Automatic milking: Chances and challenges

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Summary

In automatic milking systems (AM-systems) cows are milked by a robotic milking system without direct human supervision. The number of farms with an AM-system is growing, especially in those countries where the costs of labour are relatively high, such as in many West European countries. Many technical problems especially concerning attachment of teat cups have meanwhile been solved, but new problems arose with the spreading adoption of AM-systems by commercial farmers. Since cows visit the AM-system more or less voluntarily, a large variation in milking intervals can be observed between cows. Special attention should be paid to the design of the barn and should be based on the principle eating – lying – milking. When the first prototypes of AM-system were introduced on farms, milk quality deteriorated compared to conventional milking systems. Special emphasis should be given to free fatty acids and bacterial counts. 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. The introduction of automatic milking has a large impact on the farm, the management and the social life of the farmer. A successful use of automatic milking depends largely on the management skills of the farmer and the barn layout and farming conditions.

Key words: *Automatic milking, AM-systems, management, barn-layout, capacity, milk quality, annual costs, room for investment, labour.*

Introduction

The first ideas about fully automating the milking process were generated in the mid seventies. The growing costs of labour in several countries was the main reason to start the development of automatic milking. The final step in the automation of the milking process seemed to be the development of automatic cluster attachment systems. However it took almost a decade to convert the techniques for locating teats and attaching teat cups to fully integrated and reliable automatic milking systems. The first milking robots were installed on commercial dairy farms in the Netherlands in1992. The

breakthrough of automatic milking came at the end of the nineties and at the end of 2000, over 750 farms world-wide milked their cows automatically.

Automatic milking systems

AM-systems can be divided into single stall systems and multi-stall systems. Single stall systems have an integrated robotic and milking system, while multi-stall systems have a transportable robot device. Each stall has its own milking devices, like in a milking parlour. A single stall AM-system is able to milk 55-60 cows up to three times per day on average. Multi stall systems have 2 to 4 stalls and are able to milk a herd of 80 to 150 cows three times per day. Automatic milking relies on the cow's motivation to visit the AM-system more or less voluntarily. The main motive for a cow to visit the AM-system is the supply of concentrates, therefore all AM-systems are equipped with concentrate dispensers. An automatic milking system has to take over the 'eyes and hands" of the milker and therefore these systems should have electronic cow identification, cleaning and milking devices and computer controlled sensors to detect abnormalities in order to meet (inter)national legislation and hygiene rules from the dairy industry.

The current teat cleaning systems can be divided into three main types; cleaning with brushes or rollers, cleaning inside the teat-cup and cleaning with a separate 'teat cup like' device. Present AM-systems do not have sensors to detect the amount of dirt on the teats. Little information is available about the efficacy of teat cleaning devices. Several trials showed that cleaning with a cleaning device is better than no cleaning, but not as good as manual cleaning by the herdsman (Schuiling *et al.*, 1992). AM-systems are equipped with a variety of 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. However, the AM-system only notifies, the farmer has to take action.

Management and labour

One of the main benefits of automatic milking is an increase in milk yield from more frequent milking. Recent figures from the Dutch herd improvement organisation NRS showed an increase in lactation yield of 11.4 % one year after the introduction of the AM-system (unpublished). Changing over from a milking parlour to automatic milking will lead to big changes for both herdsman and cow. In the transition from conventional to automatic milking, cows have to learn to visit the AM-system at other times than before. This needs special attention and in the first weeks human assistance will be necessary. Another important aspect is the barn layout and design. Using the cows motivation for eating, the milking system should be situated in the route towards the feeding area. To minimise problems with udder health, it is generally recommended that cows stand

for some time after the milking to allow the teat sphincter to close. So after visiting the milking system, the cow should have free access to the feeding area. Using this milking-feeding-lying principle, the cows are motivated to use the AM-system.

Since cows visit the AM-system more or less voluntarily, a large variation in milking intervals can be observed from cow to cow. In practice the average number of milkings per day varies from 2.5 to 3.0 and more, but rather big differences in individual milking intervals are reported. There does not seem to be a big difference in average milking frequency between the one way and the free cow traffic systems in practice (Ipema, van't Land). De Koning found that 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. These cows will not show any increase in yield or may even show a decrease.

The effect of automatic milking on labour requirement is not very clear and depends largely on the management approach, barn layout and herd characteristics. Ipema et al (1998) and Van't Land reported labour demands for AM-systems from 32 minutes up to 3 hours per day. On average a 10% reduction in labour required is reported. Moreover the character of the labour left will change from manual work to managerial activities and observations of the cows and their behaviour. Management is the key-factor in a successful application of automatic milking.

Capacity

The capacity of an automatic milking system is often expressed as the number of milkings per day. The number of milkings per day will depend on the configuration of the AM-system, like number of stalls and the use of selection gates, herd size, barn layout and the characteristics of the herd, like milk yield and flow rate. Increasing the number of milkings per cow per day, does not necessarily contribute to a higher capacity in terms of kg milk per day. This is due to the more or less fixed handling time of the automatic milking system per milking and the decreasing amount of milk per milking with smaller milking intervals.

A milking visit to the AM-system consists of several activities. The cow walks to the AM-system, will be identified and if the cow is allowed to be milked, the AM-system will start the udder preparation and teat cleaning. The teats are localised and the four teat cups will be attached. The milking process will start and after teat cup take off, the teats are disinfected and the cow is allowed to leave the milking station. Each milking visit has in fact two main parts: the handling time of the AM-system and the machine on time. Handling times between 2 to 4 minutes are reported in various studies. The machine on time depends largely on the yield and flow rate of the individual cow. Between herds and between cows, the average flow rates will differ due to genetic differences. Various figures are reported

from research with AM-systems. De Koning & Ouweltjes found an overall average flow rate, which could be modelled by 2.51 kg / min + 0.051 * (Yield – 11.8). Other data showed average flow rates between 1.4 and 1.9 kg / min in various experiments with AM-systems (Devir, Sonck).

Daily capacity

The maximum number of milkings per day and the capacity in kg per day can be calculated for one stall AM-systems by using the handling time per milking visit, the machine on time per visit and the occupation rate of the automatic milking system. For example an occupation rate of 80% means that the automatic milking system operates for 19.2 hours per day and the remaining 4.8 hours are used for rinsing and cleaning of the milking machine, refused milking visits and so on. In figure 1 results are presented for different yields per milking and flow rates. Increasing the average yield per milking will result in less milkings, but in an increased capacity in kg per day. Milk flow rate and yield have a large impact on capacity in kg per day. By changing the milk criteria settings in the AM-system for individual cows, the AM-system can be optimised to realise a maximal capacity in kg per day.

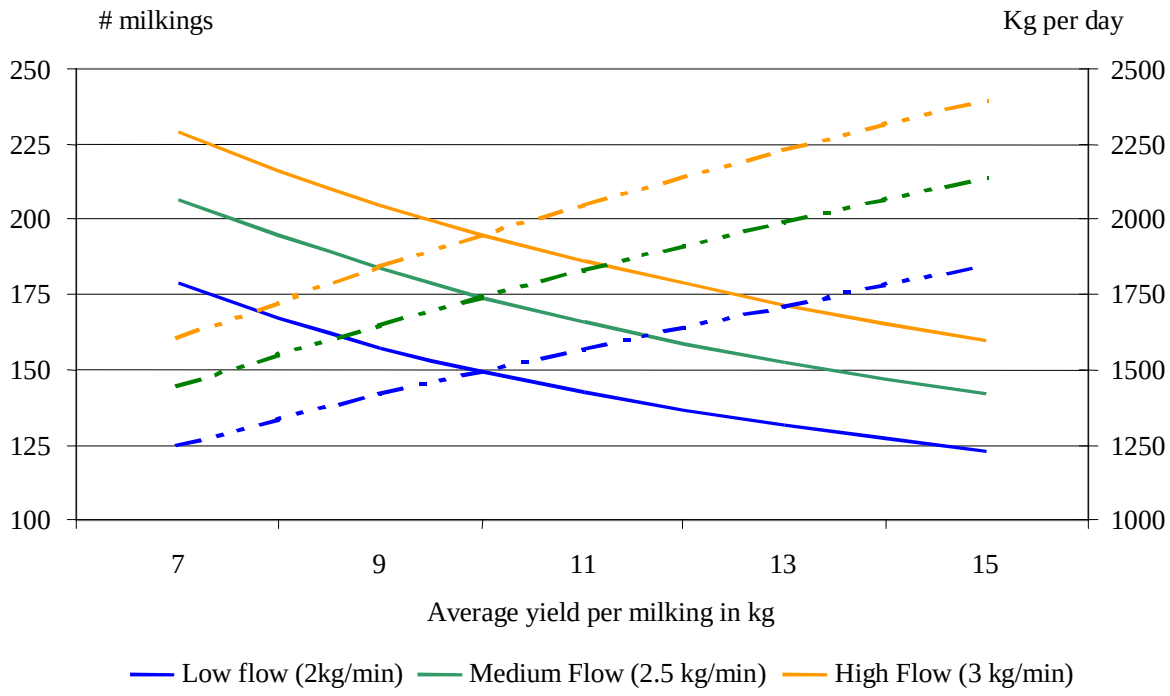

Figure 1. The calculated number of milkings per day and production per day at different yield and flow rates

Milk quality and cooling

Milk quality is without doubt one of the most important aspects of milk production on modern dairy farms. Milk payment systems are based on milk quality and consumers aspect a high quality level of the milk products they buy. Although automatic milking uses more or less the same milking principles as conventional milking, there are some big differences. The 24 hour continuous operation of the AM-system requires special cleaning procedures. Visual control during the milking process is not possible. Also teat cleaning cannot be adjusted to the degree of dirtiness. Furthermore the milking intervals will differ from cow to cow. All these aspects may influence the quality of the milk.

Bacterial counts and freezing point

At the start of automatic milking on commercial dairy farms, it was a general assumption that milk quality would be equal or even be improved after the change to automatic milking. However, results from commercial farms indicate that in many cases milk quality is negatively effected (Klungel et al, Van der Vorst). Results are presented in table 1 and show a doubling of the bacterial counts, although the levels are still relatively low and far within the penalty levels. The cleaning of the milking equipment and the cooling of the milk seem to be the most important factors regarding the increase in bacterial counts. Attention should be paid to the hygienic design of the milking machine in the AM-system, but research also showed that complete cleaning and disinfection should be carried out at least three times per day. Cleaning is also necessary after milking treated, diseased or fresh calved cows, to prevent contamination of milk. Most AM-systems also use a short rinsing between two consecutive milkings, to reduce the risk of transfer of pathogens from cow to cow. However the many cleaning and rinsing cycles in AM-systems will increase the risk of an increased freezing point. Special attention should be given to the draining of the system after cleaning, the slope of pipe lines and the use of draining valves.

Table 1. Milk quality results for farms before and after introduction of AM-system (Van der Vorst et al.*, 2000).*

	Dairy farmers		First generation		Second generation	
	2 times milking	3 times milking	Before	After	Before	After
Number of farms	60	45	39	39	62	62
Bacterial count (*1000 / ml)	8	8	8	17	8	12
Cell count (* 1000 / ml)	181	175	202	203	175	190
Freezing point (°C)	-0,520	-0.521	-0.520	-0.517	-0.521	-0.516
Free fatty acids (meq / 100 gr fat)	0.44	0.54	0.49	0.63	0.41	0.59

Cell counts, butyric acid spores

Also for cell counts a decrease was expected due to more frequent milking. Although little information is available, it seems that cell counts are not reduced in the first 12 months after the change to automatic milking. It is not clear if these changes are related to the AM-system or to the changes in management. Special attention should be given to the housing conditions of the cows, especially to the hygiene of the bedding in the cubicles and the hygiene of the slatted floors in order to keep the cows clean. Automatic manure scrapers on the slatted floors are used to keep the walking areas clean. Hygienic conditions and clean udders are also important to prevent an increase in butyric acid spores.

Free fatty acids

It is generally known that the content of free fatty acids (FFA) in milk will increase with shorter milking intervals (Ipema & Schuiling), the more so if the yield per milking is rather low. All studies with AM-systems show a significant increase in FFA levels. 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 parlours milking three times per day. Another explanation may be the increased air inlet by attachment of teat cups, during milking and at take off. Also the cooling system may play a role.

Cooling of milk

It is generally recommended that the milk should be cooled within 3 hours to, and stored at, a temperature below 4 ^{o}C. In conventional milking, cows are milked twice a day and therefore also twice a day a big volume of milk has to be cooled. In automatic milking, however, the system operates 24 hours and a relatively small amount of milk is flowing more or less continuously to the bulk tank. The average flow rate will range between 50 and 250 kg per hour from 1 to 4 milking stalls. Furthermore there may be some periods without any milk flow because of a low activity of the cows, for example in the night.

Milk can be cooled either directly or indirectly. With direct cooling of milk, the cooling process is not allowed to be started before approximately 10% of the tank capacity is filled with milk. This to prevent the risk of freezing and deterioration of milk quality. In conventional milking this 10% filling will take 1-2 hours. In automatic milking this period may increase up to 10 hours. Such a delay of cooling will increase the risk of bacterial growth, and is not allowed.

Different systems for milk storage and cooling can be applied with automatic milking systems (Wolters *et al.*). The basic requirement is that the system can handle the specific conditions of automatic milking. It may also be useful to have a cooling system which is able to store the milk

when the bulk tank is emptied and cleaned. This enables the AM-system to continue milking, thus increasing the capacity of the system. In general there are four principles to adjust the cooling system to automatic milking:
1) indirect cooling with an ice-bank tank;
2) combination of bulk and buffer tank;
3) storage tank with fractional cooling, and
4) instant cooling.

Economy

Investments required for automatic milking systems are much higher than for conventional milking systems and thus the fixed costs of milking with an AM-system will be higher. However more milk will be produced per cow and per herd with less labour than before. More milk means that the costs of milking per kg of milk will decrease. The same applies to the labour costs per kg milk. Theoretically, with an AM-system more cows can be kept with the same labour force than with the conventional milking system. But this may involve additional investments in buildings, land or feed and perhaps even milk quota. On a farm with more than one full time worker the possibility exists to reduce labour input and thus costs. However quite often that does not happen and the time saved as a result of lower labour requirement will be used for personal activities: sports, family and other. These social aspects are often very important for farmers and their families. The reasons to invest in automatic milking are quite diverse for

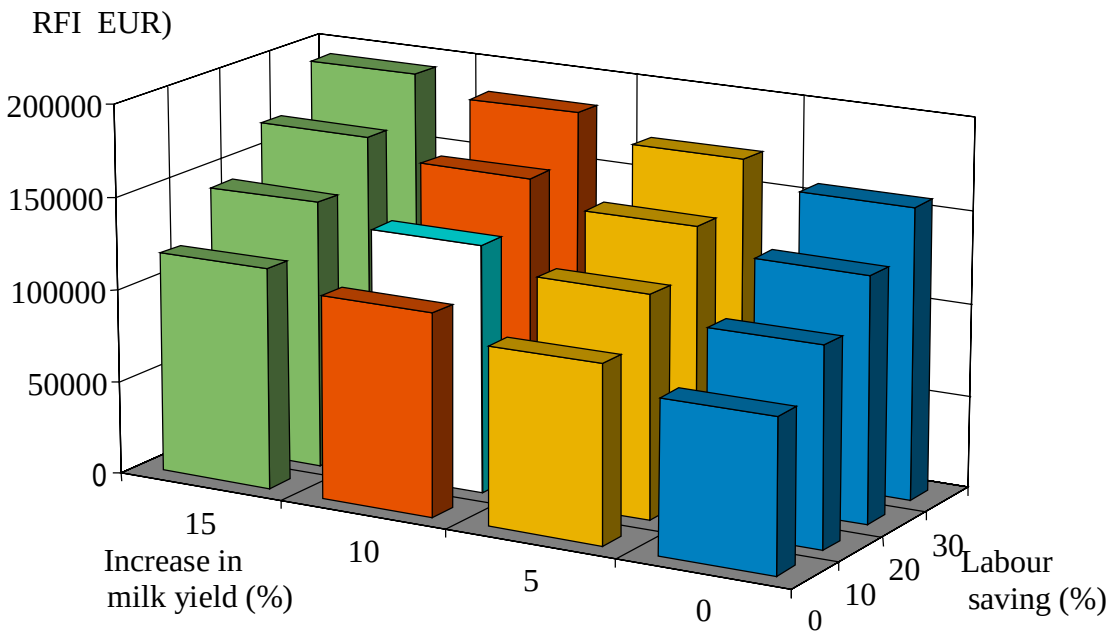

Figure 2. Room for Investment (RFI) due to labour saving and milk yield increase with annual costs for AM-system of 25% of investment.

farmers (Ipema et al, 1998) and therefore the introduction of an AM-system on a farm will effect the farm and farm management in several ways. Till now little economical information is available from commercial herds using an AM-system. Several simulation models have been developed to calculate the economical effect.

One of the basic models used, is the Room for Investment model (Mandersloot, Arendzen). This model computes the amount of money that can be invested in an AM-system, without any change of the net return compared with the conventional milking system. The RFI-value is calculated by accumulating the annual returns from increase in milk yield, annual savings in labour costs, annual savings in not investing in the conventional milking parlour and then dividing this total by the annual costs of the AM-system. The model is able to use the farm specific factors and circumstances to calculate the RFI-value. In figure 2 the results of a combined sensitivity analysis are presented. The figure shows clearly that increase in milk yield and labour savings are essential factors regarding the economy of AM-systems. The RFI-value for the basic farm with 10% milk yield increase, 10% labour saving, medium automated milking parlour and 25% annual costs of the AM-system amounts to Euro 134 000. The differences between the extremes are rather large, almost equal to the investment of a single stall AM-system.

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