Most sincere thanks to the sponsor of the symposium:
Alfa-Laval Agri International AB, Tumba, Sweden.

Automation of feeding and milking: production, health, behaviour, breeding

Proceedings of the EAAP-symposium of the Commissions on animal management and health & cattle production, Helsinki, Finland, 1 July 1988
(EAAP Publication No. 40, 1988)

J. Unshelm and G. Schönmuth (compilers)

Pudoc Wageningen 1988

CIP-data Koninklijke Bibliotheek, Den Haag

ISBN 90-220-0945-9
NUGI 835

Printed in the Netherlands.

CONTENTS

AUTOMATION OF FEEDING AND MILKING - INTRODUCTORY COMMENTS

H. Saloniemi

College of Veterinary Medicine, Helsinki, Finland

At the beginning of the seventies the first steps were taken in the field of automation of dairy cow feeding and milking. In 1970 a system was introduced in the Netherlands in which a transmitter was used to dose concentrate for cows in the milking stall (Rossing 1987). From the middle of the seventies the practical concentrate feeding systems have been in use on dairy farms. Investigations of the possibilities of automation in dairying have been developing very fast in the eighties. The key innovation in the automation of feeding and milking was the automatic cow identification. By the automatic identification systems, processes can be controlled and the required animal data be collected individually.

The amount and quality of concentrate should be controlled in order to avoid health disorders and f.ex. overfeeding resulting fat cow syndrome and low efficiency. It is shown that a daily variation of plus minus 15 percent in concentrate feeding results 5 percent less milk on the same amount of feeds (Wiktorsson & Knutsson 1977). It is also shown that individual feeding resulted in higher milk production than group feeding of cows, either tied up or in a free stall system. The controlled feeding systems for cows have been developed for concentrate feeds fairly well.

From the nutritional, cow health management and feed efficiency point of view, more attention should be given to the automatically controlled roughage feeding. Reports have been published indicating that a system which allowes individual feeding of roughage in a free stall system gives considerable economical benefits in feed consumption, lower health risk of underfeeding of cows during the first part of lactation and lower risk of overfeeding in later stages and also less conflicts in cow behaviour (Wiktorsson 1987).

The milk yield recording per cow provides the farmer a valuable data for cattle feeding and breeding management. The automation of this measurement saves much labor time. While doing this recording continuously on every milking, the information of an unexpected drop of daily milk yield acts as an effective indicator of health disturbances. Other parameters which can be measured automatically and quickly are milk temperature and electrical conductivity of the milk. It has been found that milk temperature is a good measure of body temperature (Maatje & Rossing 1976), which is a useful indicator of the health condition of the cow. The electrical conductivity of the milk of each quarter can be measured automatically during every milking. It has been found in many investigations that there is a good relationship between the milk conductivity and the number of cells in the milk.

As sufficient sensors are now available to indicate sick animals, the attachment of the milking machine can also be automated. The feed dispensing station in the cowshed is developed for the place of automatic milking. It was found by Rossing (1987), that the cows came to the feed station 5.4 times a day and were milked four times a day. It was also established that the production rose during automatic milking.

The automatic monitoring methods of cow behaviour in cowshed have been investigated widely. An increased level of activity may indicate oestrus and a reduced activity tells about health disorders. The use of electronic transducers for activity monitoring has led to observation of very high proportion of heats (Thompson & Rodrian 1983).

The automatic collection of data during milking and feeding serves a good tool for promoting the welfare of animals. The processing of collected data with the information produced by milk recording organisation and the disease recording system (which is widely used in Finland, Norway and Sweden) gives a good possibility to a very effective health management on farms (Saloniemi 1987).

The new technology and the fast development of automation in dairying is not a threat to animal welfare and health, if we take it in use carefully and only after intensive investigations. All the scientists presenting papers in this symposium have worked for promoting our knowledge about the effects of new technology in dairy production. Automation of feeding and milking is a great challenge for today's milk production.

References

Maatje, K. & W. Rossing, 1976. Detecting oestrus by measuring milk temperatures of dairy cows during milking. Livestock Prod. Science 3:85-89.

Rossing, W., 1987. Automation in dairying - Now and in the near future. Proc. Computers, electronics and control engineering in agriculture. Swedish Univ. Agric. Sciences, Dept. Agric. Engineering, Report 117, XIV:1-12. Uppsala.

Saloniemi, H., 1987. The control of animal health with the new technology. Swedish Univ. Agric. Sciences, Dept. Agric. Engineering, Report 117, XII:1-6. Uppsala.

Thompson, P.D. & J.A. Rodrian, 1983. Transducers for capture of activity data. Proc. Symp. Automation in dairying. IMAG, Wageningen, The Netherlands, p. 115-126.

Wiktorsson, H., 1987. Feeding and management of dairy cows for efficient production and good health. Swedish Univ. Agric. Sciences, Dept. Agric.Engineering, Report 117, X:1-4

Wiktorsson, H. & P.G. Knutsson, 1977. Effects on milk production of controlled variation in concentrate feeding. Swedish J. agric. Res. 7:159-162.

Automation in milk production

Hans O. Gravert

Institute for Milk Production, Federal Dairy Research Center, Kiel, Federal Republik of Germany

Summary

This introduction paper outlines the targets of automation in milk production. These are (1) to improve the animals welfare (2) to improve the working conditions for the farmer or herdsman, (3) to improve the quality of milk and milk products, (4) to achieve a better protection of the environment and (5) to reduce the costs in milk production. Some ideas are discussed especially the expected advantages of fully automated milk production which corresponds better to the natural behaviour of dairy cows than the present system.

In talking about automation we might think of electronics, computers and robots. However, automation in agriculture started originally with early farm machinery and has always been a combination of new technical aids, of new production systems and even of new plant varieties or genetically improved animals. In milk production the invention of the milking machine about 50 years ago undoubtedly has been the most revolutionary change. It took a long time, however, from the first model on the market to the sophisticated equipment of to-day. A farmer's decision to buy machinery is based on the benefits he can expect from relief from strenuous labour, from higher gross income from more and better efficiency in production. However automation in milk production should mainly aim at somewhat different targets:

Firstly, as members of a humane society we should give a high priority to all aspects of animal welfare, especially in farm animals. Since the normal working hours of men do not coincide with the circadian pattern of a cow's behaviour selection has always been directed towards a domesticated dairy cow which primarily fits the demands of the dairy farmer. With automation the close links between dairyman and cow might become more flexible giving not only the dairyman more flexibility in his daily duties but also an opportunity for the cow to return to her more "natural" behaviour. What do we mean by "natural" with respect to a dairy cow?

We dont know very much about the requirements for the welfare of a dairy cow. A beef cow nursing her calf produces a daily milk yield of about 6 kg, a low producing dairy cow will start with about 15 - 20 kg daily and a high-yielding cow will achieve about 40 kg. If we compare the lactation curves we observe the biggest differences in the early stage of lactation. In the second month p. p. the superiority of a high yielding cow versus a low production is about 23 kg, in the eighth month p.p. 15 kg only. Selection for higher milk yield apparently increases the initial daily yield more than the average yield. It is hard to believe that twice-a-day milking with up to 20 kg milk stored in the udder before milking really can help a cow's welfare.

In beef herds the frequency of suckling is about 4 to 6 times per 24 hours, in early lactation even more (table 1). Total nursing time is about three quarters to one hour, compared to a dairy cow with two milkings with scarcely 20 minutes in total. As shown by Day et al. (1987) the number of nursing bouts increases with lower milk production level. So with respect to dairy cows one might argue that 4 - 5 milkings with 10 minutes each per 24 hours would fit the "natural" pattern best.

This target can be realized with automated milking robots only. Ir. Ipema from the IMAG Institute at Wageningen will report on the current state of development which is promising though there will be a long period of trial and error until a generally acceptable stage will be achieved. Simulation studies with voluntary milking systems confirm the observations with nursing cows that the cows prefer milking intervals of 4 -6 hours with 4 -6 milking times per 24 hours (table 2). The motivation to enter the milking box, however, seems to be based more on the desire for concentrates rather than on the impetus to be milked. Therefore voluntary milking systems must be combined with automated feed dispensers.

It is a well known fact that one can expect more milk per cow after more frequent milking. The increase in the simulation trials have been 2,7 kg FCM (= 13 %) in our herd and in the Dutch experiments 2,2 kg FCM (= 8 %) and 2,9 kg FCM (= 11 %) resp. This corresponds fairly well with trials with 4 times milking versus twice-a-day. E. g. Meinhold and Rosegger found an increase between 13 % and 22 % in cows with an initial yield of 5000 kg FCM and 6300 kg FCM resp.

With regard to feeding frequency we can also be fairly sure that twice-a-day will not correspond to the "natural" behaviour of a cow. We know from behavioural studies in free-stalls that dairy cows visit the concentrate dispensers up to 15 times, the roughage silos up to 10 times, the water trough about 5 and the cubicles about 9 times per 24 hours (table 3). In total they spend about 16 hours for feeding, drinking and resting. The actual sleep of dairy cows is rather short, about 30 - 60 minutes are deep sleep and another 3 hours slow wave sleep.

Theoretically frequent feeding will increase the feed intake (table 4). Kaufmann (1976) found an additional roughage intake of up to 0.4 kg DM if he fed seven versus twice-a-day. There was also a positive effect of feeding frequency on the fat content in milk presumably as a result of a more constant pH-value in the rumen and a higher synthesis of acetic acid (table 5). With 14 feedings per 24 hours the fat content was 4.04 %, with twice-a-day feeding 3.69 % only. So frequent feeding should result in less stress for the dairy cow. However, we dont know the real optimum from the viewpoint of the cows welfare.

When we talk about the animal's welfare a good bedding, hygienic conditions and sufficient space might also be important. Cows are social animals and form a dominance order within a herd. To avoid stress and damage they have to keep a minimum social distance between each other (Wierenga, 1983). In free-stalls this can be achieved by an average area of about 4 m^2 per cow. With a voluntary milking and feeding system the number of cubicles can be less than the number of cows.

Secondly, automation in milk production should improve the working conditions for the farmer or herdsman. Milking is not only a hard physical work load but also a stringent limitation of the farmer's time. In modern milking parlours the number of cows per hour and man varies between 50 and 100 (table 6). Most time is spent on udder preparation, attaching the units and teat dip. For high-yielding cows there might be also a waiting time, expecially in herringbone parlours. Any automation will not neglect the farmers skill but decrease the burder of physical work and change over to more mental and control work, however with more free choice of the time during the day.

A third target of automation is the quality of product. In milk production healthy cows with unaffected udders are primary conditions for mastitis prevention combined with a high hygienic standard for udder preparation, milking, cooling and storage of milk. In robot milking one can expect one milking unit per about 25 cows, two units for 50 cows etc. This means that the milking machine is used permanently, with the exception of cleaning period. Therefore rinsing and disinfection between cows has to be an integrated part of the system. The milk will be gathered in small quantities which requires a small but effective cooling system. Milk delivery from the bulk tank will be independent from any fixed time during day or night. In trials with voluntary milking the cell count in milk was not affected though there is no experience so far with real robot milking. Theoretically a better udder health could be expected from more frequent milking, however, the present milking machines have been adjusted to a twice-a-day or three times-a-day milking. They might need some modification to voluntary milking systems, e. g. a lower vacuum, to avoid teat damage or irritation.

Other aspects of product quality concern taste and flavour of raw milk, the risk of spores in milk harmful to cheese making, the composition of fatty acids to achieve an optimum spreadability of butter, and the structure of casein micelles to avoid clotting in cream. Much research efforts should follow each development in automation to ensure a high quality standard of milk products.

A fourth target of automation in milk production should be a better protection of the environment. Free-stalls with concrete or slatted floors and increased herd size have created problems with liquid manure. In my opinion this development seems to become a deadlock. The liquid manure has disadvantages for the cows (feet and leg troubles), for the soil (destroying structure), for the underground water (content of nitrate) and for people (terrible odour). The only advantages are low labour costs. A dairy cow produces more than double as much wet waste as a beef cow and the biochemical oxygen demand is about twice as much (table 7). This makes it extremely difficult to treat the waste adequately and at reasonable costs to avoid the problems mentioned above.

In waste management there is a numerous variety of technical solutions from simple spreading the fresh manure to energy recovery systems. Whichever solution is preferred priority should be given to the cow's welfare and to the protection of the environment and ground water. From this point of view perhaps the straw bedding used by our grandparents was not the worst alternative.

Finally, but extremely important, one target of automation is the reduction of costs in milk production. With the present methods of milk production we force the cows to a fixed routine and we utilize most of the barn equipment only temporarily. E. g. in a free-stall all cows are gathered in a waiting area twice-a-day for about one hour. After milking they prefer to eat roughage, then concentrates, then they drink and afterwards they want to lay down for about two hours. The milking machine is used for just 3 - 4 hours per day and 20 hours it is idle.

With automation all the equipment should be used permanently, especially feed dispensers, milking machine, cubicles and rinsing or flushing devices. This would keep the costs of automation at a reasonable level. We know, however, that this target cannot easily be achieved. As an example table 8 gives the results from 568 free-stalls in Schleswig-Holstein, about half of them without and with automatic feed dispensers. In the latter group number of cows per herd and milk yield were higher, however with a higher concentrate input. So in total the feed costs per kg milk were slightly higher in herds with automatic feed dispensers.

Automation in milk production will inevitably be connected to a higher mental skill of the farmer. Increasing investments require increasing management. Any automation must be accompanied by an excellent supervision, maintenance service and regular check-up. Micro-electronics have been applied for a better and more efficient monitoring of herd data, replacing and improving old-fashioned paper work. Of course, using a computer-based herd management system requires adequate training and exercise and is therefore mostly linked to the succession of a young generation. Some components of automation are already available, others have still to be developed. Therefore we are grateful to the following speakers of this session who will talk about the present state of knowledge.

Table 1. Suckling behaviour in beef cows (Day et al., 1987).

Day of lactation	Frequency of nursing	Total min nursed
52	8,6	64
104	5,9	49
167	4,5	44

Table 2. Voluntary milking systems.

Author	Number of cows	Frequency of milkings	kg FCM/day
Ordolff 1982	Exp. 22 Contr. 29	4,6 2	24,0 21,3
Rossing et al. 1985	Exp. 14 Contr. 14	5,4 2	28,3 26,1
Rossing 1987	Exp. 19 Contr. 19	3,8 2	30,5 27,6

Table 3. Behaviour of cows in free-stall (Baehr, 1983).

Area	Number of visits	Time present (min)	Time active (min)
Feed dispenser	15,1	36,5	16,0
Self-feed silage	10,2	138	(138)
Drinking	5,3	17,9	3,4
Cubicles	8,7	745	563

Table 4. Feeding frequency and roughage intake (kg/cow) (Kaufmann, 1976).

production level FCM	Intake of concentrates 2 x	7 x	Intake of roughage 2 x	7 x
20 - 25 kg	9,5	9,5	5,4	5,6
25 - 30 kg	11,3	11,3	5,7	5,8
30 - 35 kg	12,3	12,3	5,8	6,2

Table 5. Effect of feeding frequency (Kaufmann, 1973).

	2 x	14 x	difference
Daily milk yield	23,6	23,4	- 0,2 NS
Fat-%	3,69	4,04	+ 0,35 xx
Rumen pH ($\bar{x}$)	6,28	6,31	+ 0,03 NS
pH (s)	0,23	0,20	- 0,03 x
acetic acid	55,1	60,4	+ 5,3 xx
propionic acid	21,2	20,1	- 1,1 xx

Table 6. Productivity of cow and labor requirement (Armstrong and Quick, 1986).

s/cow	Milk/cow 15,9 kg	27,7 kg
Cows in and feed	5,4	5,5
Udder preparation	10,1	12,1
Attach unit	8,9	8,9
Teat dip	7,9	8,1
Cows out	4,0	3,9
Waiting	0,9	9,2
Adjust and reattach	3,1	3,7
Floor wash	1,0	1,1
Out of parlor	1,4	1,6
Total	42,7	54,1
Cows per man hour	84	67

Table 7. Feedlot wastes per cow and day (Taiganides, 1987).

	Beef cow	Dairy cow
Total wet waste (kg)	25	65
Moisture content (%)	83	91
Biochemical oxygen demand (kg)	0,65	1,26
Nitrogen (g)	275	250
Phosphorus (g)	55	40
Potassium (g)	125	160

Table 8. Free-stalls in Schleswig-Holstein (Thomsen, 1988).

	without concentrate	with dispensers
Number of farms	294	274
Cows/Farm	59,3	67,9
Milk, kg/cow	5634	5909
Fat-%	4,14	4,16
Protein-%	3,32	3,32
Concentrate, t/cow	1,67	1,84
Feed cost/kg milk	23,2	23,4

References

Armstrong, D.V., Quick, A.J., 1986: Time and motion to measure milking parlor performance. J. Dairy Sci. 69, 1169-1177

Baehr, J., 1983: Verhalten von Milchkühen in Laufställen. Diss. Kiel, 224 p.

Day, M.L., Imakawa, K., Clutter, A.C., Wolfe, P.L., Zalesky, D.D., Nielsen, M.K., Kinder, J.E., 1987: Suckling behaviour of calves with dams varying in milk production. J. Anim. Sci 65, 1207-1212

Huth, F.-W., Schutzbar, W.v., 1981: Zur Frage des Laktationskurvenverlaufes beim Rind. Tierzüchter 33, 286-288

Kaufmann, W., 1973: Zum Einfluß höherer Fütterungsfrequenz auf die Fermentation in den Vormägen und die Leistung bei Milchkühen. Kieler Milchw. Forschungsber. 25, 245-250

Kaufmann, W., 1976: Influence of the composition of the ration and the feeding frequency on pH-regulation in the rumen and on feed intake in ruminants. Livestock Prod. Sci. 3, 103-114

Meinhold, K., Rosegger, S., 1977: Die Bedeutung der Melk- und Fütterungsfrequenz für die Wirtschaftlichkeit der Milcherzeugung. Tierzüchter 29, 444-445

Ordolff, D., 1982: Bedienungsneutraler Milchentzug. Jahresber. Forschung im BLM, Bonn, B 10

Rossing, W., 1987: Automation in dairying. Zbornik Biotehn. Fak. Ljublani suplem. 11, 87-98

Rossing, W., Ipema, A.H., Veltman, P.F., 1985: The feasibility of milking in a feeding box. Inst. Agr. Engng, Wageningen, Res. Rep. 85-2

Rutledge, J.J., Robison, O.W., Ahlschwede, W.T., Legates, J.E., 1971: Milk yield and its influence on 205-day weight of beef calves. J. Anim. Sci. 33, 563-567

Taiganides, E.P., 1987: Animal waste management and wastewater treatment. In W.A.S., Vol B 6, 91-154, Elsevier

Thomsen, J., 1988: Abruffütterungsanlagen. Bauernblatt f. Schl.-Holstein 42, 478-482

Wierenga, H.K., 1983: The influence of the space for walking and lying in a cubicle system on the behaviour of dairy cattle. EEX Seminar Farm Animal Housing and Welfare, Aberdeen, 1982, 171-180

THE EFFECTS OF AUTOMATED MILKING AND FEEDING ON THE PRODUCTION AND BEHAVIOUR OF DAIRY COWS

Ipema, A.H.[1], H.K. Wierenga[2], J. Metz[1], A.C. Smits[1], W. Rossing[1]

[1] Institute of Agricultural Engineering (IMAG), Wageningen, Netherlands
[2] Research Institute for Animal Production (IVO), Zeist, Netherlands

Summary

In the near future more and more processes on dairy farms will be automated. Milking will be fully automated, enabling cows to be milked several times daily. Cows are already accustomed to calling at the feeding station several times daily for their ration of concentrates. Therefore the feasibility of milking cows at the feeding station was studied. In two experiment cows milked more than twice daily at a concentrate feeding station were compared with cows milked twice daily in the parlour. An average milking frequency of about 4.0 times per 24 h was observed for voluntary milking. As a result of this raised frequency the increase in milk yield was about 5 kg per cow per day (20%) in the first and 3.4 kg per cow per day (14%) in the second experiment. The milkfat and protein contents were lower in the first few months of lactation.

Advances in technology and in breeding may bring about substantial increases in milk yields. This makes it desirable to optimize feeding too. Therefore, an experimental automatic forage feeding system consisting of 15 feeding stations that can be entered by free-housed cows during 24 hours a day has been developed. The amounts of forage dispensed and the leftovers removed by this system are recorded per individual animal. Research has shown that cows fed with the automatic system can achieve similar forage intake and milk yield to cows fed ad libitum in a feeding passage.

The behaviour of cows milked more frequently per day and that of cows fed by the automatic feeding system was also studied. There were no significant differences between the lying times of cows fed with the automatic feeding system and cows fed at a traditional feeding gate. In these cases the average lying times per group were between 685 and 700 min. per cow per day. In one experiment with more frequent daily milking lying times were longer compared with milking twice daily in a milking parlour. Especially for the high-yielding cows this effect was striking.
Keywords: dairy cows, automation, milking, feeding, behaviour

Introduction

Increasing productivity has long been the goal of farm development in the Netherlands. Yields of grass and feed crops, and of milk have increased dramatically during recent decades and dairy farming has been scaled up, mainly as a result of advances in mechanization and housing.

There are currently about 55,000 dairy farms with a total of 2,29 million dairy cows in the Netherlands. So, on average, there are about 40 dairy cows per farm. More than 90% of the farms with more than forty milking cows have cubicle houses. Advances in mechanization and housing have contributed to a substantial rise in labour productivity. In 1950 about 330 hours of labour were needed for one cow in a year; in 1980 this figure had fallen to only 40 hours per cow per year (Postma, 1981).

The introduction of quotas in 1984 changed the picture: futher development now requires improvements in farm management and operations. One of the options is higher milk yields per animal, with optimum nutrition. New techniques are required for this and therefore possibilities and effects of automated milking and feeding are receiving particular attention.

Results of two experiments simulating automatic milking will be discussed. In the second part the development of an experimental feeding system will be described. At the end behaviour aspects of automated feeding and milking will be dealt with.

Automation of milking

For milking in the milking parlour the individual animals can be identified electronically. The milk yield can be established with electronic milk meters and used to determine a cow's need for concentrates. These data, which also draw the dairy farmer's attention to deviations from the normal production level, have to be processed by computer (Burema & Kerkhof, 1979, Burema & Kerkhof, 1983).

Another major part of dairy cattle management is concerned with the detection of oestrus and diseases. Sick cows and cows in oestrus can be detected by determining deviations from the normal situation as with the milk yields. For this detection use is made of signs that can be measured quickly and automatically. The most suitable indicators are temperature and activity (Maatje & Rossing, 1976, Maatje & Rossing, 1986, Maatje & al., 1987). For detecting udder diseases the electric conductivity of the milk can be measured (Maatje et al., 1983, Rossing et al., 1987).

As the detection of cows in oestrus, of diseases, and of deviant milk quality can now be automated in principle, this allows the milking process to be performed without supervision. The next step in automation will then be the automatic application of the cluster to the udder. A milking robot is being developed in collaboration with a manufacturer. The first prototype was ready at the end of 1987 (figure 1).

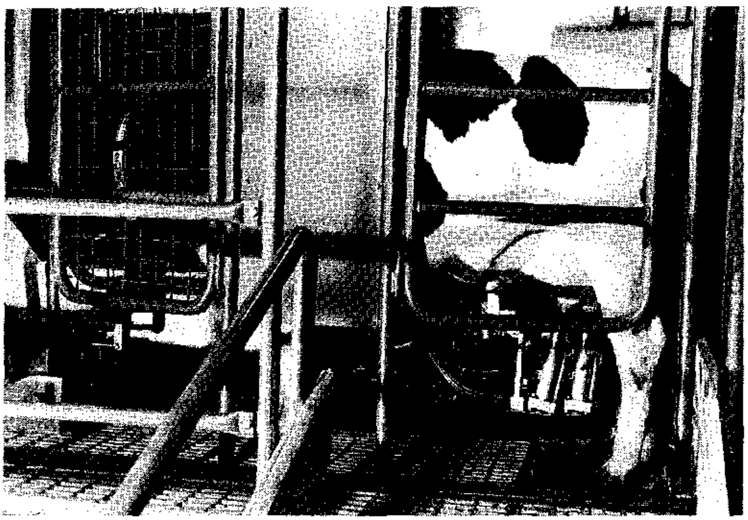


Fig.1. Prototype of milking robot.

A working milking robot would make it easy to milk cows more frequently per day. Many farms already use automatic cow identification systems combined with feeding stations that dispense the concentrates. Milking could also be done at these feeding stations. Cows visit the station several times a day and could be milked at the same time, thus obviating the need for a milking parlour.

Two experiments were carried out to simulate automatic continuous milking. In these experiments, an adapted feeding/milking station was used. Next to the feeding station there was a complete milking plant with a washer unit. The milk from this plant was stored in a separate tank outside the building. For applying the cluster the feeding station was manned for 24 hours a day. When a cow entered, the cluster was applied provided she had not been milked during the last three hours and the expected yield was at least 3.5 kg. The milking was interrupted twice daily (6.00-7.30 h and 15.30-17.00 h) so that the entire plant could be washed out.

Continuous milking: Experiment 1.

This experiment was carried out over a period of 11 weeks, from 1 February 1984 to 17 April 1984, to ascertain how often cows come to be milked and how the system affects milk production (Rossing et al., 1985). A test group of 20 animals with an even distribution of age and lactation stage was selected from a dairy herd. They were given roughage ad lib. but the amount of concentrates required per cow was determined on the basis of an estimated roughage intake, actual milk production, body weight and age.

After the start of the experiment most animals came voluntarily to the station. Some animals sometimes did not appear within 12 hours of the previous milking and were then brought to the station. In the first week a cow had to be brought to the station in less than 5% of the milkings. Later, this figure fell to less than 1%. It was a problem mainly in cows that were drying off, and also in some cows with foot problems.

On average, a cow visited the station 5.4 times daily. Each animal was milked 4.0 times a day on average, with a variation of 3.0 to 5.4. The highest milking frequency registered per day for any cow was 7.

Figure 2 gives the average standard cow production (Ann., 1983) in kg per day during a preliminary period of 4 weeks, the test period of 11 weeks and a post test period of 4 weeks. The curve for another group on the farm, milked twice a day in the milking parlour, is also given for comparison. Roughage rations were identical for both groups.

In the first 5 weeks of the trial, the standard cow production increased from about 35.5 kg in the preliminary period, up to about 47 kg in the fifth test week. The transition back to milking twice daily was accompanied by a marked decrease in production.

The other group of cows showed a gradual increase in the standard cow production during the test period. However, the level of this group remained clearly below that of the test group. After the trial was finished, both groups reached approximately the same level.

During the trial the standard cow production of the test group was on average 8 kg higher than that of the other group. With an average of 156 days in lactation and an average age of 4 years and 6 months, milk production was about 5 kg per day higher than was predicted on the basis of the production level of the other group.

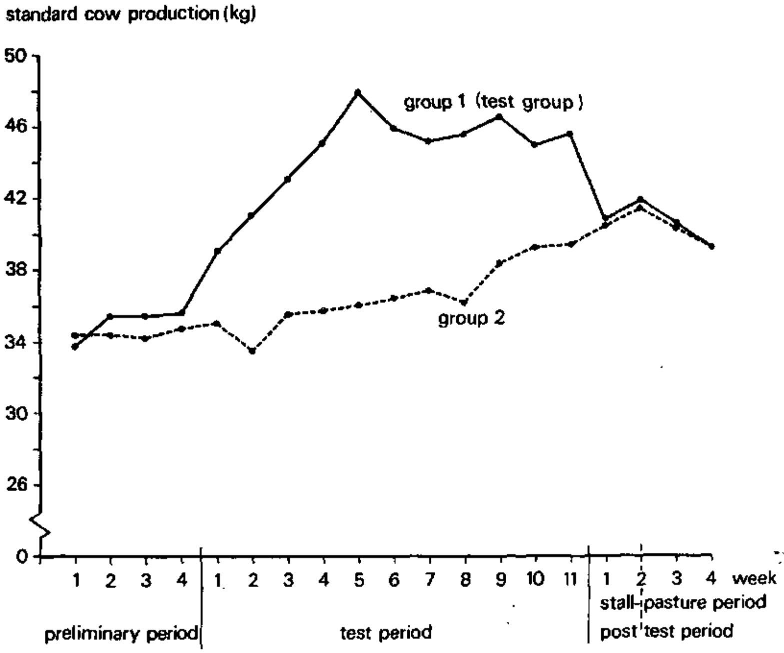


Fig. 2. Standard cow production of a more frequent milked group (testgroup (group 1)) and a group milked twice a day (group 2).

During the test period fat and protein levels for each milking were sampled over set periods of 28 hours (6x) or 72 hours (4x). Milk yields were recorded for each milking. The large deviation in fat percentages within cows was striking. The difference between milkings was 1.5 to 2%. There was considerably less variation in protein content.

The cows were milked several times a day and at different times during the day in the test period. The milking system used allowed the interval between consecutive milkings to be varied for a particular cow. The length of this interval naturally influences the yield at a given moment. In order to investigate these effects, each yield (milk, fat (grams and percentages) and protein (grams and percentages)) was compared with an predicted yield. A predicted yield was based on the average production in the appropriate week and the interval since the previous milking. Table 1 shows the milk, fat and protein production measured as a percentage of the predicted production at several predicted milk yield levels.

The influence of milk yield level on the difference between measured and predicted milk production was not very great. Milk yield level did, however, have a clear influence on fat percentage. With smaller milk yields the fat percentage measured was clearly higher and with larger milk yields clearly lower than predicted. Consequently, the relative maximum production of grams of fat was obtained with lower milk yields. The level of the milk yield affected protein percentage only slightly. The relative production of grams of protein was, therefore, mainly determined by the relative milk production.

Table 1. Relationship between predicted and measured yield (milk, fat and protein).

Predicted milk yield (kg)	No. of milkings	Production measured as % of prediction				
		milk	fat		protein	
			grams	%	grams	%
< 4	117	99	105	106	98	100
4 - 6	430	98	102	104	98	100
6 - 8	325	101	104	103	101	100
8 - 10	174	102	101	99	103	101
10 - 12	86	102	96	94	100	98
12 - 14	50	100	94	95	101	101
14 - 16	25	99	91	92	99	100
> 16	15	96	85	88	96	100

Continuous milking: Experiment 2.

In this experiment a test group and a reference group were used (Ipema et al., 1987). The reference group was milked twice daily (16.00 h. and 6.00 h.) in the milking parlour according the normal schedule, with the forage being supplied at a feeding fence.
Most of the concentrates were given at a feeding station, and only a small part in the parlour. The test group was fed forage using an automatic feeder system (described later). The forage given to both groups consisted of wilted silage and maize silage. The test group was milked at a modified concentrate feeding station.
Each group contained a maximum of 18 animals at a time. An attempt was made to achieve comparable groups, by matching animals of similar ages and calving dates. The test period lasted 36 weeks and ran from 20 September 1985 to 29 May 1986. Untill the end of January 1986 there were changes in the groups; these mainly consisted of replacing animals to be dried off by newly calved ones. Throughout the experiment there were, on average, seven heifers in each group.
Animals from the reference group were milked in the parlour twice daily, whereas those of the test group were milked more often. The average milking frequency of 19 animals that were in the test group for more than 100 days was 3.90 times a day, with individual variations of between three and five times daily.
The distribution of the number of milkings over the 24-hour period is shown in Figure 3.
On average, the number of milkings was highest in the hours after the milking pauses when the plant was being washed out; later there were slight declines. The number was lowest in the period between midnight and 6.00 h.

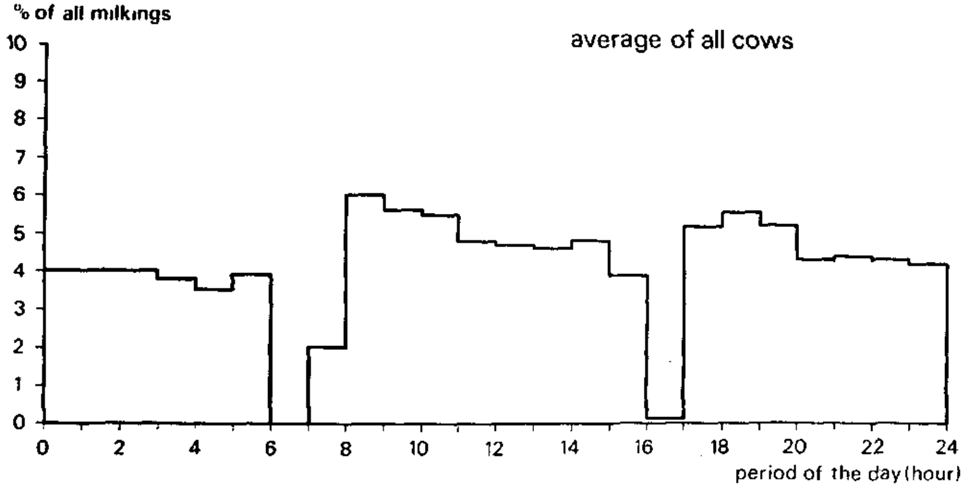


Fig. 3 . Distribution of the number of milkings over the 24-hour period.

Milk data were recorded every week during one day. Table 2 gives the average group results. These averages only refer to the pairs of animals that stayed in the test and reference groups for at least 100 days.

Table 1. Average production data of test group and reference group.

	Reference group	Test group	Difference
Number of animals	19	19	
Days in lactation	118	124	
Age at calving (years and moths)	3.05	3.08	
Milking frequency (daily)	2.0	3.9	
Milk production (kg/day)	25.1	28.5	+ 3.4 *
Milkfat content (%)	4.66	4.51	- 0.15
Protein content (%)	3.43	3.38	- 0.05
Milkfat production (g/day)	1164	1276	+ 112 *
Protein production (g/day)	859	956	+ 97 *
Fat and protein production (g/day)	2023	2232	+ 209 *

* Differences are significant ($P<0.05$)

The daily individual milk yield of the reference group was 3.4 kg higher than that of the test group. This implies an increase of 14%. The contents of protein and, in particular, of milkfat, seemed to be slightly lower in the test group. Consequently, the increases of 112 g milkfat and 97 g protein (totalling 209 g) were 10% and 11% compared with the reference group. Both the increase in milk yield and that in milkfat and protein production are statistically significant. Note that the daily individual production of the reference group (2023 g of milkfat and protein combined) was considerable.

Almost throughout the lactation the milk yield of the test group was 10% higher than that of the reference group. The percentages of milkfat and protein, however, were evidently lower in the test group in the first half of the lactation period. In the second part of the lactation the percentages for both groups were similar. As a result, the increases in milkfat and protein production were greater in the course of the lactation.

Automation of forage feeding

The introduction of the milking robot may entail substantial increases in milk yields. Biological developments are also likely to facilitate a rise in milk yields. Performances of 8000 to 10000 kg or more per lactation will be the rule rather than the exception. This implies that more attention has to be paid to the diet. High individual performances can only be realized if the animal can take up sufficient feed of high quality. The importance of a proper forage quality and intake is shown in Table 3.

Table 3. Effects of nutrient content and forage intake on a dairy cow's need for concentrates (body weight 600 kg; daily yield 25 kg FCM).

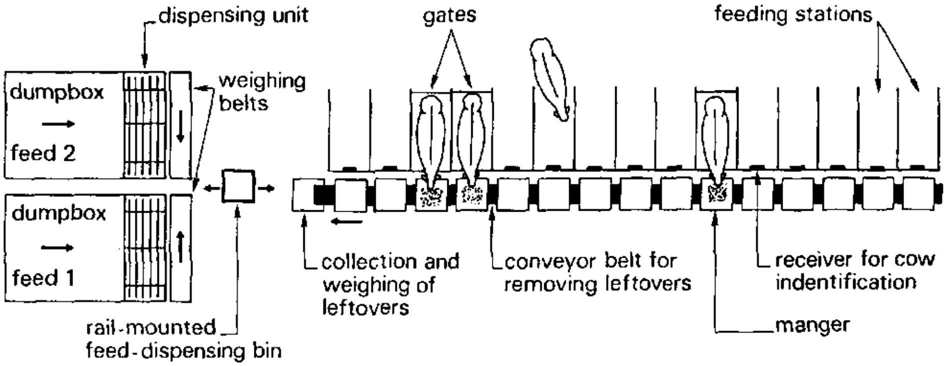
Forage		Concentrates required	
Intake kg dry matter	VEM * per kg dry matter	kg/day	%
9	750	10.3	100
10	825	8.7	84
11	900	7.0	68

* VEM = Dutch Feed Units

An increased intake and better quality of the forage could result in considerable economies in the amount of concentrates needed. Technical options that influence intake could be sought in the preparation of the feed at the moment of distribution. More frequent feeding and the preparation of a mix of different feed types tend to boost the total intake.

Traditionally, individual rations of concentrate are calculated on the basis of the animal's milk yield, fat content, body weight, age and estimated forage intake. More information on the individual forage intake is necessary so that the concentrate rations can be determined accurately. Moreover, more research is needed to develop optimal feeding systems for the high-yielding herds. Such systems should meet the requirements for feeding dairy herds with daily yields ranging from 15 to 50 kg per cow.

To study the technical possibilities for this, a system that can supply forage to individual animals fully automatically and that also allows the forage intake of individual animals to be recorded has been designed at IMAG (Ipema & Rossing, 1987).



AUTOMATIC FEEDING SYSTEM

Figure 4. The automatic feeding system.

The system (figure 4) can dose two different types of feeds or mixtures of different feeds. A cubicle house contains 15 feeding stations. When a cow enters one of these feeding stations she is identified electronically from the tag around her neck. Her number is scrutinized by a computer, and if the computer's data show that she needs food, the rear gate is closed. The computer decides which food has to be dosed to that animal. When a mixture of both feeds has to be dosed, first the weighing belts are tared. Both dispensing units start up, stopping when the calculated amount of food is approximately reached. As the system cannot dose within an accuracy of 200 grams, the amount of food on the weighing belts is weighed and the computer records that the cow has been given this amount. The belts then start up and the food from both belts is collected in a rail-mounted feed-dispensing bin. This bin is transported to the feeding station where the cow is, and the amount of food in the bin is dropped into the manger. After a certain time (normally 15 min.) the rear gate is opened and a valve in the manger is opened by a pneumatic ram. Any leftovers fall onto a belt, which starts up when the valve is opened. The food on the belt is transported to a box where it is automatically weighed. This amount of leftovers is recorded by the computer. The control system allows for the valve of only one manger to be open at any time. If the cow remains in the feeding station she is allowed another portion of food.

The food in the storage bins can be a mixed food that has been mixed previously, a normal loose material, or forage in blocks.

The whole proces is controlled by a computer in combination with a PLC (Programmable Logic Controler).

The automatic feeding system has already been used for some experiments. First the effect of adjusting the portion size will be described. In another experiment the system of feeding has been compared with feeding at a feeding fence.

Automated forage feeding: Experiment 1.

The feed is supplied in portions. The standard portion size is about 2.5 kg. A fixed time of 15 minutes is available for consuming a portion. Trials in 1985/86 showed that when standard portions are given to a group of cows the portion is almost always too big and therefore there are large amounts of leftovers. However, some cows find the portion too small. They can easily consume the portions within the fixed eating time of 15 minutes. Because of this variation in the intake rate between cows and between feeds (palatability) it is necessary to adjust the portion size in a short run. The portion size should be adjusted to the individual intake rate in such a way that the amount of leftovers does not exceed 10% of the portion and yet the time spent feeding does not become unnecessarily long. Therefore, the chosen system continuously modifies the portion size per cow, within certain limits, depending on the amount left over from the last delivered portion.

In an experiment two groups of 10 high-yielding cows were compared. One group (S) received the forage and concentrates seperately. The concentrates were fed in a concentrate feeder and the forage (dry matter content 37.3 %) was given in the feeding stations of the automatic feeding system. For the other group the concentrates and forage were mixed (group M). This mixture (dry matter content 49.2 %) was also fed via the automatic feeding system. These cows received only a small amount of concentrates in the concentrate feeder. Table 4 shows the effect of the different feed compositions on the average portion size per cow. The data were gathered over an experimental period of 8 weeks.

Table 4. Effect of the feed composition on the portion size (intake rate) per cow.

Group	Portion size (kg)							
	delivered (fresh)		intake (fresh)		intake (DM)		leftovers	
	av.	s.	av.	s.	av.	s.	av.	s.
S	2.22	0.23	2.01	0.29	0.75	0.11	10.0	3.5
M	2.15	0.09	1.93	0.10	0.95	0.05	10.4	1.4

This table shows that the average portion size (fresh material) does not depend entirely on the composition of the food. The average amount of fresh food delivered per portion was 2.22 kg and 2.15 kg for the two groups respectively. The percentage of leftovers was also similar for both groups. However, the standard deviation was smaller for the group with the mixed food (M), indicating that the system had caused a variation in the portion sizes between cows in one group and that this was dependent on the composition of the food (palatability).
The average amount of fresh material eaten per portion is also on the same level for both groups. Because of the higher dry matter content of the mixed food, the average amount of dry matter per portion was 0.20 grams higher. This means that the intake rate on a dry matter basis is 20-25 % higher for mixed food.

Automated forage feeding: Experiment 2.

An experiment was done to compare the automatic feeding system with traditional feeding in the feeding passage. If the automatic system is to be used in future in research on optimizing the feed intake it is important to know whether it produces results similar to those achieved with traditional feeding.

In the experiment two groups (G1 and G2) of 20 cows were studied. The animals were paired between the groups. An attempt was made to pair animals of similar age, calving date and production level. The experiment lasted 9 weeks. In the first 3 weeks group G1 was fed in the feeding passage and group G2 at the automatic installation. After three weeks the groups were changed over and after three weeks they were changed back again. For feeding in the feeding passage there were 20 places available at the feeding gate. In the automatic feeding system only 8 places were accessible for the 20 animals of the groups. Both groups were fed ad libitum. The forage consisted of a mixture of grass silage, maize silage and artificially dried alfalfa. The mixtures were prepared three times a week for both groups. Concentrates were fed individually in separate feeding stations. The amount of concentrates per cow depended mainly on the milk yield.

The results of this experiment are shown in table 5.

Table 5. Comparison between automatic feeding system and traditional system.

	Feeding system		
	automatic	traditional	difference
Feed intake (/cow/day)			
- forage (kg dry matter)	14.3	14.0	+ 0.3
- concentrates (kg dry matter)	6.9	6.7	+ 0.2
- total (kg dry matter)	21.2	20.7	+ 0.5
Yield			
- milk (kg/cow/day)	28.2	27.8	+ 0.4
- fat and protein (%)	8.07	8.08	- 0.01
- fat and protein (g/cow/day)	2251	2216	+35

The daily forage intake per cow with the automatic system was 0.3 kg dry matter higher than in the feeding passage. The concentrate intake was also higher. This higher feed intakes caused a higher yield of 0.4 kg milk and 35 grams fat and protein. These higher yields were, however, barely significant ($P<0.10$).

Behavioural aspects

The aforementionned developments in automation took place in the period 1984-1987. During the experiments many animal behaviour studies were carried out (Metz et al., 1987), largely to ascertain how animals would adapt to the automatic systems for feeding and milking. In the next there will be a short description of the systems studied. Some general results will be discussed.

Feeding ad libitum at the feeding fence with a number of feeding places equal to the number of cows and milking twice daily in the milking parlour was designated the standard system. Behaviour in this system was studied in 1986 (18 cows) and in 1987 (2x20 cows). The next system was feeding with the automatic system and milking twice daily in the parlour. This system was studied in 1986 (18 and 2x18 cows) and in 1987 (2x20 cows). The number of cows per forage feeding station varied between 2.5 and 2.6. In 1984 the system with feeding at the fence and milking in the concentrate feeder (simulating automatic milking) was studied (20 cows). The last system is the one in which the cows were fed in the automatic system and milked in the concentrate feeder (1986; 18 cows). The number of cows per forage feeding station was in this case 2.6.

Behaviour was observed over at least three periods of 24 hours for each system. The following activities were recorded for each cow: lying; standing (in cubicle, walking area or milking parlour); staying at the feeding places (concentrates or forage). The frequency of recording was once per 10 (or in one case, 15) minutes.

Table 6 gives an overview of the lying and forage eating behaviour at these systems. For each system the cows observed are divided in two groups. The groups "low" give the results of the cows with a milk yield less than 25 kg per day (during the observation periods) and the groups "high" do the same for the cows produced more than 25 kg milk per day.

Table 6. Lying and forage eating behaviour data for cows in different feeding/ milking systems.

System of feeding/ milking	Cows	No. of cows	Lying Min./day av.	Lying Min./day s	Lying Periods/day av.	Lying Periods/day s	Forage eating Min./day av.	Forage eating Min./day s
Fence/ parlour	all	58	686.3	117.6	8.3	2.1	243.6	46.8
	low	28	726.4	111.9	8.7	1.8	240.5	48.4
	high	30	648.8	111.9	8.0	2.3	246.4	45.9
Aut.sys./ parlour	all	94	698.3	115.2	7.2	1.6	332.8	76.0
	low	44	741.6	93.0	7.3	1.6	315.3	55.1
	high	50	660.2	120.2	7.2	1.7	348.2	88.2
Fence/ feed.stat.	all	19 *	732.4	96.2	8.5	1.5	226.2	32.4
	low	10	720.6	99.8	8.1	0.7	236.7	23.9
	high	9	745.6	96.1	9.0	1.9	214.6	37.8
Aut.sys./ feed.stat.	all	17 *	694.5	163.1	6.4	1.9	283.3	68.9
	low	8	752.9	114.9	7.2	1.1	279.2	39.5
	high	9	642.6	187.6	5.7	2.3	287.0	90.0

* one cow excluded because of severe foot problems

In the system with feeding at the fence and milking in the feeding station the lying times were longest. Here the high-producing cows lay even longer than the lower-producing cows. This could be a positive effect of the higher milking frequency in this system. The lying times for the other systems were, on average, similar. In all these cases the big difference in lying times between cows with a milk yield of more than 25 kg and less than 25 kg is striking. The extra time for standing was not used for eating (the time spent eating did not differ between the production groups within a system). In general, the high-producing cows stood in the cubicles longer; this suggests that these cows had problems in lying down because of the pressure on the udder. In the system with automatic feeding and milking in the feeding station the high-producing cows had no so long lying times as with feeding at the fence and milking in the concentrate feeder for reasons that are not clear. The variation in lying times is, especially, for this group rather high. This might be due to foot problems.

The number of lying periods seem to be influenced by the feeding system. Feeding at the automatic feeding system gave fewer, but longer, lying periods. Obviously, cows in the automatic system stand up less often for eating than cows fed at the feeding fence. This means, however, that the system of feeding (including the number of places available and the layout of the housing system) influences animal behaviour.

The times spent eating forage were longer in the automatic system. This is mainly because the time the cows were just standing in the feeding stations was included in this eating time. For eating at the fence, only the time the cow had her head through the fence was recorded as forage eating. The longer eating time in the automatic system had no clear effect on the the lying times.

The times spent eating concentrates were about 45 minutes per cow per day in the systems with milking in the parlour. In the systems with milking in the feeding station these times were in average about 10 minutes longer. On the other hand milking in the parlour took about 50 minutes which could be "saved" by the cows milked in the feeding station.

Discussion

The full automation of the milking and feeding processes seems to be technically possible in the near future. Concentrate feeding has already been automated. The detection of cows in oestrus, of diseases, and of deviant milk quality can now be automated in principle. Milking robots are being developed.

With automated milking systems more frequent daily milking will be possible. This will result in higher yields per cow. More research will be necesarry in future. Questions about optimal milking frequencies at different stages of lactation and about the effects on animal health (reproduction, udder, teats etc.) should be examined.

The results described here indicate that the automatic feeding system could be a useful instrument for further research on optimizing the feeding of dairy cows. However, also here more research will be necessary.

Aspects such as profitability, labour savings, and effects on the production, health and behaviour of the animals will determine whether the systems will be applied in practice. For an automated milking system the prospects seem to be better than for automated individual feeding systems for complete forage rations.

It can be stated that automation can create favourable conditions for the cows, such as the repeated provision of fresh feed, permanent access to the feed and the facility of adjusting the feed composition (forage, concentrates) to individual needs. More frequent milking, probably, better meets the requirements of the high-yielding cows. Higher yields and in one experiment longer lying times especially for these high-yielding cows indicate this. Future research in this field will be very interesting. Besides, attention will have to be paid to disturbances in the synchronism in behaviour in the herd and the correct timing of the individual use of the feeding and milking stations.

It is evident that the location in the stall layout where certain activities (lying, eating forage and concentrate, milking) take place is of influence on the frequency of this activities. This might be of importance for the design of future housing systems in which highly automated feeding and milking techniques are integrated.

References

Annonymus, 1983. Automation of dairy farm management. Research Report 83-1. IMAG, Wageningen.

Burema, H.J. and J.A. Kerkhof, 1979. A Dairy herd management and Health Control System. IMAG, Wageningen.

Burema, H.J., and J.A. Kerkhof, 1983. Health monitoring of lactating cows. Proceedings of the Symposium Automation in Dairying, IMAG, Wageningen.

Ipema, A.H. and W. Rossing, 1987. Automatic individual feeding of dairy cattle. Proceedings of Symposium Automation in Dairying, IMAG, Wageningen. p. 41-51.

Ipema, A.H., E. Benders and W. Rossing, 1987. Effects of more frequent milking on milk production and health of dairy cattle. Proceedings of the third Symposium Automation in Dairying, IMAG, Wageningen. p. 283 - 293.

Maatje, K., and W. Rossing, 1976. Detecting oestrus by measuring milk temperatures of dairy cows during milking. Livestock Production Science 3:p. 85-89.

Maatje, K., et al., 1983. Automation of electrical conductivity measurements during milking. Proceedings of the Symposium Automation in Dairying, IMAG, Wageningen. p. 89-99.

Maatje, K., and W. Rossing, 1986. Measuring the temperature of the milk during milking and the activity of dairy cows to detect sick cows and cows in heat. International Conference AG ENG 86, Noordwijkerhout, the Netherlands.

Maatje, K., F. Wiersma, W. Rossing, 1987. Measuring milk temperature during milking and activity of the dairy cow for detecting sick cows and cows in oestrus. Proceedings of the third Symposium Automation in Dairying, IMAG, Wageningen. p. 176-184.

Metz, J., H.K. Wierenga and A.H. Ipema, 1986. Verhalten von Kuhen beim automatischen Futtern und Melken. KTBL-Schrift 319. Darmstadt-Kranichstein. p. 138-154.

Postma, G., 1981. Van 300 naar 50 manuren per koe in 30 jaar. Landbouwmechanisatie 32(11).

Rossing, W., A.H. Ipema and P.F. Veltman, 1985. The feasibility of milking in a feeding box. Research Report 85-2, IMAG, Wageningen.

Rossing, W. et al., 1987. Practical experiences with real-time measurements of milk conductivity for detecting mastitis. Proceedings of the third Symposium Automation in Dairying, IMAG, Wageningen. p. 138-146.

EFFECTS OF AUTOMATIC CONCENTRATE FEEDING SYSTEMS ON THE BEHAVIOUR OF DAIRY COWS

H.K. Wierenga and H. Hopster

Research Institute for Animal Production "Schoonoord", P.O.Box 501, 3700 AM Zeist, The Netherlands

Summary

In dairy practice, more and more systems for the automatic feeding of concentrates are gradually being introduced. The effect of four different systems of concentrate feeding on the pattern (frequency and time) of eating concentrates and on the general activities (eating, standing, lying) of the cows were investigated.

The experiment showed that the different feeding systems each result in a different concentrates eating pattern. The cows always try to obtain concentrates as soon as they are available, even if this results in a reduced lying time or in an increased number of interruptions of lying periods.

It is hypothesized that under less favourable conditions - e.g. increased competition for a feeding station - problems will first arise with the investigated fixed-11-time system. Fewer problems may be expected under less favourable conditions with the variable-time system. It is pointed out that it is important for the cows to have information about the exact time at which concentrates are available again.
Keywords: dairy cattle, automatic feeding, concentrates, behaviour, daily rhythm.

Introduction

Gradually more and more practical farms are using systems for automatic concentrate feeding. With such systems cows can be identified individually in a feeding station and they can receive concentrates if they have not consumed their total allotted ration for that period. Per feeding station, about 25 cows can be fed concentrates. The various available systems can be roughly divided into two types: fixed-time and variable-time feeding systems. Investigations (Spiegelberg, 1980; Baehr, 1984; Collis 1980; Wierenga & Folkerts, 1986; Van de Burg et al., 1987) have shown that the two types each cause a typical pattern of visits to the feeding station. With a fixed-time system, each 24-hour period is generally divided into two 12-hour feeding cycles, which are subdivided into three 4-hour periods. When such a system is used, the number of visits is high directly after the start of a new feeding period and then gradually decreases. When, after some time, most cows have received their concentrates, the number of unrewarded visits gradually increases. Depending on the amount of concentrates given, each cow visits the feeding station about 10 times per 24 hours; only about half of these visits is rewarded (Wierenga & Folkerts, 1986; Van der Burg et al., 1987). The variable-time system involves a 24-hour period during which the cows gradually build up their allotted ration. When, after a visit, the ration has again reached a level of 50 grams, at a new visit the cow will receive concentrates. The cows visit the feeding station about 15 times per 24 hours when such a variable-time system is applied. These visits take place continuously during the whole 24 hours, and almost all are rewarded (Van de Burg et al., 1987; Wierenga & Folkerts, 1986).

The described investigations only give information about the visits to the feeding station of a group of cows as a whole. No information is available about individual differences between cows in the time and frequency of their visits, or about the possible consequences of automatic concentrate feeding for other behavioural activities. Individual differences could be substantial, because the number of feeding stations is limited, so that the cows must visit the stations in turn.

The aim of the experiments described in this paper was to obtain information about the behaviour of individual cows under various systems of concentrate feeding. In particular, the consequences of automated feeding for the lying behaviour (total time and daily rhythm) was investigated, by comparing systems with which the intake of concentrates took place at different parts of the 24-hour period. The variable-time system, with a fairly constant pattern of intake of concentrates during the 24-hour period, was compared with the fixed-time system with peaks in intake of concentrates directly after the start of a new 12-hour cycle. With the latter system the consequences of starting each 12-hour cycle at times when cows were also active with eating roughage and, on the contrary, at times when most cows normally were lying down, were investigated. For comparison feeding concentrates at the feeding rack was also investigated.

The results of such experiments give insight into the way the animals make use of the systems and thereby how the systems affect the cows. The information can be used in the development of systems for automatic concentrate feeding, but can also contribute to the development of automatic systems for milking or roughage feeding.

Materials and methods

Animals, housing and feeding

The investigation comprised three experiments (experiments I, II and III) which were performed with three different groups of 20 lactating dairy cows each. At the start of the experiments the cows were in about their third month of lactation. The age of the animals in each group varied between two and ten years.

The cows were kept in a cubicle house (fig. 1) with one row of 19 cubicles, a feeding rack with 16 places and a walking area 2.60 m wide, with a slatted floor. The concentrate feeding station was placed in the cubicle row.

The cows were milked in a milking parlour at 07.00 hr and 16.30 hr. In the three experiments the cows received maize silage (respectively 5.0, 5.0 and 4.2 kg d.m. per cow) after morning milking. In the first two experiments the cows received hay ad lib., of which part was given at 13.30 hr and the rest after evening milking. Total hay intakes in experiments I and II were 8.0 and 4.7 kg d.m. per cow respectively. In the third experiment the cows received, in addition to the maize silage, grass silage ad lib. which was also given at 13.30 hr and after evening milking. The total intake of grass silage was 5.3 kg d.m. per cow.

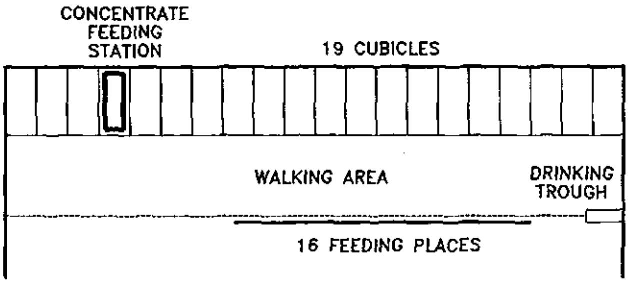


Fig. 1. Plan of experimental cubicle house.

In the first experiment each cow received 12 kg of concentrates, and in the second and third experiment 11 kg of concentrates per cow were given. With automatic feeding 9 kg of the total ration was always given via the feeding station and the remainder was given in the milking parlour. When concentrates were fed at the feeding rack, the cows received 7 kg of concentrates per cow mixed with maize silage directly after morning milking. The remaining 4 kg was given in the milking parlour.

The three systems for the automatic feeding of concentrates are described briefly. In both fixed-time systems in each cycle of 12 hours, 4.5 kg of concentrates were available for each cow. At the start of each cycle the allotted ration of each cow was set at 3.0 kg. After a period of 4 hours, 1.5 kg was added to the available ration. When a cow had not eaten any concentrates in the first four hours, then her balance became 4.5 kg. In the last 4-hour period of a cycle the balance was not increased again but those cows who had eaten only part or nothing of their concentrates, would be rewarded at a visit to the feeding station. In the first of the two tested fixed-time systems, the 12-hour cycles started at 07.00 hr and 19.00 hr (this system was called the "fixed-7-time system"). In the second system (the "fixed-11-time system") the 12-hour cycles started at 11.00 hr and 23.00 hr.

The third system which was applied was a variable-time system. Every day, each cow started at 19.00 hr with a balance of 0.2 kg. Every 14 minutes 0.1 kg was added to this balance. For instance, when a cow visited the feeding station 140 minutes after the start of the period, she could receive a maximum of 1.2 kg of concentrates. If she consumed her 1.2 kg, her balance built up gradually again, starting from 0.0 kg. This balance could grow to a maximum of 3.0 kg. When this level was reached the cow first had to visit the station and eat (part of the) concentrates before the procedure of the growing balance was started again. When a cow visited the feeding station regularly to eat concentrates, after a period of about 20 hours (so at about 16.00 hr) the maximum amount of 9 kg of concentrates was allocated.

Experimental design

The experimental design is given in Table 1. Each system in turn was tested for a period of about 3 weeks. In experiment I three systems were used; one, the fixed-7-time system, was repeated. In experiment II, concentrate feeding at the feeding rack was tested twice, interrupted for a period when the fixed-11-time system was introduced. In experiment III only the fixed-7-time system was tested once.

Table 1. Design of the experiment with three different groups of cows, fed concentrates with four different systems (further explanation see text).

Exp.period	Experiment I group I	Experiment II group II	Experiment III group III
1	Fixed-7-time system	Feeding rack	Fixed-7-time system
2	Variable-time system	Fixed-11-time system	
3	Fixed-7-time system	Feeding rack	
4	Fixed-11-time system		

Collection and analysis of data

To obtain information about time-budget and daily-rhythm, in each 3-week experimental period the cows were observed during three 24-hour periods. These observations took place in the second half (the last 10 days) of the experimental period. Two successive 24-hour observations were always interrupted by at least one day without observations (except in the third experimental period of experiment I). The observations started at 07.00 hr in the morning and finished at 07.00 hr the next day. Every 5 minutes the general activity of each cow was recorded. The following five activities were distinguished: standing (incl. eating) at the feeding rack, standing (incl. eating) in the concentrate feeding station, standing in the walking area, standing in a cubicle, lying in a cubicle. Based on the information collected with these 5-minute interval observations, the total time spent on each of the observed activities could be estimated for each cow over a certain period. Because visits to the feeding station can be short (less than 1 min. when the animals do not receive concentrates), such 5-min. interval observations only give reliable information about the time spent in the station at "group-level". To obtain information which could be analysed per individual cow, in experiments II and III the visits to the station were recorded continuously. This automatic recording was done throughout the experimental period. For statistical analysis only the data of the last 10 days of the experimental period were used (to exclude possible effects of adaptation to a new system).

In experiments I and II the collected data were analysed with an analysis of covariance with time as a co-variable. Both data of the whole

24-hour period as well as of part of the 24-hour period were analysed. For the latter analysis the 24-hour period was divided into 4-hour periods which coincided with the 4-hour periods of the fixed-time systems. Because possible group-effects could not be estimated reliably, each experiment has been analysed separately. Often, within one feeding system, only small differences were found between the groups for the most relevant parameters (eating and lying time). Therefore, the results of two or three of the experiments were sometimes described together.

To obtain information about the dominance relationships in the groups, aggressive displacements were recorded during the 24-hour observations and also during extra observations which were mostly done during feeding when many displacements could be observed. In total, in experiments I, II and III 1832, 857 and 534 displacements respectively were recorded. Based on these displacements a dominance value for each animal was calculated (see Wierenga, 1988). The five animals with the highest dominance value were called "high-ranking animals", the five animals with the lowest dominance value, "low-ranking animals".

Results

This paper considers the consequences of the four different feeding systems on eating behaviour (concentrates, roughage) and lying behaviour. In particular the lying behaviour in the night is analysed in detail.

Time-budget

For each experiment the recorded time spent in the feeding station, at the feeding rack and lying in the cubicles is given in Table 2 for each feeding system. In experiment I significant differences were found be-

Table 2. Time spent (in min./24 hrs) in the feeding station, at the feeding rack and lying in the cubicles, given for the three experiments and the various feeding systems separately. The results for the whole group as well as for the high- and low-ranking animals are given. Where, within one experiment, significant differences were found ($P \leq 0.05$, analysis of covariance) these data are marked with a different character (a, b or c).

	experiment I			experiment II		experiment III
	fixed -7-	fixed -11-	variable	feeding rack	fixed -11-	fixed -7-
in feeding station						
all animals	41.3^{a}	46.3^{b}	52.4^{c}	0.3^{a}	50.3^{b}	44.3
high-ranking cows	42.9^{a}	47.7^{ac}	62.6^{c}	0.0^{a}	47.3^{b}	44.0
low-ranking cows	43.4	46.3	52.2	0.5^{a}	50.7^{b}	44.0
at feeding rack						
all animals	186.2	183.4	192.3	292.3^{a}	232.4^{b}	236.9
high-ranking cows	176.6	161.4	176.7	266.7^{a}	203.5^{b}	244.3
low-ranking cows	192.0	158.3	202.0	278.1^{a}	211.4^{b}	223.0
lying in cubicles						
all animals	707.0^{a}	646.0^{b}	746.0^{c}	653.0	652.0	701.8
high-ranking cows	712.0	680.0	724.0	683.0	704.0	733.7
low-ranking cows	743.0^{ac}	579.0^{b}	806.0^{c}	579.0	564.0	797.3

tween the three systems in the time spent in the concentrate feeding station. The shortest time (between 40 and 45 minutes per 24 hours) spent in the feeding station was recorded when the fixed-7-time system was used. The most time was spent in the concentrate feeding station when the variable-time system was used. Analysis of the results for high- and low-ranking animals separately, gives fairly comparable results.

In experiment I for all animals together the time spent at the feeding rack was not different for the three feeding systems. In experiment II a statistically significant higher time (about one hour more) was spent at the feeding rack when concentrates were given at the feeding rack compared to the fixed-11-time system. The total time spent "eating" (concentrates and roughage), however, was not very different (292.6 and 282.7 minutes respectively). Again analysis for the high- and low-ranking animals separately gives fairly comparable results.

In experiment I, significant differences between the three feeding systems were found for the time spent lying in the cubicles. In experiment II lying time did not differ significantly between the two feeding systems. The recorded lying time was similar to the lying time recorded with the fixed-11-time system in experiment I. The lying time recorded in experiment III was similar to the lying time recorded with the fixed-7-time system in experiment I. Thus, when the three experiments are combined, the lowest lying time (about 650 minutes per 24 hours) was recorded when concentrates were given at the feeding rack or with the fixed-11-time system. When the fixed-7-time system was used, a lying time of about 700 minutes per 24 hours was recorded in both experiments. The highest lying time (746 min./24 hrs) was recorded during the variable-time system. In contrast to eating time, the lying time showed some differences between the high- and low-ranking animals. For the high-ranking animals in experiment I, no significant differences were found between the different systems. Lying time was only slightly higher with the variable-time and the fixed-7-time system compared to lying time when the fixed-11-time system or when concentrate feeding at the feeding rack was applied. For the low-ranking animals the differences between the systems are larger, and in experiment I partly statistically significant. When the results of the three experiments are combined, for the low-ranking animals we find a lying time of about 570 min./24 hr when the fixed-11-time system was applied or when concentrates were fed at the feeding rack. The lying time was about 750 and 800 min./24 hr when the variable-time system or the fixed-7-time system were applied.

Daily rhythm

The daily rhythm - presented as total time per each 4-hour period - is given in Figure 2, for the time spent in the concentrate feeding station, at the feeding rack and lying in the cubicles. When a fixed-time system was used, most time (more than 10 min. per cow per 4-hour period) was spent in the concentrate feeding station in the first two 4-hour periods directly following the start of a new 12-hour cycle. When the variable-time system was used, only at the end of the 24-hour cycle a low time spent in the feeding station (± 4 min./cow/4-hour period) was found. In the other five 4-hour periods a rather high (± 10 min./cow) amount of time was spent in the feeding station. The time spent at the feeding rack showed the same pattern for all the experimental periods. Most eating time was spent during the day, between 07.00 hr and 19.00 hr. In the evening and particularly in the night, little time was spent at the feeding rack. When concentrates were given at the feeding rack, the time spent at the feeding rack in that period increased by about one hour.

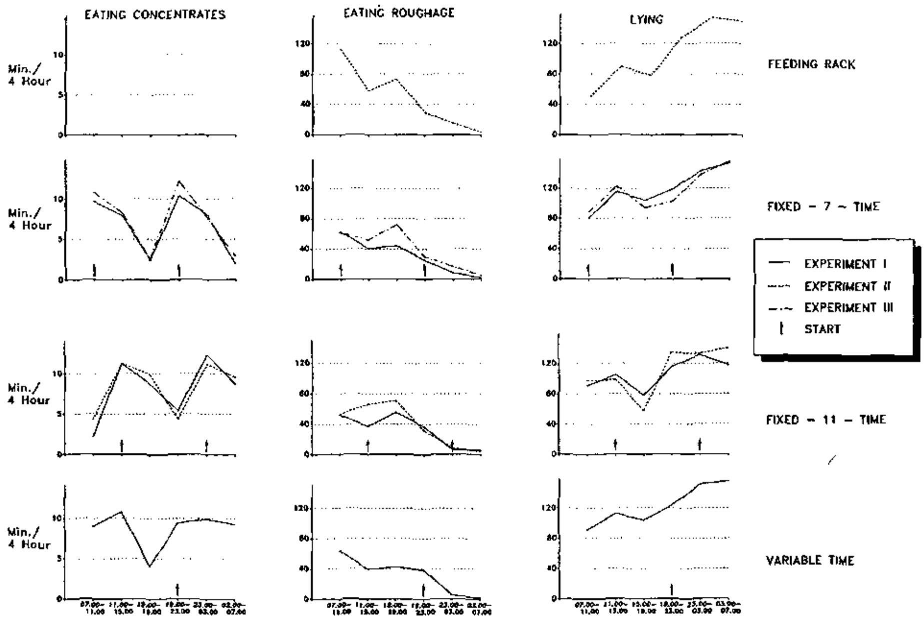


Figure 2. Daily rhythm of eating concentrates (left), eating roughage (middle) and lying (right) with the four different systems for feeding concentrates (at the feeding rack, or with the fixed-7-time, fixed-11-time, or variable-time system). The arrow ("start") indicates the start of a new 12-hour or 24-hour cycle. The results are presented for each experiment seperatedly.

During the day (07.00 hr - 19.00 hr), mostly about 100 minutes per 4 hours was spent lying. During the evening and particularly during the night more time (about 150 min./4 hours) was spent lying. When concentrates were given at the feeding rack, in the first 4-hour period lying time was reduced by about 50 minutes. Other distinct differences in lying time were found between the various feeding systems in the night. Therefore, lying behaviour in that period was analysed separately (see Table 3). In the two 4-hour periods of the night, for the group as a whole a reduced lying time was generally recorded in the fixed-11-time system. In particular in experiment I a low lying time (117.5 min.) was recorded at the end of the night (03.00 - 07.00 hr). The lying time found with the fixed-7-time system, the variable-time system and with feeding concentrates at the feeding rack did not differ much and varied between about 140 and 155 minutes (23.00 - 03.00 hr) and about 150 and 155 min. (03.00 - 07.00 hr) respectively. So, both the relatively high and the relatively low lying time per 24 hours, found for the variable-time system and for the system with concentrates given at the feeding rack respectively (Table 2), were not reflected in the night period.

Table 3. Time spent lying (min.) in the cubicles in the two 4-hour periods of the night. Further explanation: see Table 2.

	experiment I			experiment II		experiment III
	fixed -7-	fixed -11-	variable	feeding rack	fixed -11-	fixed -7-
lying in cubicles						
23.00 - 03.00 hr						
all animals	143.2^{ac}	131.5^{a}	151.3^{c}	154.1^{a}	133.1^{b}	138.3
high-ranking cows	141.4	118.3	144.3	152.3	136.6	160.7
low-ranking cows	143.6	123.2	160.0	149.3	128.1	145.0
03.00 - 07.00 hr						
all animals	153.4^{ac}	117.5^{b}	155.5^{c}	149.0	140.6	155.8
high-ranking cows	161.5^{ac}	129.9^{bc}	152.0^{c}	151.3	161.0	161.7
low-ranking cows	142.9^{ac}	57.6^{b}	160.5^{c}	130.8	124.8	166.3

When the results of the high- and the low-ranking animals are analysed separately, it appears that, compared with the results of the whole group, the differences between the fixed-11-time system and the other three systems are smaller for the high-ranking animals but larger for the low-ranking animals. In experiment I for the low-ranking animals a difference in lying time of 105.7 min. (20.4 + 85.3) was found in the night period between the fixed-7-time system and the fixed-11-time system, whereas this difference for the high-ranking animals was only 54.7 min. and for all animals together 47.6 min.

More detailed information about the daily rhythm of the visits to the concentrate feeding station of the high- and low-ranking cows is given in Figure 3. As has been explained, only in experiments II and III were suitable data collected for an analysis at an individual level. It must be realized that in comparing the fixed-7-time system and the fixed-11-time system, at the same time two different groups are being compared. The results presented show that the high-ranking cows spent the longest time in the feeding station directly after the start of a new 12-hour cycle. For the low-ranking cows however, the time spent in the station in the first 4 hours of a new cycle is not as long as for the high-ranking cows and in the second 4-hour period they spent about the same amount (fixed-7-time system) or more (fixed-11-time system) time in the feeding station. These results suggest that the high-ranking cows are able to occupy the feeding station directly after the start of a new cycle, whereas the low-ranking animals have to wait. Such a shift was evident particularly for the fixed-11-time system.

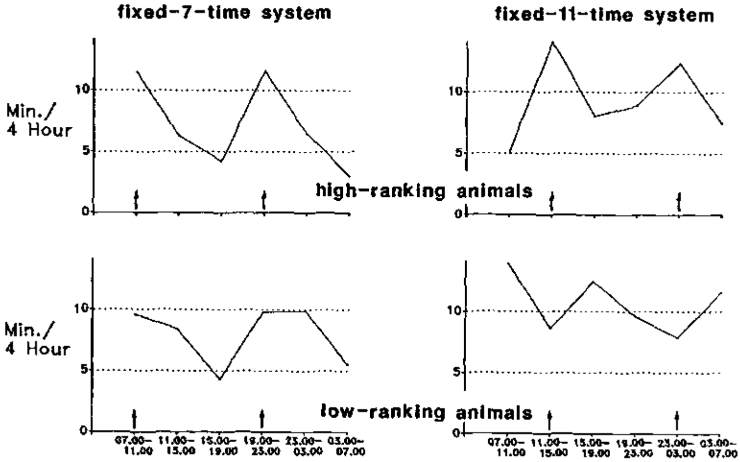


Figure 3. Daily rhythm of eating concentrates with the fixed-7-time (left) and the fixed-11-time (right) system, for the high- and for the low-ranking animals. The arrow indicates the start of a new 12-hour cycle. Results of experiment II and III.

Cubicle-periods

For the different experiments we analysed how often in each 4-hour period a so-called cubicle-period was terminated (a cubicle-period is a period during which a cow was seen - without any interruption - standing or lying in a cubicle). It must be realized that the numbers of terminated cubicle-periods were sometimes low because few cows were lying down. The results are presented for the 24-hour period as a whole and for both the 4-hour periods of the night (Table 4). In experiment I the number of terminated cubicle-periods was lowest when the fixed-7-time system was used. No difference was found between the fixed-11-time system and

Table 4. The number of terminated cubicle-periods for the whole 24-hour period and for both the 4-hour periods of the night. Further explanation: see Table 2.

	experiment I			experiment II		experiment III
	fixed -7-	fixed -11-	variable	feeding rack	fixed -11-	fixed -7-
24-hour period	10.4	10.9	11.1	9.6 a	11.7 b	11.3
night-period						
23.00-03.00 hr	1.7 a	2.0 ab	2.3 b	1.2 a	2.0 b	1.8
03.00-06.00 hr	1.1 a	2.1 b	1.9 b	1.3 a	2.0 b	1.5

the variable-time system. In experiment II the number of terminated cubicle periods was significantly lower when concentrates were fed at the feeding rack compared to feeding with the fixed-11-time system. The results obtained with the fixed-11-time system in this experiment are more or less equal to the results of the same system in experiment I. The results obtained with the fixed-7-time system in experiment III are more or less equal to the results of the same system in experiment I. So, the combined results of the three experiments show that the number of terminated cubicle-periods per 24 hours is lowest when concentrates are fed at the feeding rack; they are only slightly higher when the fixed-7-time system is used, and again somewhat higher when concentrates are fed with the fixed-11-time system or with the variable-time system. In the night, the differences in the number of terminated cubicle-periods between the systems are similar, but more pronounced and partly statistically significant.

Discussion

The results of the experiments with the various systems for concentrate feeding have shown that these feeding systems affect the behaviour of the cows. In the present paper attention has been focused on the relation between the feeding regime and the lying behaviour, in particular during the night. Other points of interest from the results of these experiments will be discussed in a subsequent paper.

Only small, but sometimes statistically significant, differences were found in total time for eating concentrates between the four systems investigated. The feeding pattern, however, differed distinctly between the systems. When the concentrates were mixed with maize silage, this resulted in an increased eating time at the feeding rack in the first 4-hour period after feeding. Apparently the cows were so interested in the mix of maize silage and concentrates that they decided to eat it immediately instead of eating part of that food at another time of the day. The three different systems for automatic concentrate feeding each provoked a typical concentrate feeding pattern. It is important to realize that the cows are not "forced" by the system to start eating concentrates immediately after the start of a new cycle. If a cow should wait, for instance, and eat concentrates at the end of the 12-hour cycle of a fixed-time system she could eat the 4.5 kg all at once. Apparently the cows appreciated the concentrates so much that they tried to obtain them as soon as they were available again. It appeared also that the cows, after the transition from one system to another, generally adapted very quickly to the new feeding system. For the fixed-time system this resulted in a shift of the feeding pattern when the start of the 12-hour cycle was changed. With the variable-time system, compared to a fixed-time system, the cows had more opportunities to obtain concentrates; this resulted in a higher number of visits (during which the cows received small portions of concentrates).

The alterations in feeding behaviour, caused by the different feeding systems, resulted in changes in the lying behaviour. At different times during the 24 hours the lying time was either slightly or more markedly reduced or increased. When concentrates were fed at the feeding rack, the increased eating time of about one hour in the first 4-hour period, resulted in an almost equal decrease in time spent lying in that period. This reduction in lying time did not result in an increased lying time during other times of the day or night, so for the whole 24-hour period lying time was reduced by one hour. Interestingly, with this feeding system the number of (terminated) cubicle-periods was the lowest compared with the other systems. This latter difference was found mainly in the night. The longest lying time per 24 hours was found when the variable-time system was used. This seems surprising, because (1) with this system the longest time spent in the feeding station was found (2) it is known (Wierenga & Folkerts, 1986; Van de Burg et al., 1987) that the number of visits is high with such a system and (3) the number of cubicle periods (= interruptions of lying) was found to be rather high. The reason that the lying time was still relatively high may be that, with this system, competition between the animals for the feeding station was lower compared with the fixed-time system. With a fixed-time system it was generally seen that after the first cow had received concentrates at the beginning of a new cycle, other cows reacted to that "signal" and immediately proceeded to the feeding station. At the beginning of each 12-hour cycle the cows receive 3.0 kg of concentrates and it takes about 10 minutes before a waiting cow can enter the station. With the variable-time system, at the beginning of a new 24-hour cycle, each cow is only allotted a small amount of concentrates and the cows can succeed each other quickly. Furthermore it is important that with the variable-time system the cows had a more or less continuous chance to obtain concentrates for a long period. Anyhow, with the variable-time system, the time for waiting will have been shorter, resulting in a higher lying time. The number of cubicle periods is high because the cows often visited the feeding station.

With the fixed-7-time system a higher lying time was found than with the fixed-11-time system. For the fixed-11-time system, in particular in the night period a reduction in lying time was found. This reduction was greater for the low-ranking animals than for the high-ranking animals. Furthermore, for this system it was found that the peak of concentrate-eating activity for the low-ranking animals did not take place in the first but in the second 4-hour period after the start of a new 12-hour cycle. One important aspect of the fixed-7-time system is that to a great extent the intake of concentrates took place at times that the cows were also eating roughage (= already active). Maybe the cows just quickly interrupted this eating for visiting the feeding station. This could also explain why, with the fixed-7-time system, no difference in the time of concentrate intake between high- and low-ranking animals was found. With the fixed-11-time system the start of a new 12-hour cycle results in many cows standing up and proceeding to the feeding station (the number of interrupted cubicle periods is high). Many cows then have to wait in the neighbourhood of the station; the high- ranking cows will be the first to enter it, resulting in longer waiting times for the low-ranking animals and a reduced lying time for them. So, for the differences in reactions of the cows between the fixed-7-time and fixed- 11-time system, two possible causes are given: (1) a cow which is lying down, will more readily go immediately to the feeding station when new concentrates are available than a cow which is eating roughage, and (2) when concentrates and (fresh) roughage are available at the same time, cows will more readily leave the "waiting area" or not even proceed to the feeding station but start, or stay, to eat roughage, resulting in a more flexible succession of cows visiting the station and fewer cows competing for the feeding station at any one time.

The cows' point of view

These experiments showed that the cows were so keen on concentrates that, at the first possibility, they tried to obtain them. The results showed that the cows are so interested in eating concentrates that they accepted changes in lying time and in the number of interruptions of lying periods. Because no differences were found in the intake of concentrates between the three systems for automatic feeding (in experiment I for the whole group the mean intake of concentrates for the fixed-7-time, the fixed-11-time and the variable-time system respectively was 172.2 kg, 172.3 kg and 173.9 kg) the question remains whether the recorded differences in behaviour are important for the cows or not. Because the cows are not forced by the system to change their pattern of intake but they still immediately reacted to changes in the availability of concentrates, it is believed that the possible costs are not so high for the cows that they cause the animals problems. However, there are differences between the systems which may be relevant for the cows. Briefly, these various aspects of the automatic feeding systems will be discussed and also what the consequences for the cows - and thus for the intake of concentrates - will be when the conditions are less favourable than in the described experiments. In particular an increased competition for the feeding station may cause problems for the cows. This competition for the station can be higher because a higher amount of concentrates is given or because more cows are kept per feeding station. In judging the systems, different aspects have to be considered. One advantage of all three automatic feeding systems is that the cows, to a great extent, have the opportunity to decide for themselves when they will eat concentrates. With concentrate feeding at the feeding rack, it is the farmer who decides about the time of eating concentrates. However, a disadvantage of the automatic feeding systems is that they do not allow the cows to synchronize their concentrate-eating behaviour. This may result in competition for the feeding station. It seems possible that a further increase in competition, in particular with the fixed-11-time system, will result in more negative effects for the cows and thus in a reduction of the intake of concentrates. In particular periods increased competition may result in longer waiting times and thereby in reduced lying time. With the fixed-7-time system the consequences of increased competition are expected to be lower, because eating concentrates takes place partly at the same time as eating roughage. The least problems may arise with the variable-time system; because the cows seem to have more opportunities to obtain concentrates, the consequences of competition may be lower. However, the rather high number of visits (resulting in a high number of interruptions of lying) which are found for this system (Wierenga & Folkerts, 1986; Van de Burg et al., 1987) are seen as a negative aspect of this system. It is believed that this high number of visits could be reduced if the minimum amount of concentrates which is "saved" before a cow is rewarded again, is higher than the current level of 50 gram.

Another aspect of the automatic feeding systems is that they do not give clear information to the cows about when they will be rewarded (with concentrates) for a visit to the feeding station and when they will not be rewarded. In particular with the fixed-time systems, it seems difficult for the cows to predict reliably at what time they will receive concentrates. Experiments with a system for individual signalling (Wierenga & Hopster, 1987), which informed each cow individually (by an acoustic signal) when concentrates were available again, showed that the cows reacted to that signal and came less often at other times. Therefore, it appears to be important for the cows to have information about the times they can obtain concentrates in the feeding station.

The results of the described experiments can be used for the further development of concentrate feeding systems and also for the development of other automatic systems, e.g. for milking.

Acknowledgements

The authors would like to thank Mrs. J.L. Senior for correction of the English text and Drs. B. Engel for statistical advice.

Literature

Baehr, J., 1984. Verhalten vom Milchkühen in Laufstallen. KTBL-Schrift 293:1-149.

Burg, A. van der, Y.S.T. Zeinstra & T.E.M. Hettinga, 1987. Geprogrammeerde krachtvoerverstekking: spaar- en periodensysteem. Veeteelt 1987/5: 547-551.

Collis, K.A., 1980. The effect of an automatic feed dispenser on the behaviour of lactating dairy cows. Appl.Anim.Ethol.6: 139-147.

Spiegelberg, E., 1980. Abrufütterung für Milchkühe. RKL-Schrift 4.2.0: 663-703.

Wierenga, H.K., 1988. Social dominance in dairy cattle and the influence of housing and management. In press.

Wierenga, H.K. & H. Folkerts, 1986. Das Verhalten von Milchkühen bei zwei verschiedene Systemen von programmierter Kraftfutterverabreichung. KTBL-Schrift 311:177-185.

Wierenga, H.K. & H. Hopster, 1987. Behavioural research for the further development of systems for automatic concentrate feeding. In: Proceedings of the third symposium Automation in Dairying, Wageningen, The Netherlands, September 9 - 11, 1987. IMAG, Wageningen, p.52-61.

FEEDING AND MILK PRODUCTION - POTENTIAL BENETFITS OF AUTOMATION ON BIOLOGICAL AND ECONOMIC EFFICIENCY IN THE DAIRY HERD

Vagn Østergaard

National Institute of Animal Science, Forsøgsanlæg Foulum, P.O.Box 39, DK-8833 Ørum Sdrl., Denmark

Summary

In high yielding dairy herds fed high quality forages ad libitum the biological efficiency will not be affected by the use of automated feeding. But if the forage is substituted by poor hay or straw, 10-15 kg DM of concentrates have to be fed per cow daily, and a positive effect can be expected by feeding the concentrates 4 or more times per day. The frequent feeding of concentrates to the individual cow requires much input of skilled labour to be sure of an optimum feeding. Identification during the grazing period and in loose housing systems also takes time. If the yield potential of the cows is very high, the exact daily feeding is important; and there is a need for a high quality of the physical work as well as the management.

If the concentrates have to be given several times a day to make efficient use of cheap roughages low in digestibility or the identification of the individual cow is difficult and time-consuming, then the automated feeding by use of transponders etc. has potential benefits on the biological efficiency and on the input of labour and management. However, the economic benefits depend on the man-power on hand and the wages - as well as the total costs of the equipment (price, depreciation, rate of interest, maintenance etc.) and the management needed for efficient use of computer aided feeding of concentrates to the high yielding dairy cow. Consequently, the capital consuming automated concentrates feeding cannot compete with cheap, skilled labour, but the competition to man-controlled feeding is strong under conditions with low rates of interest, high wages and difficulties in having skilled herdsmen.

Introduction

In big dairy herds it is a great task for the herdsman every day to ensure the optimum feeding of all the cows. The task depends on the location of the cows (on pasture, in cubicles or tie-up stalls), the ration (type of feeds, composition, digestibility and quality), the yield potential, the feeding principle, and the feeding systems (technical equipment). Assuming that most of the big herds will be grazing or located in housing systems without knowledge of individual forage intake, the topic is discussed in relation to the effect of using computer aided feeding of concentrates to forages/roughages fed ad libitum on the following items:

- Intake of feeds
- Level of production
- Utilization of the nutrients
- Requirements of equipments, buildings
- Labour and management
- Economics of the use of automated feeding.

Computer aided feeding by use of feeding dispensers or similar equipment gives the dairy farmer the opportunity to increase the feeding frequency of the suplementary concentrates. Therefore the main analysis focuses on the efffect of feeding frequency on the production and the biological efficiency as well as the economic efficiency including costs of equipment, buildings, labour and management in the dairy herd.

When looking at automation of feeding (i.e. feeding system described by the equipment), the separate concentrates feeding is concerned. The most convenient and economic feeding principle is "Strategy of feeding concentrates", i.e. a certain level and pattern of feeding concentrates through lactation combined with forage (grass, hay, silage etc.) fed ad libitum (Østergaard, 1979). The concentrates are fed restrictively, individually, and independently of daily milk yield. The forage is fed ad libitum.

Biological effect of feeding frequency

In herds which are fed small quantities of concentrates and high quality forage ad libitum, the biological efficiency expressed by feed intake, level of production, and utilization of the nutrients will not be affected by increased feeding frequency by the use of automated feeding (Johnson, 1980; Gibson, 1984; Krohn et al., 1985).

Table 1 shows detailed results of Danish experiments (Krohn et al., 1985).

The reason for no effect of increased feeding frequency is that the high yielding dairy cow does not need to be fed concentrates in large amounts. The rumination and the rumen fermentation is then optimum (Johnson, 1980). Such diets based on high quality forages fed ad libitum comprise:

- Young grass or clover grass fed fresh or grazed
- Silage/hay well conserved on basis of young grass or
- Other types of high quality silage (sugar beet top etc.).

In many herds the high quality forage is expensive to feed compared to grainmix (grain + oil cakes/meal) and is consequently substituted by small quantities of (poor) silage/hay or straw and large amounts of concentrates (more than 60% of dry matter intake = DMI). The effect of increased feeding frequency from 2 to 6(8) allotments of a certain amount of concentrates daily in such cases is a very slight increase in forage intake, an unchanged milk yield, but a 10% increased production of butterfat as the fat percentage is increased

(Krohn et al., 1985). This conclusion is based on a Danish experiment the results of which are seen from Table 1. Gibson (1984) found by reviewing the literature approximately the same effect, if the high concentrated diet by allotments per day gave a fat content in the milk markedly below the expected according to the breed.

Table 1. Feed intake and production at different level of concentrates and feeding frequency for dairy cows 3-20 weeks p.p. (Krohn et al., 1985).

Level of concentrates	Low		High	
No. of allotments	2	6	2	6
Feed intake, kg DM/d				
Concentrates	5.5	5.5	9.0	8.9
Mixed forage	12.1	11.9	6.8	7.6
Total feed intake	17.6	17.4	15.8	16.5
- net energy, SFU*	16.0	15.8	15.6	16.1
- dig. crude protein, g	2155	2130	2308	2357
- dig. dietary fat, g	602	598	837	868
- crude fibre, g	3392	3340	1769	2024
- starch, g	2618	2575	2503	2474
Chewing time, min./kg DM	40	40	33	35
Production, daily				
- milk, kg	25.0	25.2	24.5	24.3
- fat, %	4.19	4.17	3.91	4.38
- butterfat, g	1044	1052	959	1066
- protein, %	3.09	3.01	3.10	3.20
- milk protein, g	772	758	760	778
- 4% FCM, kg	25.7	25.8	24.1	25.7
- daily gain, g	46	-40	34	35

* SFU = Scandinavian Feed Unit defined by the NE of 1.00 kg barley (85% DM) corresponding to 11.92 MJ of metabolizable energy (ME).

Kaufmann (1973) also found a positive effect, but smaller (approximately 5%). Johnson (1980) reviewed - in his thesis - the literature and concluded (incl. his own experiment) that the positive effect of dividing the daily quantity of concentrates into several allotments depends on the total feed intake and the ration composition, i.e. the ratio between concentrates (starch) and forage (fibre). Krohn et al. (1985) made the same conclusion, and a higher biological efficiency cannot be expected unless the intake of concentrates (rich in starch) exceeds approximately 60% of DMI.

In Table 2 are summarized the biological main results, when feeding low quality forages (roughages) and large but certain amounts of concentrates (more than approximately 60% of DM intake) at different feeding frequencies. The total DMI is assumed high between 16 and 20 kg per cow daily.

Table 2. Biological results by feeding low quality forages and large amounts of concentrates at different feeding frequencies. High DMI (16-20 kg/d). (Johnson, 1980; Gibson, 1984; Kaufmann, 1973; Krohn et al., 1985).

	Change from 2 to 6-8 allotments/d
Ad libitum intake of forage	(+)
Milk yield, kg per day	0
Milk fat, %	++
Milk fat, kg per day	+0-10%
Body weight gain	0?
Utilization of nutrients	+

Figure 1 shows the effect on daily butterfat yield of feeding frequency of supplementary concentrates to high and low quality of forage fed ad libitum to high yielding dairy cows. The feeding level is high and equal at the different number of allotments of concentrates daily. The curves show the general picture, which can vary according to type of forage and yield potential and level of the cows. On average the positive effect on butterfat yield can be expected to be 5% and 4% during the first and second half of lactation, respectively. If the feeding and yield level is very high (9000 kg milk and 360 kg butterfat per cow yearly), i.e. 20% above medium (7500 kg milk and 300 kg fat), the corresponding figures are 6% and 5%, respectively. For lower yielding herds, medium reduced by 20%, the corresponding figures are calculated to 4% and 3%, respectively.

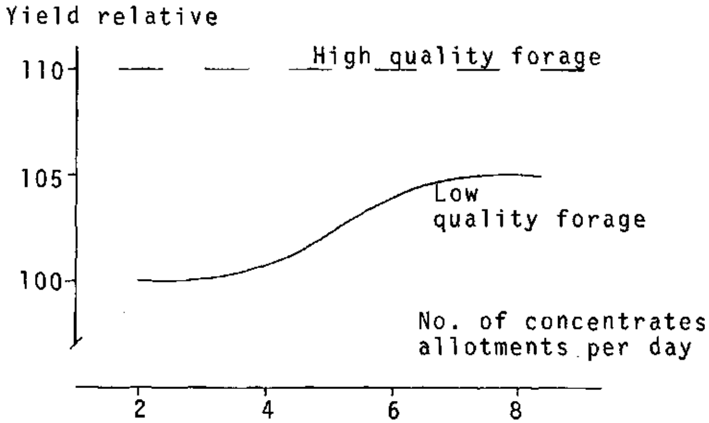


Figure 1. Effect on butterfat yield of feeding frequency of concentrates as supplement to high and low quality of forage. High and equal feeding level to high yielding dairy cows (16-20 kg DM/d). Schematically. (Sources: Tables 1 and 2; Kristensen & Nørgaard, 1987; Østergaard & Thysen, 1982).

Table 3 summarizes the positive effect of increased feeding frequency of large quantities of supplementary concentrates to forages, low in quality. No effect can be expected on milk yield and milk protein yield.

Table 3. Expected increase in butterfat yield at different herds and diets by feeding concentrates frequently compared to twice a day. Kg per cow yearly.

Yield potential, kg/year:		Kg butterfat/cow yearly at different diets		
Milk, kg	Butterfat, kg	Forage high quality	Mixed diet	High conc. diet
9000	360	0	(10)	20
7500	300	0	(7)	14
6000	240	0	(4)	8

Experiments with differences in allowances of concentrates per cow daily have been excluded.

Labour input at automated concentrates feeding

The labour input per cow for concentrates feeding depends on:

- herd size
- equipment
- feeds and quantities
- working routine and "speed".

With automation of feeding, the work can sometimes be more pleasant, but the daily input of minutes is seen from Table 4.

Table 4. Daily labour input for feeding concentrates in tie-up stalls (Keller, 1984)*.

Equipment	Variable min./cow	Constant min./herd	Total for 100 cow herd, min.
Hand cart	0.08	2.0	10.0
Feed truck	0.07	1.7	8.7
Automatic truck	0.01	-	1.0
Aut., stationary	0.005	-	0.5

* Excl. control and maintenance of equipment and management. Time for that task including training of the staff for the automated equipment is unknown, but can be considerable.

The daily physical labour input saved is 7.7 minutes (8.7-1.0) when changing from 2 hand feedings from feed truck to using automatic feed truck. By use of automaticly controlled truck (use of transponders etc.) the number of allotments can be increased to e.g. 4 or more without increased labour input.

Economics of automated concentrates feeding

The economics of automated concentrates feeding is a result of possible change in the biological efficiency as well as the savings in labour input and the costs of the extra investment needed compared to the use of a hand cart. As the costs of investment in automated (computer controlled) equipment vary very much from herd to herd, it is convenient to calculate the marginal income to pay the increased investments (and possible change in management (mgt.)).

Table 5 shows for different diets and yield potentials (feeding levels) the economic result calculated on basis of Tables 3 and 4. Also no constraints of milk quotas are assumed.

Table 5. Economics of automated concentrates feeding in tie-up stalls. Herd model. Figures per cow and year.

	Forage, diet high qty.	High conc. diets Yield: kg milk & kg butterfat 6000 / 240	7500 / 300	9000 / 360
Yield change, butterfat, kg/cow	0	+8	+14	+20
To pay increased investments. Dkr./cow:				
- sales, 30 Dkr./kg fat	0	240	420	600
- saved labour (excl. mgt.).	28	28	28	28
- total to pay investments	28	268	448	628
Max. investments. Dkr./cow:				
- at 25%/year (depreciation,	112	1072	1792	2512
- at 20%/year (rate of interest (and maintenance)	140	1340	2240	3140

* 60.- Dkr. per man-hour (corresponds to the value of 2 kg butterfat.

The figures in Table 5 demonstrate that the marginal income to pay the increased investment is only marked when high concentrated diets are fed for high feed intake of high yielding dairy herds.

If the equipment gives relatively high costs per year, i.e. 25% of the investment to depreciation, rate of interest and maintenance, then the maximum investment should be lower than 1072 Dkr., 1792 Dkr. and 2512 Dkr. for the 3 levels of herd yield (tie-up stalls), if there should be any benefits of the investment under the given conditions.

If the cows are on good pasture for 6 months, there will be no increased yield during that period according to increased feeding frequency. Therefore a beneficial investment has to be reduced to half, although there can be small benefits in the daily feeding management, if concentrates are used as a supplement to grass.

In Denmark, the investment in automated feed trucks incl. computers, transponders etc. is approximately 1000-1500 Dkr. per cow depending on herd size, among other things.

In cases where the yearly costs of using the equipment are low, i.e. 20% of the investment, the size of the beneficial investment is higher as seen from the bottom line of Table 5.

In loose housing systems (e.g. cubicles) some supplementary benefits can arise, because the computer controlled feed dispensers can also tell the herdsman about the actual feed intake of the individual cow. If the intake of concentrates is much lower than planned, the reason can be a sick cow or a cow in heat.

When building new cubicle houses with concentrates dispensing units some space of the feed bunk (forage) can be saved, if the forage is fed ad libitum. Up to 3 cows per feeding place did not influence the feed intake or the production result, including health, on the condition that a complete diet was fed ad libitum (Henneberg et al., 1986). The same result can be expected with high quality forage ad libitum and the use of concentrates dispensing units in a number which does not result in a queue of cows.

In a Danish experiment with high quality forage ad libitum the feeding of 6 kg DM of concentrates by 6 allotments instead of 2 resulted in 9% lower intake of concentrates than planned, because of too few visits to the units (Kristensen & Hindhede, 1983). Therefore both the advantages and disadvantages have to be observed before investing in automated feeding equipments.

References

Gibson, J.P. 1984. The effects of frequency of feeding on milk production of dairy cattle: An analysis of published results. Anim. Prod. 38:181-189.

Henneberg, U., Munksgaard, L., Kristensen, E.S., Konggaard, S.P. & Østergaard, V. 1986. Behaviour and production of the dairy cow at different stocking rates in cubicle houses. Rep. 613. Natl. Inst. Anim. Sci., Copenhagen. 61 pp.

Johnson, U. 1980. Feeding routines for dairy cows. The influence of the feeding sequence and frequency on milk production, rumen fermentation pattern and eating behaviour. Sveriges Lantbruksuniversitet. 152 pp.
Kaufmann, W. 1973. Zum Einfluss höherer Futterungsfrequenz auf die Fermentation in den Vormägen und die Leistung bei Milchkühen. Kieler Milchw. Forschungsber. 25:245-250.
Keller, P. 1984. Arbejdsbehov ved pasning af malkekøer i bindestalde. 22. ber. Statens jordbrugstekniske Forsøg, Horsens. 26 pp.
Kristensen, E.S. & Hindhede, J. 1983. Foderurea og tildelingsfrekvens af kraftfoder til en proteinfattig grundration til malkekøer. Short comm. No. 476, Natl. Inst. Anim. Sci., Copenhagen. 4 pp.
Kristensen, V.F. & Nørgaard, P. 1987. Effect of roughage quality and physical structure of the diet on feed intake and milk yield of the dairy cow. In: Research in Cattle Production. Danish Status and Perspectives. Det kgl. danske Landhusholdningsselskab, Copenhagen. 79-91.
Krohn, c.C., Konggaard, S.P. & Decker, L. 1985. Tildelingsfrekvensens indflydelse på køernes mælkeproduktion ved middel og højt kraftfoderniveau. Short comm. No. 596, Natl. Inst. Anim, Sci., Copenhagen. 4 pp.
Østergaard, V. 1979. Strategies for concentrate feeding to attain optimum feeding level in high yielding dairy cows. Rep. 482. Natl. Inst. Anim. Sci., Copenhagen. 139 pp.
Østergaard, V., Krohn, C.C. & Thysen, I. 1987. Feeding principles and optimum feeding of the high yielding dairy cow. In: Research in Cattle Production. Danish Status and Perspectives. Det kgl. danske Landhusholdningsselskab, Copenhagen. 126-139.
Østergaard, V. & Thysen, I. 1982. Strategy feeding concentrates. How to optimize the ration to the dairy cow. 33rd Ann. Meet. of EAAP, Leningrad. 8 pp.

POSSIBILITIES OF A COMPUTER AIDED HEALTH AND REPRODUCTION CONTROL IN DAIRY HUSBANDRY

Schlünsen, D., H. Schön & H. Roth

Institute of Farm Mechanization Management
Federal Research Center of Agriculture (FAL), Bundesallee 50
D-3300 Braunschweig-Völkenrode

1. Introduction

The following contribution deals with possibilities of computer aided animal control. Among computer aided feedings this is one of the presuppositions for a completely automated dairy husbandry as marked by the development of milking robots.

In all contries health and fertility disturbance is a high financial burden to dairy husbandry. This is caused by mistakes in husbandry and management. In times to come they can be substantially reduced by a comprehensive recording of specific animal and feeding data.

For this purpose animal and production data are to be collected during the production process by means of electronic sensors. An online computer receives and processes these data and identifies abnormal value of the animals at a very early stage (12). By this type of monitoring health and reproduction control of the animals is achieved.

2. Selection of sensors

First of all the selection and development of sensors suitable for a continuous collection has to orientate on physiological associated reaction of the animals in a way that the production process is not disturbed. For this sensors are suitable which are used for a production controlled feeding, e.g. milk yield devices, units recording live weights, automatic feeding systems and in addition special sensors monitoring animal physiological data, Fig. 1.

2.1. Sensors to monitor physiological data

2.1.1. Temperature sensors

A central value for animal control is the body temperature (1). Normally it is taken rectal or vaginal. Direct measurements are time consuming and are therefore applied only point-focal. By those neither an early detection of pathological changes nor of the time of conception can be obtained. An automatic measuring process is not possible (4). An automatic measurement of the body temperature can only be achieved by an indirect measurement of the milk temperature.

Comparative measurements indicated a significant correlation between core temperature of the body (vaginal) and milk temperature, Fig. 2. With that it could be proved that changes in the cows body temperature can be registered automatically (10).

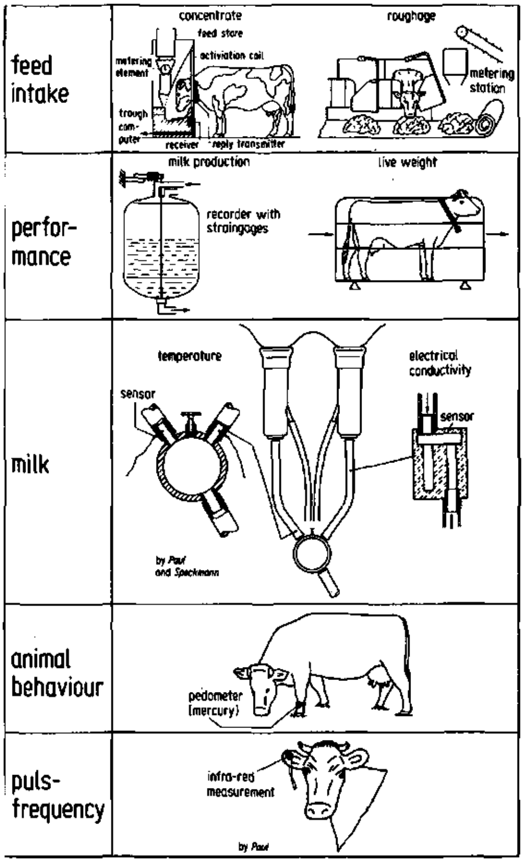


Figure 1. Sensors for herd monitoring.

By measuring the milk temperature it becomes possible to monitor the development of the cows temperature at least twice a day. Hitherto existing tests, especially concerning the oestrus control showed that

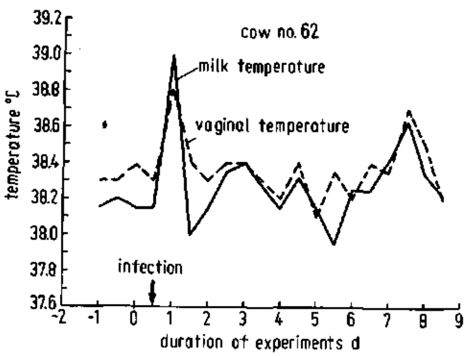


Figure 2. Mean course of the milk and vaginal temperature.

substantial information will be lost because of relative long milking intervals, i.e. measuring intervals. The aim would be continuous measurements, e.g. by subcutaneous implanted sensors.

Our tests showed furthermore that the difference of the measured temperature values of each single udder quarter is unessential. Therefore only one joint temperature sensor in the clawpiece can be considered sufficient. Because of the insignificant differences in temperature extensive and for each animal individual analyses of the obtained data are necessary.

2.1.2. Electrical conductivity sensors

Normally pathological disorder leads to changes of certain milk constituents. But for an automatic animal control only such indicating parameters can be used which can be registered automatically.

For example, certain diseases lead to impedance variations caused among other things by displacement of K-, Na- and Cl-ions. They can be registered by especially developed electrical conductivity transducers which are integrated on the collection hoses resp. in the clawpieces of the milking cluster.

During the milking process this parameter can be recorded automatically twice a day and used for the animal control. By means of conductivity measurements it is possible to register signals which are analyzed clearly and easily (5).

The development of sensors suitable for general use in practice still causes difficulties.

2.1.3. Pulse rate sensors

Another parameter is the pulse rate which reacts very sensible to disorder of the organism. Maybe in times to come the pulse rate can be registered by a pulse rate sensor developed by Paul et al. (6). It is attached to the ear as a mark, Fig. 3. Main part of the sensor is an

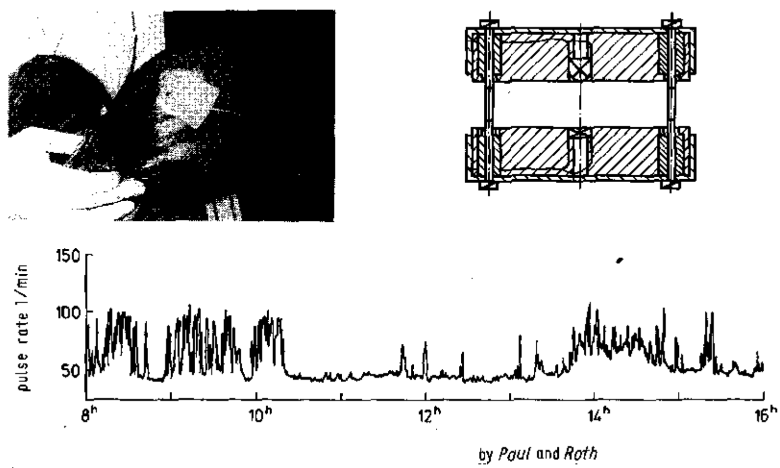


Figure 3. Pulse rate sensor and example for the pulse rate.

infrared transducer consisting of an infrared light emitting diode and a receiver. By means of a filter function the time course of the pulse rate can be determined.

2.1.4. Motion detector

In general cows in oestrus show a clearly different activity behaviour than cows not in oestrus. It is possible to register such changes with a pedometer attached to the pastern-joints of the extremities.

First measurements indicated that depending on the barn systems cows in oestrus showed up to twice as much activity than cows not in oestrus.

3. Early detection of specific disease symptoms with the aid of different sensors

The tests proved so far that pathological changes as well as the optimal time of conception can be detected earlier by automatic measurements of the milk temperature than by visual control of the animals by the milking staff. Although this does not allow a differentiated recognition of certain disease symptoms. This should be the future aim of our research work.

Therefore it was necessary to identify further physiological parameters suitable as an indicator resp. to test suitability of the respective sensors. Therefore tests were conducted aiming at an early detection of udder inflammations, metabolic disorder and the optimal time of conception.

3.1. Early detection of subclinical mastitis

By an early indication of these disease symptoms - if possible in a subclinical stage - an early therapy can be started. By this a remarkable saving of expenses could be achieved, a decrease of milk yield avoided and not repairable animal damages could be reduced to a minimum.

In certain tests udder inflammation was provoked by experiment at a fixed date by an intra cisternal application of a germ suspension (Strept. uberis) in one udder quarter of the test animals. The purpose was to find out the time and the intensity with which the parameters reacted on this application. Milk temperature, electrical conductivity, milk yield as well as feed and water consumption were automatically recorded.

To prove udder irritations the cell content of the milk was measured continuously. Immediately after the test started the cell content in the infected udder quarters increased, Fig. 4. A sudden increase of the electrical conductitity was also registered. This conductivity settled after a short period and remained on a higher level (up to 7.2 mS/cm).

After the application of the germ suspension the milk yield dicreased by approximately 5 kg.

The fat content of the milk increased by ca. 1.4 percent from 4.0 to 5.4 as expected. During the following days of the test with an increase of the milk yield the fat content normalized to the values which were measured before the test started.

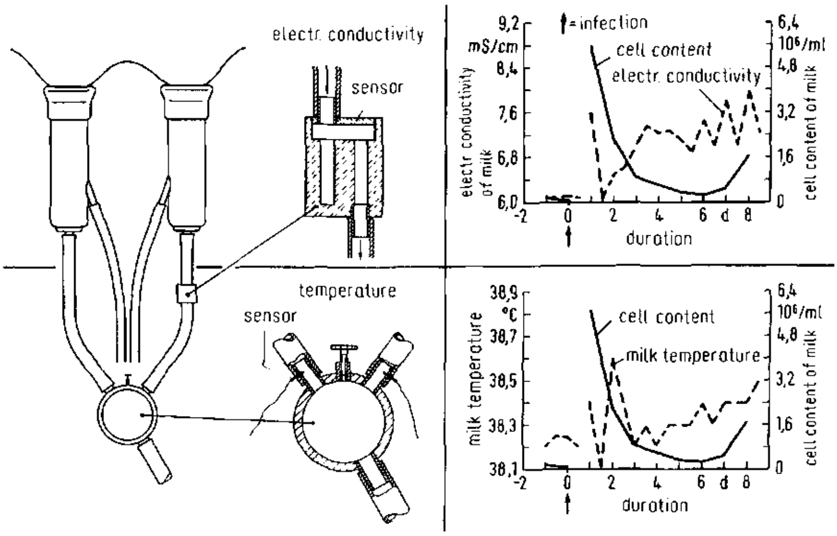


Figure 4. Computer aided monitoring of mastitis.

The water- and feed consumption showed no significant differences.

These results proved that
- the electrical conductivity of the milk,
- the milk temperature and
- the milk yield

can be used as suitable detection parameters for udder inflammations (11).

It is still difficult to determine the thresholds for these values which are able to indicate clearly this disease. Individual differences in electrical conductivity between 4.8 and 6.0 mS/cm were measured at healthy animals. This is due to a specie and animal specific variability.

If a comparison is made between each single udder quarter different values of more than 0.6 mS/cm in one quarter prove a pathological udder damage. This is true for milk temperature, too.

It is not possible to determine a threshold because of individual deviations of each animal. But an absolute difference in temperature during two following milking times suggest abnormal conditions.

Assuming an anavoidable error of the sensor of 0.2° C and a normal physiological variation of the animals of 0.2° C a difference value of more than 0.4° C compared to the normal values can be taken as proof for pathological changes.

Because of animal individual daily variations it is not possible to define a precise threshold for milk yield. It has to be respected as an additional indicator.

3.4. Early detection of metabolic diseases

Clinical and subclinical ketose are the main metabolic diseases of milk cows in countries with highly developed cattle breeding. The reason is a complex malfunction of different connected metabolic ways.

The most frequent feeding mistakes identified in case of ketose are (2):
- energetic underfeeding
- unfavorable combination of the kind of feed and
- dispensation of ketogenic feed.

Within the computer aided animal control stress was applied by oral application of ketogenic agents to investigate metabolic reactions. In three days running a dose of respectively 250 ml butyric acid dissolved in 10 l water was dispensed by a nose gullet probe to a group of 12 SB-cows who were post partum within 57 days.

During the preliminary stage of 3 days, the application stage of 3 days and an observation stage of 7 days the parameters
- roughage and concentrate intake,
- milk yield,
- live weight,
- agents of the milk content,
- electrical conductivity and
- milk temperature

were registerd automatically and compared between the therapy and control group.

The following results were obtained, Fig. 5:

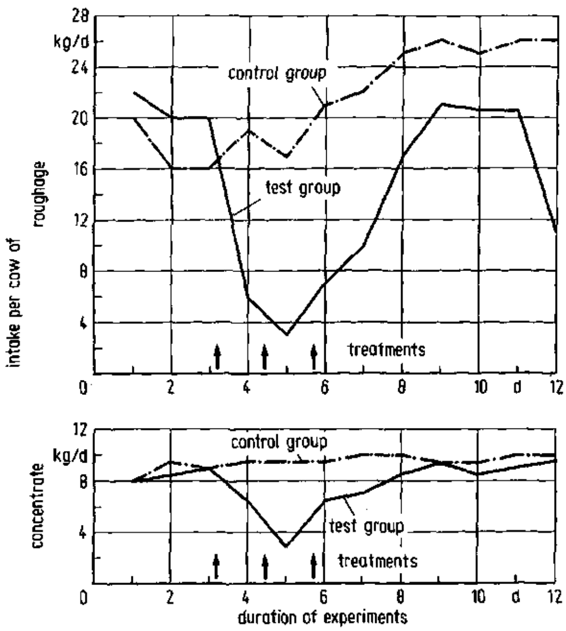


Figure 5. Intake of roughage and concentrate of metabolic diseases.

1. The intake of roughage and concentrate feed decreased during the stage of observation.
2. The milk yield decreased by ca. 7 kg until the 7. day of the test and normalized after that, Fig. 6. This result is identical with the conclusions of Röhrmoser et al. (8).

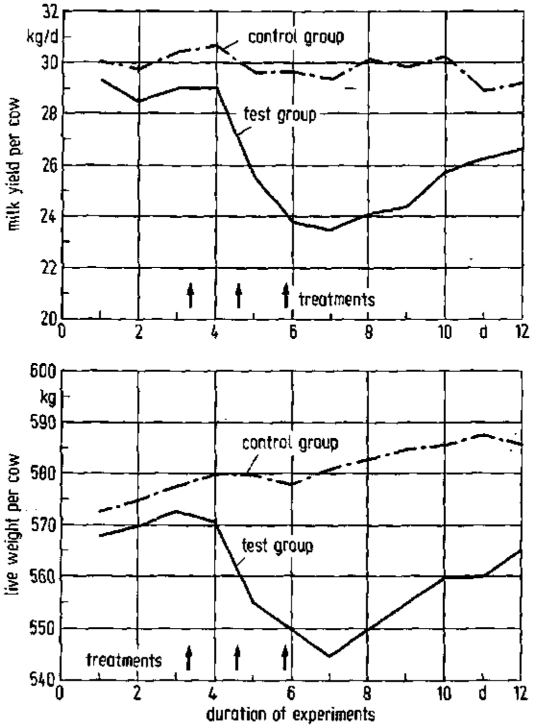


Figure 6. Milk yield and live weight of metabolic diseases.

3. Already during the stage of application the live weight showed a significant decrease of ca. 5 % from 570 to 540 kg.
4. No abnormal changes of the milk temperature could be measured.
5. During the period of the test the values of the electrical conductivity increased by more than 0.5 mS/cm.

Metabolic diseases were produced by an application of butyric acid which changed the concentration of some parameters of the milk and was proved by a computer aided animal control.

To prove metabolic diseases the following parameters are suitable:
- food consumption,
- milk yield,
- live weight and
- electrical conductivity.

To prove the validity and the reproduction of the change of these parameters more tests are necessary to clarify if the results obtained by application of butyric acid are transferable to animals fed with perishable silage fodder.

3.5. Oestrus control by recording several parameters in simultaneous consideration of a special evaluation program

Possibilities for a computer aided oestrus detection were tested by continuous automatic recording. The oestrus synchronization of the animals was produced at a fixed date (7). As all the oestrus symptoms depend in their intensity on the quantity of produced progesterone this parameter was included as a comparative value and for the description of the oestrus time and course. The tests were carried out both in the tied stall barn and the free stall barn.

3.5.1. Selection of suitable parameters

The following, automatically recorded parameters reacted clearly during the oestrus:
No matter what kind of barn system the milk temperature showed an average increase of 0.1 to 0,4 K above the mean value of the total cycle on the oestrus day. A rise in temperature, however, could only be observed in 40 to 50 % of all animals whereas up to 90 % of the animals in the free stall barn showed clear increase in temperature. This parameter alone is not sufficient for the oestrus diagnosis because many factors have an effect on the milk temperature. Concerning the other parameters recorded by the milk only the fat content of the milk indicated certain reactions while the electrical conductivity gave no indications of the oestrus and the feed intake only in a few cases.

The tests on the frequency of steps have shown that the anyhow constricted number of steps in the tied stall barn only increased by 10 to 14 % during the oestrus whereas the normally higher rate in the free stall barn (7,300 steps per day) doubled during the oestrus, Fig. 7.

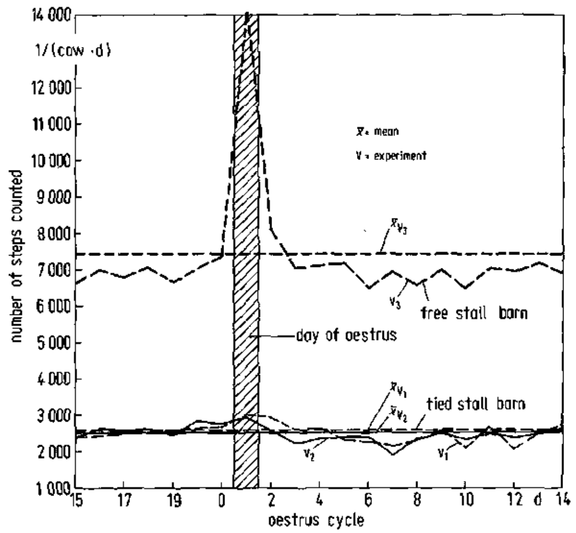


Figure 7. Number of steps per day during oestrus cycle.

For the oestrus diagnosis the number of steps in the tied stall barn is not suitable as a parameter of the animal behaviour so that in this barn system the pulse rate is recorded additionally by an ear mounted sensor.

It was found out that caused by the oestrus the absolute pulse rate per minute rises from the mean daily rate by about 7 % from 68.5 to 73.5 1/minute and that simultaneously the number of interruptions of the rest period at night increases from about 3.5 to 5.0. According to the t-statistics the two parameters indicated highly significant the oestrus.

Both the electrical conductivity intra vaginam and the pH-value intra vaginam turned out to be suitable parameters although the automatic recording is not yet possible.

3.5.2. Evaluation of the oestrus parameters with an elimination analysis

The consideration of one single parameter only leads to a higher percentage of wrong oestrus diagnosis. To reduce these wrong positive indications an elimination analysis is suggested using the parameters "milk temperature", "number of steps" (in the free stall barn), "milk yield" and "feed intake". The parameter "electrical conductivity of milk" serves to distinguish between reactions conditional on oestrus and diseases. This is demonstrated in Fig. 8 by example of the free stall barn. By observing the frequency of steps only a high quota of knowledge is achieved but the error rate reaches 60 % and therefore is not acceptable for practical purpose.

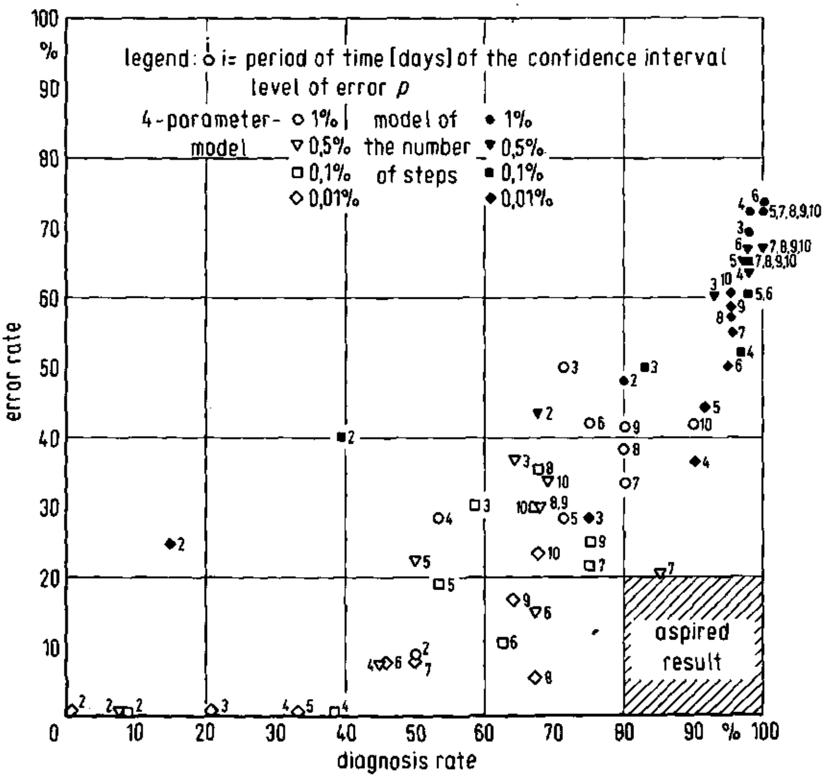


Figure 8. Computer based oestrus diagnosis. Percentage of diagnosed oestrus and error classifications for different statistic models (free stall barn).

More than 80 % of all the oestrus cases can be diagnosed with the help of a suitable statistical combination of the variables and at the same time the error rate is reduced to ca. 20 %. By using the model described above the success rate increases by 50 % compared with the conventional oestrus detection. The rate of false oestrus diagnosis is only half as high. Similar results were achieved in the tied stall barn.

4. Evaluations for the computer aided methods for early diagnosis of disease and oestrus symptoms

Due to the present results about the possibilities of an automated measurement recording of physiological parameters by means of computer aided systems for early diagnosis of pathological disturbances and oestrus control the following conclusions can be made:

1. Differentiated statements about certain diseases resp. the time of oestrus are only possible by continuous measurements of various parameters. Selective measurements of a single or several parameters do not give sufficient information.
2. To improve the health and oestrus control the simultaneous recording of the following parameters, Table 1, is sensible.
3. For health and oestrus control a program on the basis of an analysis by elimination is proposed for the evaluation of the data. The aim is a success rate of more than 90 % and an error rate of less than 10 %.

Table 1. Suitable parameters for health and oestrus control.

udder inflammation:	- electrical conductivity - milk temperature - milk yield (fat content of milk)
metabolic disorder:	- live weight - milk yield (fat content of milk) - feed consumption
Oestrus control in the	
- free stall barn:	- frequency of steps - milk temperature - milk yield - electrical conductivity of milk
- tied stall barn:	- milk temperature - frequency of steps - milk yield - pulse rate - electrical conductivity of milk

REFERENCES:

(1) Ball, J.H., S.V. Morant & E.J. Cant, 1978: Measurement of milk temperature as an aid to oestrus detection in dairy cattle. - J. agric. Sci. Cambr. 91, p. 503-597.

(2) Kronfeld, D.S., 1971: Hypoglycamic in ketotic cows. - Journal Dairy Science 54, p. 949-961.

(3) Maatje, K. & W. Rossing, 1976: Detecting oestrus by measuring milk temperature of dairy cows during milking. - Livestock production Science 3, p. 85-89.

(4) Paul, W. & H. Speckmann, 1976: Die Messung der Milchtemperatur als Mittel zur Überwachung von Tiergesundheit und Steuerung des Milchentzuges. - Grundlagen der Landtechnik Bd. 29, Nr. 6, S. 201 ff.

(5) Paul, W., H. Speckmann & W. Ihle, 1984: Die Messung der Leitfähigkeit beim Milchentzug - Meßtechnik und erste Ergebnisse. - Grundlagen der Landtechnik Bd. 34, Nr. 5, S. 192-198.

(6) Paul, W. et al., 1984: Überwachung der Herzschlagrate bei Milchkühen - Sensorentwicklung und erste Ergebnisse. - Grundlagen der Landtechnik Bd. 35, Nr. 6, S. 182-189.

(7) H. Roth, 1987: Automatisches Erkennen des Konzeptionsoptimums bei Milchkühen mit Hilfe rechnergestützter Systeme zur Herdenüberwachung. - Diss. Universität Kiel. - Landbauforschung Völkenrode Sh. 83.

(8) Röhrmoser, G. & M. Kirchgessner, 1982: Milchleistung und Milchinhaltsstoffe von Kühen bei energetischer Unterversorgung und anschließender Realimentation. - Züchtungskunde 54, S. 276-287.

(9) Schlerka, G. & J. Filar, 1981: Der Einfluß einer experimentell ausgelösten Ketose auf das klinische Bild, den Säure-, Basen- und Elektrolythaushalt, den Ketonkörpergehalt sowie auf zellige Bestandteile im Blut bei Kühen. - Wiener tierärztliche Monatszeitschrift 68, H. 12, S. 436-441.

(10) Schlünsen, D. et al., 1981: Eignung der automatischen Milchtemperaturerfassung zur Gesundheitsüberwachung und Brunstkontrolle in der Milchviehhaltung. - Landbauforschung Völkenrode 31. Jg., H. 4, S. 241-250.

(11) Schlünsen, D. et al., 1983: Eignung ausgewählter physiologischer Parameter zur automatisierten Früherkennung subklinischer Mastitiden. - Landbauforschung Völkenrode 33. Jg., H. 4, S. 219-232.

(12) Schön, H., R. Artmann & D. Schlünsen, 1984: Zukunftsorientierte Milchproduktion durch moderne Elektronik. - Arbeiten der DLG Bd. 181, DLG-Verlag, 158 Seiten.