# WELFARE STATUS OF DAIRY COWS IN BARNS WITH AUTOMATIC MILKING

***Relations between the environment and cow behaviour, physiologic, metabolic and performance parameters***

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**Information**

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# WELFARE STATUS OF DAIRY COWS IN BARNS WITH AUTOMATIC MILKING

## *Relations between the environment and cow behaviour, physiologic, metabolic and performance parameters*


**Hans Wiktorsson, prof. Dr**
**Gunnar Pettersson, MSc**
**Jan Olofsson, PhD**
**Kerstin Svennersten-Sjaunja, PhD**
**Martin Melin, MSc**
*Department of Animal Nutrition and Management*
*Swedish University of Agricultural Sciences*


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**Correspondence:**
Gunnar Pettersson
Department of Animal Nutrition and Management
Box 7024
SLU
SE-75007 Uppsala
Sweden
E-mail: Gunnar.Pettersson@huv.slu.se

## Abstract

The report highlights factors affecting the ability of the cows in AMS to maintain normal feeding, resting and social behaviour, diurnal rhythm and good health, all important cow-related welfare factors to be considered in every management system for dairy cows.

The research activities are identified to the following tasks:
1. Studies of behaviour, health, metabolic profile and performance in different cow traffic systems.
2. Behaviour, health and anti-stress profile in dairy cows.
3. Cow activity and continuity in daily rhythm.
4. Light/dark preference when resting during nights.
5. Use of welfare assessment protocol (D23) on the research herd.

The research work has been conducted at the AM-barn at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala. The barn consists of two identical parts on each side of a virtual central line, with a resting area and a feeding area in each part, and with a common waiting area and a milking unit (MU, DeLaval VMS™) in between. The milking unit operates on quarter milking and recording, and includes a concentrate feeder. There are in total 56 cubicles, 20 roughage feeding troughs, two concentrate feeders, water bowls and weighing bridges, all equipped with cow identification, time and quantity recording. The herd generally includes 45 to 55 lactating cows.

The welfare aspects of cow traffic systems: forced traffic, partially forced traffic (by-pass gate) and free traffic, have been studied. It was shown that the number of cows and the time spent in the waiting queue in front of the MU increased when more restrictions were introduced in the traffic system. The effect of more restrictions was more pronounced for the low-ranked cows than for the high-ranked ones. At forced cow traffic the average number of feeding visits was too low (3.9 visits/cow and day) to be optimal. A proportionally greater number of cows had to be fetched on the free traffic system because they frequently exceeded the upper limit for stipulated milking interval of 14 hours since last milking, which also resulted in greater variation in milking intervals. While both the forced and the free traffic systems proved to be sub-optimal, the forced traffic with pre-selection resulted in satisfactory feeding visits (6.5 – 7.1 visits/cow and day) and a low percentage of cows having to be fetched for milking.

A study of the reactions of high and low-ranked cows to denial at the by-pass gate when trying to reach the feeding area revealed that the choice to go to the nearby waiting area depended on the time since last feed intake and the number of cows already in the waiting area. After denial the low-ranked cows spent more time in the waiting area, while high-ranked, high parity cows spent more time in the resting area.

Setting the upper time limit for entering into the feeding area through the by-pass gate at 4 h instead of 8 h (and the same for milking permission), increased the average milking frequency among older cows in early lactation from 2.2 times to 3.2 times during 24 h. Heifers showed a less favourable response, which indicates difficulties coping with the short time limit of 4 hours. The ability of individual cows to adjust to a different degree of guiding calls for management systems with the possibility of individual settings.

It is common practice to have full illumination 24h a day in barns with AMS. It is however questionable whether cows prefer darkness during night hours, and if that will affect the daily rhythms of the herd. By screening between the two central rows of cubicles and towards the feeding area and milking unit, one half of the resting area had full lighting (app. 200 lux) while the other part had dim lighting (5 – 7 lux) from 23:00h to 5:00h. After 3 weeks the lighting in the two areas was reversed. The cows did not change their resting periods and the two areas were on average equally visited, but a few cows showed preferences for full lighting or dim lighting. No difference in ranking order could be observed and the total number of milkings was not affected.

A study of the oxytocin and cortisol levels in blood, and cow behaviour was implemented on high and low ranking cows (6 cows on each ranking order) at milking and resting. Contrary to the hypothesis, it was observed that the low-ranked cows had higher levels of oxytocin, both during milking and resting. These cows had also the lowest levels of circulating blood levels of cortisol, indicating that they cope well in the environment although their ability to act voluntarily and in a synchronised way is small. The behaviour studies showed that the low-ranked cows had a more effective eating pattern with less time spent in the eating area and fewer visits made to the feed troughs. However, sufficient amounts of feed were consumed.

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# 1. Introduction

Appropriate management systems for farm animals are generally expressed and regulated through the Animal Protection Act and ordinance. These are based on both objectively measured scientific findings, and ethical and public considerations of what are acceptable living and environmental conditions for farm animals (Broom,1991). The concept of animal welfare is therefore not defined once and for all.

The welfare of dairy cows depends on several factors related to the cows themselves and their social interaction with other cows in the herd: feeding and nutritional supply, barn design and in automatic milking systems (AMS) also cow traffic systems and climatic and other environmental conditions. Compared to conventional dairy cow management, cows in AMS are provided more freedom to choose their daily activities and rhythms. While conventional milking systems often force cows into extreme simultaneous group/herd cow behaviour, cows in AMS are expected to act in small groups or individually, particularly when it comes to milking, where one unit may be shared by 50 to 60 cows, forcing them to come for milking all 24 hours of a day.

### 1.1 Objectives and tasks

In this report we will highlight factors that affect the ability of the cows in AMS to avoid metabolic disturbances and other disorders, and to maintain a diurnal rhythm and normal behaviour in different cow traffic systems. We will therefore begin by giving a short general background of nutrient and feed requirements and metabolism in dairy cows, of lactation physiology and hormonal regulation, and resting and social behaviour, all important cow-related welfare factors to be considered in every management system for dairy cows.

The research activities reported here are identified to the following tasks:

1. A) Establish database, observation and registration, and B) studies of behaviour, health, metabolic profile and performance in different cow traffic systems.
2. Behaviour, health and anti-stress profile in dairy cows.
3. Cow activity and continuity in daily rhythm.
4. Light/dark preference when resting during nights.
5. Use of welfare assessment protocol (D23) on the research herd.

### 1.2 Nutrient and feed requirement and metabolism during the lactation cycle

One of the key issues for dairy cows is a balanced and continuous feed supply to support the nutrient requirement for maintenance and production. The modern dairy cow has a very high genetic potential for milk formation and production, but several feeding, management and welfare preconditions must be fulfilled before the potential can be exploited.

Ruminants and dairy cows in particular are dependent on well-functioning rumen fermentation. This is a continuous microbial process, where the major steps are degradation of carbohydrates and protein by the microbes and formation of short chain fatty acids, particularly acetic, propionic and butyric acids. The short chain fatty acids pass through the rumen wall into the blood stream and became a part of the intermediate metabolism of the cow. Acetic and butyric acids are precursors for milk fatty acids and in balanced rations form about 50 % of the milk fat. They are also important for the maintenance of normal rumen pH.

Access to structural feeds such as fresh or preserved forages of different kinds is absolutely necessary to maintain normal rumen fermentation and a healthy and productive dairy cow. Very high quality forage such as pasture may support a daily milk yield of 20 to 25 kg in addition to the maintenance requirement, while concentrate supplements are necessary for higher annual production than about 5000 kg milk per cow. However, cows are not particularly good at balancing feed rations themselves in relation to their actual nutrient requirements (Wiktorsson, 1973; Wiktorsson and Bengtsson, 1973). Therefore, in large dairy herds with conventional parlour milking, ad lib. feeding of total mixed rations (TMR) has become common practice. It has, however, not proved to be a successful concept in AMS systems, where tasty concentrate supplements in various amounts are given in the milking unit to attract the cows.

### 1.3 Lactation physiology

The welfare status of dairy cows can be measured in many ways and may be influenced by several factors. Milking is one such factor. Via the milking routine it is possible both to influence important physiological systems and, on the other hand, to get information about the welfare of the animal.

The physiology of the mammary gland relates to milk synthesis, milk storage and milk ejection. The prerequisite for milk synthesis is the availability of nutritional components. Nutritional regulation, mammary blood flow, milk synthesis and milk ejection are all controlled by different hormones such as insulin, growth hormone, prolactin, cortisol and oxytocin. The hormone oxytocin is responsible for milk let down while the other hormones at different levels are involved in the synthesis of the milk (Cowie et al., 1980). Furthermore, locally produced substances (FIL, feed back inhibition of lactation) in the udder control milk production capacity in relation to milking frequency (Wilde & Peaker, 1990). Mammary gland storage capacity such as size of gland cisterns also influences the response to frequent milking (Dewhurst & Knight, 1994).

Optimal milk production, produced under conditions where the well-being of animals has high priority, implies a management system where the cascade of hormonal events during milking are not disturbed. For instance, a disturbed milk ejection with little or no milking-related oxytocin will, in the short perspective (the present milking), decrease milk yield (Gorewit & Aromondo, 1985). If disturbed ejection occurs frequently, the whole lactation yield will probably be influenced, both as a consequence of less frequent removal of FIL from the alveoli as well as a consequence of the influence on the endocrine system regulating lactation. Indeed, the importance of strict milking routines has been demonstrated (Rasmussen et al., 1990). On the other hand, an efficient sensory stimulation of the milk ejection that results in high levels of milking-related oxytocin will have a positive effect on the milk yield since the emptying of the udder will be more efficient (Svennersten et al., 1995; Johansson et al., 1998).

However, some of the hormones mentioned, such as oxytocin and cortisol, can also be considered important for the well-being of the animals. It is well known that cortisol levels are related to stress, while it has recently been observed that the hormone oxytocin seems to be an anti-stress hormone.

The behavioural effects of oxytocin have been studied in rats. When rats were given injections of oxytocin they became calmer, less frightened and more social interactive (Uvnäs-Moberg et al., 1994; Carter & Altemus, 1997). Furthermore, the blood pressure and the levels of stress related hormones (cortisol etc) decreased in those animals (Petersson et al., 1996; Petersson et al., 1999). It is interesting that similar systems seem to exist in dairy cows. In short term experiments, where the management routines were changed, (feeding during milking instead of feeding and milking separately) the behaviour of the cows was also affected as a consequence of elevated levels of oxytocin and decreased cortisol levels. Cows with high milking related levels of oxytocin were more social interactive, were ruminating and lay more compared to cows with lower oxytocin levels (Johansson et al., 1999 a and b). The effects of elevated oxytocin levels were also reflected in factors such as shorter milking time, higher peak flow during milking and more efficient udder emptying (Johansson et al., 1998). It is, therefore, possible that some variables measured during milking can contribute to the diagnosis of animal well-being.

In systems with automatic milking the cows enter the milking station voluntarily. The cows themselves decides when to carry out the activity and the decision is probably based upon their individual physiological and psychological need (Webster, 1993). Although this should increase animal welfare, the cow's ability to act as a social unit decreases. It is not known whether this has an effect on animal welfare and the stress level of the cow; neither is it known if cows with high or low rank within the herd act differently.

In AMS, cow traffic can be managed in different ways. Free cow traffic gives the most freedom to the cow. She can move freely from the resting area to the feeding area without having to pass the milking unit (MU). The problem with this system is that cows may not pay enough visits to the MU and that many cows have to be fetched. Forced cow traffic is the opposite. Cows have to pass the MU in order to go from (usually) the resting area to (usually) the feeding area. In this system sufficient visits to the MU are guaranteed more easily, but there might be long queues in front of the MU and the welfare of cows might be impaired by the longer waiting times and the lower number of feeding area visits.

### 1.4 Resting behaviour

Cattle often show a diurnal resting behaviour with their main resting period during the hours of darkness (Olofsson, 2000). However, a number of studies show that total resting time typically exceeds 50% of the 24h-period with several resting periods also allocated during daytime. Cattle seem to prefer to lie down when ruminating although they can, of course, perform this behaviour when standing up as well (Arnold & Dudzinski, 1978). Based on results showing a higher blood flow through the udder when cows are resting and the fact that more milk is produced with an increased blood flow, one may assume that resting also affects production (Metcalf et al., 1992).

The normal getting-up and lying-down movements in cattle follow a certain pattern (Schnitzer, 1971). Deviations from this pattern can occur and are often due to health problems or physical obstacles in the close environment. Thus, studies of these movements can indicate such problems.

The general recommendation is that all cows in a barn should be able to rest at the same time. This is for instance stated as an obligation in the Swedish animal protection regulations (Swedish Board of Agriculture, 1988). Experiments show that especially cows low in rank decrease their resting time when the number of cubicles is insufficient (Wierenga & Hopster, 1990).

In general, cows in AMS follow the typical resting rhythm discussed earlier (Munksgaard et al., 2002). However, the desire for 24-hour activity in AMS may result in a less pronounced resting period during the night. Cubicles are not only used for resting. Well designed and managed, a cubicle also provides dry and soft bedding as well as privacy and protection for standing cows.

### 1.5 Social behaviour

Cattle are social animals. In the wild or at semi-natural conditions, cattle live in small maternal herds often consisting of less than 20 heads. In these groups where young animals grow into the herd, the social dominance relationships between individuals are found to change very little over the time. This hierarchy is important since it regulates the outcome of different situations with competition for resources without unnecessary violence. Cattle show the same social behaviours when kept indoors as they would at more natural conditions. There are however major differences. In dairy production, the herd usually consists only of mature or almost mature animals and the group size can be much larger. Furthermore, replacing and introducing new individuals on a regular basis constantly change the structure and ranking order of the herd. Also, the physical restrictions given by the size, use and the design of different parts of the barn have a major impact on the social behaviour of housed cattle.

Cows prefer to keep a minimum distance to other cows. With some social behaviours, e.g. social licking, cows need to have physical contact with other cows. During other behaviours, e.g. feeding, this minimum distance is often found to be between 1 and 2 m (Bouissou & Signioret, 1971). When decreasing the available space and not allowing cows to keep this distance, the number of aggressive interactions has proven to increase (Kondo et al., 1989).

The social dominance order in a group of cattle consists of all the possible number of social relationships that can be established between individual cows. Thus, a group of 50 cows consists of 1225 pairs of cows, each with an individual social relationship. However, a single cow is not believed to be aware of relationships between other herd mates. The social relationship between cows is usually established within a few days after grouping (Kondo & Hurnik, 1990). During these first days, aggressive encounters are usual. When the dominance relationships are established, conflicts are often solved through threats and avoidance.

Knowledge about the social dominance order and the dominance relationships within the herd is valuable for the researcher when studying animal behaviour. With this knowledge, high or low-ranked animals can be selectively chosen for the behavioural study. It is also valuable when interpreting data and explaining the results. Usually, dominant animals have primary access to limited resources. This has for instance been shown in situations with competition for feed (Olofsson, 2000).

Traditionally, scientists determine the social dominance by visual studies of interactions between animals. Unfortunately this is a time consuming procedure at larger group sizes. This is why the need for methods to automatically detect social dominance is evident. An accepted method for this purpose is by using data from installations that automatically register feeding behaviour (Rutter et al., 1987; Kenwright & Forbes, 1993; Olofsson, 2000). The procedure is based on the assumption that if a cow leaves a feeding place and another cow enters the same place within a certain time, the second cow is thought to be the dominant one in that specific relationship. After several measurements the relationship between the two cows can be determined.

## 2. Own studies

### 2.1 Material and methods

The research work has been linked to the AM-barn at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala. The herd consists of one breed, Swedish Red and White, but is divided in low milk fat and high milk fat selection line, respectively. The average annual milk yield of the cows was 9 700 kg ECM (4% energy corrected milk, Sjaunja et al.,1990).

The design of the barn is shown in Figure 1.

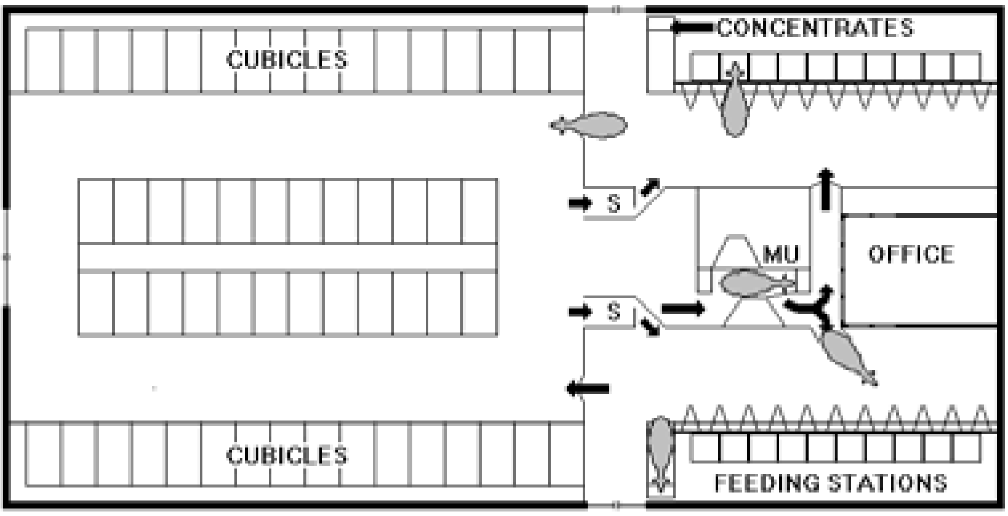



*Figure 1. Schematic drawing of the experimental barn layout. Abbreviations: S=Selection by-pass gate, MU=Milking Unit.*

The barn consists of two identical parts on each side of the central line, with a resting area and a feeding area in each part, and with a common waiting area and milking unit (MU, DeLaval VMS$^{TM}$) in between. The barn is 34.10 m $*$ 16.85 m and the cubicles are 1.20 m wide and 1.70 m long (the area where the cows lie) + 1.00 m (the area at the front end of the cubicle). The walking area (3.0 m wide) consists of a solid concrete floor sloping towards a drain in the middle and manure is removed with automatic scrapers. The waiting area also has a concrete floor. There are 56 cubicles totally, with 28 cubicles divided in two rows in each resting area. In the cubicles there are rubber mats, and cut straw and shavings were used as litter. There are 10 roughage feeding troughs (BioControl A/S) and one concentrate feeder (AlfaFeeder) in each feeding area. At the entrance to the concentrate feeder a hydraulic gate closes behind the cows after they enter the feeder and are allotted concentrate. The floor of the concentrate feeder consists of a balance, which registers the cows' weight at every eating occasion. Daylight and fluorescent lighting during daytime and fluorescent lighting at night illuminate the barn. Drinking water is continuously available in six water bowls, one in each feeding area and two near the entrance of each selection by-pass gate. Two automatically rolling brushes (one in each side of the resting area) are placed near the passage and the first cubicle in the middle rows.

The MU is available for about 22 hours / 24 hour period. The other two hours are used for cleaning and maintenance of the system. The cows can enter the MU from the waiting area. The exit from the MU leads to a narrow corridor between the two feeding areas. When leaving the MU the cows can choose which feeding area to enter. When moving from the feeding area to the resting area the cows normally have to pass a one-way gate, which prevents passage in the other direction.

The cows are identified by a neck transponder when entering the milking unit, the selection by-pass gates, the concentrate feeders, the roughage feeding troughs and the water bowls.

*Database*

The major data base registrations and observations include:

- *Cow behaviour*: continuous measurements of activity by means of synchronised video cameras with time-lapse registration and complementary visual observations. Activity measurements of each cow have been linked to the computer system with registration of time of milking, water and feed intake as well as time of passage through gates between sections of the barn.
- *Nutrient supply, feed and water consumption*: All forage/mixed rations are placed in the troughs where registrations of time, total length of visit, and consumed amount have been made for each individual cow. All water bowls in the barn were equipped with antennas for cow identification and water flow registration (Bio-control A/S, Norway). Each visit to a water bowl produced a data log consisting of cow identification, time of visit, total drinking time and total amount of water consumed. Data from the roughage feeding stations, the concentrate feeding stations and the water bowls were automatically transferred to a database for storage and analysis.
- *Feed availability* for each individual cow can be controlled.
- *Live weights*: Recorded at each visit to the feed dispensers.
- *Health status:* Registration of disorders and fertility parameters in the database for the entire station. Clinical examinations have been made with regard to udders and teats, legs and hooves. Weekly recording of somatic cells in the milk.
- *Milking and milk production*: Records of times and frequencies of milking and teat treatments before and after milking, and several parameters concerning milking, amount of milk and milk composition for each teat have been stored and will be included in the evaluation.

*Data handling and statistical methods*

All automatically collected data on the animal level concerning milking, passages through the milking station and selection gates, denials at selection gates, feed and water intake, body weight and milk samples get a timestamp together with the identification. The time stamp includes where and when the information is collected. As the data collection is done in different technical systems a regular clock calibration is made between the technical systems including the video recorder.

Daily milk yield is calculated by converting each recorded milk yield to milk production per hour and then calculating a weighted hourly mean. This value times 24 (hours) represents the daily milk production. The calculation of average milk composition always includes at least two, mostly three, consecutive milkings analysed separately. Each analysis is combined with the milk yield from that milking, and these milkings are weighted according to milk yield to get the average milk composition.

To handle data from different sources and to perform the statistical analysis, the SAS Statistical Program was used (SAS, 1996). The General Linear Model procedure (PROC GLM) and the Mixed Linear Model procedure (PROC MIXED) are commonly used statistical procedures. The statistical analysis of an experiment is normally based on individually calculated means concerning a certain period, where the period length depends on the nature of each experiment. If repeated measurements from individual cows are analysed the statistical model is changed to take account of this fact.

The statistical model normally includes selection line, cow within selection line, lactation number, treatment and period. When using the Mixed Linear Model procedure, cow within selection line (see above) is handled as a random variable.

## 2.2 Welfare aspects of cow traffic in automatic milking systems

### 2.2.1 Introduction

In automatic milking systems (AMS) there is a need to optimise the number of milkings and the number of feeding visits. At the same time, it is important to consider the welfare of the cows. All cows, the low-ranked as well as the high-ranked must have access to the feeding area and the MU a sufficient number of times per day. Feeding is the most important parameter from the cows' point of view (Prescott et al., 1997), while milk yield and feed efficiency are more important to the farmer. To achieve the optimal balance, different cow traffic systems have been developed with lower or higher degrees of restrictions on the cows.

Cows which are free to choose when and how much to eat normally have 7 or more eating periods per day (Pirkelmann, 1992). If the cows consume feed less than 5 times per day it has to be considered as there being restrictions in their free choice to consume feed.

In AMS basically three types of cow traffic systems are used; forced traffic, partially forced traffic and free traffic. Partially forced traffic is also called forced traffic with pre-selection, semi-forced traffic or guided traffic.

In this section we will discuss how the different traffic systems influence the number of milkings, daily milk yield, feed efficiency and the welfare of the cows.

### 2.2.2 Milking and feeding visits

Two experiments have been conducted at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala (Forsberg et al, 2002a and Thune, 2000). The barn design, data collection and data handling procedure are described above.

The experiments were performed in the spring of 2000 and in the spring of 2001. In the first year the experiment consisted of three periods (free cow traffic, forced cow traffic and forced cow traffic with pre-selection) and in the second year the experiment consisted of two periods (free traffic and forced traffic with pre-selection).

The cows were fed ad lib. of a mixed ration consisting of silage, concentrate and hay or straw. Concentrate was also fed in the concentrate feeders according to milk production.

*Forced cow traffic*
With forced cow traffic the cows had to pass the MU to get access to the feeding area. On their way from the feeding area to the resting area they had to pass a one-way gate, which prevented passage in the opposite direction. The cows got a small amount of concentrate (maximum 0.5 kg/milking occasion or 1.5 kg / 24 hours) in the MU to tempt them to visit the MU. Permission for milking was given 6 hours after the last milking occasion. Cows were fetched if the milking interval was longer than 14 hours.

*Free cow traffic*
During free traffic the one-way gates between the feeding areas and the resting area were removed and this made it possible for the cows to move directly from the resting area to the feeding area without passing the MU. The cows were fed up to1 kg concentrate in the MU per milking occasion but a maximum of 3 kg per 24 hours. Permission for milking was given 6 hours after the last milking occasion. Cows were fetched if the milking interval was longer than 14 hours.

*Forced cow traffic with pre-selection*
With forced cow traffic with pre-selection the cows could get access to the feeding areas through the MU or the selection gates. The gates were situated close to the waiting area but the cows were not forced to pass them to get access to the MU. The cows were permitted to pass through the gates when they had not got permission for milking. Permission for milking was given 7 hours after the last milking occasion. After a denial the cows could freely choose to return to the resting area or visit the MU. The cows were fetched if the milking interval was longer than 14 hours. The cows were fed 0.5 kg concentrate in the MU, maximum 1.5 kg per 24 hours, during milking.

### 2.2.3 Results and discussion

Results from the two experiments are presented in table 1 and table 2. Both experiments show the same trends. The number of milkings per cow per day increases and the number of feeding visits decreases when the level of restriction in the cow traffic system increases.

*Table 1. Results from the experiments by Thune(2000) (year 1) and Forsberg et al.(2002a) (year 2).*

| Parameter | Year | Free traffic | Forced traffic with pre-selection | Forced traffic |
|---|---|---|---|---|
| No of cows | 1 | 46 | 50 | 45 |
| | 2 | 45 | 46 | |
| No of milkings per cow per day | 1 | 1.98[a] | 2.39[b] | 2.56[c] |
| | 2 | 2.34[a] | 2.63[b] | |
| Milking interval Mean, h | 1 | 12.3[a] | 10.1[b] | 9.5[c] |
| | 2 | 10.4[a] | 9.3[b] | |
| standard deviation, h | 1 | 3.6[a] | 2.8[b] | 2.8[b] |
| | 2 | 3.6[a] | 2.7[b] | |
| No of additional visits to the MU/cow/day | 1 | 0.44[a] | 1.68[b] | 1.2[c] |
| | 2 | 0.91[a] | 1.26[b] | |
| No of feeding visits per cow per day | 1 | 12.1[a] | 6.5[b] | 3.9[c] |
| | 2 | 9.0[a] | 7.1[b] | |
| Fetched milkings, % of all milkings/day | 1 | 26.0[a] | 1.7[b] | 4.0[d] |
| | 2 | 14.5[a] | 2.6[b] | |
| No of cows in the milking queue | 1 | 2.2[a] | 4.1[b] | 5.1[c] |
| | 2 | 1.8[a] | 4.0[b] | |

[a, b, c] Different superscripts within row denotes significant differences
[d] Calculated during the period immediately preceding the experimental period

*Table 2. Frequency of milking intervals longer than 12 hours*

| Parameter | Year | Free traffic | Forced traffic with pre-selection | Forced traffic |
|---|---|---|---|---|
| Milking intervals > 12 h % of all milkings | 1 | 53.3 | 24.9 | 18.6 |
| | 2 | 32.9 | 15.9 | |

Although a large proportion of all milkings were fetched in the free traffic system, the variation in milking interval is significantly greater and the frequency of milking intervals (>12h) much higher than in the other systems. The limit for fetching the cows was relatively high, 14 hours since last milking.

In the two experiments it was also studied how the traffic system influences the time budget of the cows. In table 1 it is shown that the number of cows in the milking queue increases when more restrictions are introduced in the traffic system. Time in cubicles and in the milking queue is observed in these experiments for low and high-ranked cows, respectively (Table 3). The results show that restrictions in cow traffic are most unfavourable for the low-ranked cows but both high and low-ranked cows are able to spend more than 12 h in the cubicles in all traffic systems.

*Table 3. Time budgets for low and high-ranked cows (Forsberg et al., 2002a)*

| Time spent in | Rank | Year | Free traffic | Forced traffic with pre-selection | Forced traffic |
|---|---|---|---|---|---|
| Milking queue, h | High | 1 | 1.6 | 2.0 | 2.3 |
| | | 2 | 0.9 | 1.6 | |
| | Low | 1 | 1.3 | 2.8 | 4.0 |
| | | 2 | 0.9 | 2.1 | |
| Cubicles, h | High | 1 | 14.2 | 17.2 | 14.7 |
| | | 2 | 16.0 | 13.1 | |
| | Low | 1 | 14.2 | 13.4 | 12.5 |
| | | 2 | 14.6 | 12.9 | |

Haverkamp et al. (2002) has separately studied 35 cows which participated in both traffic systems during the second year. The cows were divided into three groups according to number of milking visits per cow per day, low, middle and high milking frequency. The low and high frequency groups each consisted of 25% of the cows, and the middle frequency group was 50% of the cows. In table 4, milk-related and feed-related parameters are presented from different milking frequency groups in forced traffic with pre-selection and free traffic. It is to be noted that 50% of the cows changed MF group when the traffic system changed to free traffic. Movements of cows between MF groups from forced traffic with pre-selection to succeeding free traffic mainly occurred between contiguous MF groups. Cows moving to a higher MF group were significantly younger and were lower in rank. The regulating effect of the selection gates in forced traffic with pre-selection reduced the differences in milking frequencies between low and high yielding cows compared to free cow traffic. The number of milkings of the most frequently milked cows was less affected by the cow traffic situation.

*Table 4. Milk and feed related herd characteristics per milking frequency group (MF) in forced cow traffic with pre-selection and free traffic. (Haverkamp et al., 2002)*

| Parameter | Forced traffic with pre-selection | | | Free traffic | | |
|---|---|---|---|---|---|---|
| | Low MF | Middle MF | High MF | Low MF | Middle MF | High MF |
| No of MU visits/cow/day | 2.9[a] | 3.9[b] | 4.6[c] | 1.8[a] | 3.6[b] | 4.7[c] |
| No of milkings/cow/day | 2.2[a] | 2.6[b] | 3.0[c] | 1.6[a] | 2.4[b] | 3.0[c] |
| Milk yield. kg/cow/day | 27.1[a] | 32.7[b] | 34.9[b] | 24.6[a] | 30.6[b] | 30.4[b] |
| No of feeding area visits | 5.5[a] | 5.9[b] | 6.1[b] | 6.7[a] | 9.0[b] | 9.7[c] |
| No. of roughage feeder visits | 5.4[a] | 5.7[a] | 5.9[b] | 6.3[a] | 7.7[b] | 7.8[b] |
| Roughage DM intake, kg | 14.8 | 14.3 | 14.9 | 15.7[a] | 14.4[b] | 13.4[c] |
| Total DM intake, kg | 23.8[a] | 26.1[b] | 28.1[c] | 25.7 | 26.7[a] | 24.6[b] |
| Calculated from presented results | | | | | | |
| Mean milking interval, h | 10.9 | 9.2 | 8.0 | 15.0 | 10.0 | 8.0 |
| DM consumed/kg milk | 0.88 | 0.80 | 0.81 | 1.04 | 0.88 | 0.81 |

[a, b, c] Different superscripts within row denotes significant differences

Harms et al. (2002) have presented results from an experiment with free, selectively guided and forced cow traffic (Table 5). The production level was approx. 7000 kg per cow and lactation. In this experiment two selection gates were used, one relatively close to the MU and one in the other end of the feeding area, almost in the middle of the resting area. After a denial at a selection gate the cow could freely choose to return to the resting area or visit the MU. Cows were fetched to the milking station 5 times during the day if they had "exceeded planned milking time for more than 3-4 hours". Roughage was distributed once per 24 hours (approx. at 04:30) and concentrate was fed only in the MU depending on milk yield. A minimum of 0.5 kg/cow/day was given to attract the cows to the MU.

*Table 5. Results from a study on cow traffic systems by Harms et al. (2002).*

| Parameter | Free traffic | Forced traffic + selection gates | Forced traffic |
|---|---|---|---|
| No of cows | 49 | 49 | 49-51 |
| No of milkings/cow/day | 2.29[a] | 2.56[b] | 2.63[b] |
| No of additional visits/cow/day | 0.61[a] | 0.71[a] | 1.44[b] |
| No of fetched milkings per day | 15.2[a] | 4.3[b] | 3.8[b] |
| No of cows in milking queue | 1.3 | 3.3 | 3.2 |
| Maximum no of cows observed in the milking queue | 7 | 12 | 11 |
| No of meals per cow per day | 8.9[a] | 7.4[b] | 6.6[c] |
| Roughage DM intake, kg/cow/day | 16.9[a] | 17.4[a] | 16.1[b] |
| Calculated from presented results: | | | |
| Mean milking interval, h | 10.2 | 9.3 | 9.5 |
| Fetched milkings, % of all milkings | 13.5 | 3.4 | 3.0 |
| No of feeding visits through MU | 2.9 | 3.27 | 4.07 |

[a, b, c] Different superscripts within row denotes significant differences

The results show that the number of milkings and additional visits per cow per day increases and the number of feeding visits decreases when the levels of restrictions in the cow traffic system increase. The number of cows in the milking queue is halved in free traffic compared to the other systems. The distribution of roughage just once per 24 hours probably influences this parameter. When the roughage was fed in the morning the cows tried to reach the feeding area but were trapped in front of the MU in the restricted traffic systems. In the experiment they also found 6.6 meals/cow/day during forced traffic, although the sum of milkings and additional visits to the MU resulted in only 4.0 visits to the feeding area per cow per day. The cows seemed to stay in the feeding area for a longer time per visit during forced traffic.

*Feed intake and feed efficiency*

Harms et al. (2002) found a decrease in roughage dry matter (DM) intake during the forced traffic system compared to free traffic and forced traffic with selection gates, but no differences between the latter two traffic systems (table 5). According to the presented results it would appear that the total amount of roughage distributed daily to the herd was restricted, and between 21:00 and 04:30 there was almost no roughage left in the feeding area.

Haverkamp et al. (2002) have compared forced traffic with pre-selection and free traffic by extrapolation of the values in different parameters from the first period to the succeeding free cow traffic period to avoid influences of days postpartum when comparing differences between the two periods. One group containing cows with the lowest daily milk yield during forced traffic with pre-selection (9 cows or 25 % of the cows) was identified and compared to the rest of the cows (26 cows). The groups included 4 and 5 heifers respectively. The milk criterion limit was 26.5 kg per cow per day. Predicted values from forced traffic with pre-selection are compared with actual values from free traffic in table 6.

*Table 6. Actual values from free cow traffic compared to predicted (Haverkamp et al., 2002)*

| Parameter | Low milk production group (n=9) | | High milk production group (n=26) | |
|---|---|---|---|---|
| | Actual | Predicted | Actual | Predicted |
| No of MU visits/cow/day | $3.6^{a}$ | $4.4^{b}$ | $3.3^{a}$ | $4.0^{b}$ |
| No of milkings/cow/day | $2.2^{a}$ | $2.8^{b}$ | $2.4^{a}$ | $2.8^{b}$ |
| Daily milk yield, kg/cow | 23.0 | 22.9 | 31.5 | 30.9 |
| No of feeding area visits | $8.9^{a}$ | $6.1^{b}$ | $8.5^{a}$ | $5.9^{b}$ |
| No of roughage feeder visits/cow/day | $7.5^{a}$ | $5.9^{b}$ | $7.4^{a}$ | $5.7^{b}$ |
| Total eating time, min | 215 | 220 | 204 | 206 |
| Rough.eating time, min | 183 | 191 | 156 | 162 |
| Total DM intake, kg/cow/day | $23.4^{a}$ | $20.5^{b}$ | $26.9^{a}$ | $24.1^{b}$ |
| Roughage DM intake, kg/cow/day | $14.7^{a}$ | $12.0^{b}$ | $14.5^{a}$ | $12.1^{b}$ |
| DM intake, kg/kg milk | $1.10^{a}$ | $0.92^{b}$ | $0.93^{a}$ | $0.79^{b}$ |
| Calculated from presented results | | | | |
| Mean milking interval, h | 10.9 | 8.6 | 10.0 | 8.6 |

$^{a, b}$ Different superscripts within row and group denotes significant differences

During free cow traffic the total DM intake per cow was significantly higher than predicted and an increased number of feeding area visits were made, while total time spent eating was equal for both cow traffic systems. Although there was a tendency to higher daily milk yield than predicted during free traffic, the higher DM intake gave a lower milk production per kg DM feed intake in both groups. In both groups the actual feed efficiency was almost 15-20% lower than the predicted values.

### 2.2.4 Aspects of the use of pre-selection gates

*Adaptation to selection gates*

In commercial herds two main types of selection gates are used. In a routing gate the cow is identified some distance ahead of the gate, the gate makes a decision and sets her route, and the cow never needs to halt on her passage through the selection unit. In the other type of selection gate the cow is identified and the gate opens if she fulfils the criterion for opening, otherwise she has to back out of the selection unit. This type of selection gate often closes rather quickly to stop cows that do not fulfil the criterion from hitchhiking through the gate. A study on 5 commercial farms (Olofsson et al., 2001) shows that cows need training to understand and adapt to this type of gate. The study was conducted 2 - 3 months after the introduction of the gate and less than 40% of the cows used the gate regularly. Usage of the gate varied between the farms. On one farm that had trained the cows, more than 60% of the cows used the gate daily (Table 7). An additional cause of the low frequency was the location of the gates.

In a study at Kungsängen Research Centre from April 2001 until October 2002, 45 heifers were observed from introduction in the AM-barn up to 5 weeks after introduction. The aim of the study was to see how introduced cows adapt to and use the selection by-pass gates.

*Table 7. Usage of a selection by-pass gate in 5 commercial herds (Olofsson et al., 2001)*

| Farm | Regular usage of a selection by-pass gate % of cows |
|---|---|
| A | 33 |
| B | 39 |
| C | 30 |
| $D_1$ | 61 |
| E | 41 |

During their first day in the stable the cows were trained to use the selection by-pass gates. As early as in the first week, more than 70% of the heifers passed the gates daily (Table 8). The usage increased week by week and in the fifth week almost 90% of the heifers used them daily and only 1 of 45 heifers never used the gates. Another interesting observation in the study is that although the average number of daily passes per cow is high by the second week, still 11 heifers do not use the gate daily. This shows how important it is to check individual cows and not rely on a high total number of passages or an average for the whole herd.

*Table 8. Usage of selection by-pass gates in relation to time (weeks) in the barn, 45 heifers at Kungsängen RC*

| Week in barn | Average no of daily passages/cow | No of cows not using the gate (<=0.1 passages/day) | No of cows using the gate daily (>=1 passage/day) |
|---|---|---|---|
| 1 | 2.8 | 3 | 32 (71%) |
| 2 | 4.4 | 3 | 34 (76%) |
| 3 | 4.6 | 3 | 37 (82%) |
| 4 | 4.8 | 3 | 39 (87%) |
| 5 | 5.0 | 1 | 40 (89%) |

Other types of selection gates often route the cow to a waiting area in front of the milking unit or to the feeding area. In this situation it is important that the waiting area is constructed with a back door so cows can leave the waiting area when it is full or when they for any other reason feel threatened. A low-ranked cow might otherwise be trapped for hours in a closed waiting area and if one or two cows in heat enter the area, the risk of injuries on legs and hooves could rapidly increase.

*Location of the selection by-pass unit*
When a selection by-pass gate is included in the layout of the barn the main purpose is to make it easier for the cows to get to the feeding area in a forced traffic system. The location of the unit is important to achieve more feeding visits without cows having to pass through the milking unit. In figure 2, two unfavourable locations are illustrated. In the layout to the right, the selection unit and the milking unit are situated close to each other. When the waiting area (shaded) is filled with cows waiting to be milked, it is impossible for a cow without milking permission to pass the by-pass gate.

In the other example, the selection by-pass gate is well separated from the milking unit, but there is a clear risk that the cows will not use it. When a cow is denied in the selection unit the distance back to the milking unit might be quite long. If the waiting area is filled with cows, she has to walk through the whole barn to return to the milking station from the best direction. The best location of a selection by-pass gate that gives the cows a by-pass route to the feeding area seems to be as in figure 1. The cows prefer to check if they can reach the feeding area ahead of or in the first part of the waiting area.

*Figure 2. Two unfavourable locations of a selection gate*

*Availability of feeds*
In the study on commercial farms by Olofsson et al. (2001) it was also found that roughage distribution influenced the number of cows in the milking queue (Table 9). In the experiment presented by Harms et al. (2002) the roughage distribution influenced the milking queue as well, but differently in the three traffic systems (Table 10).

*Table 9. Number of cows in the milking queue before and after roughage distribution in 5 commercial herds (Olofsson et al., 2001)*

| Farm | Roughage distribution times per day | Cow traffic system | Additional no of cows in the milking queue after vs. before feed distribution |
|---|---|---|---|
| A | 3-4 | pre-selection | + 2.7 |
| B | 3-4 | pre-selection | + 3.5 |
| C | 2 | pre-selection | + 2.3 |
| $D_2$ | 2 | forced traffic | + 4.7 |
| E | 9 | pre-selection | +/- 0 |

*Table 10. Number of cows in the milking queue before and after roughage distribution (once/24 h) at approx. 04:30 in three cow traffic systems (from Harms et al., 2002)*

| | No of cows in the milking queue | | Maximum |
|---|---|---|---|
| Traffic system | At 04:00 | at 05:00 | observed |
| Free | < 1 | 1-2 | 7 |
| Forced | < 1 | approx. 3 | 11 |
| Forced with pre-selection | approx. 1 | 3-4 | 12 |

It is probably not how many times the roughage is distributed that is important in this case. The important thing is that roughage should always be available to the cows, whenever they come to the feeding area. In restricted traffic systems this seems to be even more important than in free traffic.

This has also been confirmed by Nordin (2002) in a study at two commercial farms. She found a reduction in the number of milkings up to 3 hours prior to the next roughage distribution in a system with roughage distributed twice daily. At another farm with roughage distribution 8 times/day no effect on the number of milkings/hour related to feed distribution was observed.

### 2.2.5 Conclusions

The level of restrictions in the cow traffic system influences the number of milkings, additional feeding visits per cow per day and the time budget for the cows. Increasing the level of restrictions decreases the number of feeding visits, increases the number of milkings and forces the cows to spend more time queuing.

The need to fetch cows to the milking station due to long milking intervals is highest in free cow traffic systems and lowest in forced traffic systems with pre-selection or by-pass gates.

Feed consumption seems to increase in free cow traffic systems but can induce lower feed efficiency, especially with low yielding cows.

The location and regulation of guiding gates in an AM-barn influences the usage of the gates. It is important to train the cows in how to pass the gates.

An optimal usage of the milking station is essential in AMS. Equal numbers of milkings/hour during the whole day give a maximal number of milkings. Roughage distribution only once or twice daily and periods with no roughage available, decrease the number of visits to the milking station.

## 2.3 Behaviour of high- and low-ranked dairy cows after denial of permission to pass the selection gate in an automatic milking system

### 2.3.1 Introduction

The optimal way to manage cow traffic seems to be somewhere in between free and forced cow traffic. One system in use is the placement of selection gates. A cow enters the gate from the resting area. She is recognised at the gate and the system decides if she is to be milked or not. If she has to be milked she is sent to the MU or a locked waiting area in front of the MU, otherwise she is sent to the feeding area.

Another system is the placement of selection by-pass gates. These work in a similar way as the selection gates but have only an exit into the feeding area. If the cow does not have to be milked she can pass the by-pass gate and if she has to be milked she can return to the resting area and from there into the MU. In this system a cow can also enter the MU without entering the selection gate and there is no closed waiting area. This system seems to give the most freedom to the cow (after free cow traffic) and still sufficient visits to the MU can be guaranteed. It is like free cow traffic until she has to be milked; if she has to be milked it becomes forced cow traffic.

However it is not known how a cow behaves after she is denied permission to pass the by-pass gate and how long it takes her to enter the MU. Also the role that dominance might play in this is unknown. In this experiment, high-ranking and low-ranking cows were studied after they were denied permission to pass a by-pass gate. Continuous observations were made on their place in the barn, their general activities and interactions with other cows.

### 2.3.2 Material and methods

*Animals, housing and feeding*
The study was conducted at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala (Hermans et al., 2002). The barn design, data collection and data handling procedure are described above (Figure 1). The barn was divided virtually into seven different areas: the milking unit, the feeding area, the selection gates, the passage, the waiting area, the resting area (excluding the cubicles) and the cubicles. The waiting area measured 40 $m^2$. During the study, an average of 46 cows were milked in the barn. Cow traffic was managed in a semi-forced way by two selection by-pass gates (SG) at the entrance to the feeding areas. Cows could pass through these gates from the resting area if they did not have to be milked. If cows had to be milked they had to pass the MU to get to the feeding areas. From the feeding areas cows could go back to the resting area by one-way gates. The minimum milking interval was set for each cow according to their stage of lactation (6 or 7 h). Four cows were also involved in another trial and had either a short or a long minimum milking interval (4 or 8 h). The mixed ration consisted of a mixture of silage (70% dry matter), hay (5%) and concentrates (25%) and was fed ad lib. in the roughage feeding stations.

*Selection of high and low-ranked cows*
In the period September 2001 till March 2002, a total of 76 different lactating cows were housed in the barn. The data from the feeding stations have been used to determine the dominance position of each cow (Olofsson, 2000). On the basis of this dominance value (DV), high-ranked (DV ≥ 0.600) and low-ranked (DV ≤ 0.400) cows of which more than

50% of the possible relationships were known and that were still being milked in the MU were selected. The selection consisted of 12 cows in each group, comparable on parity (2.1 ± 1.3, mean ± standard deviation), stage of lactation (166 ± 51 days) and milk production (27.6 ± 5.5 kg/day).

*Observations*

When a selected cow was denied permission to pass the SG (start of observation, $t_o$) she was followed until she entered the milking unit or the feeding area or for a maximum of 1 h. During that time every change in the behaviour of the cow was noted. Also the number of cows in the waiting area and the passage was written down every 10 minutes during the observations. Five observations were made per cow, resulting in a total of 120. Observations were made between April 9 and May 6 2002 during the daytime. No new observations were started during the hour before the MU was cleaned to be sure the observation was finished before the start of cleaning (cows must be able to enter the MU during observation and the maximum observation time was 1 h). Videotapes (24 h per day) were analysed to obtain enough observations within the one-month observation period. For the video-analysis the observation time was the whole day except for the cleaning periods and the hour before cleaning. The data were analysed with the SAS statistical package (SAS, 1996). A general linear mixed model (GLMM) was used to analyse the end time, the time spent in the different areas, the time spent lying, drinking and brushing and the number of changes in area. Times were analysed as absolute times (in seconds) and as times relative to the total observation time.

### 2.3.3 Results

*General*

A total of 120 observations were made of which 79 observations ended with the cow entering the MU, 37 observations lasted more than 1 h and 4 ended with the cow entering the feeding area (FA) without passing the MU (Table 11). Cows could occasionally enter the feeding area without passing the MU or by-pass by going through the one-way gates in the wrong direction. This happened when a cow leaving the feeding area kept this gate open for a while.

In the barn 49 direct observations were made and the rest were made by analysing videotapes. Only the observations ending in the MU or up to 1 h were analysed, resulting in a total of 116 observations.

*Table 11. The ending of the observations on high- and low-ranked cows divided in direct and video observations.*

| Ending of observation | High-ranked | | | Low-ranked | | |
|---|---|---|---|---|---|---|
| | Direct | Video | Total | Direct | Video | Total |
| Ending in MU | 17 | 22 | 39 | 13 | 27 | 40 |
| Ending in FA | 1 | 1 | 2 | 1 | 1 | 2 |
| 1 hour | 12 | 7 | 19 | 5 | 13 | 18 |

*End time*

For the analysis of the end time, the “real end time” of 1 h observations (the time from denial of permission to pass the by-pass until the cow entered the MU or the feeding area) was calculated from registered data. The first identification, either in MU or feeding area, was taken as the end time of those observations.

The end time of the observation depended on the number of cows in the waiting area at $t_o$, the time since the last food intake and an interaction between parity and time since last milking. If there were more than 4 cows in the waiting area at $t_o$, the end time was significantly longer than with 3 or less cows in the waiting area ($P < 0.01$; Figure 3). If the time since last visit in the feeding area was longer, the end time was significantly shorter (- 12.1 min/ h since last food; $P < 0.01$). Heifers with a short time since last milking (up to 7.5 h at the start of observation) had a significantly higher end time than heifers with longer times since last milking ($P < 0.01$; Figure 4) and tended to have a longer end time than higher parity cows with a short time since milking ($P = 0.050$). There were no differences between the high-ranked and low-ranked groups.

*Time spent in different areas*
The barn was divided virtually into seven different areas: the milking unit, the feeding area, the selection gates, the passage, the waiting area, the resting area (excluding the cubicles) and the cubicles. The observation ended when a cow entered either the milking unit or the feeding area. Measurements were made of the time spent in the other areas.

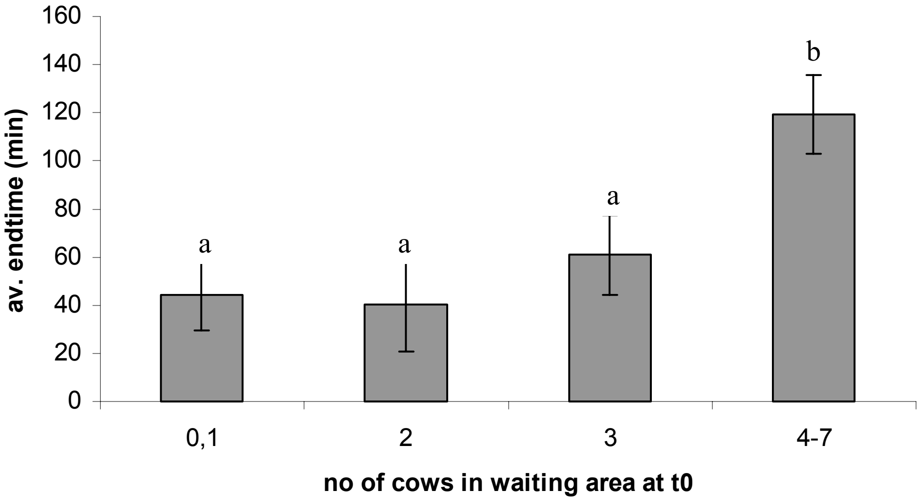



*Figure 3. Average end time versus number of cows in the waiting area at $t_0$. Different letters above the columns denotes significant differences between columns ($P < 0.01$)*

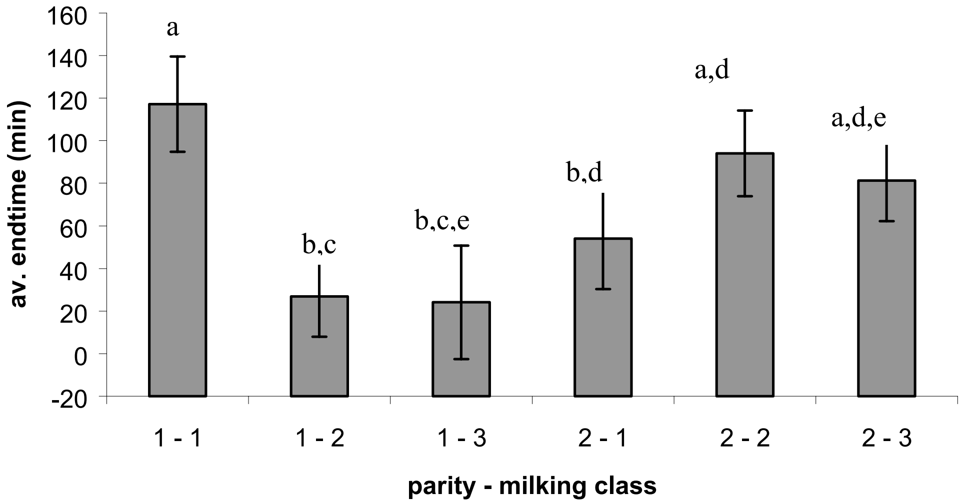



*Figure 4. Average end time versus milking class for heifers and higher parity cows. Different letters above the columns denotes significant differences between columns, a,c: P < 0.01; a,d: P = 0.0501; c,d: P < 0.05, parity 1 = heifers, parity 2 = higher parity cows (2-6), milking class 1 = time since last milking at $t_0$ up to 7.5 h, milking class 2 = between 7.5 and 9 h, milking class 3 = more than 9 h.*

*The waiting area.* The time spent in the waiting area depended on the number of cows in the waiting area at the start of the observation and on the dominance group. With zero or one cow in the waiting area the time spent there was significantly shorter than with 3 or 4 and more cows (8.0 versus 23.5 and 20.9 min respectively; $P < 0.001$) and tended to be shorter than with 2 cows (15.5 min; $P = 0.510$; Figure 5). Low-ranked cows spent significantly more time in the waiting area than high-ranked cows (20.2 versus 12.7 min; $P < 0.01$).

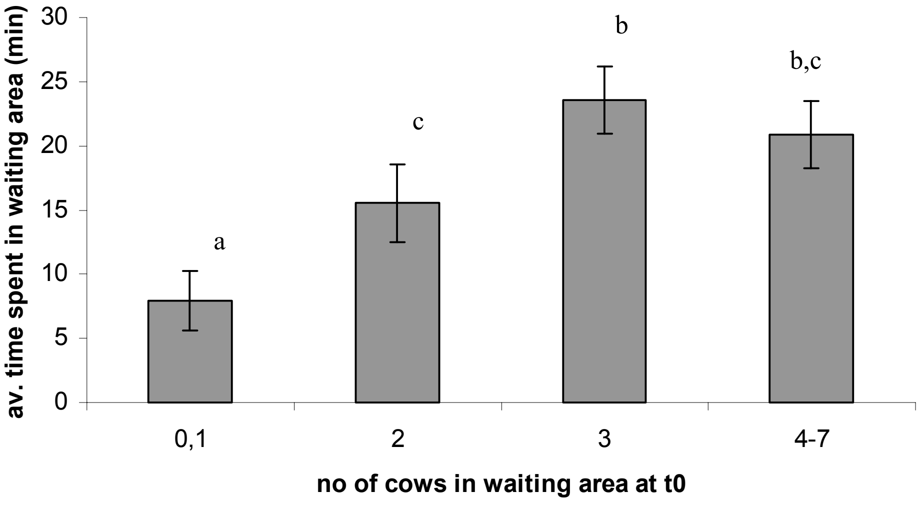



*Figure 5. Average time spent in waiting area versus number of cows in the waiting area at $t_0$. Different letters above the columns denotes significant differences between columns, a,b: P < 0.001; b,c: P < 0.05; a,c: P = 0.051*

*Social interactions*
Social interactions were not clearly visible on the videotapes and were therefore only analysed on the observations made in the barn. Of the social interactions only aggressive interactions (head butting) were analysed.

Aggressiveness was calculated as the relative number of times the focal cow was the actor in the total number of aggressive interactions she participated in during the observation. This depended on the number of cows in the waiting area at $t_0$, the interaction between the group and the end of the observation and the interaction between the group and the time since last milking. Cows were least aggressive with two cows in the waiting area (0.08 versus 0.51, 0.61 and 0.59 for 0 or 1, 3 and 4 to 7 cows respectively; $P < 0.01$). Low-ranked cows with 1 h observations were less aggressive than low-ranked cows entering the MU (0.15 versus 0.57; $P < 0.01$).

*Stereotypical behaviour*
Stereotypical behaviour was only seen during one observation of a cow rolling her tongue and during three observations of another cow licking a barn element or another cow. It was therefore not further analysed.

### 2.3.4 Discussion

*End time*
The time between entering the selection gate and entering the milking unit (end time) depended on the number of cows in the waiting area at the start of observation. If there were four or more cows, the end time was significantly higher than with three or less cows. It seems that cows are not motivated to go into the milking unit if there are too many cows waiting in front of it already.

The end time was shorter if cows had not eaten for a longer time. Thus, it seems that cows are more motivated to enter the milking unit if they have not eaten for a longer time. For the time since last milking we found that the end time was longer for heifers with a short time since last milking. We did not find a consistently shorter end time with longer times since milking, as we found for the time since last food intake. This means that a cow's motivation to pass the milking unit depends more on their motivation to eat than the motivation to be milked. This was also found by Prescott et al. (1998). The observations ending with the cow entering the feeding area without passing the milking unit (by going through the one-way gate in the wrong direction) are also evidence which support this theory.

*Number of cows in the waiting area and time since last food*
The time spent in the waiting area depended on the number of cows in the waiting area at the start of observation. More time was spent there with more cows in the waiting area. With short times since last food, more time was spent in the cubicle and spent lying. There seems to be an interaction between the time since last food (motivation to eat) and number of cows in the waiting area at $t_0$ (waiting time). A cow's decision to enter the waiting area depends on her motivation to get to the food and the time she has to wait to get there.

*Observations ending with the cows entering the milking unit and one hour observations.*
Cows motivated to enter the milking unit behave in another way than cows that are less motivated. Motivated cows enter the waiting area without much walking around, while less motivated cows drink water, brush and may lie down.

*Aggression*
High-ranked cows with 1h observations were most aggressive, followed by low-ranked cows entering the milking unit. Maybe the high-ranked cows that were not really motivated to get to the food, but were just trying to see if they could pass the selection gate. When they could not, they were frustrated and aggressive towards other cows.

Low-ranked cows have to wait a longer time to enter the milking unit and it is important that not too many other cows pass them. Maybe that is why they are more aggressive than high-ranked cows. High-ranked cows can just pass other cows without head butting.

*Differences between high-ranked and low-ranked cows*
The low-ranked cows spent more time in the waiting area than the high-ranked cows. This was also found by Ketelaar et al. (1996) in the daily time budget of high-ranked and low-ranked cows. Further the high parity high-ranked cows spent more time in the resting area than the high parity low-ranked cows. High-ranked cows also spent more time brushing and were more aggressive than low-ranked cows. Apparently after a denial of permission to pass the selection gate, the low-ranked cows try to get into the milking unit by waiting in the waiting area while high-ranked cows spent their time in the resting area and are more active. Maybe the high-ranked cows do not want to wait for their turn in the waiting area, but spend their time on other things until they can get in. Low-ranked cows have no other choice than waiting for their turn in the waiting area, because they cannot easily pass other cows standing there.

*Differences between heifers and higher parity cows*
The end time of heifers with a short time since last milking was much higher than that of heifers with longer times since milking and than that of older cows. But with most of these observations (16 out of 19) the heifers also had a short time since their last food, so they were not motivated to pass the milking unit. For the older cows with a short time since milking, the time since their last food was average, so they were maybe more motivated to enter the milking unit and had thus a shorter end time.

### 2.3.5 Conclusions

The choice of a cow to enter the waiting area, after a denial of permission to pass the selection gate, is mainly based on the time since last food intake and on the number of cows already in the waiting area.

Low-ranked cows spent more time in the waiting area, while high-ranked, higher parity cows spent more time in the resting area and more time brushing.

## 2.4 Possibilities of individual cow management in an automatic milking system based on performance and activity recordings.

### 2.4.1 Introduction and objectives

High potential dairy cows often show a negative energy balance at the beginning of lactation. The ability to consume large amount of feeds during the first 4 – 6 weeks post partum is limited, while the milk yield is at maximum 2 – 4 weeks after calving. Individual cows react differently to this negative energy balance, but there is an increased risk of metabolic disorders and reduced fertility. Stimulating even higher production through more frequent milking, while intake and access to feed are restricted due to guided cow traffic, might even worsen the problem. If the herd is composed of cows in all stages of lactation, there might be a need for individual settings of cow traffic, frequency of milking and feed quality in order to optimise the conditions for all cows and thus maintain good health and welfare.

The objectives are to study and implement:

- The influence of different milking frequency settings on performance parameters for different groups of cows. This will add knowledge to how varying milking frequency can be used for management purposes in herds with AMS.
- How on-line individual information of performance parameters could have a potential as health, oestrus and welfare indicators. Such information could be used to analyse the general barn status.

### 2.4.2 Material and methods

The study was conducted at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala. The barn design, data collection and data handling procedure are described above (Figure 1).

The semi-forced cow traffic system with selection by-pass gates was applied, and the cows could leave the feeding areas through self-closing one-way gates. During nights there was full lighting in all areas of the barn.

*Feeding*

The cows were fed a mixed diet ad lib. containing on DM-basis 70% grass silage, 5% grass hay and 25% concentrate. The dry matter content of the grass silage was measured once weekly. This diet was automatically delivered to the troughs by feeding wagons. Filling of troughs occurred at 05:00, 10:00, 16:00 and 19:00 and it was made sure that troughs never got empty except for cleaning. All cows had access to 2 kg DM of hay in one of the feed troughs in each feeding area. Additional concentrates were according to lactation stage with linear diurnal allowance, updating the allowed ratio every hour. The maximum daily amounts of concentrate fed in the dispensers were 11 kg for heifers and 15 kg for older cows. No cow was allowed to eat more than 60% of the ration as concentrates on a dry matter basis. At every milking the cows were fed 0.5 kg of concentrate in the milking unit. The maximum amount of concentrate fed in the milking unit was 3 kg per day. The mixed feed had a calculated energy content of 11.7 MJ ME per kg DM and a calculated protein content of 15.6% CP per kg DM. The mean dry matter content of the mixed diet over the trial period was 55.0%. The concentrates had an analysed energy content of 13.4 MJ ME per kg dry matter and an analysed protein content of 22.0% CP per kg dry matter.

*Experimental design*
A total of 30 cows of Swedish Red and White dairy breed (SRB), of parities 1-7 were in the trial that extended over the period September 2001 to June 2002 (Table 12). The cows were kept indoors throughout the experimental period. The average total number of cows in the barn during the period was 46 (min: 37; max: 52). The cows were observed until 19 weeks post calving beginning 8 to 19 days after calving. Before entering the AM-barn, the cows spent the first few days after calving in a pen together with their calves. The older cows had spent their previous lactation periods in this AM-barn. For the heifers, this barn was a new environment. During the time after calving until entering the AM-barn, the cows were milked two times a day.

*Table 12. Distribution of trial cows in different parities between the trial groups.*

| *Group* | *Parity 1* | *Parity 2* | *Parity 3* | *Parity >=4* |
|---|---|---|---|---|
| *Heifers, HF* | 5 | | | |
| *Heifers, LF* | 5 | | | |
| *Older cows, HF* | | 2 | 4 | 4 |
| *Older cows, LF* | | 3 | 4 | 3 |

Throughout the trial the cows were subjected to semi-forced cow traffic by assessing a time limit for milking permission. This time limit set the minimum milking interval for the cows. When within the time limit, cows had free access to the feeding areas through selection gates. Beyond this time limit cows were forced to pass the milking compartment to reach the feeding area. The cows were divided into two groups with either a high or a low milking frequency. The cows were monitored into a certain frequency by altering the time limit for milking permission. The low milking frequency group (LF group) was given a time limit for milking permission of 8 hours and the high milking frequency group (HF group) was given a time limit for milking permission of 4 hours, respectively, allowing a maximum milking frequency of three times and six times per day, respectively. The maximum milking interval was monitored by fetching cows two times a day. The cows in the low frequency group were fetched at the earliest 14 hours after the last milking and the high frequency 10 hours after the last milking. The target mean milking frequency with this strategy was 2.0 for the LF group and 3.5 for the HF group. At the 16:th week of the trial, all cows in the HF group switched from a high frequency setting to a low frequency setting and vice versa. They were then observed with these settings until the end of the trial at the 19:th week post calving.

*Data selection and analysis*
Body weight data was averaged over cow and trial day. Feed and water intake registration covers a total of 3552 cow days. Performance data was averaged per cow and day and per group and day. Because of the irregular milking intervals the milk production can better be expressed as milk yield per hour instead of milk yield per day. The milk yield (kg) was therefore divided by the milking interval (hour) of a cow. The milking interval per cow was calculated as the time difference between the start of one milking and the start of the previous milking.

A milking was defined as an overdue if the time difference of that milking and the time of getting permission to milk was more than six hours. In other words, a cow in the high frequency group was overdue for a milking if 10 hours had passed since last milking and for a cow in the low frequency group when 14 hours had passed. The frequency was then calculated as the number of milking occasions preceded by a fetching over the total number of milking occasions within a period of time. Individual data were analysed for indications of heat and diseases. A running standard deviation based on 10 days of data was calculated. A change greater than 1 standard deviation was considered to be an actual change.

### 2.4.3 Results and discussion

*Milking interval, milk yield and being overdue for milking*

The trial period was divided into five periods of analysis. Milking interval, milk yield and frequency of being overdue for milking are presented as means for each group and period (Table 13). Considering the mean intervals of the groups, the two LF groups reached a milking frequency just above 2 which was the target at trial start. But, the older HF cows reached a mean interval of a little more than 3, which is less than the targeted 3.5 milkings a day. For the heifer HF cows, with a mean interval of less than 3, the discrepancy from the targeted interval was larger. The problem of reaching a high milking frequency is also displayed in the difference between individual cows. The two most extreme cows in each group are shown in Table 13 as Min and Max. For HF heifers this difference is sometimes more than four hours (week 9-12).

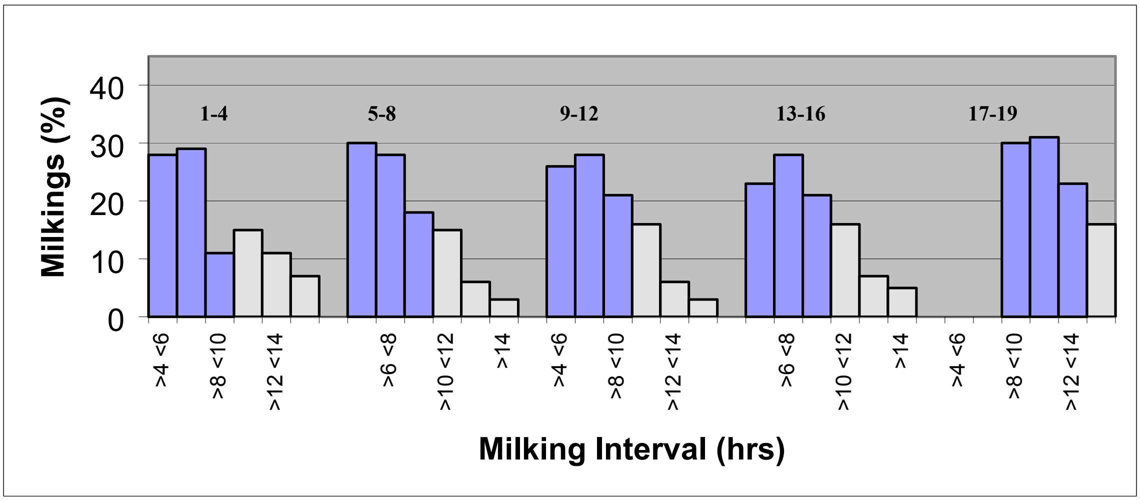
*Table 13. Milking interval (hrs), energy corrected milk yield (ECM, kg) and overdue frequency (%) of heifers and older cows with either a high (8 hrs) or a low (4 hrs) time limit for milking permission.*

| *Lactation number* | *Freq.* | *Weeks ppm* | *MF (per day)* | *Milking Interval (hrs) (Min-Max )* | *Kg ECM (SE)* | *% Overdue[1] (Min-Max)* |
|---|---|---|---|---|---|---|
| *Heifers* | *HF* | 1-4 | 2.8 | 8.7 (7.6-9.7) | 27.2 (1.1) | 32.5 ( 14.6-47.2) |
| | *HF* | 5-8 | 2.7 | 8.8 (6.6-9.7) | 25.5 (0.9) | 23.9 (4.6-42.9) |
| | *HF* | 9-12 | 2.8 | 8.7 (7.1-11.7) | 26.8 (0.7) | 24.7 (6.3-75.0) |
| | *HF* | 13-16 | 2.7 | 9.0 (7.2-12.1) | 27.0 (0.6) | 27.0 (6.4-67.7) |
| | *LF* | 17-19 | 2.1 | 11.5 (10.3-14.4) | 25.8 (0.7) | 15.5 (2.9-51.9) |
| | *LF* | 1-4 | 2.0 | 12.3 (11.2-14.6) | 26.5 (0.9) | 20.0 (13.3-44.4) |
| | *LF* | 5-8 | 2.2 | 10.8 (10.0-11.3) | 27.6 (0.7) | 3.3 (0.0-8.5) |
| | *LF* | 9-12 | 2.2 | 11.0 (10.2-11.6) | 27.1 (0.7) | 4.5 (0-12.7) |
| | *LF* | 13-16 | 2.2 | 11.1 (10.1-12.4) | 26.7 (0.6) | 5.7 (2.9-15.8) |
| | *HF* | 17-19 | 3.0 | 7.9 (6.7-8.8) | 26.9 (0.7) | 13.3 (2.8-33.3) |
| *Older cows* | *HF* | 1-4 | 3.2 | 7.5 (6.2-9.8) | 38.2 (0.8) | 13.6 (0.0-38.0) |
| | *HF* | 5-8 | 3.2 | 7.5 (5.9-10.1) | 39.5 (0.5) | 13.9 (1.0-54.5) |
| | *HF* | 9-12 | 3.2 | 7.6 (6.5-9.7) | 38.6 (0.5) | 11.9 (2.0-40.2) |
| | *HF* | 13-16 | 3.0 | 7.9 (6.4-9.8) | 37.6 (0.5) | 15.2 (2.0-40.3) |
| | *LF* | 17-19 | 2.2 | 10.8 (9.4-12.5) | 35.5 (0.7) | 5.9 (0.0-24.2) |
| | *LF* | 1-4 | 2.2 | 11.0 (10.0-12.7) | 36.6 (0.8) | 7.9(2.3-20.5) |
| | *LF* | 5-8 | 2.1 | 11.2 (9.7-12.7) | 38.1 (0.6) | 8.3 (0.0-30.2) |
| | *LF* | 9-12 | 2.1 | 11.4 (9.9-12.5) | 38.1 (0.6) | 12.0 (0.0-25.0) |
| | *LF* | 13-16 | 2.2 | 11.0 (8.6-13.1) | 36.7 (0.6) | 8.6 (0.0-28.9) |
| | *HF* | 17-19 | 3.0 | 7.9 (5.8-10.0) | 37.8 (0.7) | 15.6 (0.0-49.0) |

Overdue for milking was each milking with a milking interval>6 hrs since permission to be milked was given. That is 10 hrs since last milking for HF cows and 14 hrs for LF cows. Note the change from HF to LF and vice versa in week 17-19!

The milking interval is fairly constant over the first four periods (=16 weeks) for all groups but for the LF heifers. They begin with a mean interval of 12.3 hours in the first period to stabilise around 11.0 in periods two, three and four. The distribution of milking intervals over different time classes is presented for each group and period of lactation in Figures 6-9.

*Dry matter intake, water intake, body weight and energy balance*
Figures 10-13 show the dry matter intake, drinking water intake and body weight changes as group means for lactation weeks 2 to 19. Figure 14 shows the calculated energy balance in bars for each lactation period and group.




1

*Figure 6. The distribution of milking occasions among different milking intervals for HF older cows. Slatted bars indicate overdue milkings on basis of a maximum milking interval of 10 hours. Numbers above bars answer to period of analysis in weeks post partum. Note the change from HF to LF in weeks 17 to 19!*

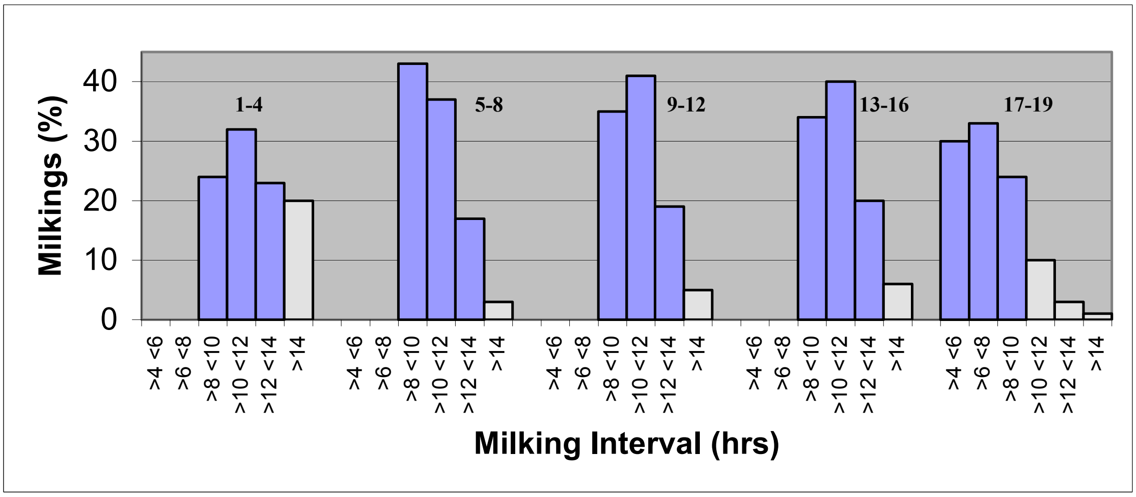



*Figure 7. The distribution of milking occasions among different milking intervals for LF older cows. Slatted bars indicate overdue milkings on basis of a maximum milking interval of 14 hours. Numbers above bars answer to period of analysis in weeks post partum. Note the change from LF to HF in weeks 17 to 19!*

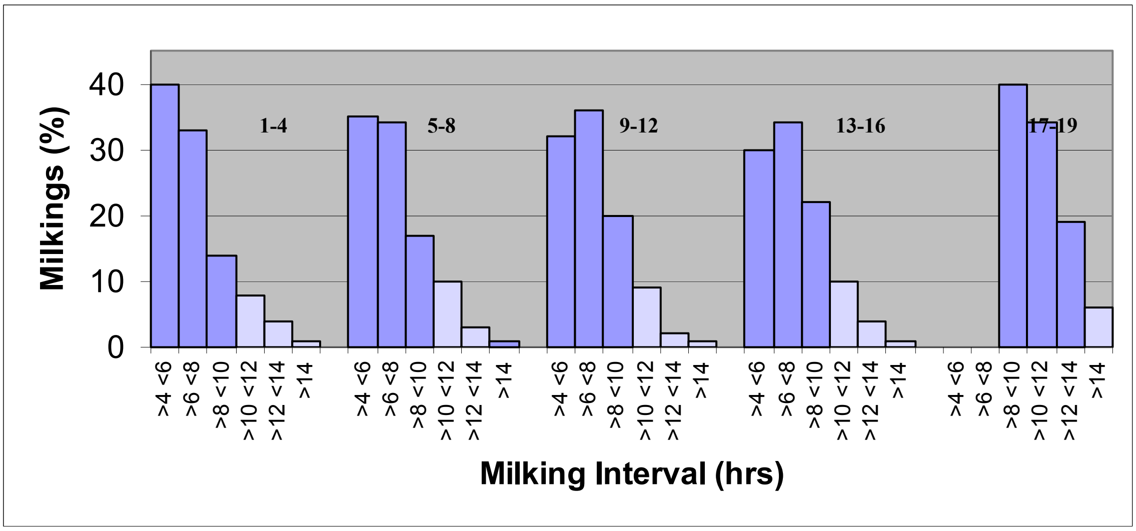



*Figure 8. The distribution of milking occasions among different milking intervals for HF heifers. Slatted bars indicate overdue milkings on basis of a maximum milking interval of 10 hours. Numbers above bars answer to period of analysis in weeks post partum. Note the change from HF to LF in weeks 17 to 19!*

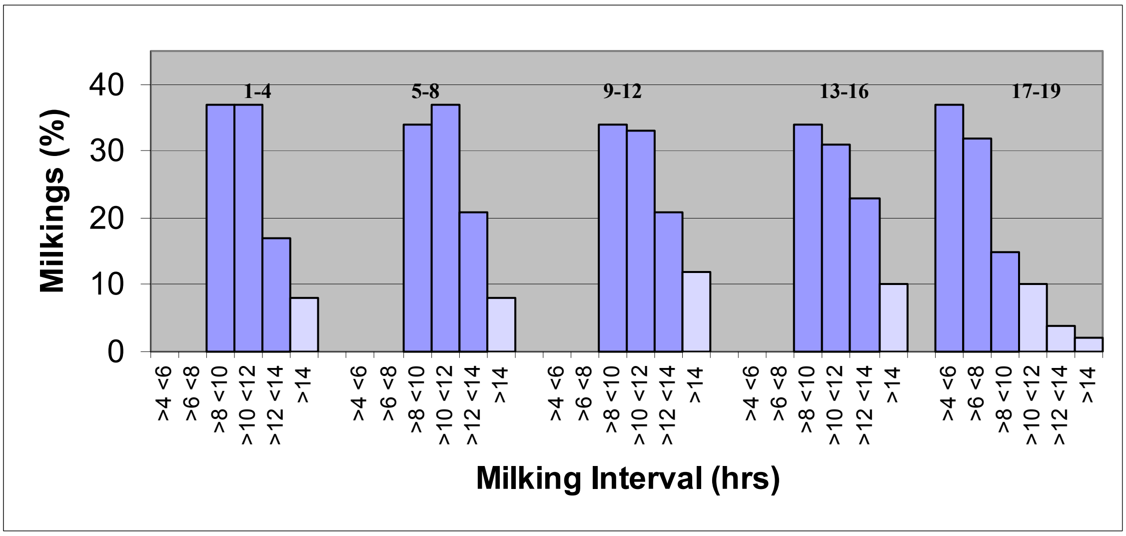



*Figure 9. The distribution of milking occasions among different milking intervals for LF heifers. Slatted bars indicate overdue milkings on the basis of a maximum milking interval of 14 hours. Numbers above bars answer to period of analysis in weeks post partum. Note the change from LF to HF in week 17 to 19!*

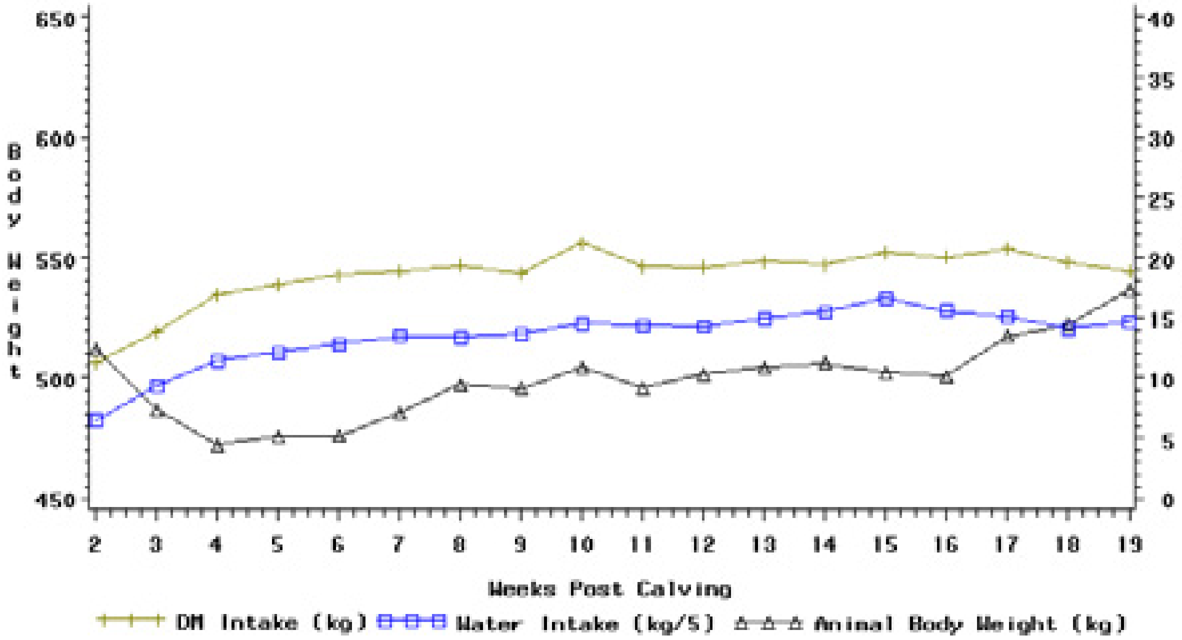



*Figure 10. Graphic display of dry matter intake, drinking water intake and body weight for HF heifers. Data is presented as means for each week of lactation post calving. Note the change from HF to LF in weeks 17 to 19!*

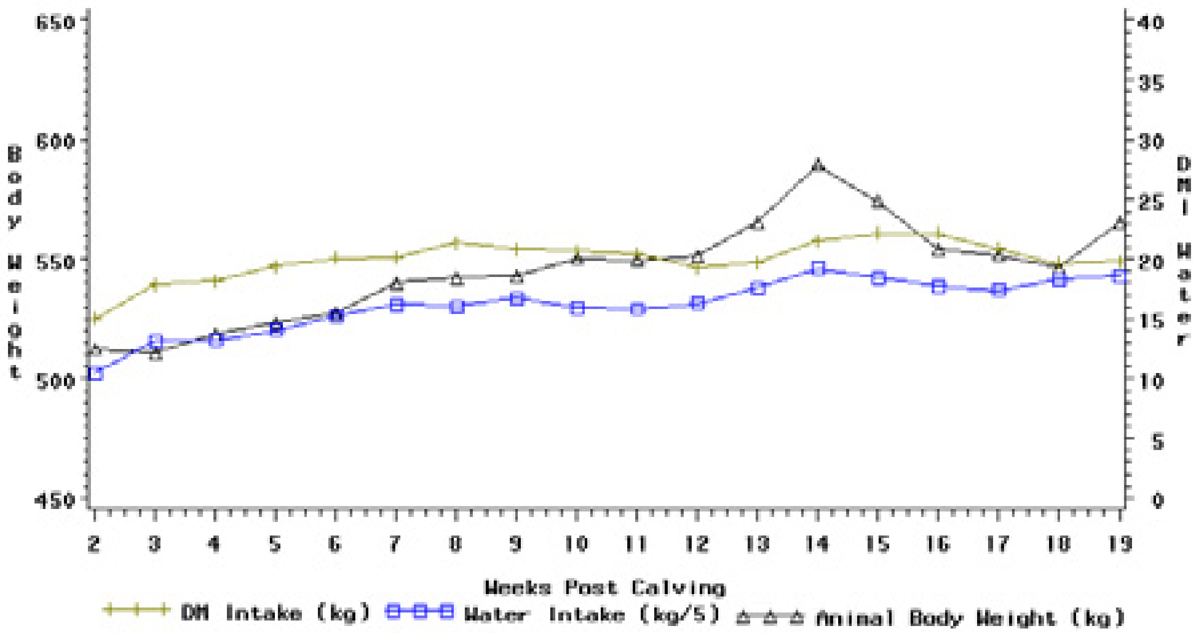



*Figure 11. Graphic display of dry matter intake, drinking water intake and body weight for LF heifers. Data is presented as means for each week of lactation post calving. Note the change from HF to LF in weeks 17 to 19!*

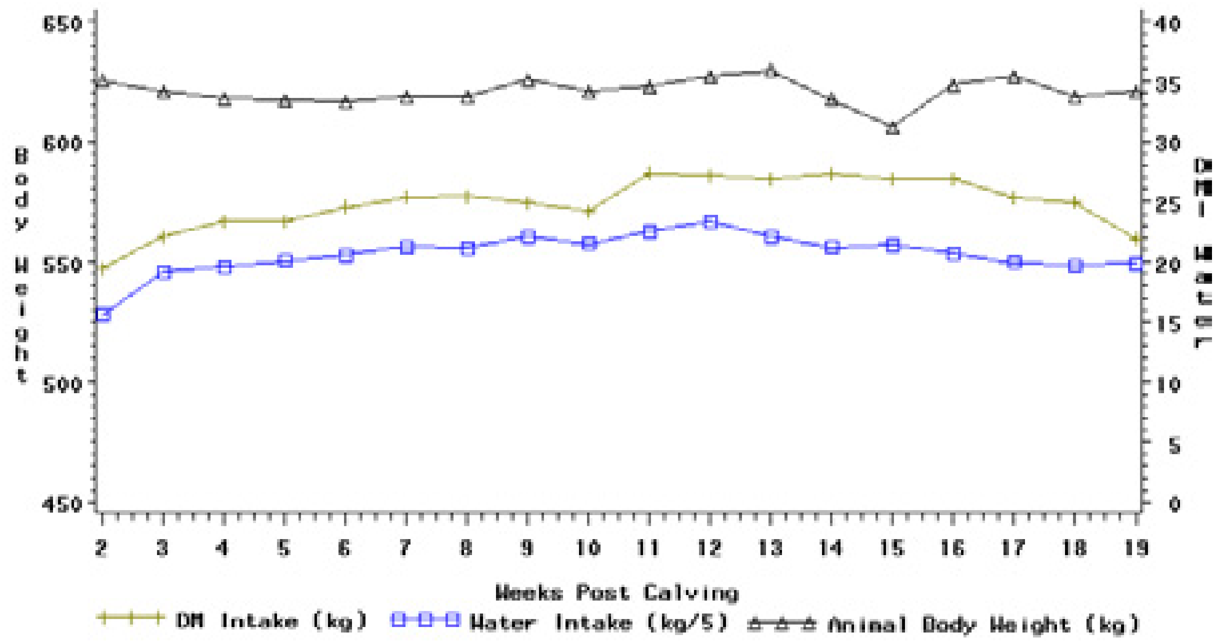



*Figure 12. Graphic display of dry matter intake, drinking water intake and body weight for HF older cows. Data is presented as means for each week of lactation post calving. Note the change from HF to LF in weeks 17 to 19!*

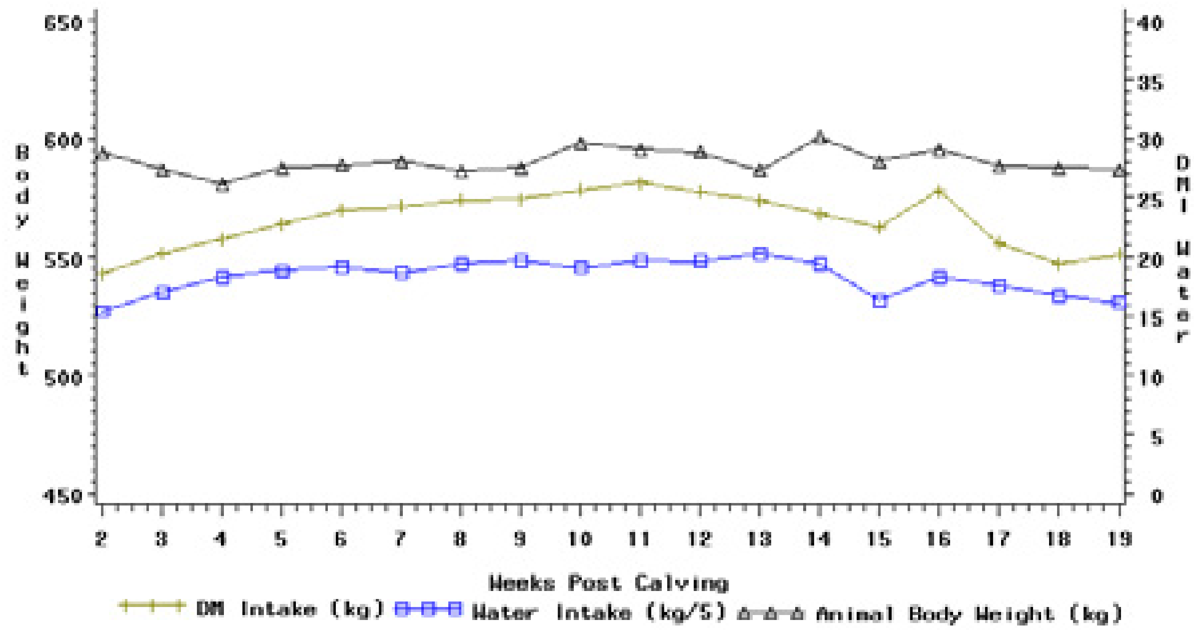



*Figure 13. Graphic display of dry matter intake, drinking water intake and body weight for HF older cows. Data is presented as means for each week of lactation post calving. Note the change from HF to LF in weeks 17 to 19!*

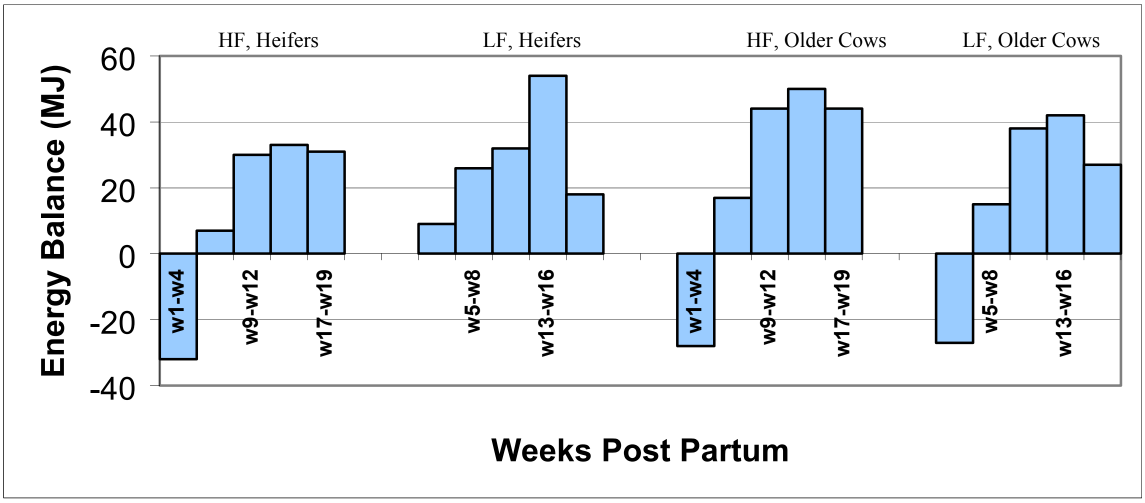



*Figure 14. Energy balance (MJ) for the four different groups. Each bar represents the mean value for the cows in one group during one period post calving. Periods are given as weeks post calving.*

The hypothesis that a higher degree of guiding challenges the cows' nutritional status is confirmed in the study. The increase in feed intake from early to mid lactation was slower for cows in the groups with a higher degree of guiding. This was more apparent for first calving cows. This results in a lower calculated energy balance in early lactation for HF heifers compared with the other groups of cows and a greater body tissue mobilisation shown as a negative body weight change the first weeks after calving. The combination of a higher milk output due to an increased milking frequency and prevention from free feed intake is not a good combination for managing cows the first weeks after calving. Given the wide range between individual cows in mean milking interval and percent overdue for milking, the need for individual management of dairy cows is apparent.

### 2.4.5 Conclusions

The conclusion is that with increasing degree of control and guiding in AMS, follows limitations of feed availability. This might decrease the possibilities of fulfilling the nutritional demands of the cow, with the risk of developing acetonemia. However, individual reactions to different degrees of guiding call for management systems with possibilities of individual settings. There are reasons to believe that such a system would benefit both animal performance and health and AMS capacity.

## 2.5 Illumination or dim light during night hours in AM barns

It is common practice to have full illumination day and night in AM barns. It is however questionable whether cows prefer or need dim light or darkness during night hours, and if that will affect the daily rhythms of the herd.

### 2.5.1 Material and methods

The study was conducted at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala (Forsberg et al., 2002b). The barn design, data collection and data handling procedure are described above (Figure 1). The resting area of the barn was divided into 2 identical sections by screening between the two central rows of cubicles and towards the feeding area and milking unit, but the passages remained unaffected. One half of the resting area had full lighting (app. 200 lux), while the other had dim light (5 – 7 lux) from 23:00 to 05:00 the following morning. After 3 weeks the lighting in the two sections was reversed. Study periods with full illumination in the whole resting area during two weeks before and two weeks after the experimental periods were included. Manual identification of every cow in the resting area and registration of her location (cubicle, with cubicle number, or scraper alley) and her occupation (standing or lying down) was performed every 12:th minute during 48 consecutive hours in the second and third week in each experimental period and once in the last week with full illumination.

### 2.5.2 Results and conclusions

The results of the studies with full lighting versus dim light (5 – 7 lux) from 23:00 to 05:00 the following morning did not reveal any obvious preference for a special side because of the illumination. The number of cows was very evenly distributed between the two parts of the resting area (Table 14). However, a number of individual cows seemed to prefer the light or the dark side and followed the changes, but there was no relation between ranking order and choice of light (Figure 15).

*Table 14. Average distribution of the cows during night (23:00 – 05:00) and daytime with full illumination in the whole resting area compared to full illumination in one side of the resting area and dim light on the other side*

| Time of day | Full illumination in both sides of the resting area | | Full illumination on the left side and dim light on the right side of the resting area | | Full illumination on the right side and dim light on the left side of the resting area | |
|---|---|---|---|---|---|---|
| | Left side | Right side | Left side | Right side (5-7 lux) | Left side (5-7 lux) | Right side |
| 05:00-23:00 | 50 % | 50 % | 50 % | 50 % | 51 % | 49 % |
| 23:00-05:00 | 51 % | 49 % | 53 % | 47 % | 50 % | 50 % |

The conclusions of the study so far are:

1. No difference between full lighting or dim light could be seen on the herd level
2. The total number of milkings were not affected
3. The cows did not change their resting periods
4. Individual preferences of full lighting or dim light could be observed, but these were not due to ranking order.

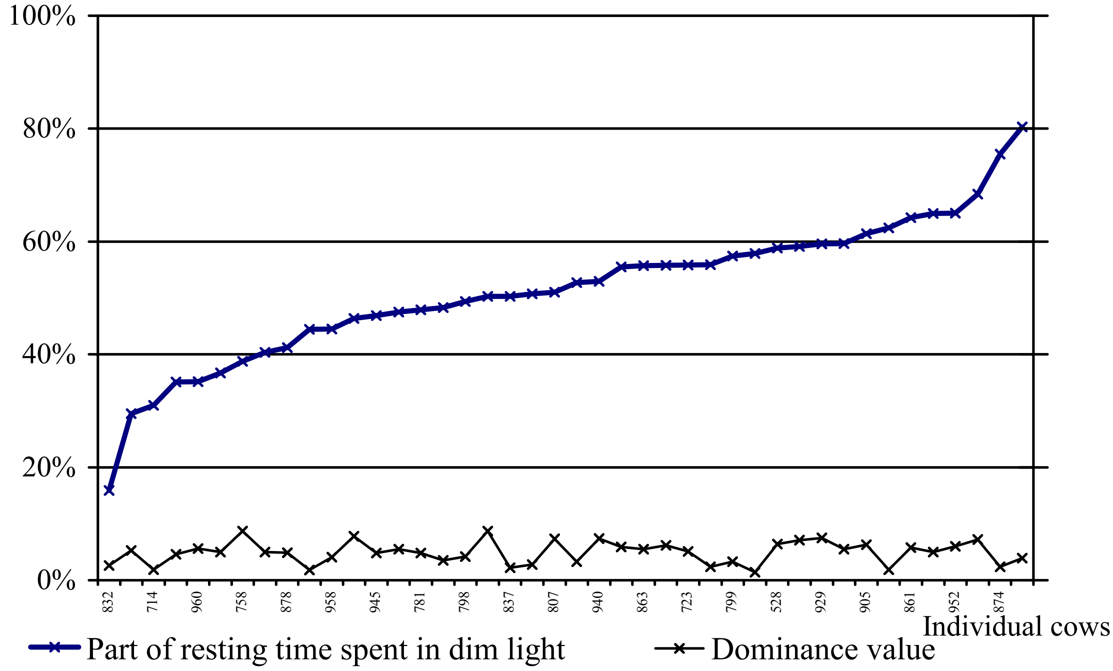



*Figure 15. Resting time from 23:00 to 05:00, distribution between fully illuminated or dim light in individual cows*

### 2.6 Behavioural and physiological stress response for cows with high or low social rank

#### 2.6.1 Introduction

One of the differences between a conventional milking system and an AMS is that the cows in an AMS can visit the milking unit voluntarily. The decision is probably based upon the cow's individual need. However, since a herd consists of both low and high-ranked cows, it is likely that there will be different milking patterns depending on the ranking order. A diurnal variation between high and low-ranked cows visiting the milking unit has been observed, where low-ranked cows prefer to be milked during the night (Ketelaar-de Lauwere, et al., 1996). High-ranked cows also seemed to visit the milking unit more frequently (Olofsson et al., 2000). How this influences the animal welfare of the low-ranked cows in particular has not been fully evaluated.

Animal welfare can be measured in several ways. One way is to measure the circulating levels of hormones related to the stress response, such as cortisol and oxytocin. Cortisol is usually related to stress, while oxytocin is related to anti-stress as discussed above . Furthermore, the behaviour of the animals and their time budget for different activities might also be indicators.

The aim of the present study was to identify the ranking order in the herd which is housed in the AMS, measure the highest and lowest ranking cows' hormonal response during milking and resting, and perform observations of their behaviour.

#### 2.6.2 Material and methods

During 2001 and 2002 a study was performed with the cows housed in an AMS (automatic milking system) at Kungsängen research station in Uppsala. In total 46 Swedish Red and White Dairy cows were housed in the system. The ranking order of the cows was automatically determined according to the method described by Olofsson (2000). The six highest-ranked and the six lowest-ranked cows were studied. Observations of the cows' behaviour (eating, resting, location in the barn etc) were made. The cows were filmed during 24-hour periods by nine video cameras covering the whole barn. Activities of the focal animals (six high-ranked and six low-ranked) were noted. Their behaviour during milking was followed and noted according to a special protocol during three different milkings for each animal. Kicking, trampling, eating, urinating and defecation behaviours were noted. Data concerning milk production and milking frequency were collected during a period of three months, and during this time the milk was analysed for its content of fat, protein, lactose and somatic cell count. Eight of the cows were provided with semi permanent catheters in the jugular vein in order to collect blood samples during resting and milking. Two milking occasions and resting periods were studied for each animal. The blood samples were analysed for the hormones oxytocin and cortisol by radio immunoassay technique. Measurements of the actual hormones were made in order to find an indication of the stress/anti-stress pattern of the animals.

#### 2.6.2 Results and comments

From the results it was observed that the low-ranked cows had the highest levels of oxytocin during both milking and resting. During resting the oxytocin values were 59 and 48 pmol/l for low and high-ranked cows respectively and during the milking the average values were 95 and 60 pmol/l. The low-ranked cows also had the lowest levels of cortisol in their blood. During resting the cortisol values were 12 and 17 nmol/l for low and high-ranked cows respectively and during the milking the average values were 22 and 36 nmol/l respectively for low and high-ranked cows. The results therefore indicate that the low-ranked animals were less stressed, which was not an expected finding. Interestingly the highest-ranked cow also had the highest level of oxytocin.

The milk yield was on average 2 kg higher in the low-ranked group, despite the milking frequency being on average 2.5 milkings in both groups. However, the higher production could be an effect of lactation stage since there was a 7.5-week difference between the two groups. But it could be an effect of different oxytocin levels as well. It has been indicated that there is a positive correlation between the hormone oxytocin and milk yield (Samuelsson et al., 1994). There was no difference in fat, protein and lactose content between the low and high-ranked cows.

However, it was indicated that the somatic cell count (SCC) in the milk was lower in the low-ranked animals. The SCC was in average 50 000 cells/ml in the low-ranked group while it was 63 000 cells/ml in the high-ranked group which also had the lowest cortisol levels. An interesting observation was that the cow with the highest SCC had the highest cortisol levels both during resting and milking.

The behavioural studies showed that the low-ranked cows had a more efficient eating pattern with less time spent in the eating area and fewer visits made to the feed troughs. However, sufficient amounts of feed were consumed. Instead of spending time in the eating area or in the alleys, these cows spent more time standing in the cubicles, suggesting that it is a more relaxing environment. The low-ranked cows were also found to be closer to the milking station, especially during resting, indicating a need for them to monitor the milking queue. Could the preference for resting close to the milking unit, and thereby more subjected to stimuli by sound from the unit, be an explanation for the higher levels of circulating oxytocin in these animals?

There was a difference in the pattern for visits to the milking unit. The low-ranked cows entered the milking unit more frequently during the night, which indicates that they had to choose the milking times when the high-ranked cows rested. There was no change in the behaviour observed during milking, such as tramping, kicking, urinating or defecation.

## 2.7 Use of welfare assessment protocol (D23) on the herd

### 2.7.1 Material and methods

The welfare protocol (D23) that has been developed by the Danish research team at Foulum is subjected to evaluation in the AMS herd at Kungsängen research centre in Uppsala. The protocol will be used at three separate occasions (April 2002, September 2002 and April 2003). In this way two tests will be done during the periods when cows are kept indoors and one test will include grazing.

The protocol includes, besides a description of the herd and the facilities, both behavioural and more health-oriented observations.

The behavioural parameters are: Behaviour during milking; Avoidance test; Resting behaviour; Getting-up behaviour; and General activity (time budget).

The behavioural part of the protocol will be evaluated by:

1. Estimating the variation within and between animals.
2. Adding more data. More data than are required by the protocol are collected for all behavioural parameters. Efforts will be made to find the optimal number of observations needed for each behaviour. This includes studies of variation.
3. Seeking other ways to measure welfare aspects. This is in a few cases done by testing new behavioural parameters to the protocol. Comparisons are also made with automatically recorded data from different data collecting systems in the barn in order to find cheap and easy ways to study welfare aspects in AMS.

The health oriented study includes observations of: Body score; Cleanliness; Fur condition; Parasites; Bruises; Hooves; General condition; Udder; Discomfort; and Lameness.

This part of the protocol will be evaluated by:

1. Comparing the protocol with a clinical study. This was done during spring 2002 when all cows were subjected to hoof trimming shortly after the welfare protocol had been used.
2. Estimating repeatability within the same observer. This was done in September 2002. All cows were examined according to the protocol routines by the same veterinarian two days in a row.
3. Estimating repeatability between two observers. This is planned for spring 2003 when two different veterinarians will examine the herd in order to evaluate differences in assessment between observers.

### 2.7.2 Results and comments

Only fragments of the collected data have been analysed so far and no results of the different parts of the protocol are available until all data are collected and analysed. However, some preliminary results and experiences can be listed.

Behavioural studies are time-consuming and consequently rather expensive. There is a great need to find cheaper and less time consuming ways to estimate welfare in order to make the protocol more suitable for practical use. For instance, the milking system can provide data concerning visiting frequencies and indicate disturbances during the milking process.

The variation in animal behaviour is considerable. For instance, the data analysed so far from the test in September 2002 showed an average "getting-up" time of 6 seconds. However the longest average time measured for one cow was 14 seconds while another cow on average rose from her cubicle in less than 3 seconds. The within cow standard deviation was in one case as high as 16 seconds. Further analysis is required before the measurement of this behaviour can be evaluated.

The herd at Kungsängen is adapted to handling and shows little or no fear of humans. This was shown in the avoidance test in September 2002. Out of the 45 cows that were tested, 43 showed an average avoidance distance of 0 m. The two other cows avoided the observer at an average distance of 0.5m. This is of course a credit to the staff who handle the cows. On the other hand, the herd may not be the most representative regarding this behaviour and lack of variation may obstruct the coming evaluation.

With the use of observations of fur condition and bruises it is possible to detect problems in the close environment. Such observations made it possible to find details in the barn that could be improved at Kungsängen fairly quickly.

## 3. General conclusions

The welfare of dairy cows in automatic milking systems (AMS) is dependent on several factors, related to the barn design and cow traffic systems, the cows themselves and social interaction with other cows in the herd, to feeding and nutritional supply, and general management, including the herdsman.

Three commonly used cow traffic systems: forced traffic, partially forced traffic (selection gate or by-pass gate) and free traffic, have been studied. It was shown that the number of cows and time spent in the waiting queue in front of the MU increased when more restrictions were introduced in the traffic system. At forced cow traffic, the average number of feeding visits was too low (3.9 visits/cow and day) to be optimal. A proportionally greater number of cows had to be fetched at the free traffic system because they frequently exceeded the upper limit for stipulated milking interval of 14 hours. It also resulted in greater variation in milking intervals. While both the forced and the free traffic system proved to be sub-optimal, forced traffic with a by-pass gate resulted in satisfactory feeding visits (6.5 – 7.1 visits/cow and day) and a low percentage of cows fetched for milking.

After denial at the by-pass gate, the cows' interest in going to the nearby waiting area and MU depended on the time since last feed intake and the number of cows already in the waiting area. Setting the upper time limit for entering into the feeding area through the by-pass gate at 4 h instead of 8 h (and the same for milking permission), increased the average milking frequency among older cows in early lactation from 2.2 times to 3.2 times during 24 h. Heifers showed a less favourable response, which indicates difficulties coping with the short time limit of 4 hours. Differences in the ability of individual cows to adjust to different degrees of guiding calls for management systems with possibilities of individual settings.

The cows seemed not to have any great preference for darkness during night hours. When comparing full lighting (app. 200 lux) with dim light (5 – 7 lux) from 23:00h to 5:00h the cows did not change their resting periods and the two areas with the two lighting conditions were on average equally visited and the total number of milkings was not affected.

The level of oxytocin and cortisol in blood, and cow behaviour at milking and resting, revealed that the low-ranked cows were less affected by the environment than the high-ranked cows. These cows also indicated that they cope well with the environment although there are small possibilities for them to act voluntarily and in a synchronised way.

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