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The effect of social rank on milking and feeding behaviour in automatic milking system for dairy cows

Tina Danielsson

Department of Animal Nutrition and Management

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Effekten av rangordning på mjölknings- och ätbeteende hos mjölkkor i system med automatisk mjölkning

Tina Danielsson

Supervisors:
Gunnar Pettersson, SLU, Department of Animal Nutrition and Management

Examiner:
Jan Bertilsson, SLU, Department of Animal Nutrition and Management

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Preface

This master thesis was conducted on the Department of Animal Nutrition and Management at the Swedish University of Agricultural Science (SLU) located in Uppsala. I wanted to specialize in a fresh area of knowledge, such as automatic milking, so that I would be in the front line of knowledge when I got my degree. I also wanted to write from a welfare point of view. When I saw that this work was announced I jumped at it immediately. Not only did it cover a very interesting subject in line with my goals, it also meant that I didn’t have to put my allergic nose into any stables and that I could write the paper from my home town.

Thanks to my boyfriend Sam for all the love and support. Thanks to all my new found friends during the education, Terhi, Linda, Elina and especially Karin – I was really looking forward to follow your career. And then it ended before it even had started. I miss you.

Also thank you Gunnar for all the help with the statistical analysis.

And thank you Hans –my boss that pushed me to finish this work!

Sammanfattning

Idag växer de automatiska mjölkningssystemen (AMS) i popularitet. I dessa system går korna lösa och måste själva ta sig till roboten för att mjölkas och till fodret. Kornas rang påverkar därmed deras välfärd. I denna studie har data från sju år i en AMS besättning analyserats. Målet var att undersöka hur kornas rang kan påverka beteendet vid mjölkning och foderintag. Hög rang sågs ge signifikant skillnad i mjölkningskurvans utseende om man jämför mot lågrankade kors kurvor. Det kunde också ses att de högrankade korna mjölkade mer. Detta kan eventuellt förklaras av att de högrankade korna åt oftare, men de åt inte mer totalt sett. Skillnaden i laktationskurvornas utseende kan också förklaras av ett kortare mjölkningsintervall hos de högrankade korna. Dessa faktorer påverkar inte bara djurens produktion men även välfärden hos de lågrankade korna pga. längre tid mellan mjölkningar etc. Att kunna hitta de lågrankade korna är av stor vikt för att kunna förbättra deras välfärd. I denna studie sågs att lågrankade kor kanske inte behåller sin rang hela stallperioden, 62 % av alla kor ökade sitt dominansvärde under laktationen.

Abstract

Today automatic milking systems (AMS) are growing in popularity. In these systems the cows are loose and have to get to the robot and the feed on their own. The cows ranking in this system affect their welfare. In this study data from seven years in an AMS was used and analysed. The aim was to investigate how ranking could affect the behaviour of the cows at milking and at feeding. It was seen that high ranking cows had significant difference in the shape of their lactation curve compared to the low ranked cows. And it was also seen that the high ranked cows were milking more. This might be explained by the high ranking cows eating more often, but they were not eating more in total. Further the difference in lactation curve could be explained by a shorter milking interval for the high ranking cows. These factors do not only affect the production but also the welfare of the low ranking cows due to long milking interval *etc*. Finding these low ranking cows is essential for being able to improve their welfare. In this study it was found that a low ranked cow might not stay low ranked the entire time in the stable, 62% of all cows had a rise in DV during lactation.

Introduction

According to Swedish law animals should be kept in environments where they are able to behave naturally (Notisum, rättsnätets hemsida, 02.02.09). Although a tied up system is allowed it won't fulfil this requirement as the cows cannot move and the welfare of the cows is then impaired (Müller *et al.*, 1989). Cows tied up have the hypothalamus-hypofysial-adrenal axis stimulated which is a sign of bad welfare (Ladewig & Smidt, 1989). From an animal welfare point of view the loose housing system therefore is a better option. Because of this reason nothing but loose housing systems should be built after the first of august 2007 in Sweden (Jordbruksverkets hemsida, 02.02.09). With a loose housing system one can either have automatic or parlour milking. With an automatic milking system (AMS) you can save work, get more milkings and other advantages. With these advantages at hand it is not surprising that the AMS is gaining popularity. According to a prognosis one third of all European milk farmers will change to automatic milking between 2000 and 2015 (Phillips, 2002). Although advantages with AMS and the technique involved -there are drawbacks. These have to be maintained at a minimum as the system plays a major role for the welfare of European cows. In this study a review of pros and cons with AMS has been made. Further the welfare of cows with different ranking is discussed.

The main aim of this study was to see how different factors in milk production in an AMS are affected by the ranking of the cow. Is an eventual difference in milk production between high and low ranking cows due to difference in milking behaviour or in feeding behaviour? The factors involved have been studied before but not with the large amount of animals as in this study. If differences between high and low ranking animals can be proven, effort in research should be taken to reduce these differences for the productions sake and perhaps also for animal welfares sake. If the number of visits to the milking unit (MU) and the frequency of these visits differ for low and high ranking animals it could affect the amount of milk produced. And if the high ranked cows get milked in the more popular hours the low ranked might have to wait longer between their visits and hence have a reduced milk production and perhaps a reduced welfare. The eventual difference in production might also be due to difference in feeding behaviour; number of feeding visits, the amount consumed every visit and the total consumption. This study also investigate if the ranking of a cow changes during her lifetime, e.g. after parturition, as the studies made in this subject have contradictive results. If cows change ranking their milk production might be changed according to eventual differences in milking and feeding behaviour. Then eventual strategies for eliminating these differences between different ranking cows might go wrong if not the cows ranking in the system is changed when her actual ranking is changed. The system might also not work if there are cows not of certain ranking, so called "avoiders". In this study different methods of picking out these cows have been thought of.

Aim of the thesis

The overall aims of this thesis were to investigate how ranking affects feeding and milking behaviour of dairy cows in automatic milking systems.

The specific aims of this thesis were to:

- Describe the ethological background of ranking in dairy cows
- Describe pros and cons with automatic milking systems with focus on welfare of the cows, and how automatic milking systems affect welfare of low ranking cows
- Investigate associations between ranking of the cows and
    - Live weight
    - Milk yield
    - Milking interval
    - Milking frequency
    - Time between feed visits
    - Length of feed visits
    - Feed intake
- Investigate how and why changes in ranking occur
- Investigate how a closed versus open waiting area affects ranking

Literature review

What determines dominance

Dominance is defined as an animal inhibiting another from getting access to a resource (Beilharz & Zeeb, 1982). Ranking in a group contains all of those dominance relations between animals. Social rank, rank order, peck order, dominance and hierarchy are all different words used to describe this phenomenon. The dominance relationship of any pair of cows is a result of learning when they meet, with many different factors involved (Beilharz & Zeeb, 1982). These rank deciding factors are for example, age or lactation number (Schein & Fohrman, 1955; Friend & Polan, 1974; Beilharz & Zeeb, 1982; Kabuga, 1992), weight and size (Schein & Fohrman, 1955; Friend & Polan, 1974; Sambraus, 1977; Kabuga, 1992) (that in turn are correlated with body weight (Friend & Polan, 1974)), feelings, fears, sensitivity and emotionality (Phillips, 2002), health (Beilharz & Zeeb, 1982), milk production (Friend & Polan, 1974) and perhaps having horns or not (Beilharz & Zeeb, 1982). As these factors change, rank might change accordingly. Also gestation might affect the rank according to Beilharz and Mylrea (1963). They showed that pregnancy leads to a slight drop in DV in heifers. Ketelaar-de Lauwere *et al*. (1996) showed that DV rises as the lactation proceeds. Heat has also been found to increase the ranking of cows (Phillips, 2002). The reason for this might be that they need to find a mate when they are in heat and therefore compete more than when they are in gestation (Beilharz & Mylrea, 1963). But according to Boiussou et al. (2001) referring to a study by Boiussou (1985, in French) neither oestrus, ovariectomy nor pregnancy modifies social rank.

Movements to settle the rank varies from a small gesture or threat to head to head butting or pushing i.e. frontal fighting (Albright & Arave, 1997). The amount of physical interactions and aggressions go down as the rank is getting established (Albright & Arave, 1997; Kondo & Hurnik, 1990; Lindberg, 2001) and fights are only seen in newly formed groups the first days or hours (Bouissou et al., 2001). Already the second day the aggressions are twice as infrequent as in the first hour (Brakel & Leis, 1976). With an increasing group size the time necessary to reach social stabilization is increased (Kondo & Hurnik, 1990). Also if the resources available need to be competed for it can prolong the hierarchy formation time. As the aggressions diminish only an interaction of threats such as a slight head swing from the dominant animal and submissive behaviour such as a little avoiding movement from the subordinate is enough to confirm status (Jensen, 1993; Bouissou et al., 2001; Phillips, 2002). It is only when this interaction fails that aggressions and prolonged fights occur (Jensen, 1993; Lindberg, 2001). The entire goal with having a hierarchy is to avoid aggression since cows don´t want to challenge each other too often as it takes energy and always contain a risk of injury (Lindberg, 2001). Especially heavily pregnant cows seem to avoid aggressive interactions (Beilharz & Zeeb, 1982).

In establishing social ranking tactile interactions, such as grooming, are also very important (Albright & Arave, 1997; Bouissou et al., 2001). Grooming confirms dominance and friendship (Phillips, 2002). Adult animals also become friends by grazing together. Licking (allogrooming) is independent of rank but is a sign of social competence (Phillips, 2002; Val-

Laillet *et al*., 2009). Smell does not affect the establishment of social rank (Albright & Arave, 1997), although it might trigger animals to become more aggressive (Klemm *et al*., 1984). Between dams and offspring (Reinhardt & Reinhardt, 1981), twins (Ewbank, 1967) and calves reared together (Boissou & Andrieu, 1978) preferential relationships are often seen, i.e. spatial proximity, reduced aggressiveness, enhanced positive interactions and tolerance in competitive situations.

When a dominance relationship between two animals is established it lasts for a long time (Sambraus, 1977). But sometimes a subordinate cow will displace or try to displace a dominant cow, or will not yield to a dominant animal (Wierenga, 1990). The occurrence of these aberrant interactions is induced and enhanced by the housing and the management systems. Particularly during crowded conditions social dominance may affect an animal´s chance of obtaining resources (Wierenga, 1990; Alm & Möller, 2004). If an important resource becomes restricted the animal´s motivation to engage in physical forms of agonistic interactions will be stronger (Kondo & Hurnik, 1990). Friend and Polan (1974) showed that a restriction of feed is highly correlated with effect of social dominance. The more intense the competition the stronger the correlation between food intake and DV will be (Friend *et al.*, 1977). Group composition and size, age, sex, the level and duration of the overcrowding and social experience of animals could also play a significant role in how much aggression that will occur (Kondo & Hurnik, 1990; Wierenga, 1990).

High ranked animals get more fitness pay-offs in the wild; more matings and priority of access to other resources (Mendl & Held, 2001). Hierarchy changes with time and that might be a reason for a low ranked animal to stay in the group in spite of negative fitness pay-off (Lindberg, 2001; Mendl & Held, 2001). They might also benefit from group protection and food-locating abilities by more dominant animals (Lindberg, 2001). But when low ranked animals cannot leave the group despite negative fitness pay-off, like in our domesticated herds, it can lead to uncalled-for aggressions and the subordinates might be the recipients of high levels of aggressions (Mendl & Held, 2001). Also in captivity the animals are not kept together long enough for the dominance value to improve so that it could outweigh the costs for being subordinate. Dominant animals in a cattle herd have priority when there is a competitive situation, for example at the feeding site (Friend & Polan, 1974; Kabuga, 1992) or when resting places are restricted (Metz & Mekking, 1984; Wierenga & Hopster, 1990). Dominant animals also get the best part of a pasture (Phillips, 2002), and probably also the best stalls when indoors. Further a small negative correlation between dominance and mastitis milk has been found (Friend & Polan, 1974). In summary low rank seem to give lower welfare, especially in our modern intensive keeping of the animals (Phillips, 2002). But cortisol levels are not higher in bullied animals according to Albright & Arave (1997). Neither a hormonal study done by Alm and Möller (2004) did show that low ranked cows would be stressed by their status. Whatever the case is about ranking and welfare at least ranking could affect the farm economics. Dominant cows produce more milk with limited access to feed because they get more access to the feed (Albright & Arave, 1997). It can also be an effect by them being more able to adapt their visiting pattern according to the feeding system (Ketelaar-de Lauwere *et al*., 1996) and therefore may keep a more even milking frequency –hence a higher yield (Ouweltjes, 1998). Low ranked cows cannot do as they please in the same extent. Low ranked cows adapt their time schedule more than dominant cows (Morita *et al.*, 1996). The low ranked cows had to wait for the dominant cows to eat first when feeding space was restricted. Olofsson (1999) did also find that cows of low social rank tended to adjust their eating behaviour to a greater extent than the more dominant cows, especially when the competition of resources was increased. According to Wierenga (1990) cows prefer lying at night, but when there was a higher crowding in the pen the low ranked cows were forced to lie less in the night. Also a study done by Wierenga and Hopster (1990) showed that overcrowding was no problem for the high-ranked animals but for the low ranked the effect of overcrowding was considerable. All these factors might affect the low ranking cows' production negatively.

To measure dominance

Access to space is the most common way of measuring dominance values and then most often the agonistic meetings that occur in e.g. an aisle are measured (Potter & Broom, 1990). The cow that "wins" the encounter gets a value of dominance (Albright & Arave, 1997). Every animal has to meet in order to receive an accurate dominance value (DV). Lowest possible variance would occur if all animals dominated exactly 50% of all other animals, or if every animal won 50% of all its encounters with every other animal (Beilharz & Zeeb, 1982). Variance decreases as herd size increases. For highest accuracy ranking data should come from a period in time where the quota between physical and nonphysical agonistic interactions is stabile (Kondo & Hurnik, 1990). The calculation of a dominance value is a useful method of summarizing the relationships existing in a group (Wierenga, 1990).

Arave and Albright (1981) say that dominant animals initiate more herdmate encounters, but more aggression is shown between animals widely separated in DV. Phillips (2002) on the other hand tell us the opposite; that animals close in rank have to prove themselves more often than animals further away on the scale. In many pairs of cows both members displace each other (Wierenga, 1990). In a study by Wierenga (1990) this occurred in 41.1 % of the pairs. Between these animals close in rank there are triangular and rectangular ranking orders (Albright & Arave, 1997). Also bigger groups contain more triangular or complex relationships and perhaps more swaps of dominance, and therefore more aggressions (Lindberg, 2001). The dairy herds of today have more complex orders of rank than feral herds that have more linear orders (Albright & Arave, 1997). It has been shown that no cow is dominant over every other in a conventional herd (Beilharz & Zeeb, 1982). These complex hierarchies are probably due to the fact that dominance rank is group specific and animals in these herds not always stay in the same group, but are regrouped when dried off, at calving and diseases etc (Beilharz & Zeeb, 1982; Lindberg, 2001). Hierarchies do not only differ between groups but also between different resources (Phillips, 2002). The hierarchy differs for example between space, feed, water, partnership and milking (Albright & Arave, 1997; Phillips, 2002). Hierarchies differ for different resources but many hierarchies correlate though. In a study by Olofsson *et al*. (2000) the DV from the succession order in the MU correlated significantly with the DV from the feeding area. But according to an older study by

Soffié *et al*. (1976) there was only a low positive correlation between the order of entrance to the milking parlor and the dominance order based on food competition test.

A dominance order constructed from known dominance relationships is always very complex. Owing to the various effects of housing and management systems, the chances for a cow to obtain resources can only be predicted to a limited degree from her DV. According to Kondo and Hurnik (1990) estimations of social hierarchies have errors from different motivational needs, surroundings and the ability of the observer to see/record subtle non-physical interactions. Wierenga (1990) enumerate aberrant interactions, triangular relationships and individual variation in frequency and direction of interactions to affect a prediction. It is important to remember that low, middle or high rankings do not tell us anything about the individual only how it is in relation to other individuals.

Access to resources often lead to aggressive encounters within an established group (Phillips, 2002). Some individuals find some resources more important to fight for than other. Motivation is the main determinant of this and the motivation varies a lot between individuals (Albright & Arave, 1997). Udder pressure can for example be one motivator where the high producing animals might be most motivated to get milked. If a cow doesn’t get milked it leads to discomfort and a more frequent urination, a sign of stress (Stefanowska *et al*., 2000). Milking is therefore a priority resource as it is a relief to lose the udder pressure but also because the cow gets food afterwards and/or during the milking (Albright & Arave, 1997; Phillips, 2002). The high producing animal might not only get a bigger reward as it has higher udder pressure but it also gets a bigger reward with the feed in the robot as it might be hungrier than the low producing (Phillips, 2002). Especially in early lactation the high producing cows might be hungrier as the gut is involuted then. A study by Prescott *et al*. (1998) supports these ideas as it showed a tendency for high yielding cows to choose to get milked 3.3 times per day compared to the low yielding who got milked 2.1 times a day. The same study showed that when cows were allowed to choose between getting milked and having feed all cows chose feed. Getting feed therefore seem to be more important than getting milked for the cows. Also a study done by Winter and Hillerton (1995) showed that feed is more important than getting milked for the cows. The fact that the number of visits to the milking unit significantly increases accordingly when concentrates are fed there, independently of cow traffic system, also supports this theory (Prescott et al., 1998; Land-Van´t *et al*., 2000). The quality of the concentrate influence how large this effect is (Land-Van´t et al., 2000). According to Phillips (2002) space also is more important than getting milked as order of entry into the milking parlour is less keenly contested than access to space.

Dominance value and weight and age

Ketelaar-de Lauwere *et al*. (1996) found no correlation between DV and age or lactation number. Kabuga *et al*. (1991) did not either find a correlation between age and dominance. But Arave and Albright (1981) found a high positive correlation between DV and age. Friend and Polan (1974) also found a positive correlation between dominance and age. Collis (1976) found a significant negative correlation between dominance value and height at withers but no correlation between DV and body weight. Kabuga *et al*. (1991) did not either find a correlation between weight and dominance. Correlations between body weight and dominance have on the other hand been demonstrated by Schein and Forman (1955), Beilharz *et al.* (1966) and Arave and Albright (1981). Friend and Polan (1974) found a positive correlation between dominance and body weight.

Dominance value and milking and feeding

The studies made show no difference in milk yield between high and low ranking cows as long as no deprivation of food occurs (Albright & Arave, 1997; Phillips, 2002). This is supported by a lot of studies which have found no correlations between dominance value and milk yield (Collis, 1976; Soffié *et al*., 1976; Friend & Polan, 1978; Beilharz *et al*., 1966; Ketelaar-de Lauwere *et al*., 1996). But also by other studies where a correlation between dominance and intake of concentrate and therefore with milk yield have been found (Beilharz, 1979; Beilharz & Zeeb, 1982).

Hierarchy differs for leadership; in voluntary movements the middle ranked animals go first followed by the high ranked, the low ranked come last (DV based on aggression index from encounters) (Arave & Albright, 1981). But in the forced movements, like herding cows from pasture, the low ranked go first. Milking order is considered a free, voluntary, movement by Winter & Hillerton (1995). Soffie *et al*. (1976) found that the order of entrance of the herd to the milking parlor was systematic. The same animal lead at the exit of the yard and at the entrance to the milking parlor; the order of the rest of the herd was not the same. No correlation between milk production and milking order was found. Other studies say that there are some tendencies for dominance order in entering the milking parlour but mostly it is the high lactating animals that go first (Gadbury, 1975; Rathore, 1982). This doesn´t seem to apply for cows with subclinical mastitis, because then the cows avoid getting milked probably as it might feel unpleasant (Rathore, 1982).

The same milking order is not as important for the cow as getting milked the same time every day (Phillips, 2002). To get this regular milking frequency the cows need a regular daily rhythm in feed consumption (Pirkelmann, 1992). Cows go to the roughage to eat seven to ten times a day in average if they have free access to roughage. Dairy cows are mainly diurnal feeders being active during the day and resting at night (Potter & Broom, 1990; Pirkelmann, 1992; Millar, 2000). This inherent rhythm is seen in today’s cow keeping. In the night (between 02:00 and 06:00 h) hardly any cow was seen eating in a study by Wierenga and Hopster (1990). Morita *et al*. (1996) found that the percentage of time spent per hour on meals from midnight to early morning appeared to be lower than that during the afternoon. The lowest milking frequency in an experiment by Wendl *et al*. (2000) was between 00.00 and 05.00- 06.00 in the mornings and the most milkings/hour in the study occurred in the mornings and not in the afternoons. According to Land-Van´t *et al*. (2000) cows want to visit the robot the entire day but a reduction occurs during the early morning hours (04.00-05.00 to 07.00-08.00). In a study by Olofsson *et al*. (2000) there was an even distribution of feeding and milking visits, only slight decreases in late night and early morning was observed. There was a distinct drop in visits during the cleaning of the MU. Millar (2000) suggests that factors for it being more attractive to get milked during the later morning and during the day other than daily rhythm could be that new feed is offered or that the MU is being cleaned. In the study by Wierenga & Hopster (1990) it was shown that the cows spent in average over four hours at the feeding rack each day. Time spent at the feed bunk is not predictive of dry matter (DM) intake when an abundance of space at the feeding is available (Friend *et al.*, 1977). Some cows utilize time at the feeding place more efficiently than other cows.

Many studies have shown that nights and early mornings (00.00 h to 06.00 h) seem non-attractive times to get milked on and that high ranking cows avoid getting milked then (Ketelaar-de Lauwere *et al.*, 1998; Olofsson, 2000). In addition it has been shown that high ranked cows visit the milking station more often between 12.00 h and 18.00 h than low ranked cows (Ketelaar-de Lauwere *et al*., 1998). Besides that high ranked cows can choose to get milked in attractive times they can also pass the milking station more often (Olsson, 2000). The low ranked cows did not get milked to the same extent as the dominant ones when there was a queue to the robot, as after cleaning. Mehlqvist (2003) found a tendency for high ranking cows to get milked more often between 06.00 h and 12.00 h. It was also found that low ranking cows spent their time in the early mornings closer to the robot, probably to find an opportunity to go and get milked without confronting high rank cows. The high rank cows preferred to rest further away from the robot, probably due to the fact that it is calmer there.

According to Ketelaar-de Lauwere *et al*. (1996) AMS trigger effects of dominance as they found the dominance value to be positively correlated with milking interval. The higher dominance value the more frequent were the visits to the robot. Also the more dominant cows spent less time waiting in the waiting pen and they could enter the robot without waiting more often. Cows with lower rank spent more time in the waiting area and also left it more often without getting milked (Ketelaar-de Lauwere *et al*., 1996; Ketelaar-de Lauwere, 1999). Olofsson *et al*. (2000) could also show that the dominant cows could get through the MU more often than the low ranked cows. But Albright and Arave (1997) found that high producing cows were entering the milking parlour more often than the low producing, independent of rank. Another study also showed that the total number of visits and the total time the cows spent lying or eating was not correlated to dominance (Ketelaar-de Lauwere *et al*., 1996).

Kabuga (1992) found that low status cows ate less frequently than medium and high status animals, while middle ranking cows were pushed out from the troughs more frequently than other dominance groups. A difference in eating behaviour between the dominance groups was also noticed by Mehlqvist (2003). The high ranking cows spent significantly more time in the feed section and tended to have more visits and meals there. They ate for a longer time than the low ranking cows, but there was no difference in feed consumption which indicated a difference in intake speed between the two groups. The dominant cows had more feedings – especially when they passed without being milked –than the low ranked cows also in a study by Olofsson *et al*. (2000). But this did not lead to a larger total consumption – they just had more small meals. Morita *et al*. (1996) found that when cows increased their daily roughage intake they did it by increasing the meal size rather than by increasing meal frequency. Friend and Polan (1978) showed that dominance value had little importance in describing dry matter intake. There have also been results supporting no correlation between feeding behaviour and

DV. Production variables, not DV, had the most influence on the time a cow spent eating in a study by Friend & Polan (1974). Friend and Polan (1974) found mean time eating ranging from 2.9 to 4.7 h per day and to be quadratic with social rank, which means that mid-ranked cows spent the least time eating.

”Avoiders”

Some studies have moved away from the classification of animals into the two categories, dominant and subordinate, and looked more at behavioural characteristics and strategies evolved by individuals. Most of the studies on domestic animals have been conducted on pigs. Jensen (1982) found so called “avoiders” among sows by using an “avoidance order”. According to that author there is no general social dominance order applicable in all interaction situations. Mendl *et al.* (1992) also studied pigs and found that some pigs can be categorized as “no success” pigs, i.e. they never displaced any other pig and were most inactive, least aggressive and showed low involvement in social interactions. The “no success” pigs had the same low level of cortisol as “high success” (dominant) pigs and this could be an indication of the different strategies being equally successful in lowering fitness costs.

Pros and cons with AMS

An automatic milking system gives more milkings (2, 0 – 2, 6 compared to 2 in conventional milking) without extra work which means that you save around 30 % working time (Ketelaar-de Lauwere, 1999; Schick *et al*., 2000; Forsberg, 2008). In studies by Koning-de & Ouweltjes, (2000) and Wendl *et al*. (2000) the average daily milking frequency varied between 2.3 and 2.8. More frequent milkings give fewer cases of clinical mastitis (Hillerton, 1994; Phillips, 2002) which leads to an improved welfare of the cows. Mastitis is also of great economical importance on the farm as at least 10% of the culled cows are culled because udder health problems (personal message Charlotte Hallén Sandgren). In a study done by Hogeveen *et al*. (2000) changing from two to three milkings a day reduced the somatic cell count (SCC) in the bulk milk and the number of cows with high somatic cell counts. More frequent milkings reducing SCC was also shown by Hillerton and Winter (1992). They also showed that SCC raises in AMS at first but only after a couple of days it drops to the level that it was on before, or even lower, when the cows were milked twice a day. The fact that SCC increases at first has also been showed by Hillerton (1994). A more frequent milking can lead to a more efficient removal of bacteria from the udder but also a high exposure as the teat canal opens more often. Open teat canals increases the risk for milk leakage. The risk with open teat canals in AMS was shown in a study done by Persson Waller *et al*. (2003). The cows in AMS were at higher risk of milk leakage than conventional cows, especially if more than four hours had passed since the last milking. Some disturbance with the previous milking also increased the risk of milk leakage. The cows with milk leakage tended to have higher cell counts.

AMS-cows that get milked separately on every udder quarter have lower cell counts in the milk than the cows that have been milked on a whole udder level in the conventional loose housing system according to Berglund *et al*. (2002). Also in a study done by Svennersten-

Sjaunja *et al*. (2000) the AMS proved to give a lower somatic cell count in the quarter milk samples. The quarter milking also reduces the risk for over milking, teat congestion and teat sinus occlusion (Phillips, 2002). And as the rear teats take 15 % longer to milk than the front teats (Wendl *et al*., 2000) quarter milking especially minimizes the risk for over milking on the front teats (Seeman, 1997). Although cows milked in an AMS get milked more often the teat end condition do not need to be worse than in conventional cows (Berglund *et al*., 2002). The conventional group in the study done by Svennersten-Sjaunja *et al*. (2000) had more extended teat canals but in the AMS it was more common with dry skin on the teats. A drawback with AMS on teat health has been presented by Neijenhuis *et al*. (2000). According to them the recovery time needed for the teats to recover from milking is 6-9 hours. That is, a shorter milking interval, which can occur in AMS without selection gates, might lead to incomplete recovery of the teats which in turn can build up to cause a teat injury. According to Forsberg (2008) a milking interval is shortest in a system with forced cow traffic, where it was in average 9.6 hours compared to free traffic that had a milking interval of 12.4 hours. In a study by Koning-de & Ouweltjes (2000) the average interval between two consecutive milkings in a voluntary system was 9. 2. Only 4. 9 % of these milkings occurred with less than 6 h intervals and 17. 7% occurred with more than 12 h intervals. This indicates that the milking interval can be regulated quite well to not go under 6 hours and therefore the risk of incomplete recovery of the teats seems negligible.

More milkings not only give a less incidence of mastitis but also a larger yield. Many studies and field trials have proven that more than three milkings instead of two raise the milk yield (Allen *et al*., 1986; Ipema & Benders, 1992; Webster, 1993; Wiktorsson *et al*., 2000; Alm & Möller, 2004). One can gain 5-25% more milk by this routine (Hillerton & Winter, 1992). In the study done by Svennersten-Sjaunja *et al*. (2000) the AMS cows gave 6.75 % more milk than the conventional. Milking four instead of two times daily have also been shown to increase milk yield (Hillerton & Winter, 1992; Ipema & Benders, 1992). But it is not proven that there is any difference in yield between 3, 4 or 6 milkings, at least not any big differences making it economically beneficial to milk four times or more instead of three (Ipema & Benders, 1992; Wiktorsson *et al*., 2000). Furthermore a milking frequency of four times daily cause more stress to the teats (Ipema & Benders, 1992).

Strict milking routines have been observed to increase milk production (Rasmussen *et al*., 1990). The closer to the maximum of milkings an AMS perform, the more even will the distribution of milking be and the better utilization of the investment will be (Land-Van´t *et al*., 2000). Uneven, long milking intervals affect the milk yield negatively (Ouweltjes, 1998). The size of the reduction in yield varies with the individual cows, but it was greatest for the high producing cows. In an AMS uneven or long milking intervals may call for extra work in collecting the animals not milked since uncompensated long intervals will cause a decrease in the daily milk yield (Koning-de & Ouweltjes, 2000). But a maximum number of milkings will also lead to an increased need to drive the cows to milking as the parlour is occupied a lot (Land-Van´t *et al*., 2000). Especially low ranked cows might not go and get milked when the parlour is full a lot as they avoid conflicts with the more dominant animals (Jensen, 1993; Phillips, 2002). Other reasons for not having an optimal usage of the AMS and long intervals might be insufficient training of the heifers, bad leg health and poor routing (Land-Van´t *et al.*, 2000). When the AMS is used optimally the cows get forced from their synchronized resting behavior. Ketelaar-de Lauwere (1999) questioned this; can this system deteriorate the gregarious cows´ welfare by making them do things individually? It might be for some cows as dairy cows show profound individual differences in their responses to social isolation (Hopster & Blokhuis, 1994).

All of the factors mentioned above affect the farm economy. In addition to the economical advantages of AMS there are more welfare advantages than a reduced frequency of suffering from mastitis. Österman and Redbo (2001) conducted a study where tied up cows´ lying behaviour was compared when the cows were milked twice or three times daily in a milking parlour. Cows milked two times did not lie as much as those milked three times the hours before milking and it took longer for them to get onto their feet. The frequency of 'eating while standing' and 'ruminating while standing' was higher in the two milking group than in the three milking group. Increased standing in cattle is often taken as a sign of discomfort or discontent and the productivity of the dairy cow may be adversely affected by this (Albright, 1987) and several studies have shown that cows prefer to lie down when ruminating (e.g. Wagnon, 1963; Ruckebusch and Bueno, 1978 ref by: Österman & Redbo, 2001). In the two milkings group there was only one lying bout longer than 90 minutes whereas for the three milkings group there were 18 (Österman and Redbo, 2001). The two milking group also had more bouts shorter than 15 minutes. According to the authors this result suggests that the cows with fewer milkings got up due to the increased udder pressure that might hurt when lying, but as they were highly motivated for lying it led to new bouts. Not only do a lot of getting ups and downs imply discomfort for the cows it also increase the risk of the teats to get trampled on and thus there is an increased risk of mastitis. All these facts lead to a decreased welfare, or even suffering, in the cows milked less often. As cows in AMS most often are milked more often than the conventional cows this indicate that AMS can increase cow welfare.

The welfare of the cows is further improved with an AMS as the cows don't need to be driven to the milking, which is stressful for them (Phillips, 2002). As 20% of the variation in milk yield is considered to be due to fear of humans (Breuer *et al.*, 2000) the variation might decrease with automatic milking without human interference. On the other hand cows might find the automatic technique stressful too. According to Phillips (2002) cows do not want to get milked more than one or two times a day as stress from the AMS might be greater than the satisfaction of an empty udder. He also suggests that this especially apply for systems with electrical driving equipment as it reduces the motivation for visits. Comparing the fear of the AMS against the fear of humans might be difficult.

Queuing is a problem as it creates frustration in the cows when they cannot be milked when they please (Phillips, 2002). Cows develop preferences to enter a specific stall at a specific time and preventing them from doing this increase their heart rate (Hopster *et al.*, 1998). Compared to conventional loose house milking the cows are queuing less in an AMS (Phillips, 2002). But in a conventional loose housing system there is no need for cows to queue to get through the MU to get into to the feeding or resting area as the case is in AMSs with forced cow traffic. In a forced system with a closed WA (waiting area) in front of the MU low ranked individuals might be put aside in the queue and therefore get an infrequent feeding pattern. In a study by Forsberg (2008) the low ranked cows queued significantly longer than the high ranked, in a forced traffic system they queued 239 min/cow compared to the high ranked that queued 139 min/cow. Less frequent feeding results in greater fluctuations regarding pH, VFA, NH_3 and osmolarity in the rumen (Robinson, 1989; Le Liboux & Peyraud, 1999). This could be a drawback with the AMS.

Material and methods

Data from the AMS-barn at Kungsängen Research Centre, Swedish University of Agricultural Sciences, Uppsala has been analysed. The data was collected during the period 2000-01-01 to 2007-10-12. The dairy cows were of the Swedish Red and White Breed (SRB). The average annual milk yield of the herd during the period was 9200 kg ECM. The milk somatic cell count was 140000.

208 lactating cows in total, with a maximum of 54 cows at a time, have been part of the AMS-group during the period. At drying off the cows were taken from the barn. The barn was of insulated free stall type with a DeLaval Automatic Milking System (VMS^{TM}) (figure 1). The barn included 54 cubicles, a milking department with a milking unit (MU), two feeding areas with 10 roughage feeding stations and one automatic concentrate feeder in each feeding area.

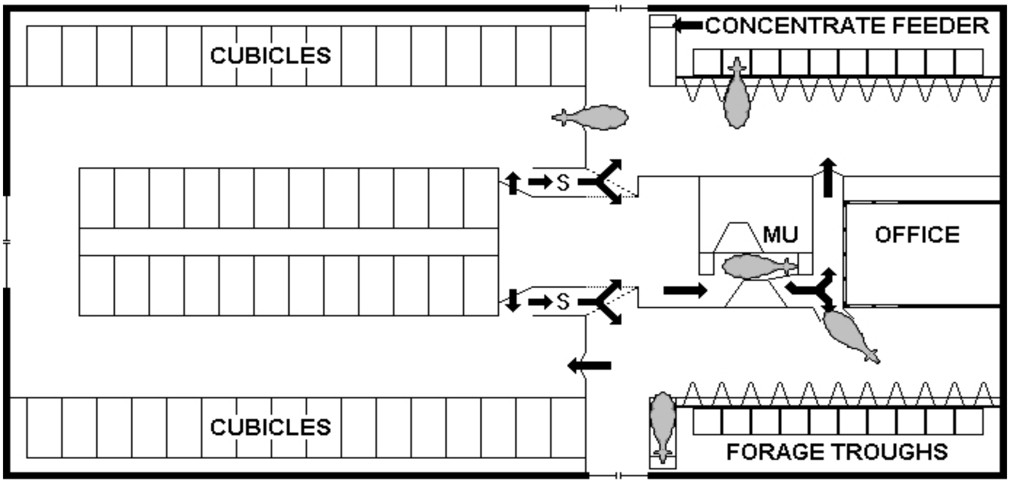

Figure 1. Barn layout

The cows could reach the feeding areas by selection gates or by passing the MU. All the cows had neck transponders. The cubicles were equipped with rubber mats covered with a mix of saw dust and chopped straw. The floor was solid concrete and the manure removed with automatic scrapers. The MU was fully enlighten 24h a day.

A reconstruction of the traffic system in the stable was conducted in March 2004. Before this the waiting area (WA) was open and afterwards it was closed. The cows had access to the milking station approximately 22 h of the day (91.7 %), including when they were out on pasture. Two hours per day were used for cleaning and maintenance of the system. Cows with more than 12-14 hours since the last milking were fetched for milking at 2-3 occasions during working hours. A computerized management system recorded MU visits and gate passages and milk yield and activity all day round. All registered data got a timestamp.

The cows got half a kg of concentrates every time they entered the MU. The available concentrate increased with 1/24 of the total daily ration every hour. The allowance was distributed continuously rectilinearly 24 hours and a new ration started at midnight. At the time when they had at least 400 grams available they could get one meal. If not all of the allowance was eaten in one day, up to 15% of the ration was fed the following day. The cows had access to roughage *ad. lib.* in feeding troughs. The troughs were never empty and were filled at 3-4 times a day, at 06.00*h*-07.00*h*, at 15.00*h* and at 17.00*h*. The MU was cleaned one hour sometimes between 12.00*h* and 15.00*h*. Mostly the cows got silage but occasionally they got some small additives of hay or straw. Fresh water was continuously available from water bowls in the feeding areas and the resting area.

The roughage feeding troughs were placed on balances. A computer registered the identity of the entering cow and time and weight of the trough at entering and exiting. The recorded data from the troughs were used to define feeding area visits of individual cows. If there was more than 60 minutes between two registrations in the feeding trough a new registration would be classed as a new feeding area visit.

The social rank order was established by the method developed by Olofsson *et al*. (2000). Registration of interactions at the feeding troughs is the main idea of this method. If a cow is registered within 60 seconds after another cow had left the trough she got a point towards the leaving cow. A cow was considered dominant in a pair when she had double the points as the other cow. In total 112 332 interactions between cows were defined as confrontations, with an average of 47.6 confrontations per cow and 4 month period. In 48.7 % of the confrontations a defined pair relation between cows. A dominance value is the quota of the number of animals the individual cow is dominant over and the known number of dominance relationships. The dominance value therefore varies between 0 and 1; a high value indicates a cow with a high social ranking. DV was calculated in rolling four month periods, i.e. when a cow got a value for one month the DV was calculated from her interactions that month and up to three previous months.

In total 208 cows were chosen for this study based on that they had to have been in the stable for at least thirty days and had 100 feeding trough visits (gone there by herself and opened the lid) during the four month period. This corresponds to approximately sixty confrontations. From the mean DV one third of the animals were classed as low (DV<0.4223), one third as medium and one third as high (DV>0.5751) ranked cows. Thirty cows that did not change ranking during the observations and had enough registrations were chosen further, twelve of the chosen were classed as high ranked and eighteen were low ranked. More information about these thirty cows can be found in appendix 1.

Statistical analysis

The statistical analysis was conducted using the statistical procedures in the SAS-package (SAS, 2002).

The relation between body weight at start and social rank was analysed in procedure GLM with social rank as a fixed effect and age as a covariate.

Number of cows in the resting area was analysed in procedure FREQ as a χ^2-test.

Milk yield, milking interval, usage of the feeding troughs and time spent in the waiting area was analysed in procedure MIXED with cow as a random effect and social rank, lactation number and interaction social rank and lactations number as fixed effects. In the analysis of lactation curve, lactation week and the interaction lactation week and social rank was included in the model.

Results

Body weight

The body weight of the cows at their first entrance into the AMS-barn was used to analyse the effect of body weight on the social ranking. A significantly higher live weight (45 kg, $p<0.05$) was found for the high ranked cows compared to the low ranked cows at their first day in the barn (Figure 2).

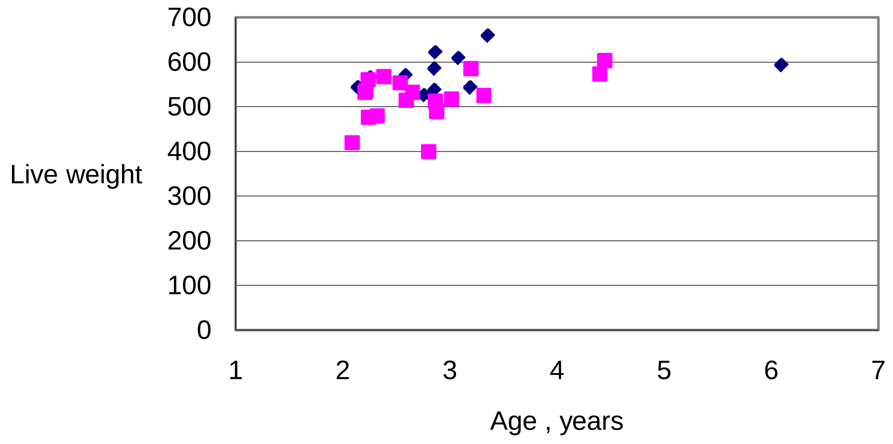

Figure 2. Age and weight for low (■) and high (♦) ranked cows of different age at first day in the barn.

Milk yield

The average daily milk yield for high ranked cows was 26.14 kg/day for the first parturition cows and 32.77 kg/day for the older cows. For low ranking cows the average daily milk yield was 23.44 kg for first parturition cows and 29.95 kg for older cows. The average daily milk yield is shown in figure 3. Cows with higher DV had higher daily milk yield than the low ranked, although the difference was not significant. The high ranked cows first parturition were milking more until week 38 of lactation and the older cows were milking more until week 33 (Figure 4a and 4b). The difference in shape of lactation curves was significant between the high and the low ranking cows.

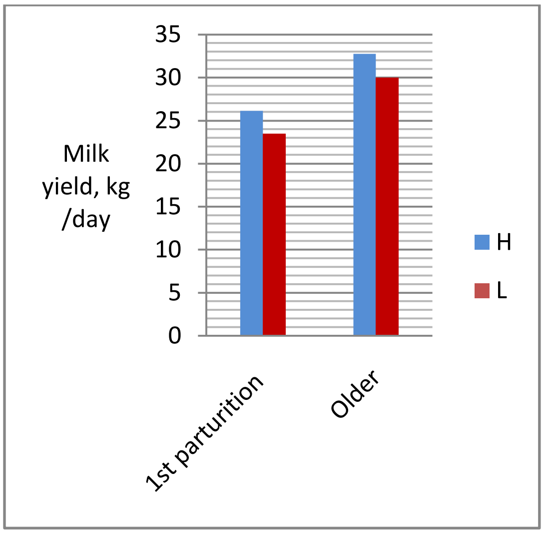

Figure 3. Average milk yield (kg/day) for high (H) and low (L) ranked for first parturition cows and older cows.

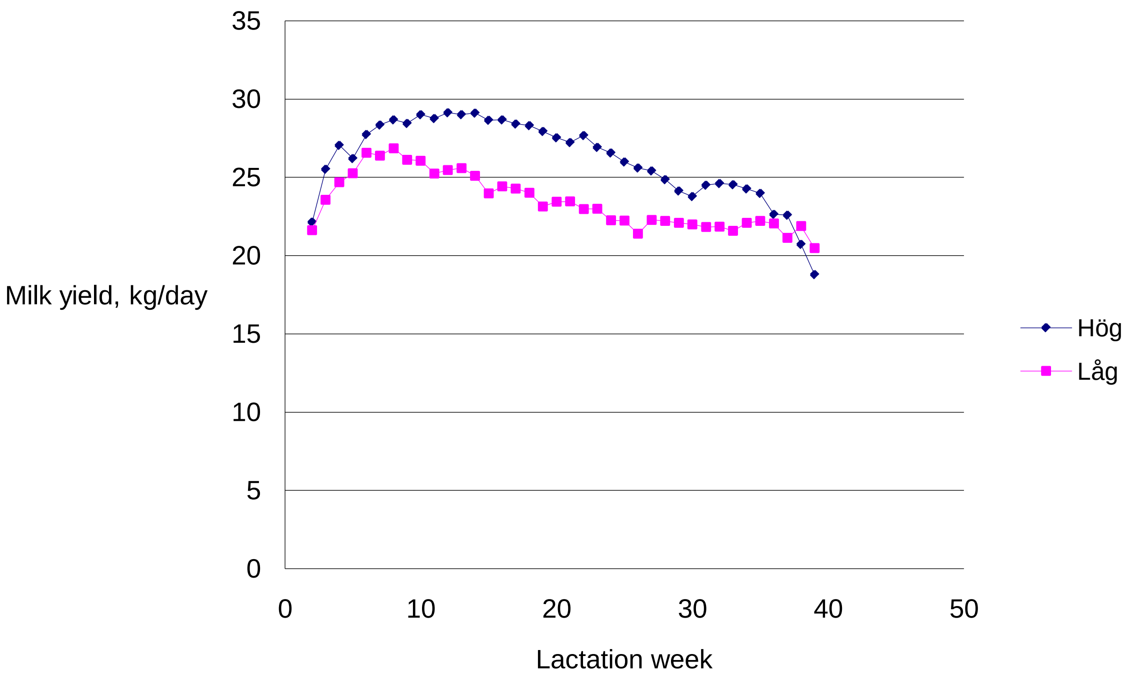

Figure 4a. Milk yield (kg/day) during different lactation weeks for high (Hög) and low (Låg) ranked first parturition cows.

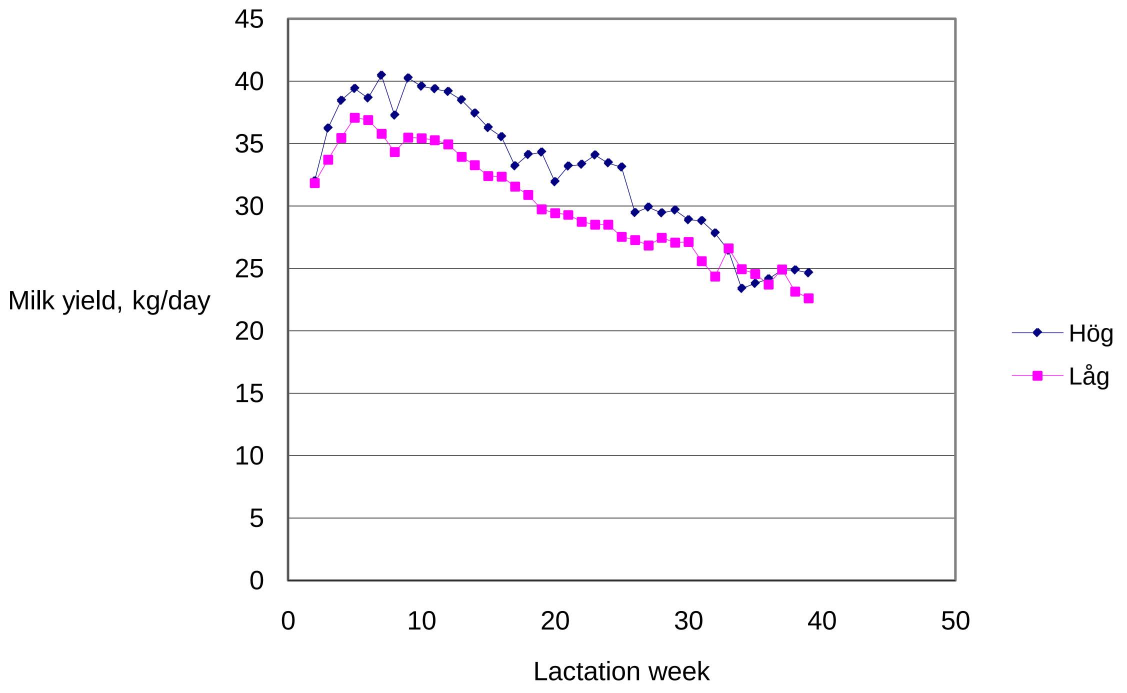

Figure 4b. Milk yield (kg/day) during different lactation weeks for high (Hög) and low (Låg) ranking older cows.

Milking interval

The milking interval (the time between two milkings) was longer for the low ranked cows compared to the high ranked on pasture (10.71 h and 9.63 h respectively) as well as indoors (9.65 h and 8.57 h respectively ($p<0.05$)). See figure 5. This means that low ranked cows were milked approximately 2.49 times a day and high ranked 2.80 times per day during the indoor season. The low ranked cows had a higher standard deviation (average 3.73 h) than the high ranked (average 3.09 h) during most of the day when the cows were on pasture. Indoors the corresponding standard deviations were 3.15 h and 2.45 h respectively ($p<0.05$). When the cows were kept indoors the standard deviation for high ranked animals was higher only at one time of the day: 05.00. The standard deviation was generally higher during the grazing season ($p<0.05$).

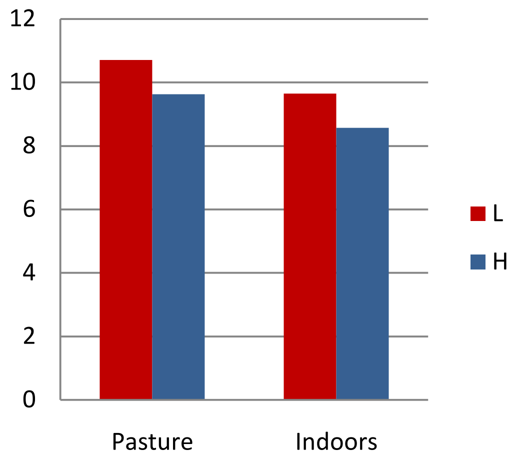

Figure 5. Average milking interval (h) for low and high ranked cows during grazing and indoor season.

Distribution of milkings over the day

During the indoor season the high ranked cows were milked more frequently between 04.00 and 07.30 and the low ranked between 01.00 and 04.00 (Figure 6). After the high ranking animals' peak in the morning the low ranked had a higher frequency again between 09.00 and 12.00. The high ranked cows had a slightly more frequent visiting pattern again 10.30. The high ranked cows milking distribution increased again between approximately 12.30 and 17.30, the low ranked followed quite closely. After this "peak" the low ranked cows got milked more frequently again between 18.00 and 21.00. Approximately from 21.00 and forward the high and low ranked followed each other quite nicely. The same trend applied for the pasture period, but the pasture period was not as distinct. There was a higher variation in milking frequency when the cows were on pasture.

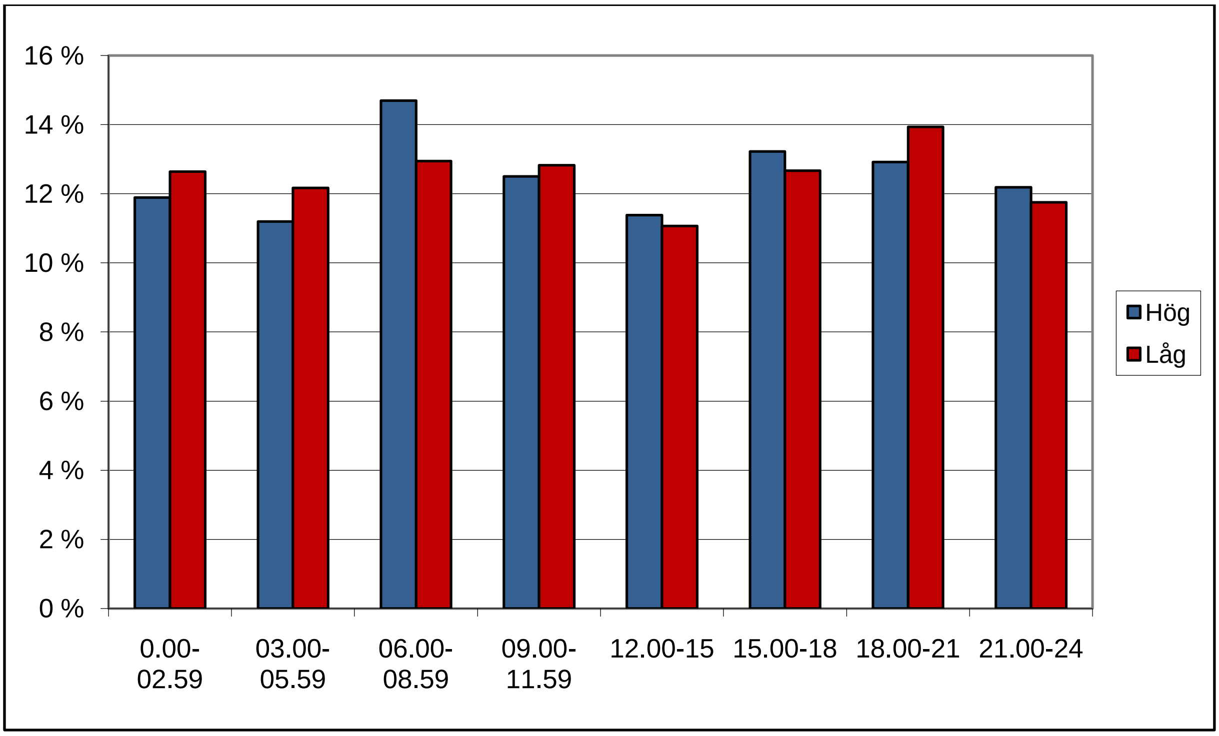

Figure 6. Milking frequency of high (Hög) and low (Låg) ranked cows during indoor season

The low ranking cows had longer time between feeding visits than the high ranking cows in lactation one, two and three (Table 1). The standard deviations for time between feed visits were higher for the low ranking cows than the high ranking (4.6 h vs. 4.0 h, $p<0.06$). For the older cows 4.1 h passed between visits of the high ranked cows and 4.3 h for the low ranked (Table 2).

The feeding visit lasted longer for the high ranking cows in lactation two and three but in the first lactation the low ranked cows spent more time in the feeding area (Table 1). For the first parturition cows the standard deviation was larger than for the older cows. In table 2 the roughage eating time per feeding area visit is shown. These figures show that low and high ranked cows had equal eating times.

Table 1. Time between feeding area visits and the length of the feeding visits for high (H) and low (L) ranking cows in lactation one, two and three.

Rank	time (h) between visits		standard deviation		Visit length (min)		standard deviation	
	H	L	H	L	H	L	H	L
1st lact.	3,99	4,53	2,36	2,96	66,4	69,97	54,25	58,07
2nd lact.	3,69	4,18	2,16	2,54	56,58	53,93	48,75	40,14
3rd lact.	4,19	4,89	2,58	3,44	58,4	51,2	50,64	36,17

Table 2. Time (hours) between feeding visits and eating times (in the feeding trough) for high (H) and low (L) ranking cows separated into 1st lactation cows and older.

	time between feeding area visits, h		eating time per feeding area visit (min)	
Rank	**H**	**L**	**H**	**L**
1st lact.	4,0	4,6	37,2	39,7
older	4,1	4,3	31,8	35,2

The low ranked cows consumed more roughage than the high ranked cows per visit, both as first parturition cows (6.5 kg versus 6.1 kg) as well as older (7.7 kg versus 6.9). The total effect (as the low ranked had fewer visits) on consumption was that low ranked heifers consumed less roughage than the high ranked ($p<0.07$). Among the older cows almost equal amounts of roughage was eaten.

The low ranked cows used several feeding troughs per visit, both as first parturition cows and as older. First lactation high ranked cows visited 7.4 troughs and the low ranked 11.2 per visit ($p<0.05$). The high ranking older cows visited 6.1 and the low 8.4 troughs ($p<0.07$).

The first time parturition high ranking cows had 3.8 visits to the concentrate feeders per day and the low ranking 5.3. The older high ranking cows had 4.1 visits and the low ranked 3.4. On average all cows consumed 94% of their daily ration and there were no effect of rank. And there was also no difference between the groups in how much of their daily ration they ate.

Low ranking cows spent significantly more time in the WA than the high ranked, approx. 46 minutes versus 23 minutes per visit ($p<0.01$). There was also a significant difference (χ^2, $p<0.001$) between the numbers of cows in the WA when low or high ranked cows enter the WA (Figure 7). The low ranked cows had a higher frequency of entering the waiting area than the high ranked, when there are 0 to 1 cow in it.

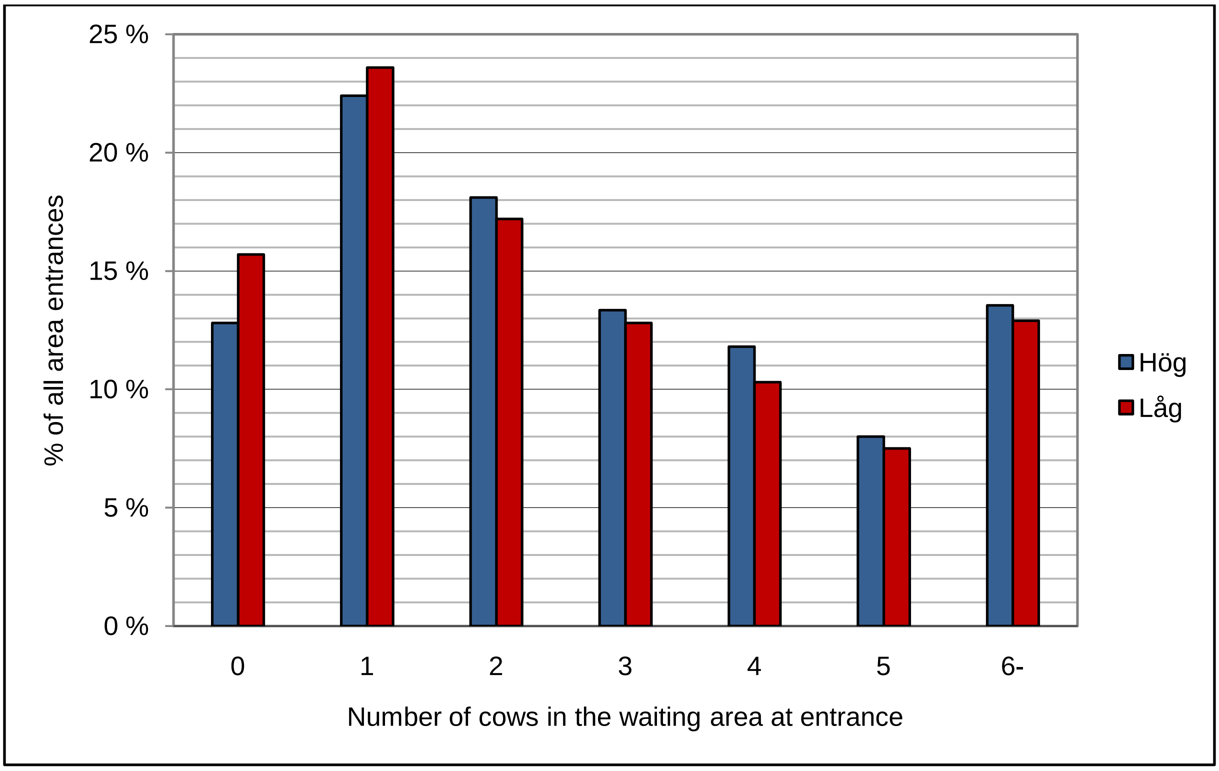

Figure 7. The number of cows in the WA when high ranked and low ranked cows entering

Changes in ranking

A statistical analysis was done on all first parturition cows and older cows on their DV changes every lactation month. There was a significant difference between first calvers and older cows ($p<0.05$) with a common trend ($p<0.05$). See figure 8.

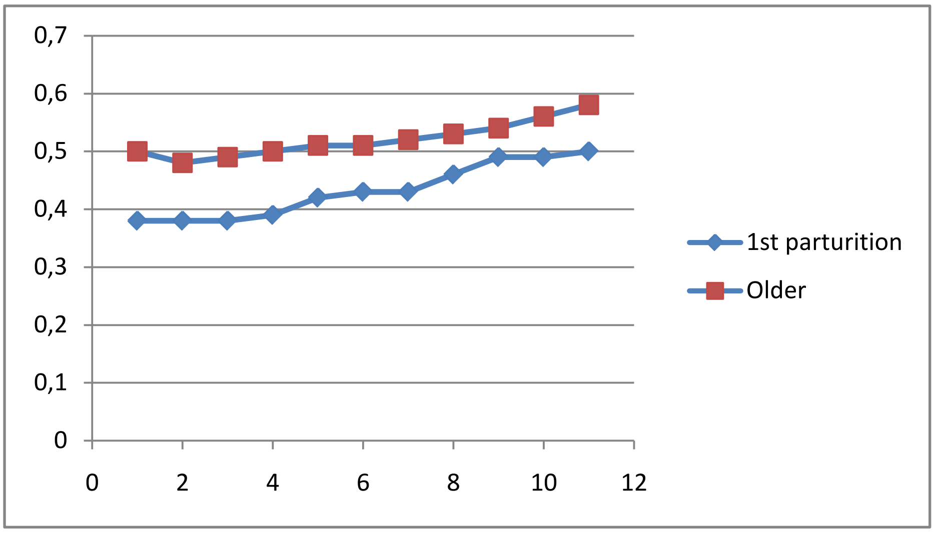

Figure 8. Changes in DV among 1st parturition and older cows during lactation month.

A subjective sorting of cows into those DV raised and those that did not rise during lactation was made. Also a difference was made if the cows had a change in ranking or if the rise in DV was within the same ranking. Only cows that had a minimum of two calvings and enough registrations for a trend to be seen were included, this added up to 138 cows. One registration in a different rank was enough for it to be called change in rank. 62 % of the cows did have a rise in DV after calving. Of these 31% was within rank. Within rank 60% of the cows were high ranked, 35% low and 5% medium. Between rank 43% were medium ranked, 37% high and 20% low. Of those not having an increase in DV after calving 49% were low ranked, 36% medium and 15% high.

Discussion

The DV used in this study was measured at feeding but mainly used for milking parameters. A ranking for milking might not be the same as for idle ranking measured at feeding or on space as DV differs for different resources (Potter & Broom, 1987). There is no dominant cow to have first access to all resources. In our study this is not necessarily a problem as they have to get milked to get to the feed. Further Olofsson *et al*. (2000) did find a high correlation between DV at feeding and at milking. And that study was conducted at the same stable and stable system as this one (open WA).

In this study it was found that the high ranking cows were of greater weight than the low ranked. Earlier studies found correlations between weight and ranking as well as not.

DV was calculated for four months rolling, this means that changes during a short period e.g. at disease would be smoothed out. But fewer months, such as three months would give a too small degree of explanation. An alternative could be to have two months before and two months after, but what will happen in the future is not known. It would be very interesting to look at dips in DV due to disease and whether ranking could be correlated with disease.

More milkings result in fewer cases of mastitis (Hogeveen *et al.*, 2000) and an improvement of welfare as the cows can lay down more (Österman & Redbo, 2001). It would have been interesting to study the correlation between mastitis and low rank in cows. To see whether low ranked cows that have been shown to have a lower milking frequency than high ranked cows in this study also suffer from higher cell count and mastitis. A more frequent milking can lead to a more efficient removal of bacteria from the udder but also a high exposure as the teat canal opens more often. Cows with subclinical mastitis avoid getting milked in the same extent as healthy cows (Rathore, 1982) so then the number of milkings might be part of the reason for a smaller production from the sick cows. Hence there might be a correlation between low rank and sickness via our productions statistics. But mastitis couldn´t be studied here as it is a much faster occurrence than DV. Also the cows in this study with mastitis were removed from the group.

It is important for cows to get milked regularly (Phillips, 2002) and low ranked cows have a harder time to do that- they have to adjust more (Hopster et al., 1998). It also seems to be a correlation between milking interval and SCC, the more infrequent milking the higher SCC (Persson Waller et al, 2003). A small negative correlation between dominance and mastitic milk has been found (Friend & Polan, 1974). These findings and ours suggest that low ranked cows being milked less frequently than high ranked cows would have a difference in welfare and incidence of mastitis. It would have been interesting to look closer at e.g. 10 cows that make a big drop in ranking between two calvings. Can we find a correlation to disease e.g. SCC in these cases as they gain their ranking again later. If further studies are made a measurement of prolonged stress, e.g. cortisol as Alm & Möller (2004) did, might be a good complement to find answers to weather low ranked cows have lower welfare than high ranked.

Maybe the low ranked cows also would have an increased frequency of getting up and laying down, as happens when the cows get milked less often. Then they might have an increased risk of trampled teats as was discussed by Österman and Redbo (2001). In an AMS it is more probable that an irregular frequency of milkings would stress the cows to get up and lay down more than the actual number of milkings. And as shown in this study the low ranked cows had a higher standard deviation in milking interval. But it has also been shown REF that the extent of trampled teats is reduced when changing from milking regularly in a conventional milking in a loose housing system to start milking in AMS (personal message Håkan Landin).

To get an even milking frequency it is also important that the cows eat regularily (Pirkelmann, 1992). This fact suggests that the highest producing animals would not necessarily have to be dominant unless there was a limited access to feed (Friend & Polan, 1974; Albright & Arave, 1997). As a tendency for the high ranking cows to produce more was found in this study and as the correlation of feed intake on milking frequency is highly interesting -feed intake had to be studied. It was found that low ranked heifers consumed more roughage than the high ranked although they had the same lengths of their feeding visits. Among the older cows almost equal amounts of roughage was eaten. At the concentrate feeder the high ranked had fewer visits than the low ranked. These results might be surprising as studies have shown that high ranked and high producing animals spend more time eating although not necessarily eating a bigger amount of feed (Friend and Polan, 1977; Olofsson *et al*., 2000; Mehlqvist, 2003). And the result does not correspond with studies suggesting that high producing cows, in this case high ranking cows, would be more motivated than the low ranking to go and get feed (Prescott *et al*., 1998; Phillips, 2002). Maybe this effect might be negligible with the quite similar milk yield in both high and low ranking animals in this study, as well as the fact that all cows almost always have a high motivation to eat (Prescott *et al*., 1998). In the roughage troughs the low ranked used several troughs per visit, which might indicate that they were chased from the trough by higher ranked individuals. After being chased out they might have tried to get feed from the concentrate station thus explaining the more visits there. These results agree with the results of Ketelaar –de Lauwere *et al.* (1996) showing that dominant cows can adapt their feeding pattern more easily than low ranked ones.

Less frequent feeding results in greater fluctuations regarding pH, VFA, NH_3 and osmolarity in the rumen (Robinson, 1989; Le Liboux & Peyraud, 1999). These changes in the rumen one might think would affect the health of the cow but maybe also the production. Several small meals perhaps could lead to a higher production as more of the feed could be utilized faster. In this study the low ranking cows had longer time between feed visits than the high ranking cows and the standard deviations for time between feed visits were higher for the low ranking cows than the high ranking. This is in accordance with earlier studies (Kabuga, 1992). With a closed WA low ranked individuals might be put aside in the queue and therefore get an infrequent feeding pattern. In a study by Forsberg (2008) the low ranked cows queued significantly longer than the high ranked. This was also the case in this study; low ranking cows spent significantly more time in the WA than the high ranked. There was also a significant difference ($p<0.001$) between the numbers of cows in the WA when low or high ranked cows entered the WA. An explanation for this is that low ranked cows avoid conflicts, hence don´t go and get milked and eat when the WA is full. Access to space is an important resource for cows to contest for; hence conflicts are probably more likely to happen when there are a lot of cows in the WA. As the low ranked individuals cannot enter the feeding area when they please their welfare might get impaired. In another traffic system with free access to the feeding area the effect would probably be smaller.

A more even milking frequency and/or a shorter milking interval could be the direct reason for high ranking cows producing more in this study (Rasmussen *et al*., 1990; Ouweltjes, 1998). In this study the milking interval was longer for the low ranked individuals. This is accordance with a study by Ketelaar-de Lauwere *et al*. (1996) where it was shown that the higher dominance value the more frequent were the visits to the automatic milker. In this study it was also seen that the standard deviation in milking interval was greater for the low ranked cows. A longer and/or uneven milking interval can also be associated with an impaired welfare for the low ranked cows. It might be against the cow’s preference and also lead to a greater udder pressure and less comfort. A greater udder pressure might increase the risk for teat trampling and mastitis. A shorter milking on the other hand could lead to incomplete recovery of the teats. With uneven or long milking intervals the cows have to be fetched which increase the need of work in the stable.

A high producing animal has a high udder pressure that would give the cow a higher motivation of getting milked. As the high ranked cows seem to give a higher yield in this study, and earlier studies have shown that they don´t need to spend as much time in the WA maybe they don’t wait as long as the other because they have a higher motivation and hence get a higher ranking in that situation. They might also get a higher ranking at feeding because they are hungrier due to the greater production. And as there is a big correlation between ranking at feeding station and milking order (Olofsson *et al*., 2000) they are classed as high ranked in total.

The results with the timing of milkings correlate with earlier studies, the high ranked cows could get milked in more attractive times. The attractive times is mainly a part of the cow’s diurnal nature but also an effect of feeding routines and the time of the automatic milker being cleaned. In this study more feed was given at the same times as when the high ranked cows had more milkings than the low ranked. The MU was cleaned in the afternoon and at the period around cleaning and after the cleaning a higher incidence of high ranking cows were milked. The high ranked could in this way make use of their ranking and get to milking and feeding when they pleased and the low ranked had to settle with more non attractive times. One could also say that in case the high ranked are producing more they would be more motivated and hence get a higher ranking.

To be able to use this information and perhaps be able to improve the welfare of the low ranked cows one needs to know which cows that are low ranked at the moment. In this study it was found that DV increases during lactation in general. Ketelaar-de Lauwere *et al*. (1996) did also find that DV rises as lactation proceeds. It seems likely that this is an effect of heavily pregnant cows avoiding encounters (Beilharz & Zeeb, 1982), hence getting a lower DV that rises again after parturition. But in this study the cows were tied up at drying off so the most probable cause would instead be a correlation with the feeding. The DV curve is kind of the opposite of a lactation curve; later in lactation the cows might not be as tired as they milk less –hence they can increase their DV. Also as the cows get further into their lactation curve their production decreases and thus they get a smaller amount of concentrate each day which would make them more motivated for eating roughage. This decrease in concentrate is on the other hand done very slowly and step by step. Cows that had a dip in ranking between two parturitions were also found. This phenomenon might also be due to an opposite lactation curve and further research on this would be interesting. Further hungrier –high producing-cows are more subjected to attacks at the feeding troughs as they have to spend more time there. The data does not support a theory that lactation peak and a fuller udder would increase the cows' motivation to get milked and in that way increase the cows DV.

If some cows are to be classed as low ranked it is important to remember that they might not always stay low ranked and that other cows would benefit more from improvements such as fast lanes. It is also important to remember that a raise in DV does not happen to every cow. In this study only 62% of the cows did have a rise in DV. 69% of these did change ranking. These figures are not totally correct though as the measurement was highly subjective. Not only do the cows seem to change ranking, some cows does not seem to fit into the ranking system. A lot of speculation of this has been done lately and ways of finding these cows could be useful. Maybe they could be found by looking at cows staying at a feeding station for long without entering a trough as they are inactive, non aggressive and have low involvement in social interactions. "No success" pigs did never displace other pigs (Mendl *et al.*,1992), maybe the avoider cow could be found by having a much lower number of displacements than other cows. In this study avoiders might be seen in the results of visits to the WA. They might be the cows entering the WA at a higher rate when there is no or only one cow in there already. Further what ranking a cow will get is highly affected by what other individuals those are in the stable during that lactation when the cow enters it.

Conclusion

The AMS should harmonize with the psychological and social tendencies in the dairy cow so that the cow can adjust and the system work well. In this study it was seen that even when effort has been made in a stable the system is not good for all cows; the low ranked fall behind. Ranking measured at feeding affect both feeding behaviour and milking behaviour. Low ranked cows get to eat less often and get chased out of the feeding troughs more often. Even though they in total eat as much as the high ranked cows this might affect their production and rumen health. Low ranked cows also have to wait longer before milking and also get milked more frequently than the high ranked. This will affect their production and comfort negatively. If we want to improve the welfare of the low ranked cows it is important to discuss the complexity of dominance and changes in ranking during a cows life. E.g. during lactation it was shown that 43% of the cows climb in rank. A certain ranking at a certain time do not tell us everything. It would be of importance to be able to recognize so called avoiders as they might be classed as low ranked at one resource even though they get access to another resource. In this study the low ranked cows displayed a sort of avoiding behaviour as they preferred to get milked when no or only one cow was in the WA. Looking closer at this behaviour was not successful in finding low ranked cows. But it was clear that high ranked cows could use their status and go and get feed –hence milked- at more attractive times of the day independent of number of animals in the WA at that time.

The practical implementations on how to make life easier for low ranking animals found in this study correlate well with general recommendations in AMS of today. Recommendations such as keeping the cows with feed at all times, not overcrowd the stable, have a lot of space in front of the robot, feed palatable feeds in the robot and if you choose to have a forced system it is good to use fast lanes for cows in need of it.

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Appendix 1

Cow number	Ranking	Birth date	Date when put into the stable	Age when put into the stable	Weight when out into the stable	Number of lactations in the study	Number of calvings during the study
528	H	25.8.1993	28.9.1999	6,1	593,0	4	3
742	H	5.8.1996	14.10.1999	3,2	543,0	2	4
787	H	4.12.1996	12.4.2000	3,4	659,0	1	1
861	H	6.1.1998	10.10.2000	2,8	526,0	3	3
896	H	2.10.1998	30.10.2001	3,1	609,0	3	4
905	H	27.10.1998	3.9.2001	2,9	537,0	2	2
917	H	20.11.1998	1.10.2001	2,9	622,0	3	3
949	H	25.3.1999	24.10.2001	2,6	570,0	2	2
1016	H	12.7.2000	14.10.2002	2,3	565,0	2	2
1048	H	17.10.2000	25.8.2003	2,9	585,0	3	4
1060	H	5.12.2000	7.10.2003	2,8	522,0	3	4
1090	H	16.8.2001	7.10.2003	2,1	544,0	3	4
707	L	22.10.1995	1.1.1999	3,2	585,0	1	2
714	L	19.12.1995	11.5.2000	4,4	573,0	1	2
779	L	1.11.1996	24.2.2000	3,3	525,0	1	2
823	L	21.8.1997	16.12.1999	2,3	479,0	1	1
832	L	20.9.1997	7.2.2000	2,4	567,0	3	3
833	L	24.9.1997	21.12.1999	2,2	476,0	2	1

837	L	14.10.1997	18.10.2000	3,0	517,0	3	2
874	L	6.4.1998	18.10.2000	2,5	554,0	3	2
924	L	28.12.1998	16.10.2001	2,8	400,0	1	1
941	L	15.3.1999	6.11.2001	2,6	532,0	3	3
976	L	18.10.1999	2.9.2002	2,9	489,0	3	5
989	L	15.11.1999	26.9.2002	2,9	512,0	2	2
1022	L	17.8.2000	18.9.2002	2,1	420,0	2	2
1038	L	20.9.2000	1.3.2005	4,4	603,0	1	4
1181	L	28.9.2002	15.12.2004	2,2	536,0	2	2
1189	L	14.11.2002	8.2.2005	2,2	561,0	2	2
1261	L	17.11.2003	31.1.2006	2,2	532,0	2	2
1276	L	11.1.2004	15.8.2006	2,6	514,0	1	1