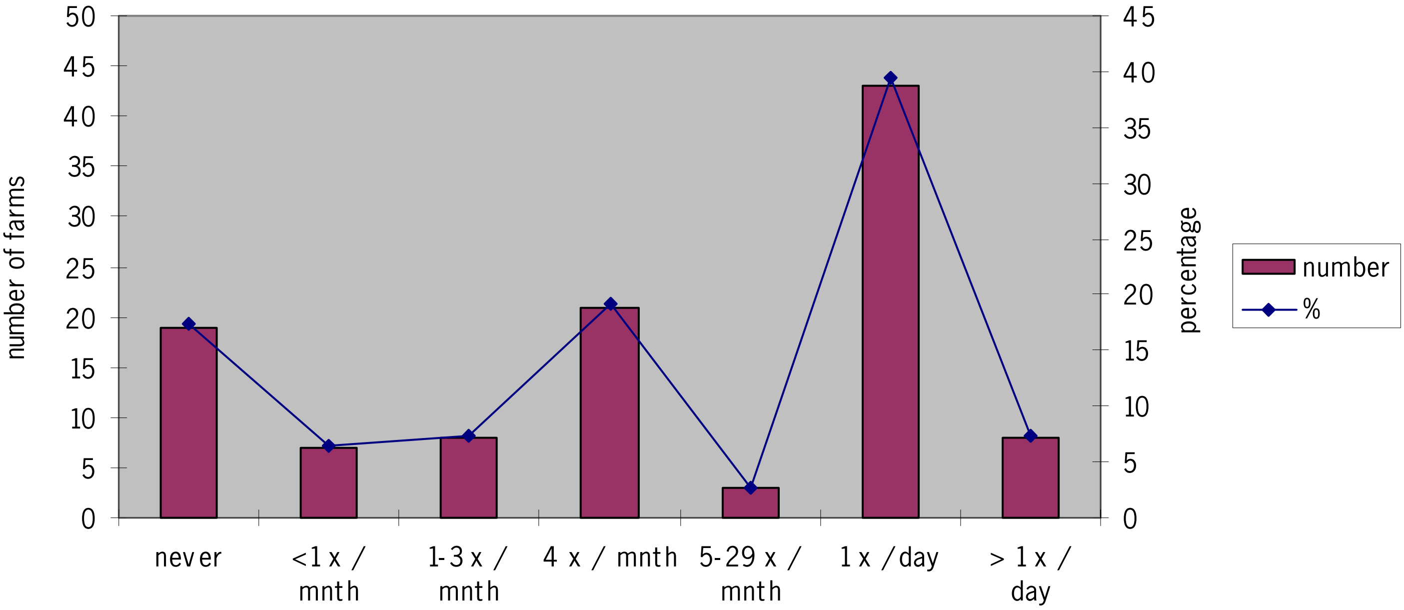
Cleaning frequencies
The frequencies at which the farmers clean (parts of) their AM-system greatly vary, as is the check-up as to this cleaning.
Eight farms (7%) never clean the clean part of the system, while 6 farms (5%) do so less often than once a week. 24% of the farms clean the system once a week. 20% do so daily and 31% more often than once a day with a maximum of 3 times a day (8 farms). The floor of the robot is cleaned more often. Only two farms never clean the floor and 14% less often than once a week. 21% of the farms clean the floor daily and 63% do so more often than once a day with a maximum of 5 times a day (1 farm).

Cleaning of the system should occur three times a day according to KKM standards, which is met by 71% of the farmers who maintain cleaning intervals of 7 to 8 hours. In practice these intervals are often longer, because first the water heater has to be heated up. Moreover, 13 of the farms (11%) have indicated to clean the system three times a day, but do not apply regular intervals, which resulted in intervals of, for example, 10-10-4 hours. 22 farms (18%) clean the system only twice a day, which is not enough if one wants to sufficiently prevent bacteria growth in the pipes (Verstappen-Boerekamp *et al*, 1998). This limited number of cleanings does not seem to be related to an overpopulation of the system. The reason is often that they want to save water and energy. This research has not revealed any relationship between the frequency of cleaning and total bacterial count (see chapter 3.4).
Most farms do apply fixed intervals for cleaning, but yet 73% of the farms indicate that intervals vary sometimes, because it cannot be prevented. Thus, also in those cases of cleaning three times a day, this can result in intervals longer than 8 hours. In 86% of the cases farms have indicated, however, that cleaning starts mainly automatically, due to which it is likely that the correct intervals are applied. On four farms this happens automatically as well as manually. 15% of the farms with an automatic start do not clean three times a day, the others do.

Use of disinfectants
As far as the use of disinfectants is concerned, by far the most farms keep to suppliers' advice as to the ratio of acid:alkaline. 55% of the farmers wait until the system indicates that the jerrycan with disinfectant has to be replaced. 42% of the farmers do not wait, however, and replace before that. The other 3% have indicated that they do not respond immediately, because in their opinion, the jerrycan is not completely empty yet.
63% of the farmers have indicated they have sometimes cleaned the system without any disinfectant, almost always an empty jerrycan being the reason. This also occurs with the brushes for teat cleaning from time to time. On 36% of the farms it has happened that the teat brushes are cleaned without disinfectant.

Inspection of the cleaning
The greater part of farmers inspect the cleaning daily (39%), which can be seen in figure 13. 7% inspect several times a day (at each cleaning) and 17% never inspect the cleaning. The farmers have also indicated that the mechanics almost always inspect the cleaning during the service, with the exception of 14% of the farms surveyed.

Figure 13 Number of times that farmer checks the cleaning (n=109)



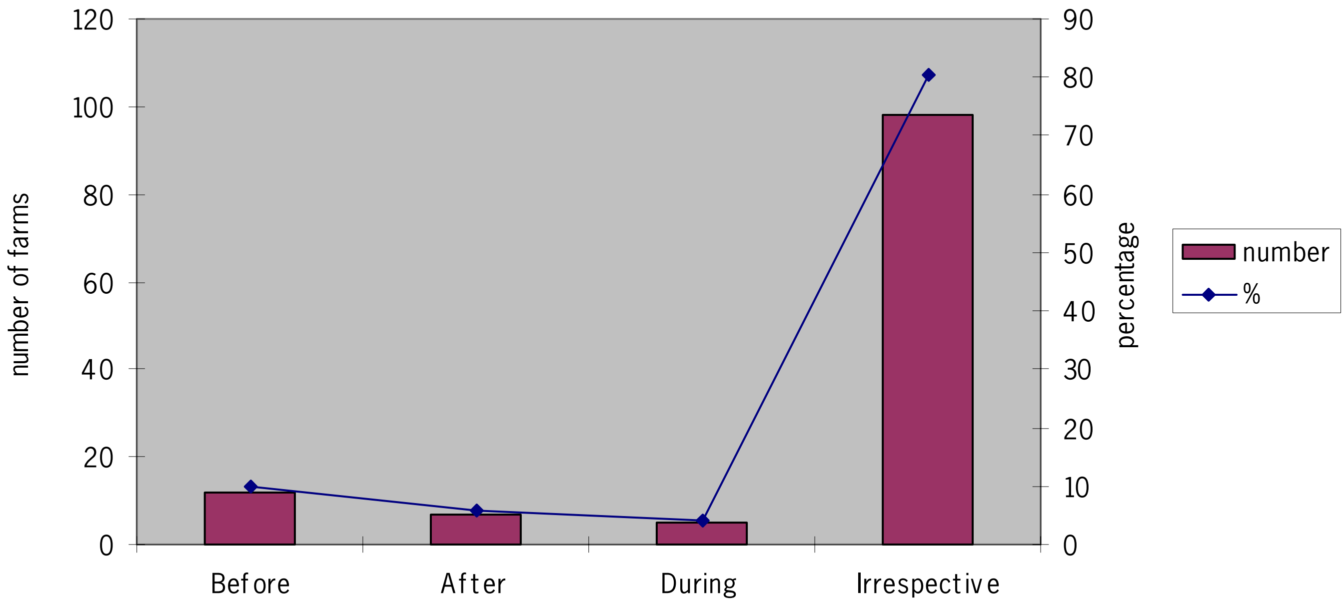
Short rinsing and flushing the cluster
89% of the farms have indicated that they rinse the cluster briefly after each cow. 90% of the farms apply a brief cleaning after a cow with antibiotics. After a colostrum cow, 96% of the farms apply a brief cleaning. Besides, 67% of the farms apply a brief cleaning after some idle time of the AM-system. On average this is after 40 minutes. The same holds for cleaning briefly after milking a particular number of cows. 41% of the farms do so after, on average, 10 cows. In 91% of the cases only water is used for these brief cleanings.

Cleaning (bulk) tank
Besides cleaning the AM-system, also cleaning the bulk tank was considered. 63% of the farmers have indicated that it is possible to clean the robot and the tank at the same time. 68% find, however, this is not appropriate, because it may lead to problems if the water heater capacity is not sufficient, due to which the water cannot be kept at the right temperature.

Water heaters
All systems have a water heater that heats water for cleaning the system. Moreover, each farm has an extra water heater for cleaning the bulk tank. The average size of water heater for the AM-system is 52 litres with a maximum of 150 litres. The average size of water heater belonging to the tank is 124 litres with a maximum of 400 litres. On 61% of the farms heat recovery is applied.

Changing milk line filter
Figure 14 shows when the farmer replaces the filter in relation to cleaning the system. It is recommended to do this before cleaning in order to have a clean filter before milking is restarted. However, only a slight 10% of the farms do so before cleaning starts. 6% replace the filter immediately after finishing the cleaning. The greater part of the farms (80%) changes the filter independent of the time of cleaning, which is thus at a random time of the day, and the operation of the filter is not utilised optimally.
Only 32% of the farmers have indicated that they change the filter 3 times per day. This should occur at each cleaning and since KKM prescribes the cleaning to be carried out three times a day, this also holds for the filter. The largest group of farms (61%) replace the filter twice a day, while 5% do so only once a day. Two farms (2%) replace the filter even less often than once a day.

Figure 14 Moment of changing the milk filter in relation to the main cleaning (n=122)



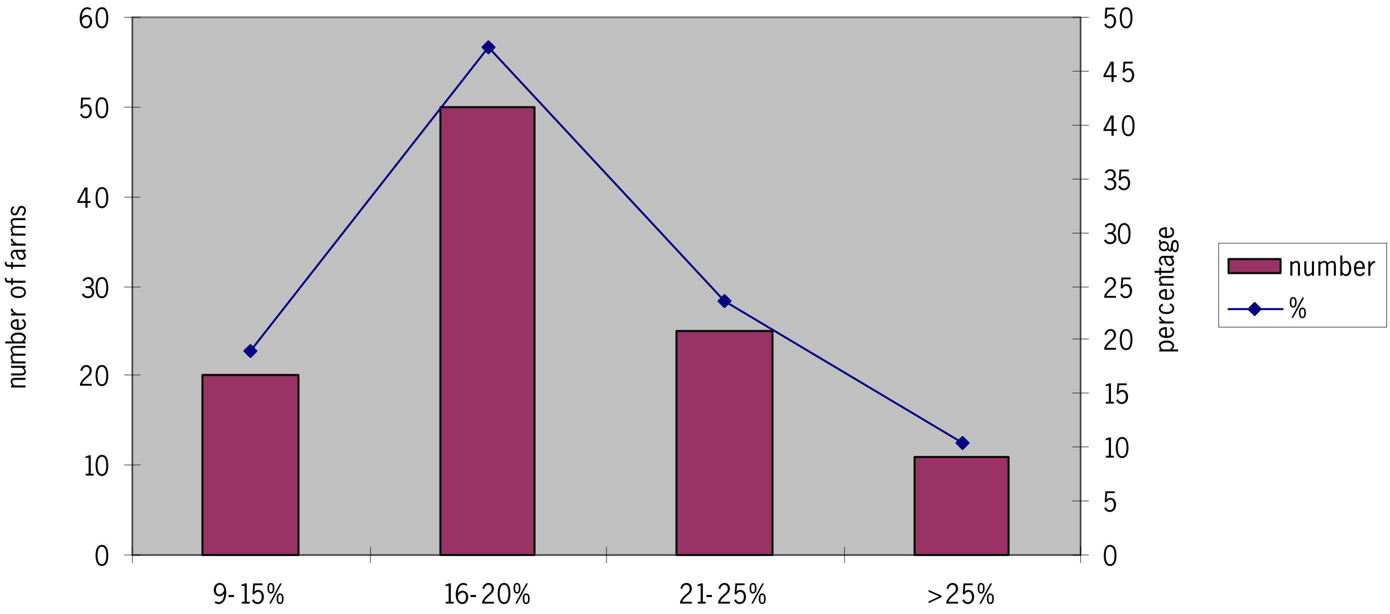
3.2.7 Cooling

Type of cooling system

By far the most farms (87%) have a buffer tank besides the main tank to store the milk. The size of the buffer tank varies from 600 to 3300 litres. Only one farm has a buffer tank smaller than 1000 litres. On 14% of the farms the volume of the tank is smaller than 1200 litres, while 24% of the farms have volumes of between 1200 and 1500 litres. 23% of the farms have tanks with volumes of between 1500 and 1800 litres and 15% of the farms have buffer tanks of 1800 litres or over. The volume of the buffer tank in relation to the main tank is presented in figure 15. On average, the volume of the buffer tank is 19% of that of the main tank with minimums of 9% and maximums of 40%. It is recommended to keep to 10 to 15%, because otherwise the milk is cooled too late or freezes if cooled too early (Minderman en Verstappen-Boerekamp, 2000). This recommendation is met by only 19% of the farms. The largest group of farms (47%) has a buffer tank with a volume of 16 to 20% of the main tank. 10% of the farms have a buffer tank with a volume of 25% or larger in relation to the main tank. Freezing of the milk or cooling too late can occur.
On 89% of the farms with a buffer tank, the milk is transported to the main tank by means of a pump. On the other farms (11%) this happens via a fall. On 11 farms (10%) it has been indicated that the pump starts after a particular amount of milk, where the amount of milk varies from 100 to 1200 litres. On 23 farms (21%), the pump is started after a particular time, which may vary between 1 and 12 hours. Starting the transfer by pumping is almost always done by hand (96%).

The greater part of the farmers (58%) does not have a pre-cooler. On 40% of the farms with a buffer tank, pre-cooling also occurs by a pipe- or plate-cooler. Ten farms use other ways of cooling than the buffer tank. Four farms use in-line cooling (with plate-coolers), three farms apply ice-pack cooling (all without pre-cooler) and three farms use a single robot tank (SRT) (two of which with pre-coolers).

Figure 15 Relation buffer tank/bulk tank (n=106)



Maintenance and functioning of cooling
By far the most farmers (94%) have indicated to be satisfied with the mechanic who maintains the cooling, while only 6% of the farmers are not. On farms with a buffer tank cooling is started manually or automatically. The moment at which cooling is started depends on the numbers of litres of volume, the number of cows having been milked or the number of minutes after the first milk comes into the tank.
In most cases (55%), cooling of the buffer tank starts automatically after a particular number of litres of milk, which varies from 30 to 500 litres. On 4% of the farms, volume is the measure, but cooling is started manually. This already happens earlier, at 20 to 150 litres. One farm has set the cooling of the buffer tank such, that this automatically starts after having received the milk of one cow. Another farmer starts the cooling manually after having milked 20 cows. On the remaining farms, time is the determining factor to start cooling. On 9% of the farms cooling is automatically started after a particular time. This can vary from immediately (0 minutes) to 60 minutes. On 30% of the farms the buffer tank cooling is started manually after a particular time, which may vary from immediately (0 minutes) to 30 minutes. If starting the buffer tank manually, particularly the time after cleaning is considered, while with starting automatically, particularly the amount of milk is important. With the remaining cooling systems (inline, indirect, SRT), cooling starts mainly automatically after a particular time.

Inspection of cooling & watchdog and response to this
Some farmers (6%) have indicated that they never inspect the tank after cleaning, 31% do so 'sometimes', 22% inspect 'regularly' and 41% always inspect the tank after cleaning. According to 22% of the farmers, the watchdog (monitoring system) never reports something, 64% of the farmers receive reports every now and then, while 14% often get reports from the watchdog. Two-thirds of the farmers look for the problem themselves, if the cooling system does not work properly; one-third of the farmers immediately call the mechanic, who will mostly only check the cooling system (93%); sometimes also the AM-system is checked. One-third of the farmers hold the mechanic responsible for the bulk tank, 65% hold themselves responsible. In only a few cases the co-worker is held responsible.

3.2.8 Housing

Floors
By far the most farms (96%) have slatted floors, some have a solid floor and 1 farm has a trench floor. On 54% of the farms, manure is removed from the (slatted) floor by a manure scraper, on 28% of the farms this is done manually, on 4% of the farms there is a combination of the two and on 14% of the farms the manure is never removed from the floor.

There is a great difference in the frequency of removing manure between automatically (by a manure scraper) and manually. Farms on which removing manure is done automatically, this is done 14 times a day on average (with a maximum of 48 times) and farms where manure is removed manually, which is done 1.8 times a day on average.
On most farms (61%) the floor in the waiting area is cleaned at the same frequency as the other floors, on 8% of the farms this is done more often and on 31% of the farms the floors are cleaned less often. On 37% of the farms the manure scraper comes close to the AM-system (1 metre before).

Cubicles and feeding places
On 16% of the farms there is no bedding in the cubicles (most farms do use sawdust, however). On 40% of the farms rubber mats are used in the cubicles, on 3% of the farms there are waterbeds and on 26% of the farms there are cow mattresses in the cubicles. The number of resting places varies from 43 to 180, which indicates that the size of the housing facilities greatly varies. On average, there are 1.25 cubicles per cow, so on average there is underpopulation. Many farms may want to expand, for not all farms milk their quota (see 3.2.1). On average there are 1.17 feeding places per cow present, which is plenty; certainly considering the fact that on farms with an AM-system the cows do not (or cannot) eat all at the same time.
On average the cubicles are cleaned two or three times a day (scraping). 13% of the farmers clean the cubicles once a day at maximum, while 19% of the farmers do so 4 to 6 times a day.
After scraping the cubicles are regularly littered down with sawdust or straw. However, 37% of the farmers do not litter down the cubicles. Of the 63% who do, 8% of the farmers litter down the cubicles less often than once a day, 27% of the farmers do so once a day and 41% of the farmers litter down once to twice a day. 14% of the farmers do this more often than twice a day. Mostly fine white sawdust is used as litter, 13% of the farms use straw.
Most farmers (65%) do not work on the cubicles more often after introduction (scraping and littering down), but there are more farmers who do (30%) than who do not (6%).

Cleaning of barn
Almost half of the farmers (49%) have indicated to never clean the barn totally. 28% do so less often than once a year, while 23% of the farmers clean the barn once a year. One farmer cleans the barn more often than once a year. According to most farmers (76%), introduction of the AM-system has not affected the frequency of cleaning the barn, but 22% have indicated that the barn is cleaned less often or has not been at all after introduction. The reason for this is that cows are inside year round.

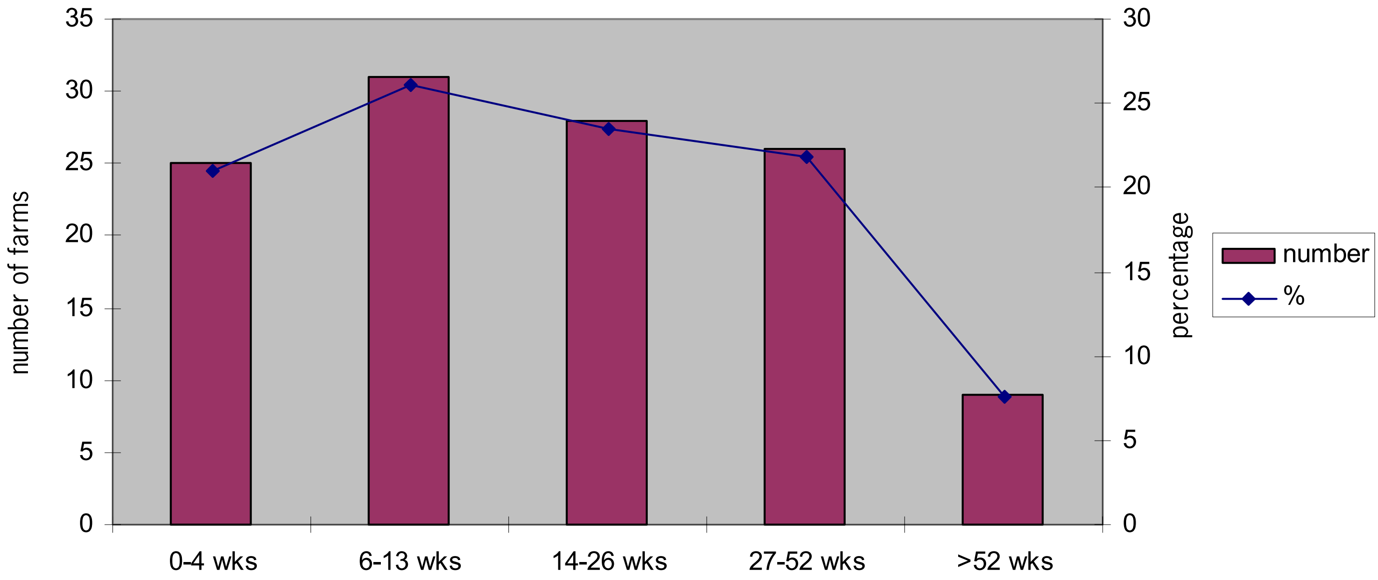
Construction of barn and AM-system
In most cases (73%) the AM-system has been built in an existing barn, 12% of the farmers have adapted their barn and 15% have built a new facility. On most farms (83%), the system is at the front of the barn. The distance to the bulk tank is, on average, 19 metres, varying from 2 to 80 metres. 57% of the farms have open sidewalls or windbreaking screens in the barn. 32% of the farms have a domed ridge and 15% a T-shaped ridge. The opening in the ridge is, on average, 33 cm for farms with an open ridge, while on 21% of the farms the ridge is closed.

3.2.9 The manager

Control
All farmers with an AM-system spend a considerable amount of time on their animals. They inspect their animals at least twice a day. The larger part of the farmers (83%) inspects their animals even more often than two times a day. Special attention is paid to oestrous and diseased or lame animals. A minority of the farmers (12%) has indicated to pay special attention to udders and teats. Moreover, 76% of the farmers also consider the entire appearance of the cows. 39% of the farmers have indicated that they know their animals better after introduction than before, while only 6% have indicated to know the animals less well now.

Habituation of farmer
It took the farmers 6 months on average to get used to the AM-system. Some farmers were used to it immediately, while one farmer needed 4 years. The distribution of the habituation period over the farms is presented in figure 16. Habituation is a broad concept and in the phrasing in the questionnaire this has been left to the interpretation of the farmers. It can mean two things: one thinks they are used to it when they can work with the system without any problems (technically speaking) or one thinks that they are used to it when they can eventually handle the new way of management and process control.

Figure 16 Length of habituation period for the farmer (n=119)



Type of farmer & work and working hours
29% consider themselves dairy farmers, 24% economic farmers and only a few farmers (7%) consider themselves robot farmers. The remaining farmers consider more characterisations applicable to themselves. The pollsters considered 47% of the farmers dairy farmers, 21% economic farmers and 11% robot farmers. The remaining 21% were distributed over various characterisations.
Two-thirds of the farmers have a farm-economic accounting system. Most of their spare time is spent on the farm, which is presented in table 4.

Table 4 Leisure activities mentioned (n=123 farms)

Activity	Number	%
Farm	47	**26**
Business in agricultural sector	42	**24**
Non agricultural business	22	12
Hobby	33	18
Family	25	14
Else	10	6

Background and reasons to purchase an AM-system
There are often more reasons (1.8 per farmer on average) for farmers to purchase an AM-system, which is shown in table 5.

Table 5 Reasons mentioned to purchase an AM-system (n=123 farms)

Reason	Number	%
Saving time	51	**41**
Increase milk yield	27	22
Gain good impression with colleagues	14	11
Flexibility	63	**51**
Improving udder health	22	18
Building a new barn	14	11
Renovating milking parlour	39	**32**

More flexibility is the reason that is mentioned most, but also the expected saving in time and renovation of the milking parlour have frequently been mentioned. Despite the need for more flexibility, most farmers (85%) prove to keep to a fixed time schedule for their activities (feeding, inspection, cleaning et cetera) after introduction. However, these activities cost less time and are less time bound than before, due to which flexibility increases. One comment for table 5 is necessary, however. Renovation or building a new barn was, of course, not a direct reason for purchasing an AM-system, but if renovation had not taken place, the AM-system had probably not been purchased either.

The AM-system comes up to the expectations of 36% of the farmers after purchase. Most expectations have been met for 47% of the farmers and for a small group of farmers (17%) expectations have been met only partly (14%) or not at all (3%). This proves that one's own expectations were met to a higher extent than anticipated by the suppliers (page 15).

3.2.10 Feeding

Silage and concentrate
The share of grass silage in the concentrates indicated by the farmer varies from 10 to 100% and is almost 65% on average. On 11% of the farms the share of grass silage is not more than 50% of the ration, on 12% of the farms the share of grass silage is larger than 80%. A large number of farms (64%) also feed by-products such as brewers' grains, pressed sugar beet pulp and pressed potato pulp. Over 50% of the farms feed once a day, 13% of the farms feed less often and 30% of the farms feed more often.
On all farms concentrates are supplied within the AM-system, 62% of the farms also use a concentrates box. In the milking box 2 to 12 kg of concentrates are fed at maximum, on average this is 7.4 kg at maximum. Concentrates are mainly fed according to the standard (85%).
Supplying minerals is done on most farms (69%), in summer as well as in winter. 18% of the farmers do not supply extra minerals at all.

Milk production groups
Subdividing the herd into production groups is done by 15% of the farmers. Fifteen farmers have two production groups, two farmers have three and one farmer has four production groups. Six of the 15 farms with two production groups have only one AM-system. The subdivision into production groups occurs by means of fences in the same barn instead of, for example, two separate areas in the barn, which is possible if there are more systems. The non-lactating cows are subdivided into two and sometimes into 3 groups on 58% of the farms. Non-lactating cows are mostly kept separately, and thus not with youngstock or dairy cattle. However, they often have the chance of looking at the lactating cows. Non-lactating cows often receive minerals for dry cows (68% of the farms) and a minority of the farms feed dry cows also hay or straw besides grass silage. On 62% of the farms, the heifers are brought into the herd of lactating cows right before calving, and also come into the AM-system.

Body condition score
Body condition score is recorded by 24% of the farmers, half of whom inspect between 1 and 4 times a year. Yet 60% of the farmers have indicated to feed according to condition. It can also be noted that 89 of the 124 farmers (72%) have an impression of the variation of the body condition score during lactation. One-third of them mean that the variation is smaller than 2 points and one-third of them think that the variation is greater than 2 points. In general (61%) the farmers see little difference between the periods before and after introduction in possibilities of directing condition. 24% of the farmers have the impression that the condition varies less after introduction than before; 19% think the changes in condition have increased since introduction. The remaining farmers do not see a difference after introduction.

3.2.11 Other factors

Problems after introduction
By means of an open question in the questionnaire the farmers were asked to indicate what the biggest problems have been since the introduction (see table 6). 18% of the farmers do not have any serious problems that are related to the AM-system. Claw disorders have been mentioned most often by the remaining farmers. It is likely that with automatic milking claw disorders lead to less frequent robot visits, which can be seen by the farmer more clearly and will thus be experienced as a problem. Keeping the cows inside may also play a role. Also problems with somatic cell count and mastitis are often mentioned as problems. Furthermore, it has been indicated that it is more difficult to pay attention to specific cows (mastitis, early lactating cows and the like). The two aspects grazing and feeding control are considered problematic. Various technical reasons (vacuum pump, compressor, connection problems, software and the like) are also mentioned as problems that have arisen after introduction. Complaints as to cleaning, power supply and electricity costs and problems as to the correct positioning of the system fall in the category 'other technical problems'. The category 'other management problems' comprises complaints as to too little confidence in the system, to have to go to the barn at unwelcome times, too many skew udders, disappointing milking frequency and cows that do not want to come. The category 'other problems mentioned' includes various issues, such as too little quota by increased production, footbath

difficult to place, increased concentrates costs and a reduced protein content. These separate problems in the last three categories were all mentioned twice at maximum.

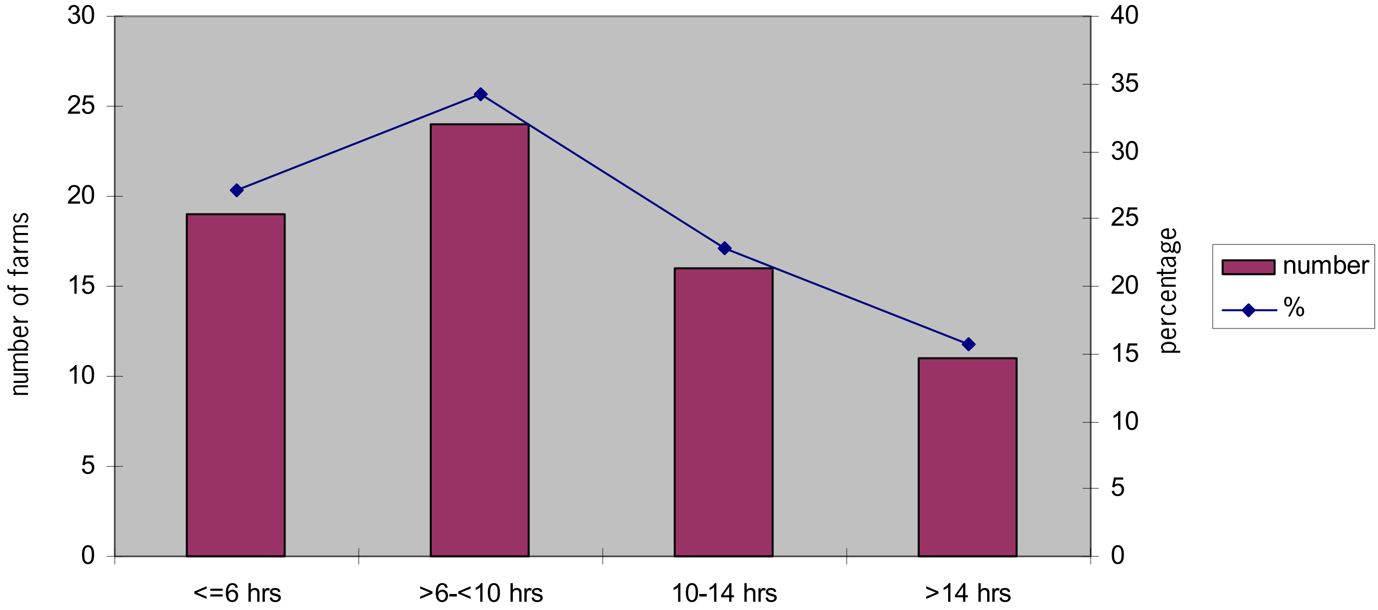
Table 6 Problems after introduction mentioned (n=123 farms)

Problem	Number
Lameness	17
Increased cell count	15
Technical failures (vacuum, software, compressor, etc.)	14
Not being able to feed individual cows	12
Habituation cow and farmer lasted longer than expected	12
Difficult to combine grazing and AM	9
Milk yield increase less than expected or decreased	7
General animal health/condition deteriorated	7
Increase in mastitis	6
Problems with free fatty acids	5
A general decrease in milk quality	5
Housing non optimal (ventilation/heat during summer)	5
Higher culling rates	5
Increased work load after introduction	5
Replacing manager is complicated	4
Fertility cows	4
Attention for individual animal is more difficult	4
Other technical problems	5
Other management problems	9
Other problems mentioned	9
No problems worth mentioning	22
Total	181

Cow traffic and grazing
The larger part of the farmers (72%) has free cow traffic in the barn, and pre-selection is an exception. Farms with one-way traffic apply pre-selection in over 50% of the cases. Grazing by dairy cattle is applied on 52% of the farms and on 6% of the farms the animals can make use of a paddock. Of the 42% of the farms that do not apply grazing or paddocks, the dry cows and/or youngstock are outside on 50% of the farms.
As a grazing system, rotational grazing is the most common practice (55%), furthermore siesta grazing is applied (18%) as is strip grazing (8%). On average, cows graze for almost 10 hours on average, varying from 3 to 24 hours. The distribution of the farms over the categories of grazing duration (including paddock) is shown in figure 17.

Of the 70 farms where animals can go outside, there are 40 farms that supply water in the pasture. On 28% of the farms, 10 cows at maximum are fetched per day, on 22% between 10 and 50 cows are fetched, on 28% of the farms between 50 and 75 are collected and on 22% of the farms more than 75 cows on average are collected daily.

Figure 17 Number of farms per category of grazing hours (n=70)



Habituation period cows
There is much difference among the farms as to the habituation period of the cows. Some farmers have indicated that their animals were used to the system within 3 days, while for others this was only after 365 days. The average is 67 days. According to 51% of the farmers, the cows were used to the AM-system within 4 weeks, and 16% have indicated that the habituation period lasted more than 150 days. The cows seem to be used to the system more quickly than the farmers. 84% of the farmers think that the cows have become quieter; only one farmer thinks the opposite is true. According to the pollsters, the cows are quiet on 95% of the farms, on the remaining farms they are somewhat restless.
On almost all farms the udders are clipped, on average this happens almost three times a year. On some farms the udders are clipped each month.

Culling reasons
22% of the farmers have not culled animals due to the introduction of the AM-system. The remaining farmers have culled on average 5 animals. Five farms have culled more than 10 animals due to the introduction. The most important reason for culling has been that the shape of the udder and the positioning of the teats were unsuitable. On 60% of the farms, replacement percentage has remained the same, on 33% of the farms this has increased and on 7% it has decreased according to the farmers. Behaviour plays a limited role here, but fertility, udder and legs are the most important reasons for culling after introduction. 80% of the farmers take the requirements as to automatic milking into account in breeding (position of the teats, quiet cows and the like), the remaining farmers do not.

3.2.12 Milking machine test report

A number of data available from the periodic test report have been considered on the basis of our own opinion and related to the data on milk quality. These data were available on only part of the farms (see table 7). Of farms with more systems, only the value of the first system has been considered.

Table 7 Data of periodic equipment test report

Variable	# farms	Average	Min.	Max.
Air inlet main milk line (l/min)	56	2.6	0	26
No. of pulsations per minute	87	59.7	52.2	69.8
Duration of a+b phase (milliseconds)	87	656	602	711
Duration of c+d phase (milliseconds)	87	345	269	455
Vacuum level (kPa)	88	43.8	39.5	50

It has been shown that not all characteristics are recorded in the same way by the mechanics. The parameter of the air inlet in the teat cups is therefore hard to interpret. This varied from 0 to 90 l/min. Nil is not possible and 90 is very much. Moreover, the average is 25, which is low, and was caused by the fact that in many reports values of around 10l/min were recorded. Presumably, some mechanics record the air inlet per cup and others per 4 cups. Besides, this parameter may depend on the fact whether more systems are connected to one delivery line or to different ones. But, still, various values cannot be explained. That is why air inlet of the teat cups cannot be presented and considered in further research, which is a shame, since the hypothesis was that the extent of the air inlet in the teat cups influences somatic cell count and particularly free fatty acids.
The pulsations per minute and the number of milliseconds of the active and rest phases do not correspond either. Normally speaking, these can be calculated back to each other. The data presented in table 7 have been taken from the reports. If, however, the pulsations are calculated on the basis of the duration of the active and rest phases as written down, this will result in an average pulsation of 60 with a minimum of 52.2 and a maximum of 61.3. Particularly the maximum differs. This demonstrates that the testing and/or notation are not always performed accurately, which makes improvement necessary.

3.2.13 Data milk recording

The averages and minimums and maximums of the annual reports of the DHIA of the statistical years 2000 and 2001 (one statistical year runs from 1 September to 31 August) are shown in table 8.

Table 8 Averages of annual reports DHIA (2000 en 2001)

	2000				2001			
Variable	#farms	Avg.	Min.	Max.	#farms	Avg.	Min.	Max.
Kg of milk	94	8627	6115	12541	105	8935	4354	12054
Kg of fat	94	377	280	542	105	391	212	521
Kg of protein	94	299	216	440	105	308	155	411
%HF	91	85	42	100	101	87	51	100
No of cows	92	70	27	138	105	68	10	158
Lactation days	93	320	287	403	105	328	289	388
Calving interval	92	404	369	522	100	407	372	490

The milk yield of the farms surveyed is higher than the national average (8601 kg in 2001); the same holds for the kilograms of fat and protein (NRS, 2002). Moreover, lactations are somewhat shorter, while calving interval is nearly the same as the national average. 20% of the farms have a milk yield of less than 8000 kg and 15% of the farms have a milk production of > 10,000 kg in 2001. On 19 farms there are animals with one or more blood portions of MRY (Dutch red and white), the share of HF increased from 2000 to 2001 and the share of MRY slightly decreased. The farms surveyed have a slightly larger herd than the national average of 62 animals (NRS, 2002).

3.2.14 Hygiene scores

The pollsters have considered a number of aspects of the farm in the categories good, moderate or poor. For an explanation of the way of scoring see section 2.3.2. It should be taken into account that no comparison has been carried out with conventionally milking farms, but that the hygiene has been considered to determine whether there is a relationship with differences in milk quality. Table 9 shows the distributions over the categories.

Strikingly many farms score moderately or poorly as to some parts. This concerns, for example, impression of the collecting yard, the stable floor and the water troughs. In general the AM-system does not score high. The floor, teat cups and the robot arm often leave much to be desired.

On average, hygiene is considered good in 63% of the cubicles. On 11% of the farms 10% of the cubicles at maximum are considered good, and on 21% of the farms at least 90% of the cubicles are considered good as far as hygiene is concerned. On average, 55% of the cows are considered clean, ranging from 10 to 100%. As to the udders, on average 68% are considered clean, varying from 10 to 100%. On only 42% of the farms farm clothing is present, which should be worn by all visitors. The number of farms with a sanitary barrier is limited (30%).

Table 9 Frequency of hygiene scores

Item judged	# farms	% good	% moderate	% poor
First impression farm	121	81	17	2
First impression stable	122	72	27	1
Impression AM-System	122	69	27	4
Impression collecting yard	111	21	51	28
Floor AM-System	122	58	28	14
Teat cups	122	39	48	13
Arm AM-system	122	43	43	14
Premilking device	104	77	18	5
Bulk tank room	121	58	29	13
Workmanship location AM-system	122	66	22	11
Feeding alley	120	65	30	5
Floor stable	122	32	43	25
Storage of bedding	99	88	11	1
Water troughs	74	28	51	20
Climate in the stable	122	79	21	0
Light in the stable	122	58	35	7
Ventilation	122	72	20	7

Data from AM-system
With respect to the data of the AM-system it can be noticed that these data are lacking for approximately one-third of the farms. These farmers do not know how to obtain these data from the computer, or they are not able to obtain them or they did not have them available during the pollsters' visit. Table 10 shows the data for farms of which the data could be recorded.

Table 10 Overview data from AM-system *per stall (data from 1 'normal' day)*

Variable	# farms	Average	Min.	Max.
Milking interval (hrs)	79	9.7	7.4	17.8
Milking frequency	79	2.5	1.4	3.3
Number of milkings	84	158	110	219
Idle time (hrs)	79	4.8	1,3	10
Cleaning time (min)	78	68	23	296
No. of refusals	77	87	5	259
Milk yield (kg)	81	1473	643	2219
Milk flow (l/min)	80	2.1	1.0	2.6

The data in table 10 concern 24 hours and have been considered to get an overview. The emphasis of the study was placed on the questionnaire and it was not meant to relate the data at cow level to the milk quality. That requires a different type of research. That is why the milk yield per cow per robot visit was not considered in this research. The average interval between the milkings is less than 9 hours (milking frequency > 2.6) on 35% of the farms. On 37% of the farms the interval is 9 to 10 hours (milking frequency 2.6. - 2.4) and on the remaining 28% of the farms the average interval is more than 10 hours (milking frequency < 2.4).
On 43% of the farms fewer than 150 milking are realised per box, on 32% of the farms 150 to 180 milkings are realised and on 25% of the farms more than 180 milkings per box.
On 28% of the farms idle time for the AM-system is 3 hours per day at maximum, on 38% of the farms this is 3 to 5 hours per day and on the remaining 34% of the farms idle time is more than 5 hours a day. Idle time is excluding cleaning time.

In total, on 39% of the farms 1 hour at maximum is spent on cleaning, on 36% of the farms cleaning time is 61 to 80 minutes and on the remaining farms at least 81 minutes are spent on cleaning.
On 31% of the farms the number of refusals is not more than 60 a day, on 39% of the farms the number of refusals is between 60 and 100 and on the remaining 30% the number of refusals is > 100.
Milk yield per box is 1200kg/day at maximum on 30% of the farms. On 43% of the farms a milk yield of 1200-1600/day is realised, and on the remaining 27% of the farms, milk yield per box is over 1600kg.
On 38% of the farms milk flow rate is less than 2.0 kg/min, on 41% of the farms this is between 2.0 and 2.2 kg/min and on the remaining farms (21%) milk flow is more than 2.2 kg/min.

3.3 Abstract of descriptive statistics

Farm data
- 64% of the farms in the questionnaire have a single-box system.
- According to the farmers a milk production increase of on average 5% can be seen after introduction (ranging from a 16% reduction to a 35% increase).
- 68% of the farms with an AM-system have a milk quota of between 450,000 and 750,000 litres.

General information
- In almost all cases the male is in charge of the management on the farm and cattle control.
- Over 50% of the farmers cannot indicate for sure whether there is a successor or not. One-third of farmers are sure that there is a successor.

Milk quality
- 84% of the farmers aim at a somatic cell count of at maximum 200 (200,000 cells/ml). Over half of them have a target level of somatic cell count of around 150,000 cells/ml.
- 74% of the farmers have indicated a target level of the total bacterial count of 10,000 bacteria/ml. 22% have a lower target level.
- By far the majority of the farmers hold themselves responsible for somatic cell count and total bacterial count (85% and 88% respectively).
- They feel less responsibility for free fatty acids and freezing point. Around 60% hold themselves responsible, but mechanics and cows are often considered co-responsible.

Animal health
- Over 95% of the farms join the milk recording system. Moreover, 84% of them use conductivity whether or not in combination with other registration to follow somatic cell count of the cows.
- 57% of the farmers indicate to have < 10% clinical mastitis at a yearly basis, which is relatively low. The question is whether this parameter is sufficiently reliable.
- 52% of the farms pay extra attention to a cow with mastitis when milking (extra milking by hand, have them milked more often, with a separate milking device and the like).
- Few farms make use of a farm treatment plan (16%) or a mastitis planner (2%).
- 69% of the farms inspect the teats from time to time. The frequency varies greatly, however. 54% of the farmers indicate that teat condition has increased after introduction.
- Conductivity, milk yield and milking interval are considered the most important output parameters of the AM-system. The majority views these parameters at least once a day (by 93%, 85% and 73% of the farmers respectively).
- After a cow's appearance on the signal list, 65% of the farmers have a look immediately if he cannot explain the signal. However, it often depends on the cow concerned and the moment of the day. On 70% of the farms, 2 to 5 cows are on the list daily.
- Only 29% of the farms consider more than 80% of the signals for conductivity correct.

AM-system
- 96% of the farmers have familiarised themselves before purchasing the system by means of farm visits within the Netherlands.
- 43% of the farmers indicate that expectations as to the system (based on the sellers' report) have been met.
- 84% of the farms apply spraying. 57% of the farmers think this happens moderately to poorly (2%).
- 74% of the farmers determine the time at which teat liners should be changed themselves.
- 78% of the farmers have their system checked 6 to 8 times a year. The large majority (93%) is satisfied with the mechanic and also mention that these keep records well. However, only 15% of the farmers check the records thoroughly after a mechanic's visit.
- Almost 59% of the farmers collect the cows that are late or with which something is wrong twice a day.
- The busiest time of the day at the system is 8 o'clock in the morning.
- 72% of the farms have failures at least once a month (5 times at maximum), which often have the same causes. 55% of the farmers solve the problem themselves.

Cleaning of AM-system
- The floor of the AM-system is cleaned more often than the clean part of the system. 84% of the farms clean the floor at least once a day and only 51% of the farms clean the clean part of the system at least once a day.

- 71% of the farmers carry out a main cleaning three times a day at fixed intervals.
- Cleaning starts automatically in 86% of the cases.
- 55% of the farmers wait until the system indicates that the jerrycan with detergent is (almost) empty before replacing this.
- 63% of the farmers indicate that cleaning sometimes occurs without disinfectant, almost always caused by an empty jerrycan.
- 46% of the farms check the cleaning at least once a day; 17% never do this.
- 89% of the AM-systems apply rinsing the cluster after each cow. After milking a cow with antibiotics or colostrum, the system applies brief rinsing (90% and 96% respectively).
- All farms have two water heaters, one at the system and one in the bulk tank room. The average size of the water heater in the bulk tank room is a bit small.
- 80% of the farmers indicate to replace the filter when it suits them, independent of the moment of cleaning. Two-thirds of the farmers replace the filter twice a day.

Cooling
- 87% of the farms use a buffer tank. In 89% of the cases transfer of milk from the buffer tank to the main tank occurs via a pump.
- 94% of the farmers are satisfied with the mechanic of the cooling.
- 41% of the farmers check the tank after each cleaning, while 6% never do this.

Housing
- 96% of the farms surveyed have a slatted floor.
- 58% of the farms have a manure scraper.
- There is on average underpopulation in the barns (1.25 cubicles per cow and 1.17 feeding places per cow).
- Cubicles are cleaned 2 to 3 times a day on average.
- 63% of the farmers litter down the cubicles; 20% do so at least once a day. There are more farms that have littered down the cubicles more often since the introduction (30%) than farms that have done that less often (6%).
- Half of the farmers never clean the entire barn in one go; almost all others do this once a year at maximum. Since the introduction cleaning seems to occur slightly less often.
- On 73% of the farms the AM-system has been placed in an existing barn. In 83% of the cases the system is at the front of the barn.

The manager
- 83% of the farmers check the cattle more often than twice a day.
- 39% say they know the cattle better than before introduction; 55% say this has remained the same.
- The farmers needed, on average, 6 months to get used to the system. Almost half of them was used to it within 3 months. Cows were used to it more quickly. According to the farmers this lasted 2 months on average.
- The most important reason for purchasing the system was more flexibility and saving time.
- Expectations as to the AM-system have been entirely or largely met for 83% of the farmers.

Feeding
- 64% of the farms supply by-products.
- Over half of the farms do not feed more often than once a day.
- Only 15% of the farms apply production groups.
- All farms supply concentrates in the AM-system. 62% also use a concentrates box.
- 69% of the farms supply extra minerals in summer as well as in winter.
- One quarter of the farmers use the body condition score as a tool.

Cow traffic and grazing

- 72% of the farms apply free cow traffic, mostly without preselection.
- Over half of the farms apply grazing, mostly rotational grazing. Moreover, 6% apply paddocks and 19% grazing for youngstock and/or non-lactating cows.
- Average grazing period is almost 10 hours a day.

Other factors

- 18% of the farmers indicate to have not had any serious problems after introduction related to the system. Other farmers mention claw health as the most serious problem.
- Unfit shape of udders and position of the teats are the most important reasons for culling extra animals surrounding introduction. On 33% of the farms replacement percentage has increased after introduction.
- Milk production on the farms surveyed is slightly higher (4%) than the national average and the farms are somewhat larger (9%). HF is the most common breed.
- Most characteristics considered as to hygiene score relatively well, but hygiene of the collecting area, water troughs, teat cups, robot arm and floor of stable should be improved.
- Less than half of the farms always use farm clothing, less than one-third have a sanitary barrier.
- Average milking frequency is 2.5 milkings a day. Per box 158 milkings are done on average. The system's idle time is 5 hours on average.

3.4 Linear regression

3.4.1 Milk quality

For the statistical analyses, the averages of the milk quality parameters have been calculated for four different periods, i.e., the last year before introduction, 7 to 1 months before introduction, the first year after introduction and 6 to 11 months after introduction. Moreover, the differences (after minus before) have been calculated for both yearly and 6-month periods. An overview of the milk quality data is given in the table below.

Table 11 Overview data milk quality

Parameter	Period	Average	Min.	Max.	Period	Average	Min.	Max.
TBC	1 yr before	8.9	2.1	41.8	7 to 1 mo before	8.7	2.3	44.8
TBC	1 yr after	12.1	4.6	35.1	6 to 11 mo after	10.9	3.0	37.5
TBC	diff after-before	+3.0	-20.4	+16.2	Diff after-before	+2.06	-23.9	+21.6
SCC	1 yr before	180.8	64.4	382.6	7 to 1 mo before	181.8	64.5	391.5
SCC	1 yr after	222.1	88.2	386.9	6 to 11 mo after	221.9	82.5	399.1
SCC	diff after-before	+40.2	-94.9	+200.4	Diff after-before	+39.1	-138.4	+226.1
FFA	1 yr before	0.421	0.260	0.779	7 to 1 mo before	0.423	0.220	0.820
FFA	1 yr after	0.644	0.309	2.698	6 to 11 mo after	0.685	0.290	2.698
FFA	diff after-before	+0.225	-0.294	+2.194	Diff after-before	+0.264	-0.400	+2.194
FP	1 yr before	-0.522	-0.505	-0.533	7 to 1 mo before	-0.522	-0.511	-0.533
FP	1 yr after	-0.517	-0.501	-0.529	6 to 11 mo after	-0.518	-0.508	-0.529
FP	diff after-before	+0.0048	-0.0095	+0.023	Diff after-before	+0.0043	-0.0075	+0.0170

TBC=total bacterial count, SCC=somatic cell count, FFA=free fatty acids, FP=freezing point

The averages before introduction can be compared well for all four parameters for both periods. This corresponds to the plane course of the averages before introduction, as presented in appendix 2. The averages after introduction show, however, small differences for total bacterial count and free fatty acids between the two periods. Also this corresponds to the course of the averages as presented in appendix 2. One comment here is that not all farms always have values for all parameters. This particularly concerns free fatty acids and freezing point for the 6-month periods. In considering the entire first year after introduction, the total bacterial count is slightly higher than if the first 5 months are ignored. This is caused by the initial strong increase in total bacterial count. As far as free fatty acids are concerned, the average value in the entire first year after introduction is lower than in the period of 6 to 11 months after introduction. The free fatty acids keep increasing gradually. For somatic cell count and freezing point both periods after introduction can be compared well on average. Both show a comparable increase. The table makes clear that there is considerable variation among the farms in the

size of the change in the parameters. On average, the milk quality reduces after introduction, but there are also farms where improvement can be seen. The total bacterial count improves on 23% of the farms in the first year after introduction compared with the preceding year. Somatic cell count improves on 15% of the farms; free fatty acids on 12% of the farms and freezing point on 18% of the farms.
Relations of the milk quality parameters before introduction with parameters after introduction and the size of the change in these parameters have been determined by linear regression. Milk quality before introduction has been divided into categories as presented in 2.4.4. The result can be seen in table 12.

Table 12 Linear regression of milk quality before introduction in relation to after introduction and to the size of the change in milk quality

	Year before/Year after		7-1 mo before /6-11 mo after	
Response variable	% accounted for*	F-prob**	% accounted for	F-prob
TBC after introduction	24.9	<0.001	16.8	<0.001
Change in TBC	39.8	<0.001	44.6	<0.001
SCC after introduction	37.6	<0.001	18.0	<0.001
Change in SCC	9.6	0.003	17.9	<0.001
FFA after introduction	1.1	0.242	0.0	0.518
Change in FFA	0.8	0.279	0.5	0.333
FP after introduction	0.0	0.793	0.0	0.485
Change in FP	34.1	<0.001	33.0	<0.001

* The percentage of the variation of the accounting variable that is accounted for by the regression
**Possibility that influence of regression factors is based on chance

The differences among the relationships found for the period of one year prior to introduction and one year after and both 6-month periods are small.
With a relatively high total bacterial count before introduction, the value is also higher after introduction on average. Furthermore, a trend can be seen that the increase is less large as the level before introduction is higher. From this, it can be concluded that factors that affect total bacterial count before introduction, are often still present after introduction and that the introduction of the AM-system causes a relatively small change for farms that already had a high total bacterial count, but have all the more effect on farms that had a relatively low total bacterial count before introduction.

Somatic cell count in the first year after introduction also depends on somatic cell count in the year prior to introduction. This is stronger than the size of the change in somatic cell count. If the year averages are not considered, but the 6-month periods, the relations of somatic cell count before introduction and those of after introduction and the changes in somatic cell count are almost equal. Farms that had high numbers before introduction, thus increase relatively less than farms that had low counts before introduction. High somatic cell counts on farms with an AM-system are partly caused by factors that had already been present before introduction, of which the herd is probably the most important one.

For free fatty acids, there is also the trend that higher values before introduction are connected with higher values after introduction, but this relationship is not significant and does not explain the variation. Thus, it seems that the increase in free fatty acids after introduction is not so much connected to the level before introduction, but is affected by other factors such as the introduction of the AM-system.
For freezing point, it can be seen that the level before introduction is related to the size of the change, but not to the level after introduction. Freezing point increases less after introduction, if this was already high before introduction.

3.4.2 Relation between milk quality and the variables studied

The milk quality parameters are related to the data of the questionnaire and the remaining information collected. The results of the milk quality data of one year before and one year after introduction well correspond to the results of those of the period of 7 to 1 mo before and 6 to 11 mo after introduction. Yet no distinction will be made among these periods in presenting the results.
Which factors showed a significant relation ($p<0.05$) with the level after introduction and with the size of the changes is discussed below for total bacterial count, somatic cell count, free fatty acids and freezing point. The results shown concern the year prior to introduction and the year after. More information about the factors used and the distribution over the categories can be found in appendix 1. As was described in materials and method (2.4.4), the regressions were carried out per connecting cluster (for example, housing) of variables (for example,

type of floor). For this use was made of marginal (one variable in model) and conditional (adding variables to existing model of one cluster) models. Only some conditional models were found to be significant. Then the combined percentage of variation, which is explained by factors within this cluster, is presented.

Total bacterial count

The significant relations found for total bacterial count after introduction are in table 13.

Table 13 Significant relations with the TBC *level* after introduction

Cluster	Variable	% AV*	Explanation
General	Age worker	5.0	40-50 year old farmers have the lowest TBC, farmers > 50 years the highest
Milk quality	Who is first responsible for the total bacterial count	5.7	If the farmers hold others primarily responsible, the TBC is higher
Health	Participation in milk recording system	16.7	Participants of milk recording system have resulted in lower total bacterial count
AM-system	- Replacement of teat liners - Replacement of teat brushes - Collecting criteria	23.7	- Farmers who determine the moment themselves have a higher total bacterial count - Brushes not being replaced within 6 months are connected to higher total bacterial counts - If cows are not only collected on the basis of robot signals, but if also other criteria (disease etc) apply, the total bacterial count is higher
Cooling	Starting of cooling	5.4	Automatically starting of cooling is connected with a lower total bacterial count
Housing	Cleaning barn	6.0	Higher total bacterial count with cleaning more often
Milk recording system data	Milk yield in 2001	7.3	At a higher production, a lower total bacterial count
Hygiene check	Teat cups	9.5	Higher total bacterial count with poor hygiene of teat cups

* The percentage of the variation of the milk quality parameters that is accounted for by the variables mentioned

Feeling responsible for total bacterial count has to do with feeling committed. If the farmer holds others responsible, it may be that the general commitment is less and that attention for total bacterial count wanes. Timely replacement of teat liners and teat brushes favourably affect total bacterial count. Moreover, automatically starting the cooling seems to be favourable. If such activities are done automatically, a low total bacterial count seems to be guaranteed better. Also adequate hygiene of the teat cups seems to be connected to a lower total bacterial count. This also gives an impression of the farmer and his perception of hygiene in the AM-system.
At a higher production per cow, the total bacterial count is usually lower. An explanation might be that high-productive cows come to the system more often, so that there is less milk that stands still in the pipes. However, in that case there would also be a relation with milking interval and/or population rate, which could, however, not be observed.

Some of the relations found cannot be interpreted well. They are probably of little practical importance. Here particularly the relation with the farmer's age is meant (are younger farmers more precise?), participation in the milk control system (total bacterial count is not on the lists), collecting criteria and cleaning of the barn. These relations are probably not causal. The latter, cleaning the barn, is even against the perception of barn hygiene. This may be the chicken-and-egg problem. Farmers with a high total bacterial count may clean the barn more often, due to which a relation is demonstrated. However, on most farms the barn is only cleaned sporadically, thus it is difficult to assume a causal relationship.

The significant relations for the change in total bacterial count are shown in table 14.

Table 14 Significant relations with the *change in* TBC after introduction (after minus before introduction)

Cluster	Factor	%AV	Explanation
AM-system	Indicators of mastitis	6.5	If conductivity and flakes on the filter are the most important indicators, the increase is larger
Housing	AM-system placed in new or existing facility	8.8	Placing of AM-system in new facility results in a lower total bacterial count increase than placing in an existing facility
Other	Cow traffic	3.8	Free cow traffic is connected with a lower increase in total bacterial count than forced cow traffic

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

It is shown that the change in total bacterial count cannot be related to the same variables of total bacterial count after introduction. In fact, the increase in total bacterial count is larger, if the automatic milking system is placed in an existing facility. This is presumably related to the fact that in a new facility designed for placing an AM-system, total bacterial count can be controlled in a better way by good management. What exactly the reason is that there is less increase in total bacterial count cannot be indicated on the basis of this research. The relation with indicators of mastitis cannot be explained easily and is probably not causal either. The relation with cow traffic cannot be explained either, but is yet interesting enough to study further.

Factors that are present in appendix 1, but not in tables 13 and 14 do not show a significant relation with total bacterial count after introduction.

Somatic cell count

The significant relations with the level of TBC after introduction are in table 15.

Table 15 The significant relations with the level of TBC after introduction

Cluster	Factor	%AV*	Explanation
Farm data	Change in production	8.0	Larger increase in production is related to lower total bacterial count
Milk quality	Target level total bacterial count	5.9	At a higher target level, a higher total bacterial count applies
AM-system	- Replacement of teat liners - Cleaning of teats	11.5	- At a later replacement, total bacterial count is higher - At cleaning teats more often, total bacterial count is lower
Other	Quietness of cows	6.7	Total bacterial count increases less if cows are quieter after introduction
Milk control system data	Milk yield in 2001	7.7	The highest production category has the lowest total bacterial count
Output AM	Milk flow	11.8	The lowest total bacterial count is at a milk flow of 2-2.2

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

The lower total bacterial counts at higher productions correspond to the anticipations. This is partly connected with the dilution effect, but also healthy cows result in a higher production.
The relation between a higher target level and a higher total bacterial count can be interpreted in various ways. Firstly, farms with a high target level of total bacterial count may have fewer requirements, and yet pay less attention, as to the fact to keep it low. Secondly, these farms may be constantly high in total bacterial count and do not know why, while they try to reduce it. By setting the target level higher, this can be lowered in small steps, while working on a reduction in total bacterial count. Dealing with an extremely low target level with an on average high total bacterial count is not realistic farm management.
Furthermore, it is shown that particularly a timely replacement of the teat liners, accurate cleaning of teats and a slightly lower milk flow are important to control total bacterial count. Also a calm herd plays a role. These aspects are in fact not different from those in conventional milking.

The significant relations with the change in TBC after introduction are in table 16.

Table 16 Significant relations with the change in TBC (after minus before introduction)

Cluster	Factor	%AV	Explanation
Farm data	Change in production	9.7	Larger increase in production is connected with a lower increase in total bacterial count
Health	Inspecting teat condition	10.5	Farms with the smallest increase in total bacterial count never inspect the teat condition
AM-system	Replacement of teat liners	13.8	The increase in total bacterial count is considerably larger if the farmer waits whether the teat liners have to be replaced
Cleaning	Starting cleaning of the AM-system	8.5	At automatic starting the cleaning of the AM-system, the increase in total bacterial count is smaller
Other	Shaving udders	4.4	Increase in total bacterial count is smaller at shaving udders twice or more often

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

Table 16 also shows that total bacterial count increases less by the dilution effect due to an increase in production. The relation between inspecting the teat condition and total bacterial count increase is probably affected by the fact that farms with udder health problems are more inclined to pay extra attention to the teat condition. Farms without total bacterial count increase will probably inspect the teats less often if they have not done this before.

A larger increase in production and the timely replacement of teat liners prove to be important, not only for the level of TBC after introduction (table 15), but also for the size of the increase in TBC (table 16). With this, there is a considerable correspondence in influential factors between both parameters for TBC. Moreover, udder hygiene proves to be important, because shaving the udders has a positive effect on total bacterial count.
Also the start of cleaning seems to have an effect. 86% of the farms start cleaning automatically, 85% of which clean three times a day. Cleaning three times a day (which is mostly done with automatically starting) has probably more effect on TBC than whether or not starting automatically. At cleaning, also the cluster is cleaned with disinfectant, which is not done at rinsing after each cow. This result poses some questions as to the effectiveness of rinsing in order to prevent cross-infection, if they are compared with the effectiveness of cleaning.

Factors that are present in appendix 1, but not in tables 15 and 16 do not show a significant relation with total bacterial count after introduction.

Free fatty acids

The significant relations with the free fatty acids after introduction are in table 17.

Table 17 Significant relations with the level of free fatty acids after introduction

Cluster	Factor	%AV	Explanation
Farm data	Change in production	4.8	Larger increase in production is connected with more free fatty acids
Cleaning	- Teat brushes - Control cleaning	23.6	- At cleaning brushes sometimes without disinfectant, fewer free fatty acids - At a better control of the cleaning, free fatty acids are fewer
Housing	Cleaning collecting area	5.3	Cleaning less often of collecting area is connected to fewer free fatty acids
Data of milk recording system	Production category %protein	9.0	Highest production category %protein is connected with fewer free fatty acids

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

More free fatty acids with a larger increase in production can possibly be explained by the fact that at a higher production also the time of machine milking increases. Strikingly, no relation was found with milking interval or milk flow. It is possible that the limited determination frequency (twice a year) of free fatty acids plays a role here. Due to this, the farm averages can be calculated less accurately. It is not clear what the background of these lower free fatty acids at high protein percentages is.

Furthermore, particularly cleaning seems to be important for the free fatty acids. This relation is unexpected and cannot be explained by current knowledge.

The significant relations with the change in free fatty acids are in table 18.

Table 18 Significant relations with the change in free fatty acids (after minus before introduction)

Cluster	Factor	%AV	Explanation
Cleaning	- Cleaning AM-system without disinfectant - Number of control points cleaning	16.7	At incidentally cleaning without disinfectant, the increase in free fatty acids is smaller With more than 3 control points of the cleaning of the AM-system, the increase in free fatty acids is smaller

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

It can be seen that the size of the change in free fatty acids is only significantly related to the cleaning. Just as for the level it could not be proven that milking interval, milk flow or other variables are related to the increase. It is possible that not so much the average interval is important, but particularly its variation for the fat separation. However, it is important here to note that the level of the free fatty acids on AM-farms is comparable to farms that milk three times a day.

Factors that are present in appendix 1, but not in tables 17 and 18 do not show a significant connection with the free fatty acids after introduction. As has been mentioned earlier, the data as to air inlet in the periodic equipment test report were too unreliable to be related to the free fatty acids. The hypothesis is that more air inlet goes hand in hand with more free fatty acids, due to increased fat separation.

Freezing point

The significant relations with the freezing point after introduction are in table 19.

Table 19 Significant relations with the level of the freezing point after introduction

Cluster	Factor	%AV	Explanation
Health	Milking mastitic cows	6.0	Due to milking differently (for example, by hand, more often etc.) of mastitic cows, the freezing point is higher
Cleaning	- Start of cleaning AM-system - Cleaning teat brushes	18.1	- With an automatic start of cleaning the AM-system, the freezing point is higher - With cleaning teat brushes without disinfectant, the freezing point is lower
Other	Grazing	3.5	Grazing results in a higher freezing point

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

A higher freezing point with milking mastitic cows separately can possibly be the result of more water consumption by applying extra rinsing. The connection of automatically starting cleaning with the freezing point after introduction can be related to the fact that this concerns mainly farms that clean three times a day as opposed to cleaning less often. The higher cleaning frequency can lead to more water in the milk. However, a direct relation with the frequency of cleaning has not been demonstrated.
The relation with grazing cannot be explained well and the question remains to what extent it is important. It is probably the high water consumption, higher frequency of cleaning and a shorter period for drainage with AM-systems that are responsible for a rising freezing point with automatic milking.
The significant relations with the change in freezing point are in table 20.

Table 20 Significant relations with the change in freezing point (after minus before introduction)

Cluster	Factor	%AV	Explanation
Cleaning	- Time between cleanings - Cleaning teat brushes	21.2	- Largest increase with a short interval between cleanings - Smaller increase with cleaning brushes without disinfectant
Cooling	Control of cleaning tank	4.4	Larger increase with controlling more often

* percentage of variation of the milk quality parameter that is accounted for by the factors mentioned

Just as for the level, it also seems to hold for the change in freezing point that particularly water consumption plays an important role. The relation between control of the cleaning of the tank and the freezing point cannot be explained. It is possible that farms that have already suffered penalty points a few times due to too high a freezing point control the tank more often or control the drainage after cleaning.

Factors that are present in appendix 1, but not in tables 19 and 20 do not show a significant connection with the freezing point after introduction.

It is striking that there are no relations between housing and milk quality, as is the minor importance hygiene seems to have. However, the way of inspecting may also play a role, hygiene was judged fairly generally (3 classes), because the emphasis of the research was on the questionnaire. Cooling does not show clear relations either. It is likely that due to the maintenance contracts and the current techniques structural influence can no longer be discovered.

4 Conclusions and points of interest

It is possible to obtain a good milk quality with automatic milking. However, on average the milk quality reduces after introduction of an AM-system. This study has tried to indicate the most important risk factors for this reduced milk quality. The regression analysis has shown some possible relevant risk factors, but because the accounted variation was largely low, it should be interpreted with caution.

For total bacterial count, replacing the teat brushes and teat liners and hygiene of the teat cups seem to be particularly important. Placing the system in a new facility results in a lower increase on average in total bacterial count than placing the system in an existing barn. Also for somatic cell count, a timely replacing of the teat liners seem to be important, besides a smooth but not too high milk flow. For the free fatty acids, increased machine milking time and cleaning are supposedly important. The higher freezing point with milking automatically is particularly related to the rinsing frequency and other aspects of cleaning. It seems that the factors that also play a role in conventional milking as to the milk quality are also the most important factors in automatic milking and that hygiene and housing do not influence the quality directly.

The factors studied provide an extensive overview of the management and issues surrounding the AM-system on dairy farms after introduction of the AM-system, some of which are presented below. A distinction has been made among technique, management and other (management) issues. These points of interest do not have a direct causal relationship with the milk quality, but provide a brief picture of the way in which farms deal with an AM-system, and may help in solving the problems as to milk quality.

Points of interest as to technique:
- Only 20% of the farms consider over 80% of the signals for conductivity correct.
- 43% indicate that expectations as to *the system* have been met (based on the sellers' report).
- 84% of the farms apply spraying. 57% think this happens moderately or poorly (2%).
- 72% of the farms experience system failures at least once a month (5 times at maximum).
- 87% of the farms use a buffer tank.
- 58% of the farms have a manure scraper.

Points of interest as to animal management:
- Conductivity, milk yield and milking interval are considered the most import output of the AM-system. The majority views these parameters at least once a day (by 93%, 85% and 73% of the farmers respectively).
- 83% of the farmers check the animals more often than twice a day.
- Almost 59% of the farmers collect the cows that are late or with which something is wrong twice a day.
- 39% of the farmers state they know the cows better after introduction. 55% say this has remained the same.
- Over half of the farms do not supply feed more often than once a day.
- 62% feed concentrates in the AM-system as well as by a separate concentrates box in the barn.
- 72% of the farms apply free cow traffic, mostly without preselection.
- Over half of the farms apply grazing.
- Claw health, increase in somatic cell count and failures are mentioned as the most important problems surrounding introduction.

Points of interest as to other management:
- By far the majority of the farmers hold themselves responsible for somatic cell count and total bacterial count (85% and 88% respectively).
- There is less sense of responsibility for free fatty acids and freezing point. Approximately 60% hold themselves responsible. Mechanics and cows are often held 'co-responsible'.
- 71% of the farmers apply major cleaning three times a day at fixed intervals.
- 46% of the farms inspect the cleaning at least once a day; 17% never do this.
- 89% of the farms apply rinsing of the cluster after each cow.
- Two-thirds of the farmers replace the filter twice a day.
- Farmers need on average 6 months to get used to the system.
- Average milking frequency is 2.5 milkings a day.

Other points of interest:
- Milk production increases by 5% on average after introduction.

- On average there is underpopulation in the barns (1.25 cubicles/cow and 1.17 feeding places/cow).
- One's own expectations as to automatic milking have been (entirely or largely) met for 83% of the farmers.
- Most parameters considered score well as to hygiene, but the collecting area, water troughs, teat cups, robot arm and barn floor can be improved.

The factors from this inventory will be studied more closely within the EU-project Automatic Milking (http:\\www.automaticmilking.nl).

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Appendices

Appendix 1 Division into categories for linear regression

Questionnaire

Categories for component A (General farm data):

Question	categories	Description
A09	3	Size milk quota: 1 = <550.000, 2 = 550-<800.000, 3 = >=800.000 Kg
A10	2	All quota used (1 = yes, 2 = no)
A11/12	4	Change milk yield (after-before): 1 = ≤0, 2 = >0 –1000, 3 = ≥1000 kg

Categories for component B (General data):

Question	categories	Description
B01	3	Age farmer 1: 1 = <40 jaar, 2 = 40-50 jaar en 3 = >50 year
B02a	2	Who responsible for management 1 = just farmer, 2 = other
B02f	3	Who check cows: 1 = farmer, 2 = also relatives and 3 = other
B03	3	Will child take over farm: 1 = yes, 2 = no and 3 = unknown
B06	2	Join farmers discussion groups: 1 = yes, 2 = no

Categories for component C (milk quality):

Question	categories	Description
C01	3	Strive value BMSCC: 1 = ≤150, 2 = 150-200, 3 = >200
C07	2	Who responsible for BMSCC: 1 = also farmer, 2 = mostly others
C08	3	Strive value TBC: 1 = <10, 2 = 10, 3 = >10
C12	2	Are tank and cleaning checked? (1 =yes, 2 =no, other interferences)
C13	2	Primary responsible for TBC: 1 =farmer, 2 = others
C15	2	Primary responsible for FFA: 1 =farmer, 2 = others
C17	2	Primary responsible for FP: 1 =farmer, 2 = others

Categories for component D (Animal Health):

Question	categories	Description
D01	3	Join milk production registration: 1 =no, 2 = 3 or 4 times per week, 3 = less often
D02	2	MP registration, BMSCC and conductivity all 3 used to manage SCC: 1 = yes, 2 = no
D03	2	Drying off and/or culling high cell count cows: 1 =yes, 2 = no
D06	3	Treat mastitis with antibiotics: 1 =always, 2 =usually, 3 = generally not
D07	3	Treat mastitis with alternative methods: 1 = preventive, 2 = with antibiotics, 3 = no
D08	2	Treat antibiotics and alternative methods: 1= no, 2 = yes
D10	2	Bacteriological samples take during past year: 1 = no, 2 = yes
D13d	2	Risk cows fetched more frequently to be milked: 1 = no, 2= yes
D13f	2	Rinse milk cluster after every cow: 1 = no, 2= yes
D14	2	Milk cows w/ mastitis alternative (eg. More attention, more frequent milking, milk by hand, extra rinsings, etc.): 1 = no, 2 = yes
D20	3	Score teat condition: 1 = never, 2 = <1*/month, 3 = ≥1*/month
D21	2	Teat condition improved after introduction: 1 = yes, 2= no
D22c	3	Frequency checking conductivity list: 1 =never, 2 = 1* per day, 3 = >1* per day
D23	2	After notice/attention always undertake action: 1= yes, 2 = no
D28	3	Percentage correct attentions: 1 = 0-25%, 2 = >25-75%, 3 = >75%
D30	2	Farm guidance by veterinarian: 1 = yes, 2 = no

Categories for component E (AM-system):

Question	categories	Description
E04/05	3	Spraying of teats: 1 = no, 2 =with iodine, 3 = other substance
E06	2	Min. 1* per year cleaning of head of spray installation (1 = no, 2 = yes)
E07	3	Teats being sprayed well: 1 = yes, 2 = no, 3 = n.v.t.
E08	2	Farmer decides upon time replacing liners (1 = yes, 2 = no)
E09	3	No. Of milkings after liners are replaced: 1 = t/m 4000, 2 = >4000 t/m 8000 en 3 = >8000
E10	3	Replacing teat brushes within 6 months: 1 = yes, 2 = no
E11B	3	Frequency cleaning teats before milking: 1 = 1*, 2 = >1*
E13	3	Frequency per year of equipment testing: 1 = 0/1, 2 = 2*, 3 = >2*
E14	4	Type vacuum pump: 1 = waterring, 2 = schoepen, 3 = anders
E15	2	Conductivity and clots most important indicators for mastitis: 1 = yes, 2 = no
E19	3	Fetching cows: 1) = only on basis of attentions of AM system, 2= also other criteria, 3 = only other criteria
E20	3	Frequency fetching cows per day: 1 = max 1*, 2 = max 2*, 3 = more often
E26	2	Solving failures: 1 =usually farmer himself, 2 = usually not farmer himself
E29	2	Read logbook mechanic of AM-system after visit: 1 = yes, 2 = no.

Categories for component F (cleaning of AM-system):

Question	categories	Description
F01	3	Cleaning man side of AM-system: 1 = ≤1*/week, 2 = <2*/day, 3 = more often
F02	3	Cleaning floor AM-system: 1 = = ≤1*/day, 2 = ≤2*/day, 3 = more often
F03	3	Longest time between cleanings: 1 = <8 hrs, 2 = 8 hrs, 3 = >8 hrs
F05	2	Start cleaning automatically: 1 = yes, 2 = no
F06	4	Relation acid/base cleaning: 1 = <0.2, 2 = ≤0.33, 3 = >0.33
F07	3	Action according to attention AM-system empty can: 1 = yes, 2 =before, 3 = other
F08	2	Cleaning sometimes without chemicals: 1 = no, 2 = yes
F09	3	Cleaning brushes without chemicals: 1 = no, 2= yes
F10	3	Check cleaning: 1 = <1*/month, 2 = <1*/day, 3 = ≥1*/day
F11	3	No. Of checking points cleaning: 1 = ≤1, 2 = 2-3, 3 = >3
F12	2	Clean tank and AM-system at same time: 1 = yes, possible, 2 = does not happen
F15	3	Short cleaning after 30 min idle time: 1 = yes, 2 = later
F17	2	Change filter more often than 2*/day: 1 = no, 2 = yes

Categories for component G (Cooling):

Question	categories	Description
G01	2	Use pre cooler: 1 = yes, 2 = no
G03	3	Size bulk tank: 1 = ≤6400, 2 = <9000, 3 = ≥9000 liter
G08	2	Start cooling automatically: 1 = no or unknown, 2 = yes
G09	4	Relation acid/base cleaning: 1 = <0.2, 2 = ≤0.33, 3 = >0.33
G10	4	Check tank after cleaning: 1 =never, 2 =sometimes, 3 =often, 4 = always
G11	3	Notice of tank guard: 1 =never, 2 =sometimes, 3 = often
G12	2	Use retention of heat: 1= yes, 2 = no
G13	2	During failures try to solve by farmer himself: 1 = yes, 2 = always call mechanic
G16	2	Responsible for cooling bulk tank: 1 = also the farmer, 2 = mostly others

Categories for component H (Housing):

Question	categories	Description
H01	2	Manure scraper present: 1 = no, 2 = yes
H02	2	Frequency removing manure: 1 = ≤6*/day, 2 = >6*/day
H03	2	Waiting area in front of AM-system cleaned less often: 1 = yes, 2 = no
H04	4	Floor cubicle: 1 = none, 2 = rubber mat, 3 = waterbed / mattress or 4 = other
H05	2	Frequency cleaning cubicles: 1 = ≤2*/day, 2 = >2*/day
H06	3	Filling/adding up cubicles: 1 =never, 2 = ≤1*/week, 3 = >1*/week
H09	3	Cleaning entire barn: 1 =never, 2 = <1*/year, 3 = ≥1*/year
H13	2	AM-system placed in existing situation: 1 = yes, 2 = no

Categories for component I (The farmer):

Question	categories	Description
I01	2	Check animals more often than 2*/day: 1 = yes, 2 = no
I03	2	Farmer knows cows better after introduction AM-system: 1 = yes, 2 = no
I07	2	Farmer has economical bookkeeping: 1 = yes, 2 = no
I09	2	Reduction of labour motive for purchase AM-system: 1 = yes, 2 = no
I10	3	Expectations came true: 1 = all, 2 = most, 3 = other

Categories for component J (feeding):

Question	categories	Description
J01	3	% grass silage in ration: 1 = ≤50%, 2 = ≤70%, 3 = >70%
J05	3	Max, concentrate supply in AM-system: 1 = ≤6kg, 2 = 7-8kg, 3 = ≥8kg

Categories for component K (Other):

Question	categories	Description
K02	2	Cow traffic: 1 =one way, 2 = free
K03	2	Grazing: 1 = yes, 2 = no
K09	3	Length adjusting period cows: 1 = ≤14 days, 2 = 14-90 days, 3 = ≥90 days
K10	2	Cows more relaxed after introduction AM-system: 1 = yes, 2 = no
K12	3	Heifers to calf soon in herd: 1 = yes and in AM-system, 2 = yes, but not in AM-system, 3 = no
K13	3	Frequency shaving udders: 1 = ≤1*/year, 2 = 2*/year, 3 = >2*/year
K16	3	Replacement percentage after introduction: 1 =higher, 2 =same, 3 = lower
K18	2	Breeding important for AM-system (type of cows): 1 = yes, 2 = no

Periodic equipment test report

Categories for component 'periodic equipment test report':

Code	categories	Description
V2	3	Pulsation ratio (a+b) milliseconds: 1 = <645, 2 = 645-650, 3 = >650
V3	3	Pulsation ratio (c+d) milliseconds: 1= <344, 2 = 344-349, 3 = >349
V4	4	Vacuum: 1 = ≤42.5, 2 = >42.5-≤44, 3 = >44≤46, 4 = >46

Milk recording system data

Categories for component 'milk recording system data':

Code	categories	Description
V1	3	Kg milk in 2000: 1 = <8500, 2 = 8500-9500, 3 = ≥9500
V2	3	% fat in 2000: 1 = <4.30, 2 = 4.30-4.50, 3 = > 4.50
V3	3	% protein in 2000: 1 = ≤3.40, 2 = >3.40-3.50, 3 = > 3.50
V4	3	No. Of cows on list: 1 = <55, 2 = 55-75, 3 = >75

Hygiene checklist

Categories for component 'hygiene checklist':

Code	categories	Description
V1	3	Impression AM-system: 1 = good, 2 = moderate, 3 = poor
V2	3	Waiting area in front of AM-system: 1 = good, 2 = moderate, 3 = poor
V3	3	Floor AM-system: 1 = good, 2 = moderate, 3 = poor
V4	3	Teat cups: 1 = good, 2 = moderate, 3 = poor
V5	3	Robot arm AM-system: 1 = good, 2 = moderate, 3 = poor
V6	3	Udder preparation: 1 = good, 2 = moderate, 3 = poor
V7	3	Bulk tank room: 1 = good, 2 = moderate, 3 = poor
V8	3	Finishing AM-system: 1 = good, 2 = moderate, 3 = poor
V9	3	First impression farm: 1 = good, 2 = moderate, 3 = poor
V10	3	First impression barn: 1 = good, 2 = moderate, 3 = poor
V11	3	Feeding alley: 1 = good, 2 = moderate, 3 = poor
V12	3	Floor barn: 1 = good, 2 = moderate, 3 = poor
V13	4	% clean cubicles: 1 = ≤20, 2 = 30-60, 3 = 70-80, 4 = >80
V14	4	% clean cows: 1 = <40, 2 = 40-60, 3 = 60-80, 4 = ≥80
V15	4	% clean udders: 1 = ≤40, 2 = >40-80, 3 = 80, 4 = >80
V16	2	Climate: 1 = good, 2 = moderate
V17	3	Light: 1 = good, 2 = moderate, 3 = poor
V18	3	Ventilation: 1 = good, 2 = moderate, 3 = poor
V19	3	Roof cover: 1 =dome, 2 =T-shape, 3 = other

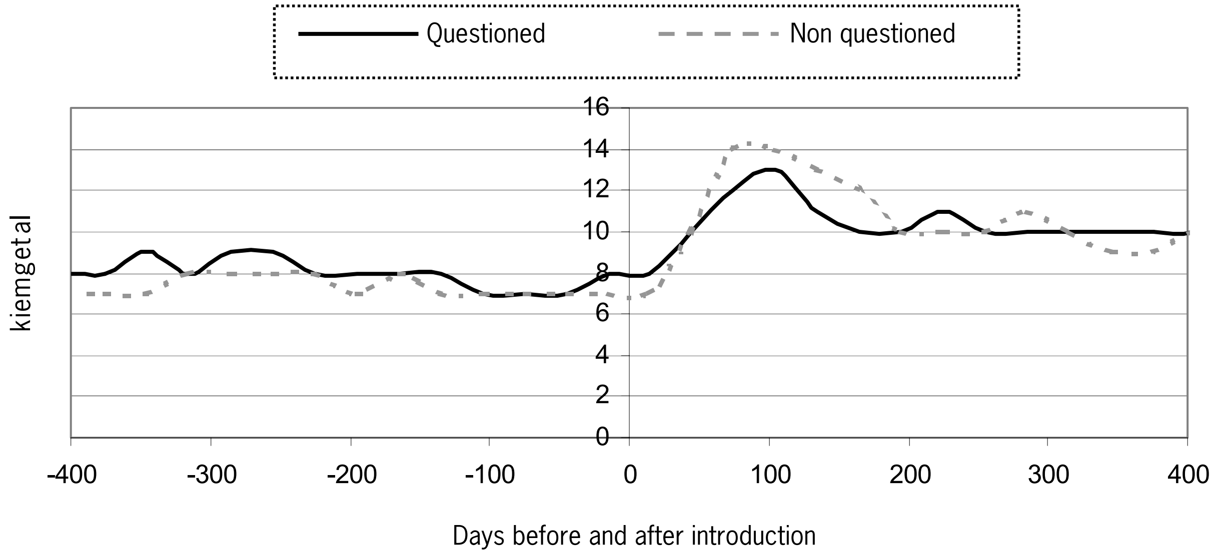
Data from management program of AM-system

Categories for component 'data from management program of AM-system':

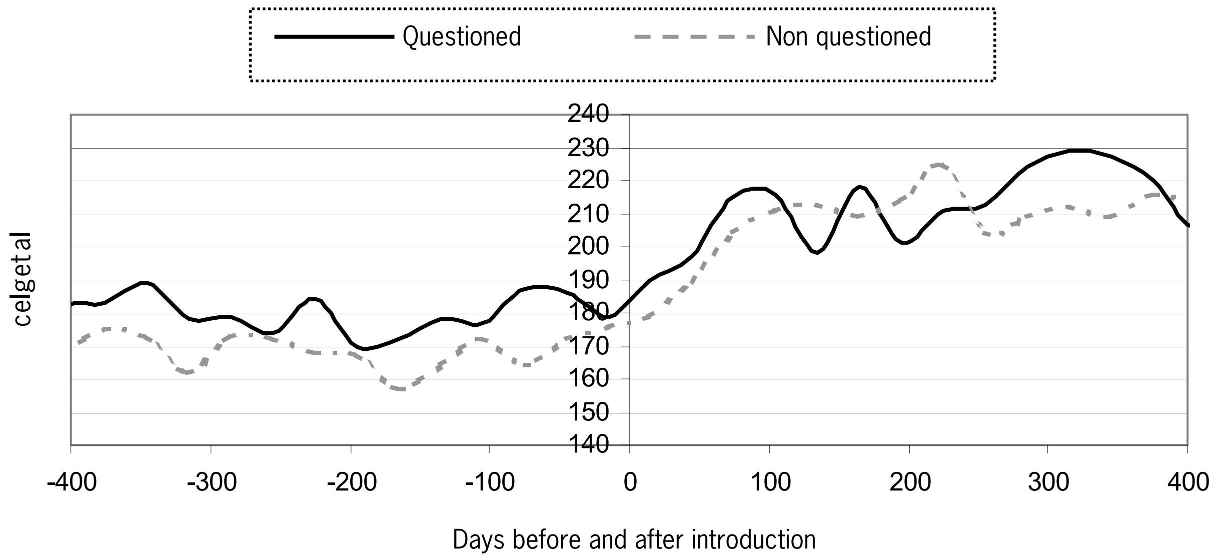
Code	categories	Description
V1	3	Average milking interval: 1 = <9, 2=9-10, 3 = >10 hours
V2	3	Average milking speed: 1 = <2; 2 = 2-2,2; 3 = >2,2

Appendix 2 Representativeness of farms

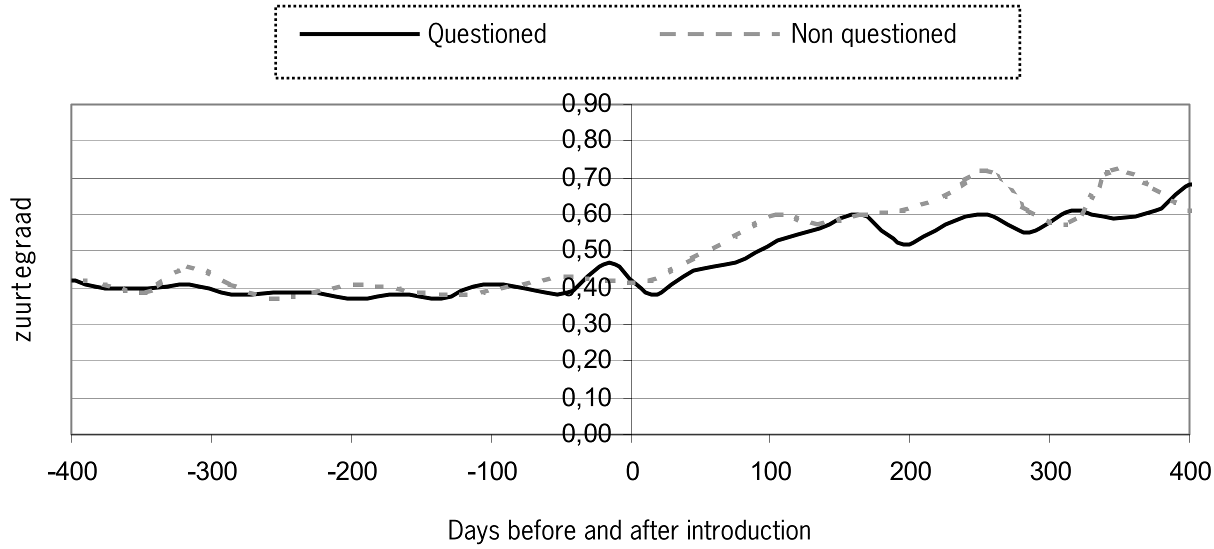
Appendix 2a Course of TBC (cfu/ml x1000) before and after introduction on questioned and non-questioned farms



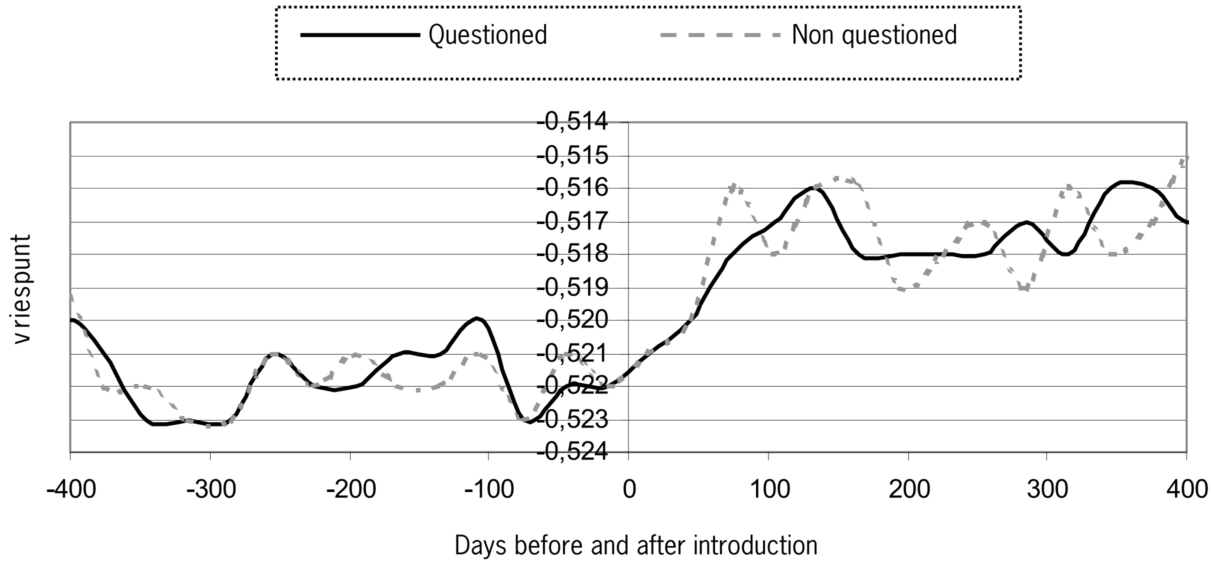
Appendix 2b Course of BMSCC (cells/ml x1000) before and after introduction on questioned and non-questioned farms



Appendix 2c Course of FFA (meq/100 g fat) before and after introduction on questioned and non-questioned farms



Appendix 2d Course of FP (degrees Celsius) before and after introduction on questioned and non-questioned farms



Appendix 3 List with Tables and Figures

Tables

Figures