AUTOMATIC MILKING: LESSONS FROM AN EU PROJECT

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Abstract
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 labour, a better social life for dairy farm families and increased milk yields due to more frequent milking are recognised as important benefits of automatic milking.

Automatic milking changes many aspects of farm management since both the nature and organisation of labour is altered. Manual labour 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 effected, 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. A potential risk is that fertility of the herd may decline faster than the current trend for conventional dairy farms. The only obvious change was that milk cell count, often an indicator of the prevalence of mastitis, increased overall.

Automatic milking systems require a higher investment than conventional milking systems. However increased milk yields and reduced labour requirements may lead to a decrease in the fixed costs per kg milk. Automatic milking is gaining widespread acceptance and is estimated to be in use on more than 2500 farms in over 20 countries worldwide.

Introduction
Interest in fully automated milking began in the mid-seventies, and was initially driven by the growing costs of labour in Europe. Since machine milking, and automatic detaching, and teat spraying were already in common usage, automatic cluster attachment became the focus of European work. Although various prototypes demonstrated this capability, it took a decade before fully integrated and reliable automatic milking became a reality.

The term “Automatic Milking System” refers to a system that automates all the functions of the milking process and cow management undertaken in conventional milking, by a mix of manual and machine systems. In contrast to conventional milking, where humans bring the cows to be milked at regular times (usually twice a day), automatic milking places emphasis on the cows motivation to be milked in a self-service manner several times a day by a robotic system without direct human supervision.

In modern society consumer concern about methods of food production include food safety, as well as ethical questions related with animal welfare, animal health, housing conditions and access to grazing. Because unsupervised, automatic milking, raised a number of questions, an extensive EU research project was started at the end of 2000 (www.automaticmilking.nl). This project focussed on farm-level adoption determinants of automatic milking, on-farm social-economic and environmental implications, societal acceptance, impact on milk quality, impacts on animal health and welfare, including the combination of automatic milking with grazing and requirements for management information systems. Other research groups around the world have also contributed substantially to progress in our understanding of automatic milking and related management considerations.

Automatic milking systems
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 milk 55-60 cows, 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 milking. An automatic milking system has to take over the ‘eyes, ears and hands” of the milker. Such a system includes 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’ cleaninge device. Several trials showed that cleaning with a device is better than no cleaning (Schuiling, 1992, Knappstein et al, 2004), it is 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 primarily in response to expensive labour and the farm structure of family farms. 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 1998 (Figure 1). From that year on automatic milking became an accepted technology in the Netherlands and other European countries, but also Japan and North America. At the end of 2004, worldwide some 2500 commercial farms are expected to use one or more AM-systems to milk their cows. More than 85% of the world's automatic milking farms are located in north-western Europe.

<Figure 1. Number of farms using an automatic milking system at the end of 2003>

Automatic Milking and Management Aspects

Switching from a milking parlour to automatic milking results in big changes for both the herdsman and the cows and can cause stress to both. Although with AM-systems immediate supervision of milking is eliminated, new labour tasks 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. Generally, a 10% labour saving is reported (De Koning & Rodenburg, 2004).

However, the biggest change is the nature of labour. 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 parlour milking the input of labour 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 in 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 5-10%. 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 they adapt to the new surroundings and milking system.

Milking frequency

In practice, the average number of milkings per cow day varies from 2.5 till 3.0, but rather big differences in milking intervals are reported by commercial farms. A typical figure is presented in figure 2 (De Koning and Ouweltjes, 2000). Almost 10% of the cows realised a milking frequency of 2 or lower over a two year period milking with an 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 (De Koning & Ouweltjes, 2000)>

Such cows will not show an increase in yield and 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. In a large study on 124 farms in the Netherlands, Van der Vorst & Ouweltjes (2003) found that in farms where cow numbers were 25% or more under the capacity of the system, cows were rarely fetched. On almost 50% of farms cows were fetched twice a day when the interval exceeded 12 hours and on 35% cows were fetched 3 or 4 times per day. These studies also showed that too long intervals cannot be prevented completely. Fetching cows three times per day that have exceeded an interval of 12 hours, means that the maximum interval will be 20 hours. Fetching cows with intervals shorter than 12 hours is time-consuming and moreover may lead to some habituation of the cows.

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). French data show an average 3 % increase in milk yield and up to 9% for farms that utilized the AM-system for more than 2 years (Veysset et al, 2001). In the study of Van der Vorst & Ouweltjes (2003) an average increase of 5% with a range of – 16% to + 35% was reported. In many larger herds with highly automated conventional parlours, 3 times daily milking is commonplace. For 3x herds adopting automatic milking, a production decrease of 5 to 10% would be expected.

Attitude and expectations

One important factor in successful implementation of an AM-system is the attitude and expectation of the dairy farmer (Hogeveen et al, 2001, De Koning et al, 2002, Ouweltjes& de Koning, 2004). 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. 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 on the AMS resulted in ongoing high labour input for manual intervention. During the start up period, automatic milking requires a high input of labour 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 behaviour

Grazing
In most European countries, grazing during summer time is routine (Van Dooren et al, 2002) or in some Scandinavian countries even compulsory. Moreover, from an ethological point of view, many consumers in North Western Europe believe grazing is essential for cows and one Dutch dairy pays a premium for milk from grazed herds. In the Netherlands grazing is common practice (>80%). However, about 52% of the farms with an AM-system apply grazing, showing that grazing in combination with AM is less common, but still possible (Van der Vorst & Ouweltjes, 2003). Grazing is critical to low cost milk production in New Zealand, and while there is no commercial use of AMS in that country at this time, the “Greenfield” project uses automatic milking in a 100% grazing system under very different circumstances than those found in Europe.

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. Results from commercial farms in Europe (Klungel et al, 2000, Van der Vorst & Hogeveen, 2000. Pomies et Bony, 2001, Van der Vorst et al, 2002) and North America (Rodenburg and Kelton 2001) indicate, that milk quality is somewhat negatively effected after introduction of automatic milking. In general data show an increase in bacteria counts, although the levels are still relatively low and well within the penalty limits. Helgren and Reinemann (2003) determined that SCC and bacteria counts in the US were similar to conventional milked herds. Both the cleaning of the milking equipment and milk cooling are critical factors in controlling bacteria counts. Also cell counts are not reduced after the change to automatic milking, despite the increased milking frequency.
With increasing milking frequency a small decrease in fat and protein percentage and an increase in the free fatty acids levels has been reported (Ipema and Schuiling, 1992, Jellema (1986),Klei et al, 1997). Van der Vorst et al (2003) found both technical and management factors influencing FFA levels. Wiking and Nielsen (2003) found relations with FFA levels and fat globule size and showed that feeding and cooling strategies affect FFA levels. In studies from Van der Vorst et al (2002) and Svennersten & Wiktorsson (2003) increased FFA levels were also found with increased milking frequencies using conventional milking methods.

The general conditions of hygiene in milk production in the EU are currently defined by the Commission Directive 89/362/EEC (1989) but not all elements apply to automatic milking (Rasmussen, 2004). The following text is proposed to be included in the coming EU Hygiene Directive: “Milking must be carried out hygienically ensuring in particular, that milk from an animal is checked for abnormalities by the milker or by a method achieving similar results and that only normal milk is used for human consumption and that abnormal, contaminated, and undesirable milk is excluded”.
AM-systems have accurate cow identification and this also means less chance of human errors than in conventional milking, which might have a positive effect on lowering the presence of inhibitors in milk, as reported from North America. In this way automatic milking also potentially enhances food safety and quality.

Animal Health
Within the EU project Automatic Milking, special attention was paid to animal health. In Denmark, The Netherlands, and the UK, 15 herds each were recruited 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 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 (Dearing et al, 2004). 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 (Hillerton et al, 2004). The only major deterioration was in average milk cell count and the proportion of cows with a cell count above a threshold, where only two of the herds produced better quality milk. Average milk yield in the Dutch herds decreased in continuation of a trend starting up to 12-months prior to installation of the AMS and the cows became thinner with only a small reduction in DIM. Overall there is 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 have been 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. Clearly AMS succeeds but its longer-term promises for animal welfare and milk quality are unfulfilled to date (Hillerton et al, 2004).

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 labour force than with conventional milking, but this may involve additional investments in buildings, land or feed and perhaps milk quota. On a farm with more than one full time worker the possibility exists to reduce labour input and thus costs. Quite often that does not happen and the time saved as a result of lower labour requirement is used for personal activities. Mathijs (2004) reported that two third of AM-farmers state social reasons for investing in automatic milking, such as increased labour flexibility, improved social life and health concerns. On average total labour was reduced with 20% compared with the conventional twice daily milking.

Little economical information is available from commercial herds using an AM-system. The high-tech farm at Waiboerhoeve experimental station realised a cost price, which was approximately € 1,50 per 100 kg higher compared with a the cost price of a reference group of farms using conventional milking. The small plus on the cost price is mainly due to increased machinery costs per kg of milk, despite the decreased costs of labour (Van der Kamp et al, 2003). An extra 10% more milk harvested per year would lead to a reduction in cost price of approximately 3 € per 100 kg milk.

Several simulation models have been developed to calculate the economic effect.

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 labour, and savings in not investing in a milking parlour 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 labour savings are essential factors regarding the economy of automatic milking. The RFI-value for the basic farm with 500 kg per cow yield increase, 0,75 hour net labour saving per day (~10% labour saving), compared with a highly automated milking parlour and 25% annual costs of the AM-system amounts € 136,942. Both labour saving and yield increase have a large effect on the RFI value.

<figure 3>

Since capital costs tend to decrease while labour costs tend to increase, more widespread adoption of automatic milking in nearly all areas of the developed world would appear to be only a matter of time.

Conclusion

The number of farms milking with automatic milking has increased significantly since 1998. In areas where labour is expensive labour or in short supply, automatic milking is a valid alternative to traditional parlour milking. However if labour is available, and particularly where herd sizes are large conventional milking, often with rotary or rapid exit parlours 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 labour may lead to lower fixed costs per kg milk. 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 on the contrary till now no particular benefits for the health of the cows have been found.

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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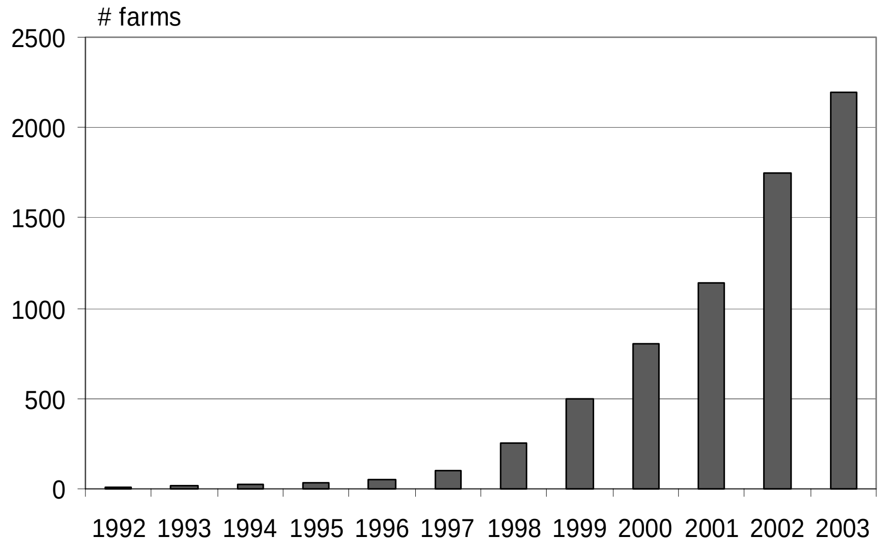

Figure 1. Number of farms using an automatic milking system at the end of 2003

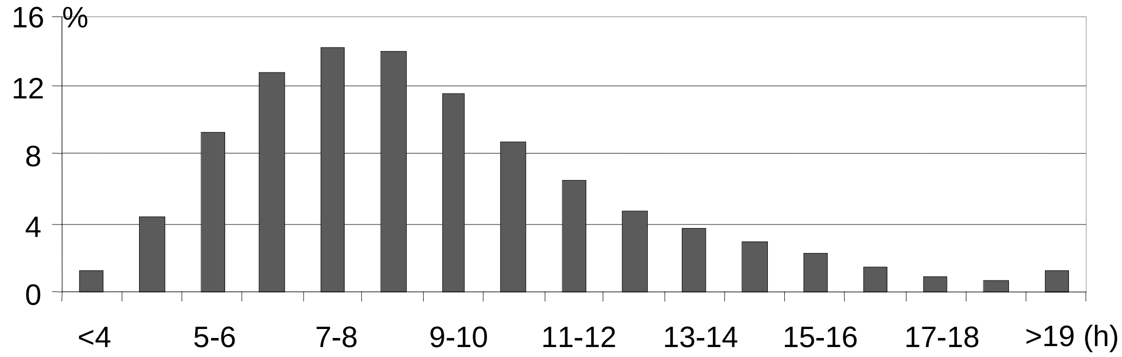

Figure 2. Frequency distribution of milking intervals in hours over a 2-year period (De Koning & Ouweltjes, 2000)

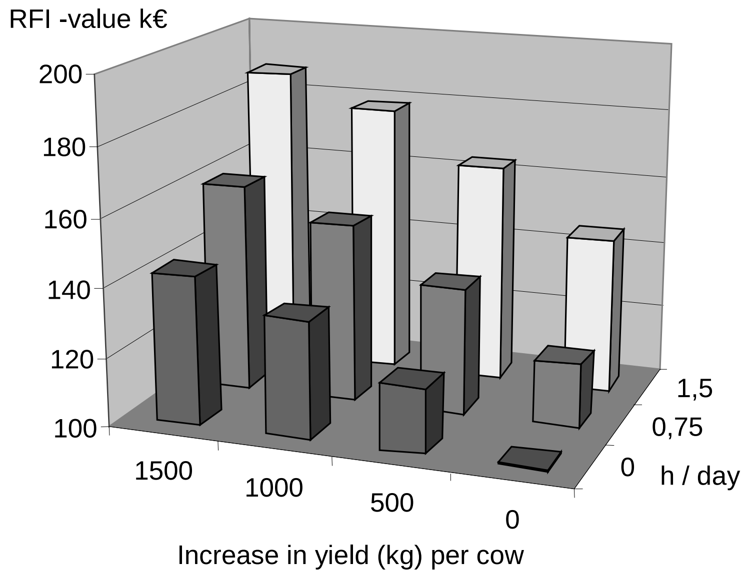

Figure 3. Room for Investment (RFI) due to labour saving and milk yield increase with annual costs for AM-system of 25% of investment. Comparison made with an highly automated milking parlour.