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AUTOMATIC MILKING – CHANGES AND CHANCES

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SUMMARY

An overview is given of the development of automatic milking with special emphasis on management aspects and milk quality. Risk factors, changes, opportunities and challenges are discussed. Changing over from a milking parlour to automatic milking will lead to big changes for both herdsman and cow and can cause stress to both. Important aspects of successful implementation of an AM-system are the attitude and expectations of the dairy farmer. Results from commercial farms indicate, that in many cases milk quality is somewhat negatively effected, although the levels of bacterial counts and somatic cell counts still are relatively low and far within the penalty levels. However, after some time the BMSCC decreased in all countries to a comparable level of the conventional farms. 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 kilogram of milk. Automatic milking today is common practice on more than 1250 farms worldwide and a further increase in the number of systems is expected, mainly in the countries with high labour costs.

INTRODUCTION

The first ideas about fully automating the milking process were generated in the mid-seventies. The growing costs of labour in several countries were 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.

In automatic milking systems (AM-systems) cows are milked by a robotic milking system without direct human supervision. The first milking robots were installed on commercial dairy farms in the Netherlands in 1992. The breakthrough of automatic milking came at the end of the nineties and at spring 2002, more than 1250 farms worldwide milked their cows automatically (1).

AUTOMATIC MILKING SYSTEMS

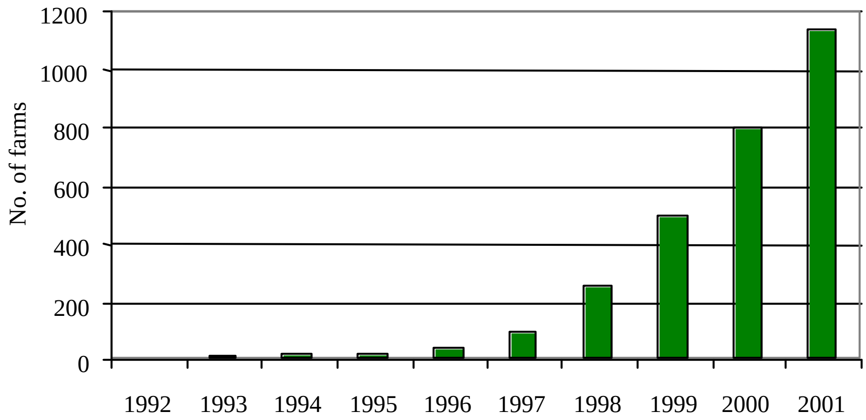
AM-systems can be divided into single stall systems and multi-stall systems. Single stall systems have an integrated robotic and milking system, while multi-stall systems have a transportable robot device. Each stall has its own milking devices, like in a milking parlour. A single stall AM-system is 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 international 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. 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 (2). AM-systems are also 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.

FARMS WITH AUTOMATIC MILKING SYSTEMS

The first AM-systems on commercial farms were implemented in North Western Europe. The reasons for these countries to start the development of AM-systems most probably were related to the expensive labour and the farm structure with family farms. Increasing costs of labour, land and buildings and machinery, while milk prices tended to decrease, forced farmers to increase their output per man-hour. Average herd-size showed a continuous increase and this phenomenon is still ongoing. In the first years after the introduction of the first AM-systems, the adoption went slow, until 1998 (Figure 1). From that year on, in the Netherlands, automatic milking became an accepted technology by the dairy sector and in the same period also other countries adopted AM-systems, like Germany, Denmark and France. More than 90% of all dairy farms with an AM-system are located in north-western Europe. Most dairy farms with an AM-system can be found in the Netherlands. However, AM-systems are also regarded to have potential for the USA and Canada too (3).

Figure 1. Number of farms with automatic milking systems (1)



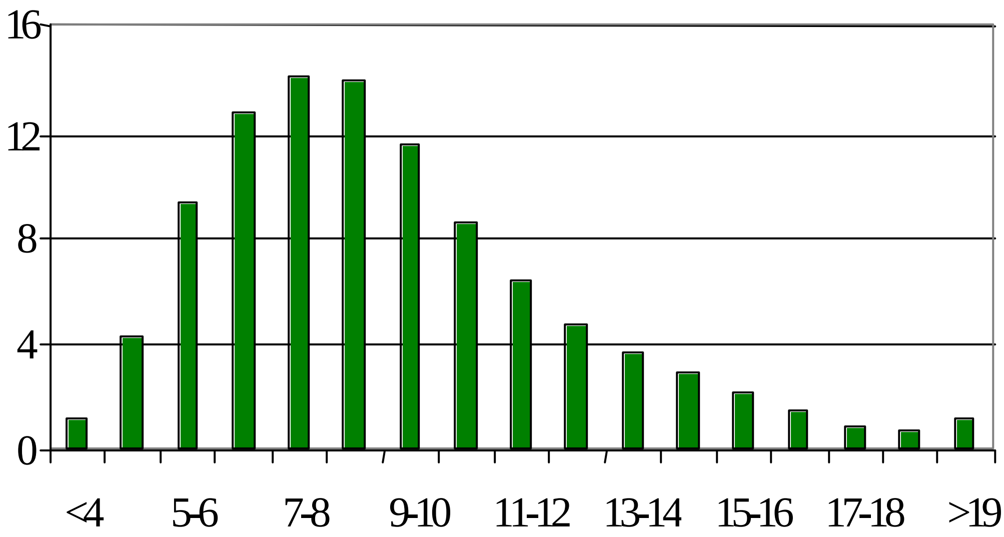
AUTOMATIC MILKING AND MANAGEMENT ASPECTS

Conversion from a milking parlour to automatic milking will result in big changes for both herdsman and cow and can cause stress to both. With automatic milking, the milking process does not require permanent supervision anymore. However, this does not mean that the hours spend on traditional milking will be spared. New labour tasks arise with the implementation of automatic milking on the farm like 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. Little field data are available on the labour savings when applying automatic milking. Several model studies showed physical labour savings of 30 to 40% compared with conventional milking systems (4,5). Ipema *et al.* (6) and Van't Land *et al* (7) reported labour demands for AM-systems from 32 minutes up to 3 hours per day. On average a 10% reduction in total labour demand is reported compared with the conventional milking system with twice milking per day (8).

The biggest change however, is the change in the character of the labour. Instead of mainly handwork during milking, the herdsman has to check several times per day attention lists from the computer of the AM-system. Decisions have to be taken accordingly. However, the work is less time bound compared with the milking parlour system, thus enabling a more flexible input of labour. This can be especially attractive on family farms. On the other hand, because milking has changed into a 24-hour process, system failures can occur for 24-hours per day. Therefore, there should always be a person on duty to react on system failures. Practical experiences show that system failures occur approximately once every two weeks. Good maintenance and attendance can decrease the number of failures. For instance, sensor failures might occur because the sensors are dirty, because they were not cleaned. This type of failure can easily be prevented by a well-organised working method.

The impact on the cows can be large. The AM-system might not be suitable for all cows, because of udder shape and teat position, or behaviour. Nevertheless, the culling rate of cows, because they are not suitable for automatic milking, is estimated to be no more than 5-10%. More important is the introduction period, cows should be handled quietly and consistent, to learn so that they adapt to the new surrounding and milking system. Automatic milking places emphasis on the cow's motivation to visit the AM-system to be milked more or less voluntarily. For this reason all AM-systems are equipped with concentrate dispensers. In the transition from conventional to automatic milking, cows have to learn to visit the AM-system frequently. Special attention is needed and in the first weeks, human assistance necessary.

Figure 2. Frequency distribution of milking intervals in hours over a 2-year period (9)



In practice, the number of milkings per day varies from 2.5 till 3.0, but rather big differences within the milking intervals are reported from commercial farms. De Koning and Ouweltjes (9) found that almost 10% of the cows realised a milking frequency of 2 or lower over a two-year period milking with a single stall AM-system (Figure 2). This occurred even though cows with too long an interval were fetched three times per day. These cows will not show any increase in yield or might 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. However, fetching cows cannot guarantee that long intervals are prevented as the data showed. Fetching cows three times per day that have exceeded an interval of 12 hours, means that the maximum interval may amount to 20 hours. Fetching cows with shorter intervals is quite time-consuming.

One of the main benefits of automatic milking is an increase in milk yield from more frequent milking. It is known that milk production, in terms of milk production per hour, is dependent on the milking interval. An increase in milk yield from 6 to 25% in complete lactations has been shown when increasing the milking frequency from two to three times per day (10). Dairy herd information records in The Netherlands show that daily milk production increases by 11.4%, when farms change from milking two times per day in a milking parlour to automatic milking (unpublished data). French data show an average 3% increase in milk yield up to 9% increase for farms that utilized the AM-system for more than 2 years (11,12).

Important aspects of successful implementation of an AM-system are the attitude and expectations of the dairy farmer (13). When expectations are too high, disappointments will also be high. Automatic milking requires, especially initially, a high input of labour and management. Almost all manufacturers of AM-systems have had customers who afterwards, went back to a traditional milking system. The exact reasons are not always known. Key factors of a successful implementation of AM-systems are:

- Realistic expectations
- Good management 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
- Technical functioning of the AM-system and regular maintenance

BARN LAYOUT, CAPACITY OF THE AM-SYSTEM AND MILK COOLING

Cows should have easy access to the milking system, using the cow's motivation for eating. The main motive for a cow to visit the AM-system is the supply of concentrate. AM-systems are equipped with concentrate dispensers, to attract cows to the AM-system to be milked. Therefore, the routing in the barn should be according the Eating – Lying – Milking principle. Cows should have an easy access to the milking stall. Selection gates, long alleys and so on should be minimised. The AM-system should be a part of the free stall barn (14). A central position of the AM-system in the barn minimises the walking distances of the cows. However, for matters of hygiene, in many countries the dairy industry requires the placement of the AM-system close to the milking room. Moreover, it is required that the AM-system be reached through a clean route.

After visiting the milking system, the cow should have access to the feeding area. Using this milking-feeding-lying principle, the cows are motivated to use the AM-system. Moreover, sufficient roughage should be available 24-hours a day. This is a prerequisite to have optimal cow traffic. 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 (6,7). The one-way cow traffic system is a very effective way to utilize the AM-system and to learn for cows. However, there is a consensus that for animal welfare, free cow traffic is better. Cows spend more time in the waiting area in a one-way cow traffic system (15). Especially for AM-systems with a high occupancy rate, this might affect the number of visits to the roughage station and thus result in a limited intake of roughage.

In most European countries, grazing during summer time is routine or even compulsory. Moreover, from an ethological point of view, many consumers in North Western Europe believe grazing is essential for cows. In the Netherlands, about 53% of the farms with an AM-system graze, showing that grazing in combination with AM is possible (17). One milk buyer in The Netherlands started with paying a bonus on the milk price when grazing is applied.

Capacity of an AM-system

The capacity of an automatic milking system is often expressed as the number of milkings per day, but this number will largely depend on the configuration of the automatic milking system, like the number of stalls and the use of selection gates, milking frequency, machine on time, herd size and cow traffic system. Increasing the number of milkings per cow per day, does not necessarily contribute to a high output capacity in kg of 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 when cows are milked more frequently. Milk flow rate and yield have a large impact on capacity in kg per day (9). By changing the milking criteria for individual cows, the AM-system can be optimised to realise a maximal capacity in kg per day. Besides effects on capacity, negative effects of certain milk intervals, such as increase of free fatty acids (FFA) with shorter milking intervals and possibly an increase in somatic cell counts (SCC) with long and short milking intervals must also be taken into account.

Cooling of milk in an AM-system

Milk should be cooled within 3 hours to a temperature below 4°C. The basic requirement is that the system can handle the specific conditions of automatic milking. In general there are four principles (19) to adjust the cooling system to automatic milking; a) indirect cooling with an ice-bank tank, b) combination of bulk and buffer tank, c) storage tank with modified cooling system and d) instant cooling. For an ice bank tank and modified cooling system, it may be useful to have an additional buffer tank, 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.

MILK QUALITY

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 expect a high quality level in the milk products they buy. Although automatic milking uses more or less the same milking principles as conventional milking, there are some big differences. Results from commercial farms indicate, that milk quality is adversely effected (12,16,19,20,21) in many cases after introduction of automatic milking. Data show almost a doubling of the bacterial counts, although the levels are still relatively low and far within the penalty limits. 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. Also cell counts are not reduced after the change to automatic milking, despite the increased milking frequency. In a Danish research (21) an increase in the number of new infections was reported during the first months after the introduction of the AM-system. It is suggested that more attention should be paid to the introductory period.

Within the EU project “Implications of the introduction of automatic milking on dairy farms” (QLK5 2000-31006) as part of the EU-programme 'Quality of Life and Management of Living resources', an international study regarding milk quality aspects and automatic milking (22) was undertaken on Danish, German and Dutch farms. The farms were divided in comparable groups based on the installation date.

1) Before January 1, 1998 (AM1), no farm data were available from Germany and Denmark.
2) January 1, 1998 - March 31, 1999 (AM2)
3) April 1, 1999 - June 30, 2000 (AM3)
4) July 1, 2000 - December, 2000 (AM4)

Significant differences in milk quality were found after introduction of the AM-system. The results (predicted means and recalculated geometric means) are presented in Table 1. Averages of conventional farms are also presented as a reference, however not statistically tested in the model.

Table 1. Predicted and recalculated geometric means before versus after the introduction of the AM system with figures of conventional farms as reference (22)

Country	Group	No. of farms	TPC cfu/ml		BMSCC Cells/ml		FP °C	FFA Meq/100 g fat	
			PM	GM	PM	GM	PM	PM	GM
DK	C2*	All	-	9,000	-	246,000	-	-	-
	Before	99	2.080ˣ	8,000	5.558ˣ	259,000	-	-	-
	After	99	2.633ʸ	14,000	5.633ʸ	279,000	-	-	-
D	C2*	All	-	21,000	-	181,000	-	-	-
	Before	33	2.835ˣ	17,000	5.302ˣ	201,000	-0.521ˣ	-	-
	After	33	3.033ʸ	21,000	5.313ˣ	203,000	-0.516ʸ	-	-
NL	C2*	295	1.995	7,000	5.169	176,000	-0.521	-0.8142	0.44
	C3*	40	2.016	8,000	5.214	184,000	-0.522	-0.5870	0.56
	Before	262	2.006ˣ	7,000	5.138ˣ	170,000	-0.522ˣ	-0.9310ˣ	0.39
	After	262	2.559ʸ	13,000	5.320ʸ	204,000	-0.517ʸ	-0.5569ʸ	0.57

* dark shaded sections not included in model
ˣ and ʸ = averages with different superscripts within each column and country differ significantly ($p<0.05$)

The European limit for total plate counts (TPC – 100,000 cfu/ml) and bulk milk somatic cell counts (BMSCC – 400,000 cells/ml) are laid down in legislation (Council Directive 92/46/EEC). The German penalty limit for freezing point (FP) is –0.515°C. The Dutch limit is –0.505°C. The Dutch limit for free fatty acids (FFA) is 1,0 mmol/100 g fat. From Table 1 it can be concluded that, the milk quality in all three countries deteriorated slightly after the introduction of the AM-system. This can also be concluded from Table 2, presenting the percentage of milk deliveries exceeding the European or National penalty limits after the introduction of the AM-system in comparison to before introduction.

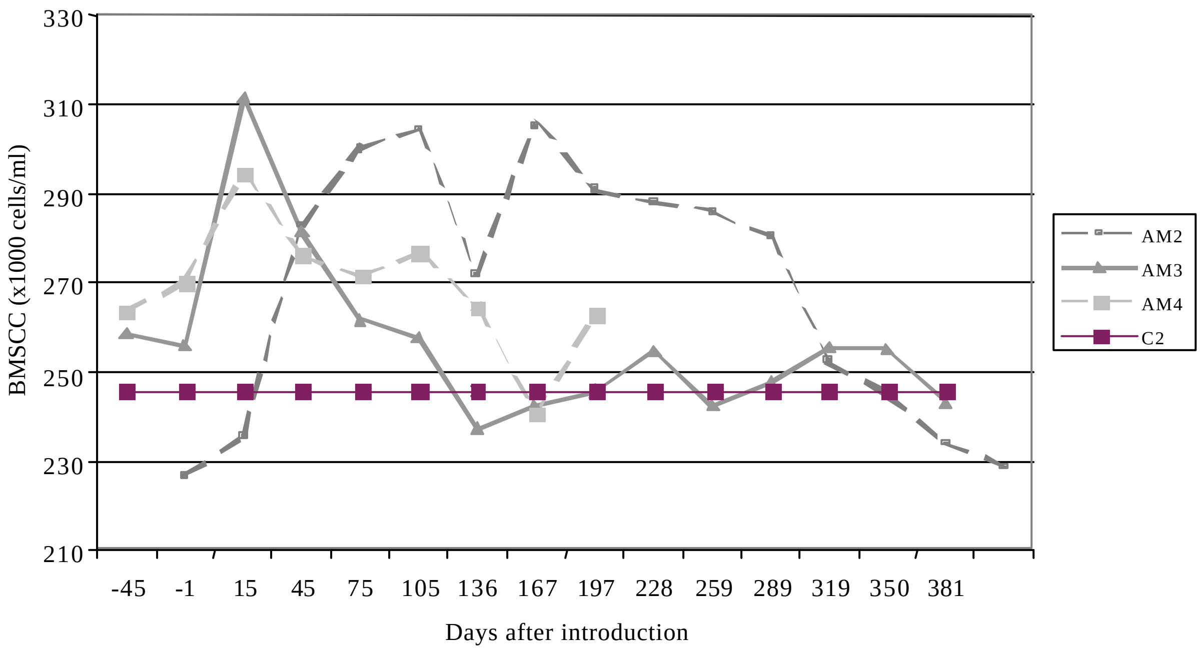
Table 2. Percentage (%) of bulk tank milk exceeding penalty limits before versus after the introduction of the AM-system, with conventional farms as reference (22)

Country	Group	TPC cfu/ml	BMSCC Cells/ml	FP °C	FFA Meq/100 g fat
		>100,000	>400,000	>-0.505	>1.0
DK	**Before**	0.8%	9.1%	-	-
	After	2.5%	11.1%	-	-
D	**Before**	2.9%	6.0%	1.1%	-
	After	7.7%	9.3%	2.8%	-
NL	**Before**	0.8%	2.4%	0.4%	1.6%
	After	2.8%	5.5%	1.4%	7.3%

Trends in BMSCC

The BMSCC increased slightly during and just after introduction of the AM-system. However, after some time the BMSCC decreased in all countries to a level comparable to the conventional farms. The lowest decrease was found in Denmark (see Figure 3) where the AM3 group (largest number of farms) reached the conventional level about 110 days after introduction of the AM system.

Figure 3. Course of BMSCC after introduction of the AM-system on Danish farms (22)



Trends in TPC, FP and FFA

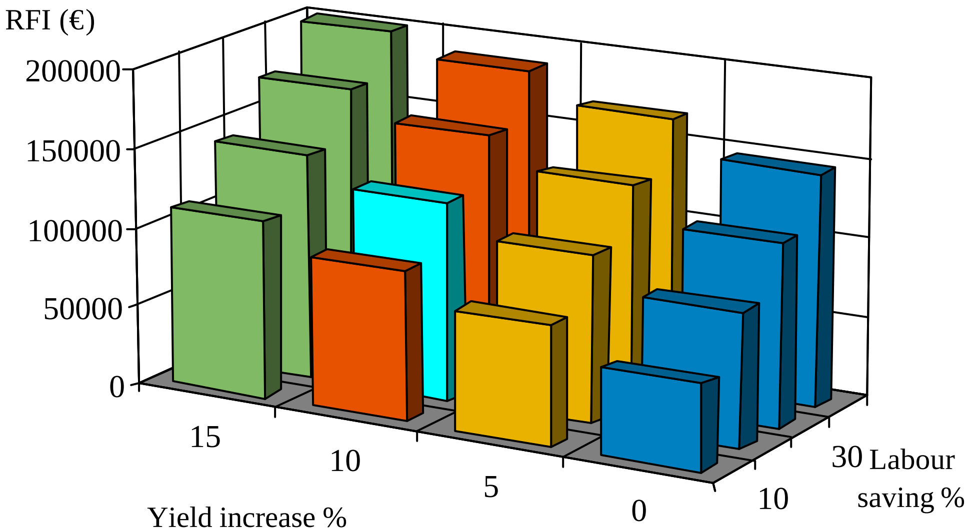
Similar effects on TPC, as for BMSCC, were found. For the freezing point (FP), the increase was seen immediately after introduction of the AM-system and it remained higher than conventional levels. Little fluctuation was found after introduction. Regarding FFA, the increase was less obvious after introduction, however it appeared to rise slowly. More research is necessary on this parameter to study the causes of the increase and to evaluate whether the increase is ongoing, and when it reaches its maximum.

ECONOMICAL ASPECTS

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 farmers (1,6,11) and therefore the introduction of an AM-system on a farm will affect the farm and farm management in several ways. Until now little economical information is available from commercial herds using an AM-system. Several simulation models have been developed to calculate the economical effect.

Figure 4. Room for Investment (RFI) due to labour saving and milk yield increase with annual costs for AM-system of 25% of investment



One of the basic models used, is the Room for Investment model (23,24). 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 4 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 €125,044. The differences between the extremes are rather large, almost equal to the investment of a single stall AM-system.

CONCLUSION

The number of farms milking with an AM-system has increased rapidly since 1998. In regions with expensive labour or a shortage of labour, automatic milking is serious alternative for a traditional milking parlour. The introduction of automatic milking has a large impact on the farm and affects all aspects of dairy farming. Since cows visit the AM-system more or less voluntarily, a large variation in milking intervals can be observed between cows. The introduction of automatic milking has a large impact on the farm, the management and the social life of the farmer. Automatic milking systems require a higher investment than conventional milking systems. However increased milk yields and reduced labour requirements may contribute to a decrease in the fixed costs per kg milk. A successful use of automatic milking depends largely on the management skills of the farmer and the barn layout and farming conditions.

REFERENCES

1. De Koning C.J.A.M., van de Vorst, Y., and Meijering, A. (2002) Automatic milking experience and development in Europe. *Proc. 1st North American Conf. on Robotic Milking*, Toronto, Canada, pp I1–I11.
2. Schuiling H.J. (1992). Teat cleaning and stimulation. In: *Proc. Intl. Symp. on prospects for automatic milking*, EAAP publication 65, pp 164-168.
3. Rodenburg, J. and Kelton, D.F. (2001) Automatic milking systems in North America: Issues and challenges unique to Ontario. *Proc. Natl. Mast. Council Annual Meeting* pp 163-169, NMC, Madison, WI, USA
4. Sonck, B.R. and Donkers, J.H.W. (1995) The milking capacity of a milking robot. *J. Agr. Eng. Res.* **62**: 25-38.
5. Schick, M., Volet, M.-R. and Kaufmann, R. (2000) Modelling of time requirements and milking capacity in automatic milking systems with one or two milking stalls. Page 32-37 In: H. Hogeveen and A. Meijering (editors) *Robotic milking*. Wageningen Pers, Wageningen.
6. Ipema A, Smits, A. and Jagtenberg, C. (1998) Praktijkervaringen met melkrobots. In: Praktijkonderzoek, 98-6, pp 37-39 (in Dutch).
7. Land, A. van ‘t *et al*, (2000) Effects of husbandry systems on the efficiency and optimisation of robotic milking performance and management. In: *Robotic Milking, Proc. Intl. Symp.* held in Lelystad, pp 167-176.
8. Koning, C. de, (2001) Automatic milking; chances and challenges. In: A.Rosati, S. Mihina, C. Mosconi (editors), *Physiological and Technical Aspects of Machine Milking*, pp 131-140, ICAR TS 7, Rome, Italy.
9. Koning C.J.A.M. de, and Ouweltjes, W. (2000) Maximising the milking capacity of an automatic milking system. In: *Robotic Milking, Proc. Intl. Symp.* held in Lelystad, pp 38-46.

10. Erdman, R.A. and Varner, M. (1995) Fixed yield responses to increased milking frequency. *J. Dairy Sci.* **78**: 1199-1203.
11. Veysset P., Wallet, P. Prognard, E. (2001) Automatic milking systems: Characterising the farms equipped with AMS, impact and economic simulations. In: A. Rosati, S. Mihina, C. Mosconi (editors), *Physiological and Technical Aspects of Machine Milking*, pp 141-150, ICAR TS 7, Rome, Italy.
12. Billon P. (2001) Les robots de traite en France; impact sur la qualité du lait en le système de production. In: *Proc. Il Robot di Mungitura in Lombardia*, Cremona, Italy.
13. Hogeveen H., van der Vorst, Y., de Koning, C. and Slaghuis, B. (2001) Concepts et implications de la traite automatisée. In*: Symp. sure les bovines laitiers*, pp 104-120, CRAAQ, Canada.
14. Lind O., Ipema, A.H., de Koning, C., Mottram, T.T. and Herrmann, H.J. (2000) *Automatic milking, Bulletin of the IDF* 348/2000, pp 3-14.
15. Hogeveen, H., van Lent, A.J.H. and Jagtenberg, C.J. (1998) Free and one-way cow traffic in combination with automatic milking. In: J.P. Chastain (editor) *Proc. 4th Intl. Dairy Housing Conf*. ASAE 01-98, pp 80-87, Michigan, U.S.A.
16. Vorst, Y. van der, and Hogeveen, H. (2000) Automatic milking systems and milk quality in the Netherlands. In*: Robotic Milking, Proc. Intl. Symp.* held in Lelystad, pp 73-82.
17. Van Dooren, H.J., Spordnly, E., and Wiktorsson, H. (2002) Automatic milking and grazing, Applied grazing strategies in Europe, Deliverable D25 from EU project Implications of the introduction of automatic milking on dairy farms (QLK5 2000-31006).
18. De Koning C.J.A.M., Verstappen-Boerekamp, J.A.M. and Schuiling, H. (2002) Milk cooling systems for automatic milking. In: *Proc. 1st North American Conf. on Robotic Milking*, Toronto, Canada, pp V25 – V35.
19. Klungel, G.H., Slaghuis, B.A. and Hogeveen, H. (2000) The effect of the introduction of automatic milking on milk quality. *J. Dairy Sci.* **83**:1998-2003.
20. Pomies D. and Bony, J. (2001) Comparison of hygienic quality of milk collected with a milking robot vs. with a conventional milking parlour. In: H. Hogeveen and A. Meijering (editors) *Robotic Milking*, pp. 122-123, Wageningen Pers, Wageningen, The Netherlands.
21. Rasmussen, M.D., Blom, J.Y., Nielsen, L.A.H. and P. Justesen, P. (2001) Udder health of cows milked automatically. *Livest. Prod. Sci.* **72**:147-156.
22. Vorst, Y. van der, Knappstein, K. and Rasmussen, M.D. (2002) Effects of Automatic Milking on the Quality of Produced Milk, Deliverable D8 from EU project Implications of the introduction of automatic milking on dairy farms (QLK5 2000-31006).
23. Mandersloot F., van Scheppingen, A.T.J. and Nijssen, J.M.A. (1999) A dairy farm budget program as a tool for planning and evaluation. In: *Book of abstracts, 50th annual meeting* EAAP, p 216.

24. Arendzen, I. and van Scheppingen, A.T.J. (2000) Economical sensitivity of four main parameters defining the room for investement of AM-systems on dairy farms. In: *Robotic Milking, Proc.Intl. Symp.* held in Lelystad, pp 201-211.