AUTOMATIC MILKING – COMMON PRACTICE ON DAIRY FARMS

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An overview of historical development of automatic milking, as well as the current situation and perceived challenges and opportunities for future development are discussed. Since the first commercial systems appeared in 1992, automatic milking systems (AM-systems) have been installed at an increasing rate. No other new technology since the introduction of the milking machine, has aroused so much interest and expectations among dairy farmers and the periphery. Reduced labor, a better social life for dairy farm families and increased milk yields due to more frequent milking are generally recognized as important benefits of automatic milking. Without doubt automatic milking changes many aspects of farm management since both the nature and organization of labor is altered. Manual labor is partly replaced by management and control, and the presence of the operator at regular milking times is no longer required. Visual control on cow and udder health at milking is, at least partly, taken over by automatic systems. Facilities for teat cleaning and separation of abnormal milk are incorporated into the automatic system and several adaptations are needed to accommodate continuous milking. Cow management including routing within the barn, the opportunity for grazing and the use of total mixed rations is altered. A high level of management and realistic expectations are essential to successful adoption of automatic milking. Results from commercial farms indicate, that milk quality is somewhat negatively affected, although bacterial counts and somatic cell counts remain well below penalty levels. In terms of quality control, AM-systems offer extra means to assure milk quality and food safety. No adverse effects of the transition have been found for body condition, lameness or teat condition. Automatic milking systems require a higher investment than conventional milking systems. However increased milk yields and reduced labor requirements may lead to a decrease in the fixed costs per kg milk. In recent years the first mobile automatic milking systems appeared on dairy farms in Denmark and The Netherlands. Automatic milking has gained widespread acceptance and is now estimated to be in use on more than 8000 farms in over 25 countries worldwide.

Introduction

The main reason to start the development of automatic milking in the eighties of the last century, was the need for improved labor efficacy due to the growing costs of labor in many dairy countries (Rossing et al, 1985; Rossing & Hogewerf, 1997; Lind et al, 2000). Milking is on many dairy-farms a time consuming activity, which takes about 25 to 35% of the annual labor demand. In this way the milking activities contribute also substantially to the costs of the farm enterprise. Apart from substituting manual labor by technology, robotic milking affects the whole farming operation. The farmer's presence at regular milking times is no longer required. The nature and organization of farm labor changes such that manual labor dealing with milking is largely replaced by management and control activities. Regular visual checks of cow and udder health during milking is, taken over by automated monitoring using smart sensor technology. Satisfactory cleaning of cows and teats, as well as milk analysis and separating abnormal milk is required. An AM-system is in use for 24 hrs a day, which requires a high reliability of the system as well as the adaptation of cleaning and cooling systems. Permanent access to the milking system may require specific cow routing within the barn and is likely to affect the possibilities of grazing. Although less than with conventional milking systems, many AM-farms are able to apply (partly) grazing. Reduced labor demand and better social circumstances for the dairy farmers are the attractive benefits of AM-systems. Other potential benefits are improved animal health and well being and increased milk yields.

Technical aspects

After the development of the milking machine, milking parlors and automatic cluster removers in the sixties and seventies of the last century, automatic attachment of the teat cups was the only missing step in the complete automation of the milking process. The development of AM-systems started with the development of equipment for automatic attachment of the teat cups (Rossing & Hogewerf, 1997). However automatic milking requires more than automatic teat cup attachment. An AM-system has several main modules, like the milking stall itself, the teat cleaning system, the teat detection system, a robotic arm device for attaching the teat cups, a control system including sensors and software and of course the milking machine.

AM-systems include single stall systems with integrated robotic and milking functions and multi-stall systems with a transportable robot device, combined with milking and detachment devices at each stall. Single stall systems are able to milk 55-65 cows several times a day, while multi-stall systems with 2 to 4 stalls milk 80 to 150 cows up to three times per day. Automatic milking strongly relies on the cow's motivation to visit the AM-system voluntarily. The main motive for this is the supply of concentrates dispensed in a feed manger in the milking box during the milking process. An automatic milking system has to take over the 'eyes, ears and hands' of the milker. Therefore such a system is equipped with electronic cow identification, cleaning and milking devices and computer controlled sensors to detect abnormalities in milk, in order to meet international legislation and hygiene rules from the dairy industry. Teat cleaning systems include brushes or rollers, inside teat-cup cleaning or a separate 'teat cup like' cleaning device. Several trials showed that cleaning with a device is better than no cleaning (Schuiling, 1992, Knappstein et al, 2004), although these systems are not as good as manual cleaning by the herdsman. AM-systems are also equipped with sensors to observe and to control the milking process. Data are automatically stored in a database and the farmer has a management program to control the settings and conditions for cows to be milked. Attention lists and reports are presented to the farmer by screen or printer messages. The AM-system also provides remote notification to the farmer if intervention is required.

Farms with Automatic Milking Systems

The first AM-systems on commercial farms were implemented in the Netherlands in 1992. Increasing costs of inputs while milk prices decreased, forced farmers to increase their output per man-hour. After the introduction of the first AM-systems, adoption went slowly, until the end of the nineties. From 2000 automatic milking became an accepted technology in the Netherlands and other European countries, but also Japan and North America. At the end of 2009, worldwide over 8000 commercial farms used one or more AM-systems to milk their cows (Figure 1). The majority of farms are family run with 1 to 3 milking boxes, however also operations with more than 10 units can be found. More than 90 % of the world's AMS farms are located in north-western Europe. The largest number AM farms is found in the Netherlands with almost 2000 farms, however as a percentage of the national number of farms the greatest adoption is in the Scandinavian countries.

To date, adoption of AMS has taken place in areas where there is a fairly high density of dairy production. Since AMS systems have a fairly high requirement for technical support, this has made servicing these systems manageable. In view of the importance of continuous operation, future adoption in less intense dairy production areas will result in new challenges regarding maintenance services.

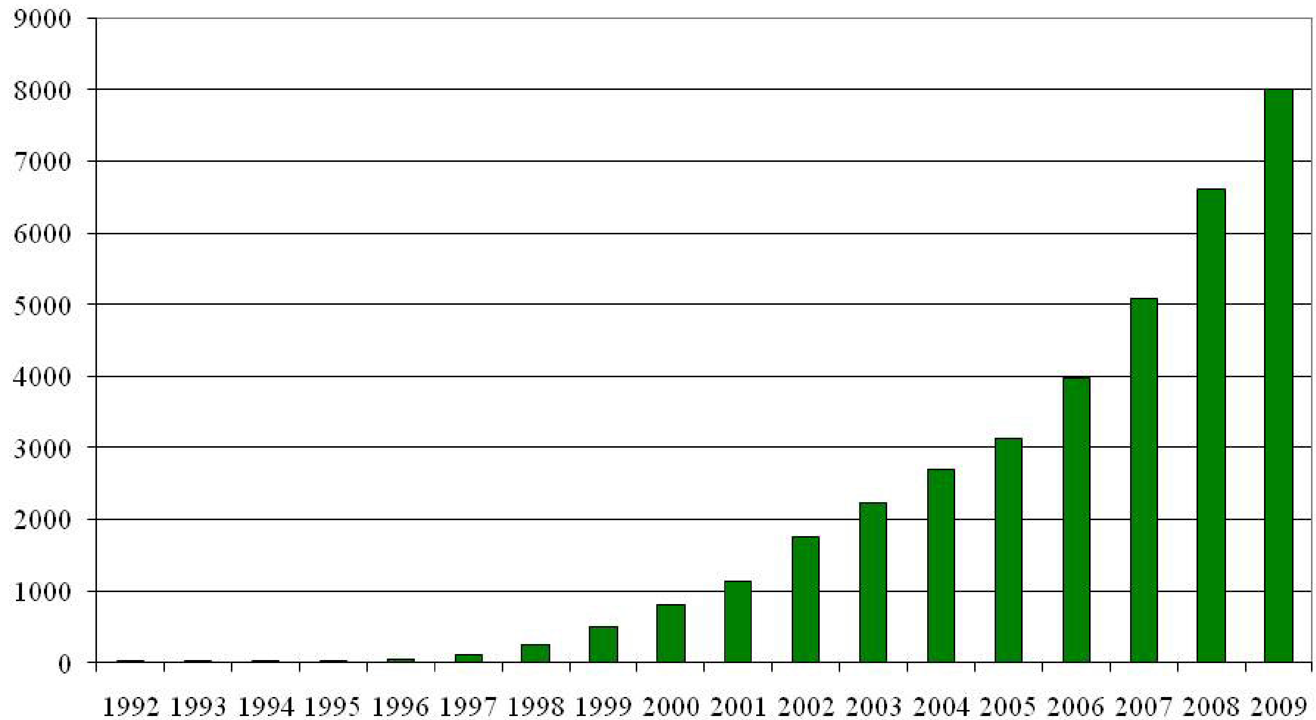

Figure 1. Development of the number of AM-farms world-wide since first introduction in 1992.

Automatic Milking and Management Aspects

Switching from a milking parlor to automatic milking results in big changes for both the herdsman and the cows. Although with AMS immediate supervision of milking is eliminated, new labor tasks appear ((Schön et al, 1992; Lind et al, 2000; De Koning et al, 2002). They include control and cleaning of the AM-system, twice or three times a day checking of attention lists including visual control of the cows and fetching cows that exceeded maximum milking intervals. Compared with the conventional twice daily milking there is an average of 20% - 30% reduction in total labor, but large variations between farms can be found. Especially in the first transition year, automatic milking might take extra time.

The biggest change without doubt lies in the nature of the labor. The physical work of machine milking, is replaced with management tasks such as frequent checking of attention lists from the computer and appropriate follow up. This work is less time bound than parlor milking, so the input of labor is more flexible. This is attractive on family farms. But because milking is continuous, and system failures can occur anytime there must be a person “on call” at all times. System failures and associated alarms typically occur about once every two weeks although this varies with the level of maintenance and management. In terms of the impact on cows, the AM-system is not suitable for all cows. Poor udder shape and teat position may make attachment difficult and some cows may not be trainable to attend for milking voluntarily. In new installations, the number of cows found to be unsuitable is generally reported to be less than 5% (De Koning & Rodenburg, 2004). In the transition from conventional to automatic milking, cows must learn to visit the AM-system at other than traditional milking times. Training and assistance in the first weeks should involve quiet and consistent handling, so the animals adapt quickly to the new surroundings and milking system.

Milking Frequency

In practice, the average number of milkings per cow day varies from 2.5 till over 3.0 milkings per day, but rather big differences in milking intervals are reported by commercial farms. A typical figure is presented in Figure 2. Almost 10% of the cows realized a milking frequency of 2 or lower over a two year period milking with a single stall AM-system. This occurred even though cows with a too long interval were fetched three times per day.

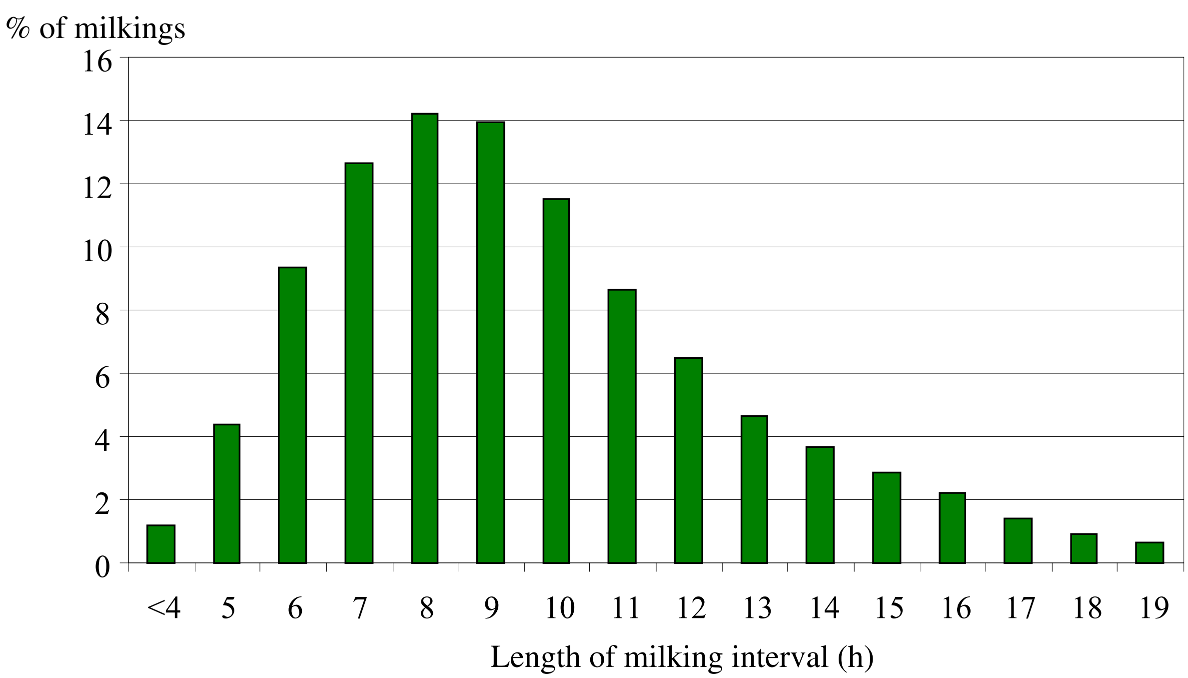

Figure 2. Frequency distribution of milking intervals in hours over a 2-year period (data high-tech farm Waiboerhoeve)

Such cows will not show an increase in yield or may even show a production loss. By changing the milking parameters of the AM-system, it is quite easy to prevent cows from being milked at low yields or short intervals. But it is much more difficult to prevent cows from being milked with long intervals. This means it will be necessary to manage the intervals by fetching cows that have exceeded a maximum interval. Usually this is done several times per day at fixed times around the cleaning procedures of the AM-system.

Increase in Milk Yield

One of the benefits of automatic milking is increased milk yield from more frequent milking. An increase from 6 to 25% in complete lactations has been shown when milking frequency increases from two times to three times per day (Erdman & Varner, 1995). As can be deducted from figure 2, several cows are milked less than twice a day in automatic milking and may therefore produce less milk. Data from all over Europe indicate a production increase of 5-10% for herds milked automatically (De Koning & Rodenburg, 2004, Bach et al, 2007, Bijl et al, 2007), however large variations can be seen. In many larger US herds with highly automated conventional parlors, 3 times daily milking is commonplace. For 3x herds adopting automatic milking, a production decrease of 5 to 10% would be expected (De Koning & Rodenburg, 2004).

Dynamic Milking and Feeding

Within automatic milking systems, a considerable variation in milking characteristics between individual cows, as well as in interval sensitivity as in feed efficiency can be seen. Current decision support systems do not account for this variation. This is due to lack of applications that estimate individual response parameters from real time process data. Suitable models to enable on-line estimation are dynamic linear models (DLM), based on a Bayesian approach to time series analysis. A prototype for dynamic milking and feeding was developed and tested on the high-tech farm of Wageningen UR Livestock Research, both for milking frequencies as concentrate feeding (André et al, 2007, 2010). The first results show a considerable increase in feed efficiency and a better utilization of the AMS capacity.

Sensors and Data Handling

AM-systems are also equipped with sensor technology and integrated data management systems to observe and to control the milking process. Data are automatically stored in a database and the farmer has a management program to control the settings and conditions for cows to be milked. Attention lists and reports are presented to the farmer by screen or printer messages. With their sensors AM systems collect enormous amounts of data, which have to be processed with appropriate software (Hogeveen & Ouweltjes, 2003, De Koning & Ouweltjes, 2004). The challenge for both manufacturers as end users is to detect in the data the abnormalities, so actions can be taken. Because abnormalities are rare this is called management by exception. One of the problems for example is clinical mastitis, especially in relation to abnormal milk. By definition, milk of cows that suffer from mastitis has an abnormal visual appearance. It is also one of the most frequently occurring diseases in dairy cattle, and is responsible for the majority of abnormal milk. Despite this, milking a cow with abnormal milk is a rather exceptional event on most dairy farms. As an example, assume that abnormal milk is always caused by mastitis, that 25% of all cows have one

case of mastitis each year, and that each mastitis case causes 10 milkings with abnormal milk. For a 100 cow herd with 310 days in milk per cow per year and 2.5 milkings per cow per day, only 0.32% of all milkings will be abnormal. This figure clearly indicates that, even with a high mastitis frequency, the percentage of abnormalities is very low.
Modern AM-systems are equipped with various sensors ranging from sensors to control the milking process till sensors that analyze the milk quality in several ways, like milk composition, cell counts, blood detection, conductivity, progesterone, and so on. All these sensors require smart data handling solutions in order to help the farmer to make the right decision. Special guide lines for automatic milking were developed and approved for automatic milking systems and involved sensor technology within the framework of the International Standards Organization (ISO20966, 2007).

Attitude and Expectations

One important factor in successful implementation of an AM-system is the attitude and expectation of the dairy farmer (Mathijs, 2004, Ouweltjes & De Koning, 2004). Almost all manufacturers have had some customers switching back to conventional milking systems. While there is considerable variation in level of satisfaction with different types of systems, an estimated 5-10% of owners have switched back to conventional technology (De Koning & Rodenburg, 2004). In some cases expectations were not realistic, in others farmers were unable to adapt to the different management style, and in some cases a high rate of failures of the AM-system discouraged the farmer to continue. However this figure seems to decrease in more recent years, showing that farmers improved their decision process before buying and also that hardware technology has been improved. During the start up period, automatic milking requires a high input of labor and management. Key factors of a successful implementation of AM-systems are:

- Realistic expectations
- Good support by skilled consultants before, during and after implementation
- Flexibility and discipline to control the system and the cows
- Ability to work with computers
- Much attention to the barn layout and a good functioning cow traffic
- Good technical functioning of the AM-system and regular maintenance
- Healthy cows with good feet and ‘aggressive’ eating behavior

Barn Layout

Since automatic milking systems largely depend on voluntary attendance, a well laid-out free stall barn is essential for success (Lind et al, 2000). The main motive for a cow to visit the AMS is the concentrate provided in the manger of the milking box. Cows should have easy access to the milking stall and selection gates: long alleys, steps and other obstructions should be avoided. A central location for the AM-system minimizes walking distances of the cows. In many countries regulations from the dairy industry require that the AM-system has to be located close to the milking room and that the system is accessible to the operator or the service technician via a clean route.

Cow Traffic

After visiting the milking system, the cow should have access to the feeding area. In “forced traffic” systems she has to pass the milking system in order to get access. In “controlled traffic” systems one-way-gates, with cow identification and selection capabilities, restrict cows to go directly to the feeding area only when the interval since the last milking exceeds the pre-set minimum.

AM-systems with a high occupancy rate and forced traffic may affect the number of visits to the roughage station or feeding fence. In “free cow traffic” systems access to the feeding area is unrestricted and only the concentrate fed in the AM system is used to attract cows. Forced traffic can improve the number of voluntary milkings, however it alters eating and lying behavior (De Koning & Rodenburg, 2004, Hams, 2004, Bach et al, 2009). This might even result in reduced intake of roughage and therefore also production losses. Free, semi-free and forced cow traffic have been tested in several studies. Harms (2004) observed that free cow traffic resulted in lower milking frequencies and higher number of fetched cows due to long milking intervals. Milk yield did not differed much, but tended to be higher in the free traffic system. Unlimited access to feed is a prerequisite for cow traffic and milking visits. Harms (2004) reported that in all tested traffic systems repeated lack of feed resulted in decreased number of milkings.

There is general consensus that for animal welfare, (semi) free cow traffic is preferred An example of the semi free cow traffic is the Feed-First principle which is used as a mix between controlled cow traffic and free cow traffic. The system also relies on the cows motivation to eat. Without doubt, a well-functioning cow traffic is a key-factor for successful automatic milking. This can be achieved when feed is available for 24h/day.

Grazing

In most European countries, grazing during summer time is common routine, in some Scandinavian countries like Sweden even compulsory. Moreover, from an ethological point of view, many consumers in North Western Europe believe grazing is essential for cows and several Dutch dairies pay a premium for milk from grazed herds. In the Netherlands grazing is common practice (>80%). The basic principle of grazing cows is that they need to walk at least twice a day to a barn with a milking parlor to be milked. This is faced with problems. The development of large-scale farms and the related large dairy herds lead to long walking distances, increased labor demands and, in many cases, milk production losses. Often the allocation of land makes grazing impossible or leaves too little area for the purpose, causing high leaching potentials due too large urination and defecation surplus.

The introduction of automatic milking induced extra problems, caused by the reluctance of cows to come voluntarily when distances to the barn are longer than 500 meters. In The Netherlands only about 52% of the farms with an AM-system apply grazing, showing on one hand that grazing in combination with AM is less common, but on the other that it is still possible (Van der Vorst & Ouweltjes, 2003; Mathijs, 2004). Overcapacity of the AM-system, e.g. fewer cows per AM-system can partly compensate but this solution is inefficient due the increased fixed costs of the robots. In respect of capacity use of the milking system and percentage of cows to be fetched, restricted grazing systems perform better than unrestricted (Van Dooren et al., 2004). Walking distances of up to 500 meters seem to be of little influence on the frequency of robot visits, however longer distances show a negative effect. Moreover the natural synchronized behavior of the cows when moving to the milking unit in the barn causes cueing in front of the AM-system and also ineffective feeding. Several solutions are available to overcome (partly) the disadvantages. Smart pasture gates or selection boxes that control the cow traffic to and from the pasture can be a very helpful tool to the farmer. Only those cows that have recently been milked are sent outside, while the cows that still need to be milked, have to stay inside. Cows have to be attracted to go outside and inside the barn. Grass quality, walking distances, cow health, weather conditions and water supply are important factors within a grazing systems. It is widely accepted that water supply should not be limited, nor be used as a motivation for cow to return to the barn.

Grazing is critical to low cost milk production in Ireland, Australia and New Zealand. An extensive research project in New Zealand, the “Greenfield” project showed that automatic milking in a 100% grazing system under very different circumstances than those found in Europe is quite well possible (Jago et al, 2004).

Mobile Automatic Milking Systems

While AM-systems are always positioned in a fixed place within the barn, some years ago the idea was born to design a mobile milking robot. Recently prototypes of mobile automatic milking equipment have been developed in Denmark and the Netherlands. A Mobile Automatic Milking System (MAMS) follows the cows to the pasture. This solves the problem of long distances between the grazing cow and the immobile automatic milk system in the barn. The development of mobile automatic milking systems might also be an opportunity to maintain grazing with bigger herds and on grassland not close to the farm. While the Danish mobile milking system (Oudshoorn et al, 2008) uses a transportable automatic milking system positioned for several months at the pasture, the Dutch mobile milking system can drive from one place to another (Lennsinck & Zevenbergen, 2007). The system has caterpillar tracks resulting in a very low pressure per square centimeter to prevent grassland damage. The system is equipped with all necessary machinery bulk tank, vacuum pump, cleaning systems and an automatic milking system so it can operate independently for 2 days. The system was tested in 2008 during the grazing season with a herd of 35 cows with good results, both technically as with respect to the cows (Houwelingen et al, 2009). During the 2009 grazing season a herd with 60 cows was managed by the mobile milking system. The research focused on the grazing system and the relation with cow traffic and the milking frequency. The mobile milking system was capable to combine a herd of 60 cows with 24 hour grazing without additional roughage supply while producing a rolling average of 7500 kg milk/year. Offering fresh grass when passing the milking robot really motivates cows to visit the robot. Development of selection units preventing individual cows to enter fresh grass without being milked might or strip grazing might increase milking frequencies (De Haan, 2010, personal communication).

Milk Quality

Milk quality is a critical concern on modern dairy farms because milk payment systems are based on milk quality and consumers expect a high level of quality and safety from the milk products they buy. Although automatic milking uses the same milking principles as conventional milking, there are major differences. The AM-system is in use for 24 hours continuously. Visual control during the milking process is not possible. Cows will visit the AM-system more or less voluntarily and this will result in a big variation in the milking frequency from cow to cow. All these aspects may influence the quality of the milk produced.

Somatic cell count (SCC) and Total Bacterial Count (TBC) are, respectively, measurements of the number of white blood cells and the total number of bacteria present in a milk sample. A high SCC might indicate reduced udder health due to Mastitis (udder infection) and implies a lowered milk quality. The cleaning of the milking equipment and the cooling of the milk seem to be the most important factors regarding the increase in TBC. In general AMS herds consistently show slightly higher SCC and TBC values than conventionally milked herds (Klungel et al, 2000; Rasmussen et al, 2002; De Koning et al, 2004). Table 1 presents the results for 4 quality parameters. In general differences are relatively small and far within the requirements of the dairy industry. Nevertheless with 24h operation, milk hygiene requires continuous attention from the herdsman. Special attention has to be paid to teat cleaning and the cleaning of the teat cups and the milking machine including transfer line to the bulk tank, Hygiene management should not only focus to the automatic milking system, but also to the general hygiene standards in cubicles and the floors in the barn.

Table 1. Milk quality results for farms before and after introduction of AM-system (adapted: De Koning et al, 2004)

	Conventional milking		Automatic Milking	
	Two times milking	Three times milking	Before	After
Bacterial count (*1000/ml)	8	8	8	12
Cell count (* 1000/ml)	181	175	175	190
Freezing point ($^{\circ}$C)	-0,520	-0,521	-0,521	-0,516
Free fatty acids (meq/100 g fat)	0,44	0,54	0,41	0,59

Free fatty acids

Free Fatty Acids (FFA) in milk are formed as a result of hydrolysis of milk fat by milk lipase, also called lipolysis. Milk fat is protected from lipase activity because the milk fat is protected by a membrane around the milk fat globules. Lipolysis can be initiated either by physical damage to milk fat globules during milking or pumping, stirring or cooling of milk or by animal-related factors such as the cow’s health status, lactation stage, the frequency of milking and dietary factors.

It is generally known that the content of free fatty acids (FFA) in milk will increase with shorter milking intervals, all the more if the yield per milking is rather low. All studies with AM-systems show a significant increase in FFA levels for AM-systems (Ipema & Schuiling, 1992; Klungel et al, 2000; Rasmussen et al, 2002, De Koning et al, 2004). This increase cannot be explained solely by the shorter intervals, because the increase of FFA with AM-systems is even bigger than with conventional milking parlors milking three times per day. In a Danish study (Rasmussen et al, 2006) small but statistically significant differences in average FFA concentration of milk between five different brands were detected. Apart from differences in diameter or length of "short" milk tubes, the technical specifications of the AM systems could not explain these differences.

AM systems generally have about 3 to 4 times higher air intakes (air inlet) during milking than conventional milking clusters. It is known that excessive air intake increases lipolysis in raw milk. The higher air intake of AM systems has been recognized as a factor that can partially explain higher FFA concentrations of raw milk. Rasmussen et al (2006) also reported on visits to 55 farms with high FFA levels. For 31 conventional farms most frequent faults were air leakage (71% of the herds) and intake of too much air in the cluster (61%) and pumping and stirring faults occurred on 29% of the farms. The main faults for 24 AM system farms concerned stirring of milk at very low levels in the bulk cool tank (79%), pumping of milk (67%) and the cooling of milk (58%). Low milk yields and low-energy diets increase the FFA level of milk. However, many aspects of the role of nutritional factors in lipolysis and FFA levels are still unclear and require further investigations.

Animal Health

Within a large EU project Automatic Milking carried out between 2000 and 2004, special attention was paid to animal health. In Denmark, The Netherlands, and the UK, 15 herds each were selected for monitoring the impact of transition to automated milking on animal health (Hillerton et al, 2004). The herds recruited represented the types of AMS marketed in each country. Each farm was visited at least twice before installation of the AMS and a minimum of twice, but often up to six times, after installation. On these visits assessments were made of at least half of the cows or fifty animals on body condition and locomotion, and forty cows for teat condition (on some farms in the Netherlands and UK only). Farm data including milk production, milk quality, animal records on individual cow milk cell count, fertility, animal treatments, animal movements, veterinary purchases were collected.

The body conditions varied more between countries than in response to the introduction of AM (Hillerton et al, 2004). In Denmark and the UK there was no change in body condition between 3-6 months prior to AM installation and 6 months post installation. A slight but not significant drop occurred with the Dutch cows. On the Dutch farms the range of body condition narrowed significantly from 1.35 to 0.98 points score suggesting that the farms are managing body condition better.

No change in locomotion was seen one month after AM installation. The scores in Denmark and UK increased slightly by 3 months after installation, but not significant. In the UK the average score increased on seven farms whilst unchanged on 6 farms. Scoring was continued on 12 of the UK farms. Twelve months after installation of AMS the lameness has increased significantly. Prior to installation eleven of fourteen UK herds were grazed but only six after installation. The poorer locomotion may reflect the increase in constant housing (Hillerton et al, 2004). The overall impact of conversion to AM was assessed by comparing how each individual farm handled the main indicators of animal health during and after the transition to automatic milking. Comparing 12 Dutch farms only one farm improved in locomotion, body condition as well as cell counts. Overall, little change was apparent. Locomotion improved in five herds and deteriorated in five herds. Body condition score decreased in eight herds but only by a small amount. It increased in two herds but not making the cows any fatter, just more typical. The only major deterioration found was an increase in somatic cell count and the proportion of cows with a cell count above a threshold, where only two of the herds produced better quality milk. Overall there was little evidence of major changes occurring in the common measures of fertility. None of the changes were statistically significant but all suggestive of poorer fertility, at least in the transition period from conventional milking to AM.

Hillerton et al (2004) conclude that no major problems in converting from conventional milking to AM could be identified but equally none of the 44 farms has been found to achieve a substantial improvement in any aspect of cow health. The transition period to AMS comprises a period of higher risk to health that extends from weeks before installation when resources start to be diverted from cow management. The length of the transition will vary on individual farms related to many unique factors. Several potential problems may develop in the longer term and anticipation of these is necessary.

A large study to risk factors related with automatic milking in The Netherlands (Neijenhuis et al, 2009) showed that risk factors for mastitis are more or less comparable with those found at conventional milking. However the udder health status in the period just before the transition to automatic milking showed a large correlation with the udder health status afterwards. Other factors are mainly related to management strategies and the use of information and data from the AM-system.

Economical Aspects

Investment required for AM-systems are much higher than for conventional milking systems and thus the fixed costs of milking are higher. However more milk with less labour means that the costs of milking per kg of milk will decrease. Theoretically, with an AM-system more cows can be kept with the same labor force than with conventional milking, but this may involve additional investments in buildings, land or feed and perhaps in milk quota. On a farm with more than one full time worker the possibility exists to reduce labor input and thus costs. Quite often that does not happen and the time saved as a result of lower labor requirement is used for personal activities. Meskens and Mathijs (2002) found that two third of AM-farmers state social reasons for investing in automatic milking, such as increased labor flexibility, improved social life and health concerns. In parts of North America, with large-size herds and numerous milkers, it may turn out that savings on labor costs may become a decisive motive to implement automatic milking

Simulation Models

Several simulation models have been developed to calculate the pure economic effect of investment in automated milking. The “Room for Investment” model computes the amount of money that can be invested in an AMS, without a decrease in net return compared with conventional milking (Arendzen & van Scheppingen, 2000). The RFI-value calculates the annual accumulated return from increased milk yield, savings in labor, and savings in not investing in a milking parlor and divides this by the annual costs of the AM-system. The model can use farm specific factors and circumstances to calculate the RFI-value. Figure 3 shows the results of a combined sensitivity analysis illustrating that increased milk yield and labor savings are essential factors regarding the economy of automatic milking. The RFI-value for the basic farm (700.000 kg milk, 8500 kg milk per cow per lactation, 82 cows, 75 hrs of labor per week) with 500 kg per cow yield increase, 0,75 hour net labor saving per day (~10% labor saving), compared with a automated milking parlor and 20% annual costs of the AM-system amounts € 137.000. In this example this would be sufficient for investment in a single box (investment ~ €120,000). Both labor saving and yield increase have a large effect on the RFI value.

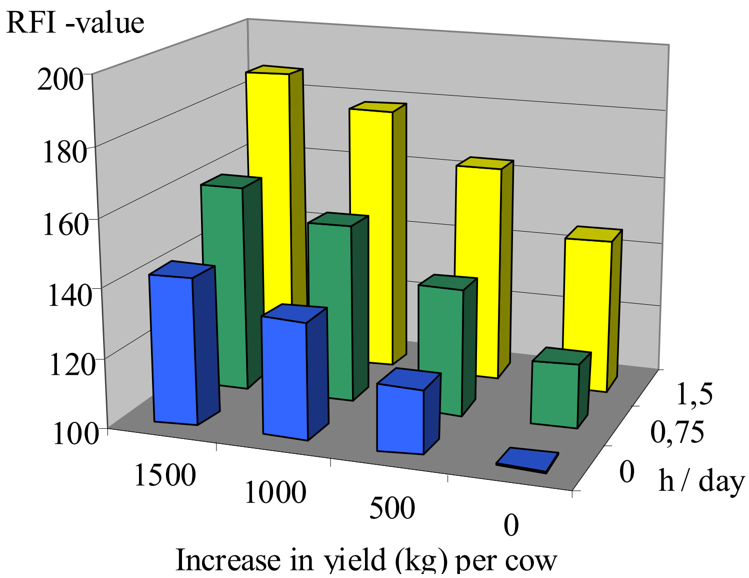

Figure 3. Room for Investment (RFI) due to labor saving and milk yield increase with annual costs for AM-system of 25% of investment. Comparison made with an highly automated milking parlour

American models (Rodenburg, 2002; Rotz et al, 2003) suggest that on large farms, as the hours of use of large automated milking parlors increase, their relative economic advantage over AM-systems increases. These studies showed that on farms with 60 to 180 cows, capital investment in automatic milking is only slightly higher than in conventional milking systems, in part because of smaller space requirements than for parlors with large holding areas. Lower labor input for AM-systems makes them competitive in this herd size range. For herds with more than 240 – 270 cows, extending the hours of use of conventional parlors, without additional capital investment made parlor milking much more efficient. It follows that in the central and western United States, where herds of 500 to several thousand cows predominate, widespread adoption of automatic milking will not occur unless capital cost of these systems decrease or labor costs increase substantially. Since both of these parameters are highly likely to trend in this direction, more widespread adoption of automatic milking in nearly all areas of the developed world would appear to be only a matter of time.

Economic Results from Commercial Farms

Economic results from commercial farms show that the use of AM-systems in general is profitable, although highly depending on the extra milk yield and labor savings. A Dutch case control study (Bijl et al, 2007) between farms with AM-systems and farms with conventional milking systems showed no differences in margin, although fixed costs for the AM-farms were higher. AM-farms saved 29% labor and therefore when economical results were transformed to full time equivalents (FTE), AM-farms in the case control study had greater revenues, margins, and gross margins per FTE than the farms with conventional milking systems. So when deciding between investment in an AM-system or in a conventional milking system, dairy farmers must weigh decreased labor needs for the AM-system against the increased fixed costs of milking with an AM-system. Therefore in many cases adoption of an AM-system is for many dairy farmers a socio-economic decision, rather than just a purely economic decision (Mathijs, 2004; Bijl et al, 2007).

Concluding Remarks

The number of farms milking with automatic milking has increased significantly since 2000. In areas where labor is expensive or in short supply automatic milking is a valid alternative to traditional parlor milking. However if labor is available, and particularly where herd sizes are large conventional milking, often with rotary or rapid exit parlors equipped with features to increase throughput per man hour will remain popular. The introduction of automatic milking has a large impact on the farm and affects all aspects of dairy farming. Because milking is voluntarily there is large variation in milking intervals. Both farm management and the lifestyle of the farmer is altered by automatic milking. AM-systems require a higher investment than conventional milking systems but increased milk yields and reduced labor may lead to lower fixed costs per kg milk and increased margins per FTE.

Successful adoption of automatic milking depends on the management skills of the farmer and the barn layout and farming conditions. Animal health and well-being is not negatively affected by automatic milking, but till now no particular benefits for the health of the cows have been found. Grazing is a common routine in many countries and although grazing with automatic milking requires extra attention from the herdsman, grazing is still profitable. New solutions like mobile milking systems might be an alternative for large herds. Improved sensor technology will help farmers to manage the individual cow within the herd. A better understanding of the characteristics of automatic milking systems will help farmers to make the right decision. Both conventional and automatic milking will be used on dairy farms in modern dairy countries in the foreseeable future.

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