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- med eller utan lockgiva vid mjölkning

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Abstract

A common automatic milking system (AMS) is the single box AMS, designed for 60 to 70 cows per unit (Bach & Cabrera, 2017), but there is also the automatic milking rotary (AMR; DeLaval Automatic Milking Rotary – AMR™, Tumba, Sverige) with 24 bails and a higher capacity (Kolbach *et al*., 2013; Jacobs & Siegford, 2012a). Feed allowance in AMR can lead to advantages and affects cow traffic, both in the barn and in relation to the AMR (Scott *et al*., 2014; Kolbach *et al*., 2013). The aim of this study was to investigate the effect of giving teaser feed in AMR during voluntary cow traffic. The aim was also to investigate the effects of different length of adjustment periods in the experimental design. Furthermore, we hypothesized that primiparous cows would adapt faster to the system than multiparous cows and therefore spend less time than multiparous cows in the premilking area. We theorized that results after a longer adjustment period would have less variance and a more reliable outcome than results after a short adjustment period. To examine this, four treatments were implemented: No teaser feed – 1 week adjustment period, Teaser feed – 1 week adjustment period, Teaser feed – 3 weeks adjustment period and No teaser feed – 3 weeks adjustment period. The study was performed in 2018 at the Swedish Livestock Research Centre at Lövsta, Swedish University of Agricultural Sciences, Uppsala and 113 ± 10 cows were included and housed in an insulated naturally ventilated free-stall barn. A trough was installed at the first bail in the AMR to provide the cows with teaser feed (~ 50 g concentrate) when they entered the AMR. All experimental periods, *i.e.*, when data was collected, had the length of one week and followed after every treatment. Data was collected with video recordings and the herd management software DelPro™ (DeLaval International AB, Tumba, Sweden) and was used to analyse how fast the cows entered the AMR, how many cows were needed to be fetched by staff and how long time the cows spent in premilking areas. When analysing how fast the cows entered the AMR and how long time they spent in premilking areas, parity and lactation stage was taken into account. To include parity and lactation stage, ~ 30 focal cows were marked. Video observations from 821 entering's and data from 72 milkings showed that teaser feed made the cows enter the AMR with faster speed and less cows were needed to be fetched by staff than without teaser feed, independent of adjustment period. Results from 464 observations showed that cows spent less time in premilking areas after one week with teaser feed compared to after three weeks without teaser feed. Primiparous cows entered the AMR with faster speed compared to multiparous cows but both primi- and multiparous cows spent the same amount of time in premilking areas, independent of treatment. In retrospect, results regarding adjustment period in this study are weak and should not be used in future research. However, length of adjustment period did not seem to influence the numerical variance but providing teaser feed led to a numerical decrease in variance in data. Overall, this study indicates that offering teaser feed in AMR can be beneficial and have a potential to improve cow traffic.

Keywords: Automatic milking rotary, cow traffic, teaser feed

Sammanfattning

Ett vanligt automatiskt mjölkningssystem (AMS) är singel-roboten, designad för 60 till 70 kor per robot (Bach & Cabrera, 2017), men det finns även fler system på marknaden. Den automatisk mjölkningskarusellen (AMR; DeLaval Automatic Milking Rotary – AMRTM, Tumba, Sverige) har 24 mjölkningsplatser och därmed en högre kapacitet (Kolbach et al., 2013; Jacobs & Siegford, 2012a). Att ge kraftfoder i AMR kan ha fördelar och påverka kotrafiken, både i lösdriften och i direkt relation till AMRen (Scott et al., 2014; Kolbach et al., 2013). Målet med denna studien var att undersöka effekten av att ge lockgiva i AMR under frivillig kotrafik. Målet var också att undersöka effekterna av olika längder på tillvänjningsperioder i experimentets upplägg. Vidare trodde vi att förstakalvare skulle vänja sig snabbare vid systemet och därför spendera mindre tid än de äldre korna i väntfålla och drivgångar. Vi trodde att resultaten efter en längre tillvänjningsperiod skulle ge mindre variation och ett mer pålitligt resultat än efter en kort tillvänjningsperiod. För att undersöka detta så användes fyra behandlingar: Ingen lockgiva – 1 vecka tillvänjning, Lockgiva – 1 veckors tillvänjning, Lockgiva – 3 veckors tillvänjning och Ingen lockgiva – 3 veckors tillvänjning. Studien genomfördes år 2018 på Lövsta Forskningscentrum, Sveriges lantbruksuniversitet, Uppsala och 113 ± 10 kor var inkluderade och installade i en varm lösdrift. Ett tråg installerades vid den första mjölkningsplatsen i AMRen för att förse korna med lockgiva (~ 50 g kraftfoder) när de steg på AMRen. Alla experimentperioder, det vill säga när data insamlades, var en vecka långa. Data insamlades med videoinspelning och besättningens management-system DelPro™ (DeLaval International AB, Tumba, Sweden) och användes för att analysera hur snabbt korna steg på AMRen, hur många kor som behövde hämtas av personal och hur lång tid korna spendera i väntfålla och drivgångar. När det analyserades hur snabbt korna steg på AMRen och hur lång tid de spendera i väntfålla och drivgångar så togs kalvningsnummer och laktationsstadie i beaktande. För att inkludera kalvningsnummer och laktationsstadie så markerades ~ 30 fokaldjur. Video-observationer från 821 påstigningar och data från 72 mjölkningar visade att en lockgiva gjorde att korna steg på AMRen snabbare och att färre kor behövde hämtas av personal med lockgiva än utan, oberoende av tillvänjningsperiod. Resultaten från 267 observationer visade att korna spenderade mindre tid i väntfålla och drivgång efter en vecka med lockgiva än efter tre veckor utan lockgiva. Förstakalvarna steg på AMRen snabbare än de äldre korna men både förstakalvare och äldre kor spenderade lika mycket tid i väntfålla och drivgångar, oberoende av behandling. I efterhand kunde vi konstatera att resultaten kopplade till tillvänjningsperiod i denna studie är svaga och bör inte användas i framtida forskningsartiklar. Hur som verkade längden på tillvänjningsperiod inte påverka den numeriska variansen men bara att ge lockgiva däremot minskade den numeriska variansen. På det hela taget indikerar denna studien att ge lockgiva i AMR kan vara fördelaktigt och har en potential att förbättra kotrafiken.

Nyckelord: Automatisk mjölkningskarusell, kotrafik, lockgiva

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1. Introduction

The first automatic milking system (AMS) was launched in the Netherlands in 1992 and has the last decade been a common milking system all over Europe (Svennersten-Sjaunja & Pettersson, 2008b). Statistics from Sweden's biggest livestock association showed that at least 40 % of cows in Sweden were milked in automatic milking systems in year 2020 (Växa Sverige, 2021). Arguments for installing AMS are mostly a mixture between economic and social arguments (Bijl *et al.*, 2007; Mathijs, 2004) and the conversion from conventional milking system to AMS is reported to have many benefits, including lower labour costs and an overall better lifetime quality (Mathijs, 2004). In fact, farmers in countries such as Belgium, Germany, Denmark and The Netherlands claim they are saving near 20 % in working hours with the transition to automatic systems (Mathijs, 2004).

A common AMS system is the single box AMS, designed for 60 to 70 cows per unit (Bach & Cabrera, 2017), but other automatic systems are available on the market as well. The automatic milking rotary (AMR; DeLaval Automatic Milking Rotary – AMR™, Tumba, Sverige), with a capacity for 300 to 800 cows per unit (Jacobs & Siegford, 2012a), was developed as an alternative to the single box AMS (Kolbach *et al.*, 2013). The AMR was, at its beginning, developed for big pasture-based herds typically for grazing countries, such as Australia and New Zeeland, requesting a system with lower capital investment than the single box AMS (Kolbach *et al.*, 2013). Today, the AMR is used in housed dairy systems too and has 24 bails, proceeds up to 1600 milkings per day and milk up to 90 cows per hour, depending on the configuration (Kolbach *et al.*, 2013; Jacobs & Siegford, 2012a).

Automatic milking systems and its potential can be affected by many factors such as cow traffic (Svennersten-Sjaunja & Pettersson, 2008b), herd structure (Halachmi, 2009), occupancy rate (Scott *et al.*, 2014) and feeding strategy (Jago *et al.*, 2007). One of the most influential challenges is to motivate the cows enough to enter the milking unit voluntary without help from staff (Bach & Cabrera, 2017; Scott *et al.*, 2014; Jacobs & Siegford, 2012a). Cows that will not enter a milking unit voluntary need to be fetched which in turns counteracts with one of the most common arguments for installing AMS: the need of less labour (Bach & Cabrera, 2017; Mathijs, 2004). Manufacturers of AMS often recommend farmers to give concentrate in the milking unit as motivation for the cows (Bach *et al*., 2007), which is in line with what research studies has come to: receiving feed is a higher motivation for cows than just being milked (Prescott *et al*., 1998). Further, giving concentrate in AMS to attract cows to milking is standard (Bach & Cabrera, 2017; Jacobs & Siegford, 2012a). However, not all AMRs are equipped with in-bail feeding (Scott *et al*., 2014; Kolbach *et al*., 2013). However, providing teaser feed in AMR can lead to advantages and affect cow traffic, both in the barn and in direct relation to the AMR (Scott *et al*., 2014; Kolbach *et al*., 2013). For example, feed supply in AMR has shown to almost halve the time cows spend in the premilking area (Scott *et al*., 2014) and improve the utilization of the AMR with nearly six times (Kolbach *et al*., 2013).

2. Aim and hypothesis

The aim of this study was to investigate the effect of giving a teaser feed in the AMR during voluntary cow traffic. An additional aim was also to investigate the effects of applying different adjustment periods. To examine this, two lengths of adjustment periods (one and three weeks) combined with teaser feed or no teaser feed in AMR were applied. We hypothesized that teaser feed would motivate the cows to enter the AMR faster than without teaser feed. The cows would spend less time in the premilking area and enter the AMR faster than without feeding. Furthermore, we hypothesized that primiparous cows would adapt faster to the system than multiparous cows and therefore spend less time than multiparous cows in the premilking area. We theorized that results after a longer adjustment period would have less variance and a more reliable outcome than results after a short adjustment period.

3. Literature study

3.1. Cows' adaption to automatic milking systems

For AMS to work properly it is of importance that cows adapt to the system and milking routines. One typical management routine for AMS farms is fetching cows for milking which is time consuming and increases labour and production costs as it in practice generally means that staff gathers relevant cows from barns and premilking areas to milking (Bach & Cabrera, 2017; Rousing *et al*., 2006). The need for this routine arises when cows will not go voluntary to milking, risking long milking intervals, which further has been associated with increased risk of mastitis (Hovinen & Pyörälä, 2011). It has been shown in an early study on AMS, that cows are able to adapt to new milking routines in a rather short time (~10 days after calving) (Devir, 1995). In addition, in a more recent study on AMS, the percentage of cows needed to be fetched decreased from around 40 % after the first week to only 5 % after one month (Jacobs & Siegford, 2012b).

However, the need of fetching cows varies amongst herds and milking strategies. For example, one recent study was made in a free-stall barn with two milking robots, using moving fences in the sections to attract cows to milking. Without the moving fences, staff spent five hours a day on fetching cows compared to one hour per day when moving fences were used (Drach *et al*., 2017). Studies have also shown that some cows are more likely to be fetched than others. For instance, cows in very early lactation (≤ 14 days) need to be fetched more often and spend more time in premilking areas than cows in late lactation (Scott *et al*., 2014; Rousing *et al*., 2006). Further, it has been shown that multiparous cows are more likely to be fetched than primiparous cows (King *et al*., 2017a) and that primiparous cows are more willing to visit milking units than multiparous cows (Bach *et al*., 2009; Borderas *et al*., 2008). Although primiparous cows seem to be more willing, one study by Jacobs & Siegford (2012b) indicated that primiparous cows are more nervous when being introduced to automatic milking than multiparous cows. Increased movements can be used as a sign of agitation (Grandin, 1993) and the primiparous cows in this study, which had never been milked in AMS before, kicked and moved more before and after cup attachment compared to the multiparous cows (Jacobs & Siegford, 2012b).

It has also been seen that a high stocking density in adjacent to a milking unit can result in more cows to fetch (King *et al*., 2017a). Halachmi *et al*. (2009) performed a simulation model including 67 cows and one milking robot. The simulation was meant to correspond to a crowded day when all cows had to pass the robot at approximately the same time. According to this simulated situation, a low ranked cow could wait for up to seven more hours than a high ranked cow. In addition to the conclusions Halachmi *et al*. (2009) came to, it has been seen that cows wait longer for every additional cow in a situation with more than 20 cows (14 cows/100 m^2) in the premilking area (Scott *et al*., 2014). A high stocking density is not only related to more cows to fetch but also to lameness, as lameness and stocking density seem to be positively correlated (King *et al*., 2017b). Unsurprisingly, lameness has a negative effect on a cow's willingness to enter a milking unit voluntary (King *et al*., 2017b; Borderas *et al*., 2008) and cows suffering from lameness have been seen to be twice as likely to be fetched more than once a day compared to healthy cows (King *et al*., 2017a). Besides stocking density, lameness can also originate from decreased time spent lying down (Fisher *et al*., 2002; Leonard *et al*., 1996) which in turn has been shown to be one of the consequences of unsuccessful milkings. Unsuccessful milkings appear in AMS when teat cups fail to be attached, most commonly because of unusual appearance of the udder (Bach & Busto, 2005; Stefanowska *et al*., 2000). In fact, unsuccessful milkings seem to have a negative effect on cows' comfort as cows with unsuccessful milkings spend longer time standing and urinate twice as often during the first hour after milking than cows with successful milkings (Stefanowska *et al*., 2000).

3.2. Planning of stable

To overcome the problem with exceeding milking intervals and to reach a successful automatic milking system, planning of cow traffic and movement patterns in the stable can be crucial (Svennersten-Sjaunja & Pettersson, 2008a). In forced cow traffic, cows must be milked before they can access a feeding or laying area (Jacobs & Siegford, 2012a). This cow traffic is related to more visits to milking units and consequently less fetching of cows compared to systems with free cow traffic, where cows move around freely between lying area, feeding area and milking units (Bach *et al*., 2009; Ketelaar-de Lauwere *et al*., 1998). Why forced cow traffic is associated with less fetching of cows is partly a consequence of the fact that the cow actually must pass a milking unit before she can access either feeding or lying area (Hermans *et al*., 2003; Ketelaar-de Lauwere *et al*., 1998). Although forced traffic is related to less fetching, the cow traffic system is also related to negative consequences such as decreased roughage intake, shorter ruminating time and shorter eating time compared to free traffic (Melin *et al*., 2007; Hermans *et al*., 2003). In addition, a large-scale study, on-going for 4 years and including 635 dairy farms in North America, showed that forced cow traffic resulted in lower milk yield compared to free traffic (Tremblay *et al*., 2016). Forced cow traffic can further lead to more non-milking visits, *i.e.*, cows that visit a milking unit without milking permission and without being milked (Bach *et al*., 2009). These non-milking visits can be eliminated by applying voluntary (or guided) cow traffic (Drach *et al*., 2017; Melin *et al*., 2006). Because cows in free cow traffic can move freely between a milking unit, feeding and lying area, guided traffic can be seen as a system in-between forced and free traffic. In guided traffic, selection gates direct cows with milking permission to milking when they go from lying or feeding area, and cows without milking permission are free to move between feeding and lying area (Jacobs & Siegford, 2012a; Melin *et al*., 2006). Guided traffic can be managed as feed first or milk first. In feed first, cows move from feeding to milking and then to laying area (Paddick *et al*., 2019). In milk first, cows move from laying area to milking and then to feeding (Drach *et al*., 2017).

3.3. Milking frequency

Amongst pasture-based farms in New Zealand, one argument for installing automatic milking systems is the potential to reach three instead of two milkings per day without increased labour (Jago *et al*., 2007). In conventional systems, it is common to milk twice a day (Stockdale, 2006) but with an AMS it is not unusual with at least an average milking frequency of 2.5 visits/day (King *et al*., 2017b; Gygax *et al*., 2007; Melin *et al*., 2005a). Because AMS rely on cows' voluntary movements (Bach & Cabrera, 2017), the milking frequency varies more within AMS herds than within conventional herds (Lyons *et al*., 2013). A high milking frequency is further known to be an indicator of cow's performance (Lyons *et al*., 2013) and is desirable since it is known to be positively correlated with milk yield (Melin *et al*., 2005a; Wagner-Storch & Palmer, 2003). One study has shown milk yield to increase by 9 % with one more milking per day (Melin *et al*., 2005b) which shows great potential of the system although the installation of AMS itself automatically will not lead to higher milk production but depends on many other factors as well. In fact, one big-scale survey conducted on data from Dutch farms showed an increase in milk production with only 2 % on farms that installed AMS (Wade *et al*., 2004).

3.4. Feed allowance during milking

Prescott *et al*. (1998) established the fact that feed is a stronger motivation for cows than just being milked. In automatic milking systems, feed can either be supplied as a part of the cow's daily ration or in smaller amounts as teaser feed to attract cows to milking (Bach & Cabrera, 2017; Scott *et al*., 2014; Halachmi *et al*., 2005). Offering feed during milking seems to have a positive effect on milk yield (Ferneborg *et al*., 2016; Halachmi *et al*., 2005; Johansson *et al*., 1999) and has been associated with oxytocin release and thus a more rapid milk let-down (Johansson *et al*., 1999; Svennersten *et al*., 1990). To further investigate the relationship between milk yield and feed, a study was performed by Ferneborg *et al*. (2016) comparing feed allowance (maximum 2 kg concentrate) and no feed allowance in a AMS combined with different take-off levels (*i.e.*, different levels of milk flow when cups were taking off the teats). Regardless of take-off level, results showed feed to have a positive effect on milk yield. Milk yield increased from 27.9 kg/day to 29.1 kg/day with the high take-off level (800 g/min) and from 28.4 kg/day to 30.0 kg/day with the low take-off level (200 g/min). Milking interval slightly increased with feeding from 9 h 20 min to 9 h 23 min and 9 h 18 min to 9 h 58 min for the high take-off level and low take-off level, respectively. According to the authors, the increase in milk yield was most likely depending on oxytocin release since cows were brought to milking equally throughout the study and therefore only had a slight difference in milking interval. Jago *et al*. (2007) also investigated the effect of providing concentrate in an AMS but on a herd in New Zealand where cows had access to pasture according to a rotational grazing scheme. The treatments included two different milking intervals (minimum of 6 or 12 hours) and different concentrate rations (1 kg/cow and day or no concentrate). Feed had no effect on number of milkings per day but it did increase the number of visits to the selection unit on pasture, and it increased the milk yield with 1.1 kg per cow and day. In this case, the authors theorized feed had no effect on milk let down as no changes were found on cup attachment time or time cows spent in the milking unit.

Providing feed in milking robots has not only been associated with positive consequences but also with increased shuffling (a movement when the cow shifts weight from one hoof to another) during the attachment of the cups (Prescott, 1995). However, that feed in milking robot would lead to increased movements was rejected in later research (Jago *et al*., 2007). It has also been discussed that providing a limited source, such as concentrate in a milking unit, possibly can create competitive situations and by that generate aggressive behaviours (Albright & Arave, 1997). Aggressive behaviours can, in turn, have a negative impact on especially low ranked cows as dominant cows tend to push aside low ranked cows to reach their goal while low ranked cows wait until there is no que and can only then reach their goal (Halachmi, 2009). This behaviour of low and high ranked cows has been anchored in research where it has been shown that low ranked cows wait significantly longer in premilking areas than high ranked cows (Halachmi, 2009; Melin *et al*., 2006; Ketelaar-de Lauwere *et al*., 1996).

3.5. AMR and feed allowance

Since the AMR was developed in 2010 (Jacobs & Siegford, 2012a) there are few studies conducted on AMR and feed allowance. Furthermore, most studies found regarding AMR are studies performed on pasture-based herds, mostly from New Zealand and Australia (Scott *et al*., 2014; Kolbach *et al*., 2013; Jago *et al*., 2007). However, according to Swedish regulation (SJVFS 2019:18), the minimum length in Sweden for keeping milking cows on pasture is around 2 months. Therefore, how to manage AMR together with pasture can be relevant also for non-typical pasture-based production.

One study performed on feed allowance and AMR is a study by Kolbach *et al*. (2013). The study was conducted on a pasture-based research farm in Australia where a 16-bails prototype AMR was used. The cows were managed in a cow traffic system described as voluntary which in this study refers to a system where cows on pasture had access to an AMR all day and were directed to a feeding area with partial mixed ration after milking. The study investigated whether feed allowance in the AMR have a potential to improve cow traffic. In order to examine this, approximately 0.3 kg concentrate per visit was provided at the first two bails in the AMR during a feed allowance period. The results showed that feed allowance led to a seven times reduction of idle time, *i.e.*, when the system is ready for an action but is delayed because of cow's behaviour such as not walking on the platform and thereby stopping the AMR from rotating. In addition to this, bails were utilized almost six times more when cows were provided feed (Kolbach *et al*., 2013). Another study, done by Scott *et al*. (2014), was performed with similar conditions at the same research farm as the previous mentioned study. This study also analysed the effect of providing approximately 0.3 kg concentrate per visit. Without concentrate allowance, the median time cows spent in the premilking area was 129 min with 30 % of all cows waiting more than 4 hours. With concentrate allowance, on the other hand, cows spent half the time in the premilking area and according to the statistics, situations with more than 20 cows present in the premilking area at the same time seemed to occur more rarely (Scott *et al*., 2014).

3.6. Amounts of feed

In a single unit AMS, cows will have the time it takes to be milked to consume the provided feed (Bach *et al*., 2007) while the solution for an AMR often is to offer concentrate at the first one or two bails (Scott *et al*., 2014; Kolbach *et al*., 2013). In an AMR, this means less eating time and is the reason for only providing a small amount of concentrate (Bach & Cabrera, 2017). A smaller amount of concentrate in AMR can also be preferable for farmers restricted to low concentrate ratios (Scott *et al*., 2014; Halachmi *et al*., 2005). It may also be preferred in order to limit the risk of overfeeding because of the opportunity for the subsequent cow to eat both the ration that was meant for the first cow and the ration meant for her, if the first cow did not finish her ration (Scott *et al*., 2014).

Even though high concentrate allowances can lead to higher milk yield, it can also cause feed related diseases and have economic effects as concentrate is costly (Jago *et al*., 2007; Halachmi *et al*., 2005). Throughout the years, studies have compared different ratios of concentrate provided in automatic milking systems and analysed its consequences. Prescott *et al*. (1998) provided six high yielding cows 4 kg of concentrate per day in a milking unit while six low yielding cows were provided 2 kg of concentrate per day. The high yielding cows visited the milking unit more often compared to when no feed was supplied, but the low yielding cows did not, probably affected by the fact that they were not as hungry and motivated as the high yielders. This study showed feed to be a strong motivation for cows to visit a milking unit but did not show any clear results regarding the amount of feed.

Some years later, Halachmi *et al*. (2005) compared a ration of approximately 3.5 kg concentrate per day with a ration of approximately 5 kg per day. The herd, consisting of 100 cows, was managed with free cow traffic and two milking robots. The group, receiving the highest amounts of concentrate, obtained higher milk yields and established a new pattern more rapidly (< 15 days) than the low allowance group. A new pattern in this study meant that the cows figured out when to visit the robot for maximum concentrate allowance. The higher milk yields were explained by the fact that the high allowance group obtained a higher total energy intake while the lower allowance group did not compensate the low concentrate intake by eating more from the total mixed ration. However, despite the higher milk yields and quicker adaption, there were no changes in voluntary visits between the treatments (Halachmi *et al*., 2005). Similar results were found by Bach *et al*. (2007) who performed a study with free cow traffic and one milking robot, comparing an in-bail ration of up to 3 kg concentrate per day with a ration of up to 8 kg per day. The number of cows to fetch did not differ between the treatments and neither did the number of voluntary visits or milk yield. This study also showed that excessive amounts of concentrate can have a negative effect on the total feed intake as the cows receiving up to 8 kg concentrate per day had a lower total dry matter intake (Bach *et al*., 2007). Furthermore, Paddick *et al*. (2019) recently performed a study in Canada in a herd with guided traffic (feed first) comparing concentrate allowances of 0.5; 2.0; 3.5; and 5.0 kg per day. In addition to the concentrate, cows were also fed a partial mixed ration. Results showed no changes regarding milk yield or milking frequency between the treatments, which is in line with previous mentioned articles. However, in contrast to what Bach *et al*. (2007) came to, results from this study showed no changes in total dry matter intake (Paddick *et al*., 2019).

4. Material and methods

4.1. Animals and housing

This study was performed from February to June 2018 at the Swedish Livestock Research Centre at Lövsta, Swedish University of Agricultural Sciences, Uppsala. A total number of 113 ± 10 (range 99-124) cows of the breeds Swedish Holstein and Swedish Red were included, housed in an insulated naturally ventilated free-stall barn (fig. 1). The cows were divided in two sections: K1 and K3. Each section contained 64 cubicles and housed 62 ± 1 cows, thus a stocking density of ≤ 1:1 (cow:cubicle). Around 30 % of the cows in both K1 and K3 were primiparous cows and around 70 % were multiparous cows.

Silage was fed ad lib in troughs (K1) and feed table (K3) and was refilled at 06:00, 11:30, 15:00, 20:00 and 23:00. Concentrate was fed according to daily needs in total four concentrate feeders. Cow traffic was managed in such way the cows could move freely from resting area to feeding area by selection gates and back from feeding to lying area through one-way gates (fig. 1).

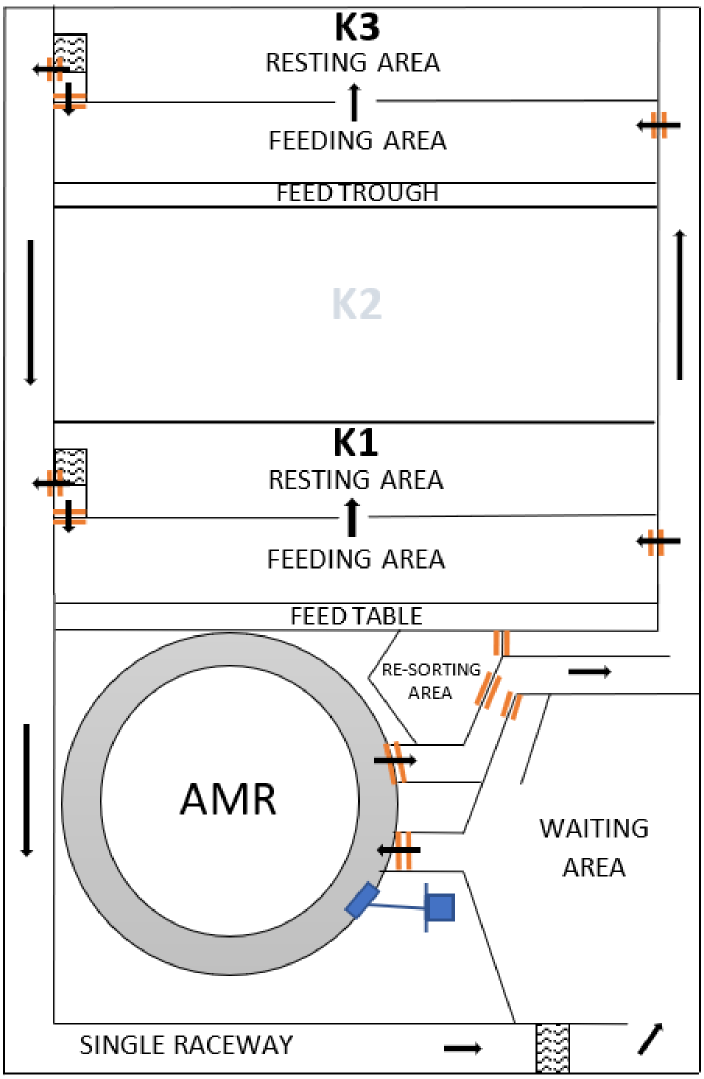

Figure 1. Drawing of the stable layout. Arrows represents cow traffic directions; plotted boxes identification passages; orange stripes selection gates; and the blue boxes represents a feed dispenser and a single feed trough.

4.2. Milking system

Milking was performed in an AMR (AMR; DeLaval Automatic Milking Rotary – AMR^{TM}, Tumba, Sverige) equipped with 24 bails (milking stalls), five task specific robots and quarter level milking. The first and second robot were responsible for cleaning, pre-milking and drying teats. The third and fourth robot attached cups and the last robot sprayed teats after milking. The AMR was mostly working in automatic mode and was set to rotate one milking place if no cow entered the AMR for 60 s. If a cow stopped half way entering or leaving the AMR, stopping the AMR from rotating for ≥ 10 min, the AMR had to be manually activated to function again. Some of the bails were sporadically inactive during the study due to technical issues. The AMR automatically rotated when an inactive bail where present.

Before this study, cows in K1 and K3 were batch milked in the AMR two times a day at around 05.30 and 15.30. All cows were manually collected by staff to the waiting area and then to milking by a crowd gate. The average milk yield for the three weeks before the beginning of the study was 15.3 l/cow and milking.

4.3. Milking routines

During the study period, cows could access the AMR for ten and a half hours a day split into three milking windows (fig. 2). The milking windows started at 05:00, 14:00 and 22:00 and lasted for three and a half hours. During a milking window, the selection gate between lying and feeding area in every section selected cows to milking instead of to feeding. The AMR was prepared and activated 15 minutes after each milking window's start. After milking, raceways and selection gates led the cows back to their respective feeding area. Incomplete milked cows were directed back to the waiting area to be milked again and some cows were led to a sorting area directly after milking according to another ongoing study.

After the three hours milking window, staff collected remaining cows that had not been milked from the sections. These cows were manually led to the waiting area and then to the AMR by a crowd gate. During night milking, staff were only allowed to collect cows from raceways and premilking areas and not from the sections due to work safety reasons. Consequently, all cows were milked at minimum two times a day. When the milking window ended, a full system wash was performed.

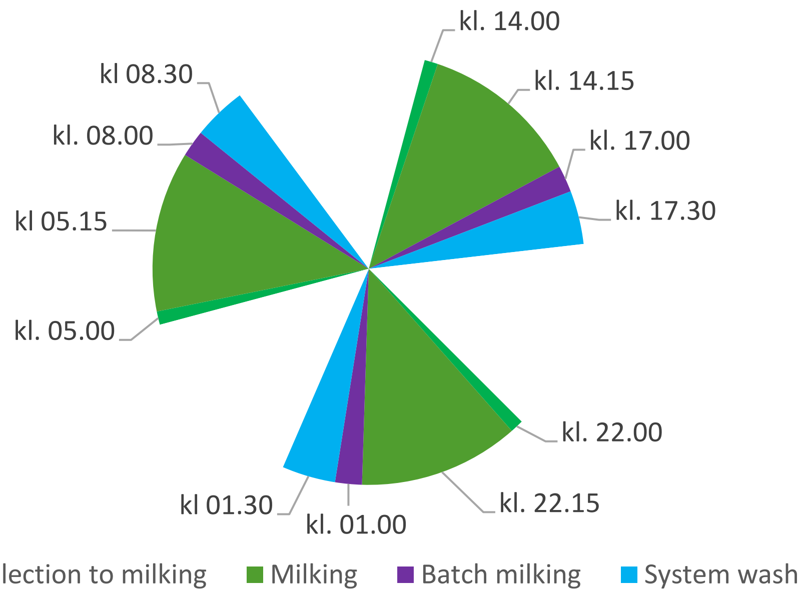

Figure 2. A 24-hour activity scheme regarding the AMR. Times show when the activity started. During morning and evening milkings, batch milking included K1 and K3. During night milking, batch milking included only cows from raceways and waiting area.

Furthermore, staff were instructed not to interact with any cow or to affect cow traffic in any way during the milking window's three hours. Exceptions were made for problems such as if the AMR were out of function or if a cow for obvious reasons stopped cow traffic. Heifers and cows new to the AMR were assisted the four first milkings if needed. CMT (California Mastitis Test), milk tests and bacteria tests were performed when required.

4.4. Treatments

The experimental design included four treatments that followed each other and differed in length of adjustment period and access to teaser feed in the AMR (table 1). Adjustment periods were set to one and three weeks respectively and all experimental periods, *i.e.*, when data was collected, had the length of one week (21 milkings). The experimental periods were in total four weeks and started at 14:00 the first day of the week and ended at 14:00 at the last day of the week. The study, including adjustment periods, was running for in total 12 weeks and overall, this resulted in 84 milking's.

Table 1. *All treatments summarized. The treatments are presented in the same order they were implemented.*

Treatment	Teaser feed	Adjustment period
1	No feed	1 week (1wk)
2	Feed	1 week (1wk)
3	Feed	3 weeks (3wk)
4	No feed	3 weeks (3wk)

During treatments with so called teaser feed, a ration of approximately 50 g concentrate was given in a single feed trough at the first bail in the AMR (fig. 3). The feed trough was installed and attached to the outside of the AMR, thus was not rotating when the platform of the AMR rotated. The trough could only be reached at the first bail in the AMR before it rotated and concentrate was refilled in the trough automatically when the platform rotated. The cows in this study had never been exposed to feed in the AMR before.

Figure 3. The concentrate dispenser with a pipe to the single feed trough. When the picture was taken, the feed trough was raised due to washing.

4.5. Data collection

Cow traffic data was collected using video recordings and by automatic registrations in the herd management software DelPro^{TM} (DeLaval International AB, Tumba, Sweden). In total, 7 cameras were installed in the barn and around the

AMR (fisheye view, n = 3; SAMSUNG SNF-8010VMP, cameras with regular view, n = 4; SAMSUNG QNV-7010RP). A 32-channel network video recorder (SAMSUNG XRN-2011) was recording 24 hours a day during experimental weeks. During adjustment weeks, only milkings were recorded in case of unforeseen events.

In each section, approximately 30 focal cows were marked across the top of the hips with an animal friendly spray every third day to be clearly visible. Selected primiparous and multiparous cows were marked in the section K1 while only primiparous cows in different lactations stages were marked in K3.

4.5.1. Time to enter the AMR

Data for Time to enter the AMR, *i.e.*, how long time it took for a cow to enter the platform of the AMR, were manually calculated from video recordings (n = 821 entering's). Recordings from two cameras located above the waiting area and the single raceway were used (fig. 4).

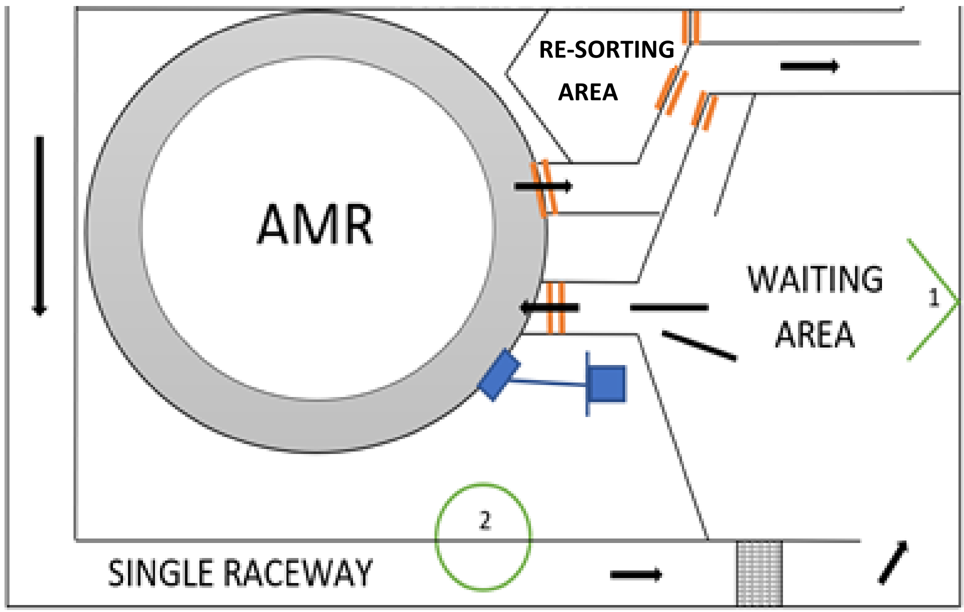

Figure 4. Green symbols represent cameras used to analyse the time it took for a cow to enter the AMR. Camera 1 with regular view and camera 2 with fish eye view.

The entering process was divided into following three moments (fig. 5)

1) when the gate closest to the platform opened
2) when the cow put one hoof on the platform and
3) when the cow had all four hoofs on the platform

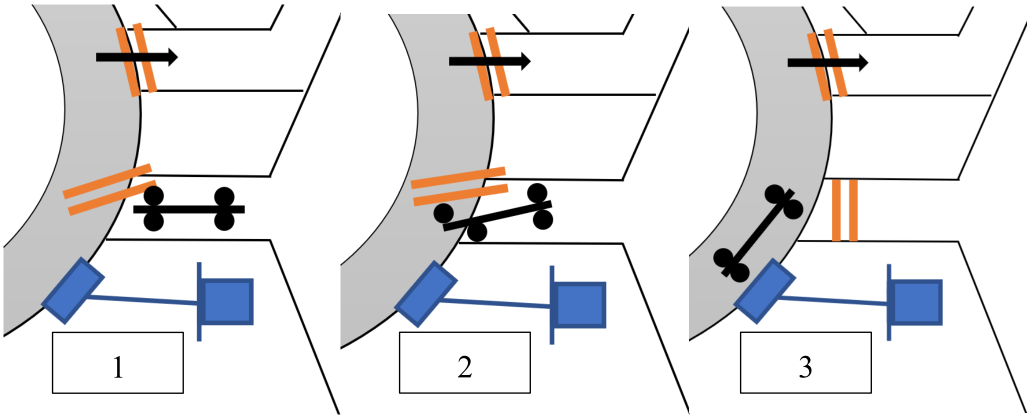

Figure 5. Showing a cow entering the AMR divided into three moments. 1. Gate opens 2. One hoof on the platform 3. Four hoofs on the platform.

The exact time for all moments was registered to calculate the total entering time. Two morning milkings, two evening milkings and two night milkings from each experimental period (n = 24 milkings) were analysed. All cows that entered the AMR voluntary during these milkings were analysed. Milkings affected by abnormal circumstances (hoof trimming, milk analysis, technical issues, staff running late etc.) and cows affected by human interaction were not analysed.

4.5.2. Number of cows to fetch

Number of cows to fetch, *i.e.*, how many cows were not going voluntary to milking but needed to be collected by staff, was calculated based on the automatically collected data from milkings and the total number of cows included in the study that day. The cows relevant for fetching were cows that had not walked to milking voluntary during the three-hour milking window. The number of milked cows was calculated for each milking session using milking data from DelPro^{TM} (n = 72 milkings; DelPro^{TM}). Statistics was calculated in percentage because the number of total cows could vary from day to day. The number of fetched cows included cows from raceways, waiting area and sections.

4.5.3. Time spent in premilking areas

Time spent in premilking areas, *i.e.*, the time cows spent in raceways and waiting area during the milking window's three hours, was calculated with ID passages from the selection gate at the section to the raceway and manually registrations from video recording from when the cow was entering the AMR (n = 464 registrations). When a cow was entering the AMR was defined as when the gate to the platform of the AMR opened.

4.6. Data handling

The final dataset consisted of 72 milkings as 12 (out of 84) milkings had to be excluded due to technical issues (n = 5), regular milk sampling (n = 3) and human errors (n = 4) (table 2).

Table 2. Number of milkings included in the study in total and per time slot during the day, as well as mean number of cows per treatment.

Treatment	Morning	Evening	Night	Total milkings	Mean number of cows
No feed –1wk	7	6	7	21	100
Feed – 1wk	5	6	7	19	107
Feed – 3wk	5	6	7	21	123
No feed – 3wk	5	6	5	19	123
Total	22	24	26	72	113

To analyse if milk yield had an effect on the results and if high-milking cows were more willing to enter the AMR than others, stage of lactation was included in the model for statistical analysis. To enable comparisons including lactation stage, cows were grouped by early (<55 DIM), mid (56 – 159 DIM) and late (>160 DIM) lactation. To analyse if differences existed between cows in different parity, primiparous cows were compared with multiparous cows. Data for number of cows to fetch did not contain information of the individual cows, and the model did therefore only include treatment as a fixed factor.

4.6.1. Focal cows

Registrations from focal cows were used for an in-depth estimation of Time to enter the AMR and Time spent in premilking areas. Regarding time to enter the AMR, 691 entering's from focal cows were registered. Regarding time spent in premilking areas, data on individual level at one selection gate and from video observation at the AMR were needed. Because of technical issues with the selection gate, some cows were never registered. Therefore, only 464 registrations (out of 691 registrations) from focal cows could be used for analyses. No data or outliers were excluded because all data were thought to have relevance to the results and show important differences. A summary of events analysed in relation to cow traits can be seen in table 3.

The time cows spent in premilking areas were analysed for K1 and K3 separately. Otherwise, the effect of the walking distance from the stable sections to the AMR were thought to have too big impact on the results. The statistical model for K3 and time spent in premilking areas did not include parity as the distribution of primiparous and multiparous cows were too irregular.

Table 3. Distribution over events analysed based on parity, lactation stage and stable section.

Factor	Section	Trait	Number of events analysed
Time to enter the AMR	n/a	Primiparous	504
		Multiparous	187
		Early	69
		Mid	429
		Late	193
Time spent in premilking areas	K1	Primiparous	82
		Multiparous	115
		Early	6
		Mid	124
		Late	67
	K3	Early	52
		Mid	145
		Late	70

4.6.2. Statistical analysis

A mixed linear model, tested in the mixed procedure in SAS (SAS 9.4, SAS Institute Inc., Cary, NC, USA), was used to estimate the treatment effect on Time to enter the AMR and Time in premilking areas. The model for Time to enter the AMR and Time in premilking areas for focal cows included treatment (1, 2, 3 and 4), stage of lactation (early <55 DIM, mid 56 – 159 DIM, and late lactation >160 DIM) and parity (primiparous and multiparous) as fixed factors. This was estimated with an autoregressive covariance structure (AR(1)), and Tukey's adjustment for post-hoc pairwise comparisons. Time spent in premilking areas was also estimated per section/group.

In addition, a simple model for Time to enter the AMR and Cows to fetch, including only treatment as fixed effect but comprising all cows, was run with a compound symmetry covariance structure and Tukey's adjustment for post-hoc pairwise comparisons.

Due to non-normality, data for Time to enter the AMR and Time spent in premilking areas was transformed using the natural logarithm. Results are presented as Least Square Means (LSMeans) +/- Standard Error of Means (SEM) unless else is stated. Results are significant if $P < 0.05$.

5. Results

5.1. Time to enter the AMR

5.1.1. All observations

When including all observations (n = 821), all cows and comparing treatments, cows entered the AMR faster with teaser feed than without ($P < 0.001$) (table 4, appendix 1). The pairwise comparisons showed that during Feed – 1wk, cows entered the AMR more than twice as fast compared to during No feed – 3wk. In addition, during No feed – 1wk, cows entered the AMR quicker than during No feed – 3wk. No other pairwise comparisons were significant (table 4). Extreme values and spreading over data can be seen in figure 6 and figure 7. Figure 6 includes all observations. In figure 7, the 1 % values with the most seconds are excluded to show more clearly the spreading of data.

Table 4. Time to enter the AMR (n = 821) according to treatment. Superscript letters within treatment and variable indicate significant differences ($P \leq 0.05$). Values are presented as logged values and values within parentheses are back-transformed to seconds. AMR = automatic milking rotary.

Treatment	Mean (log) ± SE Mean (log) (s)
No feed – 1wk	1.02 ± 0.025^{a} (10.6)
Feed – 1wk	0.81 ± 0.022^{b} (6.5)
Feed – 3wk	0.09 ± 0.020^{b} (7.5)
No feed – 3wk	1.12 ± 0.027^{c} (13.2)

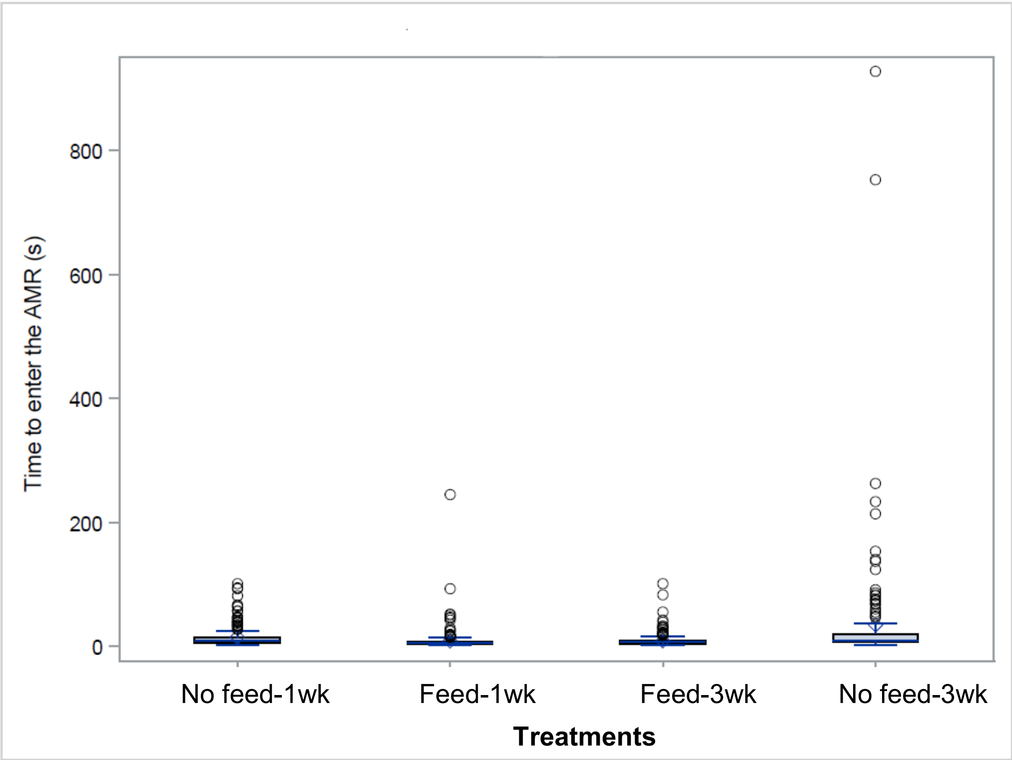

Figure 6. Boxplot of Time to enter the AMR according to treatments. This boxplot includes all observations (n = 821) and no values are excluded. Treatment 1 = No feed – 1wk, 2 = Feed – 1wk, 3 = Feed – 3wk, 4 = No feed – 3wk.

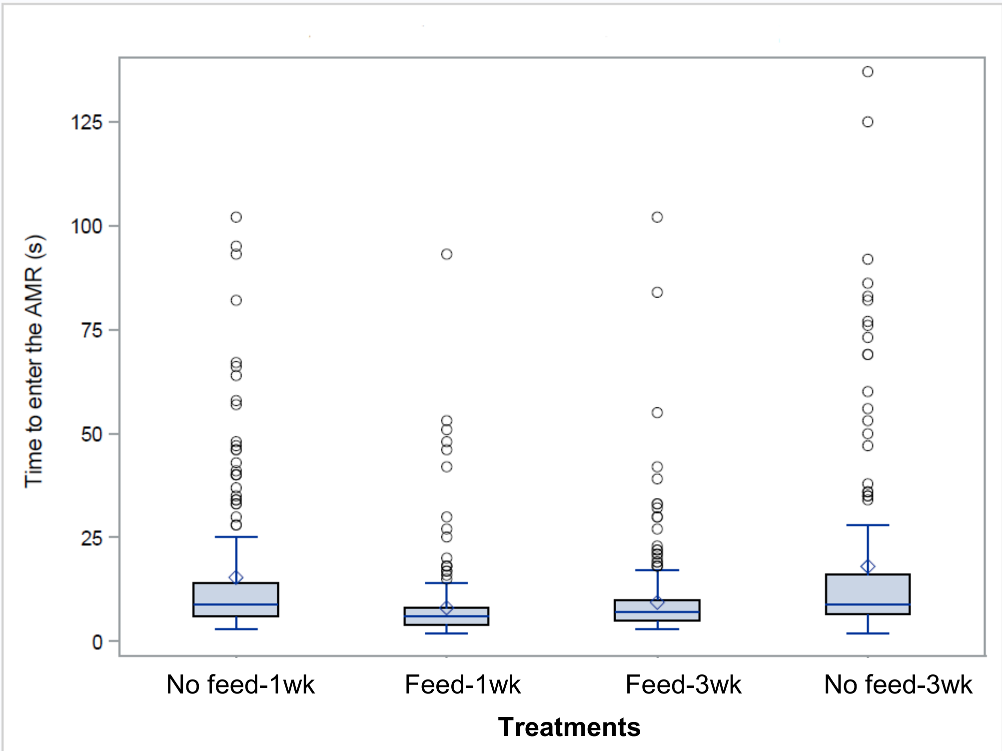

Figure 7. Boxplot of Time to enter the AMR according to treatments. This boxplot includes all observations (n = 821) but the greatest 1 % values are excluded. Treatment 1 = No feed – 1wk, 2 = Feed – 1wk, 3 = Feed – 3wk, 4 = No feed – 3wk.

5.1.2. Observations from focal cows

When analysing only observations from focal cows (distribution can be seen in table 3) in relation to treatment, no differences were seen between the treatments No feed – 1wk and Feed – 3wk (table 5). However, during the treatment No feed – 3wk, cows entered the AMR slower compared to all other treatments.

Table 5. Time to enter the AMR for focal cows, according to treatment (n = 691). Superscript letters indicate significant differences (P ≤ 0.05). Values are presented as logged values and values within parentheses are back-transformed to seconds.

Treatment	Mean (log) ± SE Mean (log) (s)
No feed – 1wk	0.92 ± 0.031^{a} (8.3)
Feed – 1wk	0.78 ± 0.027^{b} (6.1)
Feed – 3wk	0.84 ± 0.026^{ab} (6.9)
No feed – 3wk	1.05 ± 0.029^{c} (11.2)

There was no interaction effect of parity and treatment but parity did have an overall effect on how fast cows entered the AMR. Primiparous cows entered the AMR in average 2.94 seconds faster than multiparous did (P < 0.001). There was also a greater numerical variance in data within the multiparous group (table 6). Stage of lactation did not affect the time to enter the AMR.

Table 6. Time to enter the AMR for focal cows depending on parity, independent of treatment (n = 691). Superscript letters indicate significant differences (P ≤ 0.001). Values are presented as logged values and values within parentheses are back-transformed to seconds.

Parity	Mean (log) ± SE Mean (log) (s)
Primiparous	0.82 ± 0.018^{a} (6.5)
Multiparous	0.98 ± 0.027^{b} (9.5)

5.2. Number of cows to fetch

5.2.1. All observations

There were less cows to fetch in both treatments with feed, compared to both treatments without feed (table 7, appendix 1). The greatest difference was between Feed – 1wk and No feed – 1wk (P < 0.001), where Feed – 1wk resulted in lowest proportion of cows to fetch (fig. 8). Regardless of adjustment period, fewer cows were needed to be fetched in treatments including feed compared to when no feed was provided. With feed allowance, 40 % of all cows were needed to be fetched. When no feed was provided, 54 % of all cows were needed to be fetched (P ≤ 0.01) (fig. 9).

Table 7. Proportion of cows to fetch (data from 72 milkings), according to treatment. Superscript letters indicate significant differences ($P \leq 0.05$).

Factor	**Treatment**	**Mean (%) ± SE Mean (%)**
Number of cows to fetch	No feed – 1wk	51.0 ± 1.63^a
	Feed – 1wk	38.1 ± 1.72^b
	Feed – 3wk	42.5 ± 1.76^b
	No feed – 3wk	57.2 ± 1.83^a

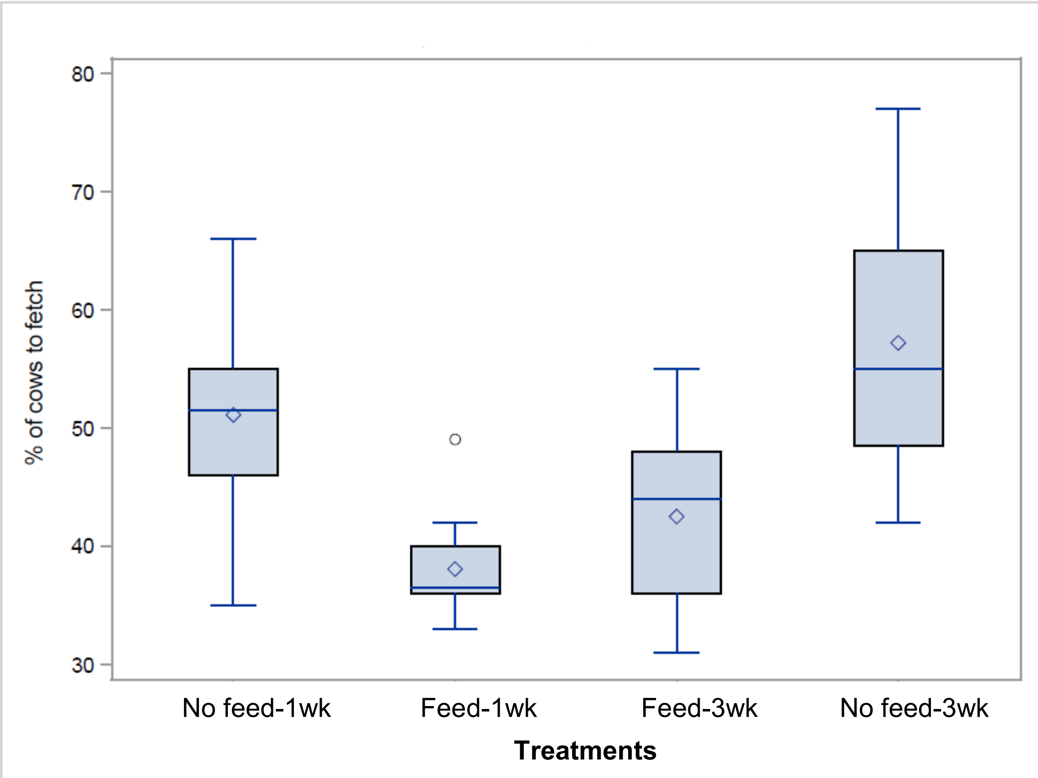

Figure 8. Boxplot of proportion of cows to fetch according to treatments. This boxplot includes all milkings (n = 72). Treatment 1 = No feed – 1wk, 2 = Feed – 1wk, 3 = Feed – 3wk, 4 = No feed – 3wk.

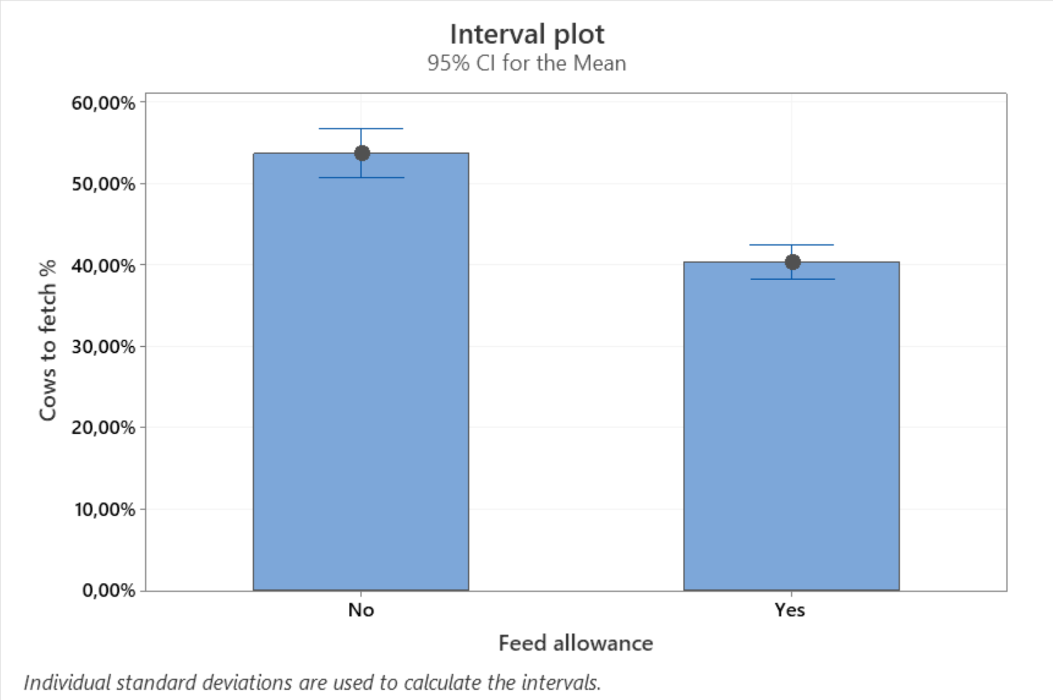

Figure 9. Interval plot and 95 % confidence interval of proportions of cows to fetch with and without feed in the AMR, independent of treatment.

5.3. Time spent in premilking areas

5.3.1. All observations

The cows in K1 spent less time in premilking areas during Feed – 1wk compared to when no feed was provided, independent of adjustment period (table 8, fig. 10, appendix 1). Further, no differences were seen between No feed – 1wk and Feed – 3wk. The cows in K3 spent less time in premilking areas during Feed – 1wk compared to No feed – 3wk (table 8, fig. 10). No differences were seen between Feed – 1wk and No feed – 1wk. When comparing Feed – 3wk and No feed – 3wk, no differences were seen either.

Table 8. Time spent in premilking areas (K1: n = 197, K3: n = 267, n^{total} = 464) according to treatment. Superscript letters within treatment and variable indicate significant differences (P ≤ 0.05). Values are presented as logged values and values within parentheses are back-transformed to minutes.

Treatment	Section	Mean (log) ± SE Mean (log) (min)
No feed – 1wk	K1	6.36 ± 0.176^{ac} (9.6)
Feed – 1wk		5.78 ± 0.185^{b} (5.4)
Feed – 3wk		6.09 ± 0.188^{bc} (7.4)
No feed – 3wk		6.78 ± 0.194^{a} (14.7)
No feed –1wk	K3	6.57 ± 0.159^{ab} (11.9)
Feed – 1wk		6.28 ± 0.117^{a} (8.9)
Feed – 3wk		6.42 ± 0.104^{ab} (10.2)
No feed – 3wk		6.78 ± 0.121^{b} (14.6)

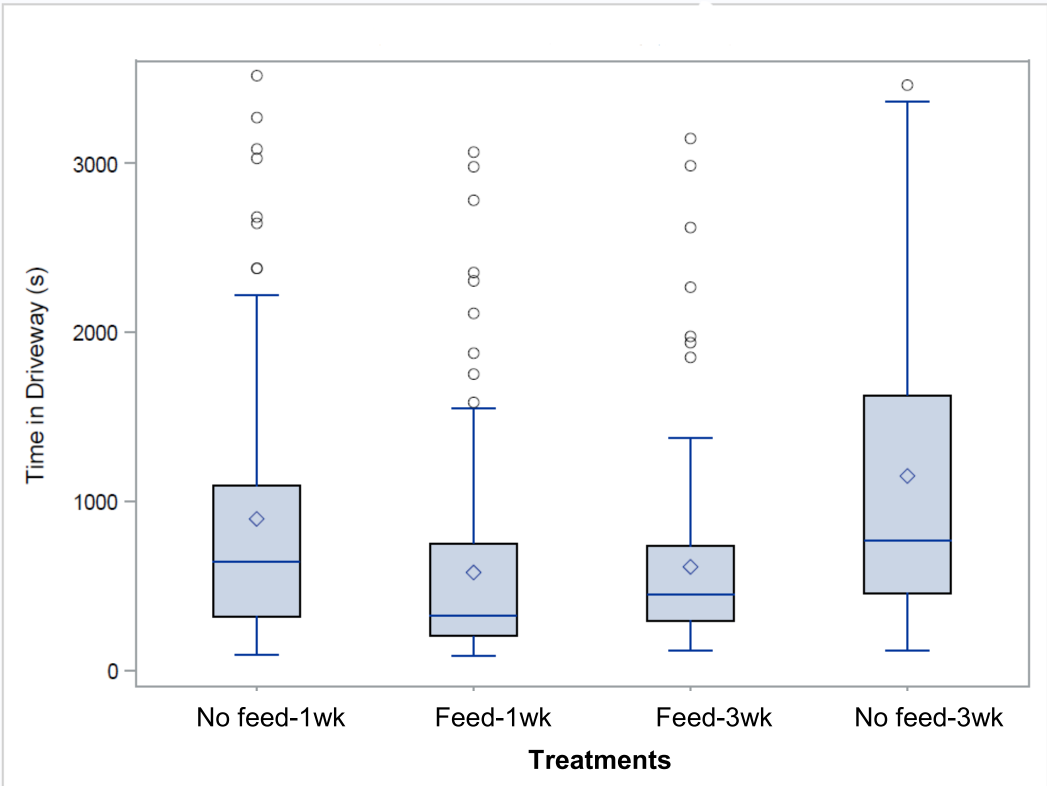

Figure 10. Boxplot of Time spent in premilking areas according to treatments. This boxplot includes all observations (n = 464). Treatment 1 = No feed – 1wk, 2 = Feed – 1wk, 3 = Feed – 3wk, 4 = No feed – 3wk.

5.3.2. Observations from focal cows

The effect of parity was only analysed for K1 (197 observations) and there were no differences between primiparous and multiparous cows. Both primiparous and multiparous cows spent less time in premilking areas when given feed compared to when no feed was given. Stage of lactation (464 observations) did not affect how long time cows spent in premilking areas either.

6. Discussion

Because of lack of other studies performed with feed in AMR there are few results to compare the results from this study with. However, the results from this study points towards the same direction as results presented by Kolbach *et al*. (2013) and Scott *et al*. (2014). Kolbach *et al*. (2013) described a better utilization of the AMR with feed allowance which could be seen in this study as well. Further, Scott *et al*. (2014) showed that cows spent half the time in the premilking areas with feed which also is in line with the results from this study. Not surprisingly, one thing seems to be sure. Providing feed in the AMR increased the efficiency of the AMR: fewer cows were fetched for milking and the cows spent less time in premilking areas. In addition, an important improvement was the numerical decrease in variance in data, both regarding how fast the cows entered the AMR and how long time they spent in premilking areas. As mentioned previously, labour saving is a common argument for transition from conventional to automatic milking system (Bach & Cabrera, 2017; Mathijs, 2004) and in many cases, cows that distinguish from group average can be the most labour-intensive ones as these individuals often regards manual handling.

6.1. Ability to adapt

The choice to include adjustment period in the treatments in this study was made by the research team after technical problems with a camera in the beginning of the study. In retrospect, this was a comparison one should have skipped and the results regarding adjustment period are weak and should not be used in future research. The comparison is weak because the first treatment in the study could be thought of as a control period. This treatment was without feed which means the cows practically behaved like they did before the beginning of the study. During the second treatment, concentrate was provided. This was the first time the cows experienced concentrate in the AMR which might have been why the effects came out strong. Probably, the cows were more interested in the feed allowance in the beginning. During the third period, concentrate had been given to them for five weeks in total so maybe the interest waned. When the feed then was taken away from them during the fourth period, it might had been frustrating and upsetting for the cows. To get a more accurate result one could have runed the treatments parallel and not sequential. Another way to eliminate these effects in the future could be to implement treatments in different herds, or to get the cows used to the treatments during a longer time period.

As mentioned, the comparisons regarding adjustment period in this study are weak. However, the strongest and most positive effects from feed allowance were seen after one week adjustment period. After three weeks with feed, the effects tended to fade some. In addition, the negative effects from when the feed was taken away tended to be stronger after three weeks adjustment period than after one week. So, even if it has been shown that cows adapt fast (Halachmi *et al*., 2005; Jacobs & Siegford, 2012b) it seems that the length of adjustment period influenced the results. Therefore, longer adjustment period should be preferable to get more secure and stable results. Longer adjustment periods should also be preferable in future research to eliminate behaviours that arises when cows are newly exposed to new routines.

6.2. Parity and social ranking

Primiparous cows entered the AMR faster than multiparous throughout the whole experiment, independent of treatment. Difference between parity was only seen for Time to enter the AMR and unexpectedly, no differences were seen for Time spent in premilking areas. The fact that primiparous are more willing to be milked in automatic milking system has been established in previous studies (Bach *et al*., 2009; Borderas *et al*., 2008). No explanation was found why primiparous cows did not spent less time in premilking areas in this study and is something that would be interesting to analyse further in future studies, preferably including a greater number of observations.

Except for parity it would have been of interest to also analyse the cows social ranking order as low ranked cows do wait longer in premilking areas than high ranked cows (Halachmi, 2009; Melin *et al*., 2006; Ketelaar-de Lauwere *et al*., 1996). Some regrouping of cows occurred during this study which meant some cows were new to the system. Being introduced to a new herd and social ranking probably affected these cows' behaviours in relation to the AMR. Further, Albright & Arave (1997) concluded that providing a limited source, such as concentrate, to a group of cows could create competitive situations and Halachmi (2009) found that low ranked cows did not dare to approach the concentrate in their study. In this study, cows that entered the AMR with much different speed than the group average were considerable fewer, especially amongst multiparous, with feed allowance than without. However, some cows tended to stand still on their way on the platform, which hypothetically could be a sign of fear. If the cows would have felt fear, it was probably more because of entering the rotating platform than fear of other cows because the first bail, which she was supposed to enter, was always free from other cows. Further, no other cow could reach the concentrate at the first bail so the risk for creating competitive situations by the concentrate trough were minimal.

6.3. Feed allowance and milk yield

Offering feed during milking has been shown to increase milk yield (Ferneborg *et al*., 2016; Halachmi *et al*., 2005; Johansson *et al*., 1999) and has been associated with a more rapid milk let-down (Johansson *et al*., 1999; Svennersten *et al*., 1990). Further, milk yield has been shown to increase with visits to a milking unit (Melin *et al*., 2005a; Wagner-Storch & Palmer, 2003) but in this study, visits to the AMR was not included in the data collection. However, all cows were taken to milking at least two times a day but had the chance to three milkings per day. During treatments with feed, less cows were needed to be fetched which could mean that milking frequency, and thus milk yield, increased with feed in the AMR. Milk yield was not analysed in this study but the effect on milk yield from giving concentrate in milking robots should be of interest to analyse in future research.

As mentioned, milk yield was not analysed but we did analyse if cows in different lactation stages entered the AMR in different speed and spent different time in premilking areas depending on treatment. To group cows depending on lactation stage were thought to be a way to estimate the effect from milk yield but, in this study, we could not see any differences between cows in different lactation stages. This outcome might had been different if data on actual milk yield were included in the statistical analyse and if groups were based on milk yield instead of lactation stage. Why lactation stage did not affect our results in this study can be discussed. Cows in peak lactation have higher energy demand and are probably hungrier than low yielding cows (Prescott *et al*. 1998), so theoretically cows in peak lactation should have been more willing to visit a milking unit and therefore enter the AMR faster and spend less time in premilking areas. However, even if the high yielding cows were hungrier, maybe the amount of feed in the feed dispenser was too small, or the time cows had to finish their meal was too short. Concentrate was refilled when the AMR rotated which resulted in one situation regularly spotted by the staff, some cows did not have time to finish or even taste the concentrate before the AMR rotated. If this situation had a negative effect on oxytocin release, made the cows frustrated or less willing to enter the AMR next time is unknown but it might have affected the cow's behaviour. However, the settings of the concentrate feeder could be adjusted if it was thought to be a permanent solution.

6.4. Effect of walking distance

In this study, cows were divided in two sections, one close and one more far away from the AMR. Cows closest to the AMR naturally spent shorter time in premilking areas, as they had shorter distance to walk from their section to the AMR. Because of the different walking distances, the sections were analysed separately so that it would not have impact on the effects of the treatments. Further, because the two sections were analysed separately, we could not draw any conclusions about if and how the distance affected our results. However, the distance should not have affected the results from this study as studies have been made with pasture-based herds with long distances to milking (Scott *et al*., 2014; Kolbach *et al*., 2013; Jago *et al*., 2007) and these studies have come to similar conclusions regarding feed allowance in automatic milking as this study with much shorter distances.

6.5. Outliers

No outliers were excluded from the data because the outliers were thought to have relevance for the results. This means outliers could have affected the outcomes in this report to look more significant than if outliers were excluded and probably many outliers were a consequence of the same cow's behaviour. However, this was considered in the statistical model by including cow in the variance model. In that way, if the same individual always gave rise to extreme values, it would not have affected the significance of the results. Another factor that could have influenced the cow's behaviour in relation to the AMR was their health status. For example, lame cows are less willing to move fast (King *et al*., 2017b; Borderas *et al*., 2008). In this study, no in-depth analyse of outliers were made but in future research, this could be of interest.

6.6. Sources of error in the statistical analyse

Amongst the factors analysed in this study, most significant differences were seen when analysing how fast cows entered the AMR. Results regarding time spent in premilking areas, the number of fetched cows and entering time did not consequently follow one another. For example, no differences between parity were shown when analysing time in premilking areas. One explanation could be that cows maybe acted different closer to the AMR and the concentrate dispenser than in the premilking areas. Further, observations regarding time spent in premilking areas got affected by the fact that the selection gate did not work properly at the time and did not register all individuals. Therefore, the number of observations were not as many as wished. With more observations, maybe the results might have been more similar to the results regarding how fast the cows entered the AMR.

7. Conclusions

Teaser feed motivated the cows to enter the AMR faster than without teaser feed. Further, less cows were needed to be fetched with teaser feed than without. The cows also spent less time in premilking areas after one week with teaser feed compared to after three weeks without teaser feed. Primiparous cows entered the AMR with faster speed compared to multiparous cows but primi- and multiparous cows spent the same amount of time in premilking areas, independent of treatment. Stage of lactation had no effect on how fast the cows entered the AMR or how long time they spent in premilking areas. The results regarding adjustment period in this study are weak and should not be used in future research. However, Length of adjustment period did not seem to influence the numerical variance but providing feed led to a numerical decrease in variance in data. Overall, this study indicates that offering teaser feed in AMR can be beneficial and have a potential to improve cow traffic.

8. References

Albright, J.L. & Arave, C.W. (1997). The behaviour of cattle. Cambridge: CAB International.

Bach, A. & Busto, I. (2005). Effects on milk yield of milking interval regularity and teat cup attachment failures with robotic milking systems. Journal of Dairy Research, 72(1), pp. 101-106.

Bach, A. & Cabrera, V. (2017). Robotic milking: Feeding strategies and economic returns. Journal of Dairy Science, 100(9), pp. 7720-7728.

Bach, A., Devant, M., Igleasias, C. & Ferrer, A. (2009). Forced traffic in automatic milking systems effectively reduces the need to get cows, but alters eating behavior and does not improve milk yield of dairy cattle. Journal of Dairy Science, 92(3), pp. 1272-1280.

Bach, A., Iglesias, C., Calsamiglia, S. & Devant, M. (2007). Effect of amount of concentrate provided in automatic milking systems on milking frequency, feeding behavior, and milk production of dairy cattle consuming high amounts of corn silage. Journal of Dairy Science, 90(11), pp. 5049-5055.

Bijl, R., Kooistra, S.R. & Hogeveen, H. (2007). The profitability of automatic milking on Dutch dairy farms. Journal of Dairy Science, 90(1), pp. 239-248.

Borderas, T.F., Fournier, A., Rushen, J. & de Passillé, A.M.B. (2008). Effect of lameness on dairy cows' visits to automatic milking systems. Canadian Journal of Animal Science, 88(1), pp. 1-8.

de Koning, K., Slaghuis, B. & van der Vorst, Y. (2003). Robotic milking and milk quality: effects on bacterial counts, somatic cell counts, freezing point and free fatty acids. Italian Journal of Animal Science, 2(4), pp. 291-299.

de Passillé, A.M., Rushen, J. & Martin, F. (1995). Interpreting the behaviour of calves in an open-field test: a factor analysis. Applied Animal Behaviour Science, 45(3-4), pp. 201-213.

Devir, S. (1995). The dairy control and management system in the robotic milking farm: IMAG-DLO.

Drach, U., Halachmi, I., Pnini, T., Izhaki, I. & Degani, A. (2017). Automatic herding reduces labour and increases milking frequency in robotic milking. Biosystems Engineering, 155, pp. 134-141.

Ferneborg, S., Stadtmuller, L., Pickova, J., Wiking, L. & Svennersten-Sjaunja, K. (2016). Effects of automatic cluster removal and feeding during milking on milking efficiency, milk yield and milk fat quality. Journal of Dairy Research, 83(2), pp. 180-187.

Fisher, A.D., Verkerk, G.A., Morrow, C.J. & Matthews, L.R. (2002). The effects of feed restriction and lying deprivation on pituitary-adrenal axis regulation in lactating cows. Livestock Production Science, 73(2-3), pp. 255-263.

Galton, D., Adkinson, R., Thomas, C. & Smith, T. (1982). Effects of premilking udder preparation on environmental bacterial contamination of milk. Journal of Dairy Science, 65(8), pp. 1540-1543.

Grandin, T. (1993). Behavioral agitation during handling of cattle is persistent over time. Applied Animal Behaviour Science, 36(1), pp. 1-9.

Gygax, L., Neuffer, I., Kaufmann, C., Hauser, R. & Wechsler, B. (2007). Comparison of functional aspects in two automatic milking systems and auto-tandem milking parlors. Journal of Dairy Science, 90(9), pp. 4265-4274.

Halachmi, I. (2009). Simulating the hierarchical order and cow queue length in an automatic milking system. Biosystems Engineering, 102(4), pp. 453-460.

Halachmi, I., Ofir, S. & Miron, J. (2005). Comparing two concentrate allowances in an automatic milking system. Animal Science, 80, pp. 339-343.

Hermans, G.G.N., Ipema, A.H., Stefanowska, J. & Metz, J.H.M. (2003). The effect of two traffic situations on the behavior and performance of cows in an automatic milking system. Journal of Dairy Science, 86(6), pp. 1997-2004.

Hovinen, M. & Pyörälä, S. (2011). Invited review: Udder health of dairy cows in automatic milking. Journal of Dairy Science, 94(2), pp. 547-562.

Jacobs, J.A. & Siegford, J.M. (2012a). Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. Journal of Dairy Science, 95(5), pp. 2227-2247.

Jacobs, J.A. & Siegford, J.M. (2012b). Lactating dairy cows adapt quickly to being milked by an automatic milking system. Journal of Dairy Science, 95(3), pp. 1575-1584.

Jago, J.G., Davis, K.L., Copeman, P.J., Ohnstad, I. & Woolford, M.M. (2007). Supplementary feeding at milking and minimum milking interval effects on cow traffic and milking performance in a pasture-based automatic milking system. Journal of Dairy Research, 74(4), pp. 492-499.

Johansson, B., Uvnas-Moberg, K., Knight, C.H. & Svennersten-Sjaunja, K. (1999). Effect of feeding before, during and after milking on milk production and the hormones oxytocin, prolactin, gastrin and somatostatin. Journal of Dairy Research, 66(2), pp. 151-163.

Jordbruksverket. SJVFS 2019:18. *Statens jordbruksverks föreskrifter och allmänna råd om nötkreaturshållning inom lantbruket*. Jönköping: Statens jordbruksverk.

Ketelaar-de Lauwere, C.C., Hendriks, M., Metz, J.H.M. & Schouten, W.G.P. (1998). Behaviour of dairy cows under free or forced cow traffic in a simulated automatic milking system environment. Applied Animal Behaviour Science, 56(1), pp. 13-28.

Ketelaar-de Lauwere, C.C., Devir, S. & Metz, J.H.M. (1996). The influence of social hierarchy on the time budget of cows and their visits to an automatic milking system. Applied Animal Behaviour Science, 49(2), pp. 199-211.

King, M.T.M., LeBlanc, S.J., Pajor, E.A. & DeVries, T.J. (2017a). Cow-level associations of lameness, behavior, and milk yield of cows milked in automated systems. Journal of Dairy Science, 100(6), pp. 4818-4828.

King, M.T.M., Pajor, E.A., LeBlanc, S.J. & DeVries, T.J. (2017b). Associations of herd-level housing, management, and lameness prevalence with productivity and cow behavior in herds with automated milking systems (vol 99, pg 9069, 2016). Journal of Dairy Science, 100(11), pp. 9476-9476.

Kolbach, R., Kerrisk, K.L., Garcia, S.C. & Dhand, N.K. (2013). Effects of bail activation sequence and feed availability on cow traffic and milk harvesting capacity in a robotic rotary dairy. Journal of Dairy Science, 96(4), pp. 2137-2146.

Leonard, F.C., Oconnell, J.M. & Ofarrell, K.J. (1996). Effect of overcrowding on claw health in first-calved Friesian heifers. British Veterinary Journal, 152(4), pp. 459-472.

Lyons, N.A., Kerrisk, K.L. & Garcia, S.C. (2013). Effect of pre- versus postmilking supplementation on traffic and performance of cows milked in a pasture-based automatic milking system. Journal of Dairy Science, 96(7), pp. 4397-4405.

Mathijs, E. (2004). Socio-economic aspects of automatic milking. Lelystad, the Netherlands: Wageningen Academic Publishers, pp. 46-55.

Melin, M., Hermans, G.G.N., Pettersson, G. & Wiktorsson, H. (2006). Cow traffic in relation to social rank and motivation of cows in an automatic milking system with control gates and an open waiting area. Applied Animal Behaviour Science, 96(3-4), pp. 201-214.

Melin, M., Pettersson, G., Svennersten-Sjaunja, K. & Wiktorsson, H. (2007). The effects of restricted feed access and social rank on feeding behavior, ruminating and intake for cows managed in automated milking systems. Applied Animal Behaviour Science, 107(1-2), pp. 13-21.

Melin, M., Svennersten-Sjaunja, K. & Wiktorsson, H. (2005a). Feeding patterns and performance of cows in controlled cow traffic in automatic milking systems. Journal of Dairy Science, 88(11), pp. 3913-3922.

Melin, M., Wiktorsson, H. & Norell, L. (2005b). Analysis of feeding and drinking patterns of dairy cows in two cow traffic situations in automatic milking systems. Journal of Dairy Science, 88(1), pp. 71-85.

Paddick, K.S., DeVries, T., Schwartzkopf-Genswein, K., Steele, M., Walpole, M. & Penner, G. (2019). Effect of the amount of concentrate provided in an automated milking system on dry matter intake, milk yield, milk composition, ruminal digestion, and behavior of primiparous Holstein cows fed isocaloric diets. Journal of Dairy Science.

Prescott, N. (1995). Dairy cow behaviour and automatic milking. Diss.: University of Bristol.
Prescott, N.B., Mottram, T.T. & Webster, A.J.F. (1998). Relative motivations of dairy cows to be milked or fed in a Y-maze and an automatic milking system. Applied Animal Behaviour Science, 57(1-2), pp. 23-33.
Rousing, T., Badsberg, J.H., Klaas, K.C., Hindhede, J. & Sorensen, J.T. (2006). The association between fetching for milking and dairy cows' behaviour at milking, and avoidance of human approach - An on-farm study in herds with automatic milking systems. Livestock Science, 101(1-3), pp. 219-227.
Schreiner, D. & Ruegg, P. (2003). Relationship between udder and leg hygiene scores and subclinical mastitis. Journal of Dairy Science, 86(11), pp. 3460-3465.
Scott, V.E., Thomson, P.C., Kerrisk, K.L. & Garcia, S.C. (2014). Influence of provision of concentrate at milking on voluntary cow traffic in a pasture-based automatic milking system. Journal of Dairy Science, 97(3), pp. 1481-1490.
Stefanowska, J., Plavsic, M., Ipema, A.H. & Hendriks, M. (2000). The effect of omitted milking on the behaviour of cows in the context of cluster attachment failure during automatic milking. Applied Animal Behaviour Science, 67(4), pp. 277-291.
Stockdale, C.R. (2006). Influence of milking frequency on the productivity of dairy cows. Australian Journal of Experimental Agriculture, 46(6-7), pp. 965-974.
Svennersten-Sjaunja, K. & Pettersson, G. (2008a). Pros and cons of automatic milking in Europe. Journal of Animal Science, 86(13_suppl), pp. 37-46.
Svennersten-Sjaunja, K.M. & Pettersson, G. (2008b). Pros and cons of automatic milking in Europe. Journal of Animal Science, 86(13), pp. 37-46.
Svennersten, K., Nelson, L. & Uvnasmoberg, K. (1990). FEEDING-INDUCED OXYTOCIN RELEASE IN DAIRY-COWS. Acta Physiologica Scandinavica, 140(2), pp. 295-296.
Tremblay, M., Hess, J.P., Christenson, B.M., McIntyre, K.K., Smink, B., van der Kamp, A.J., de Jong, L.G. & Dopfer, D. (2016). Factors associated with increased milk production for automatic milking systems. Journal of Dairy Science, 99(5), pp. 3824-3837.
Växa Sverige. 2021. Husdjursstatistik/Cattle statistics. Växa Sverige, Uppsala https://www.vxa.se/globalassets/dokument/statistik/husdjursstatistik-2020.pdf
Wade, K., Van Asseldonk, M., Berentsen, P., Ouweltjes, W. & Hogeveen, H. (2004). Economic efficiency of automatic milking systems with specific emphasis on increases in milk production. Automatic milking: a better understanding. Wageningen Academic Publ., Wageningen, the Netherlands, pp. 62-67.

Wagner-Storch, A.M. & Palmer, R.W. (2003). Feeding behavior, milking behavior, and milk yields of cows milked in a parlor versus an automatic milking system. Journal of Dairy Science, 86(4), pp. 1494-1502.

Appendix 1 Summary of the results from all treatments when including all observations

Time to enter the AMR (n = 821), Number of cows to fetch (72 milkings) and Time spent in premilking areas (K1: n = 197, K3: n = 267, n^{total} = 464) according to treatment. Superscript letters within treatment and variable indicate significant differences ($P \leq 0.05$). Values for Time to enter the AMR and Time spent in premilking areas are presented as logged values and values within parentheses are back-transformed to seconds and minutes. AMR = automatic milking rotary.

Variable	**Treatment**		**Mean (log) ± SE Mean (log) (s)**
Time to enter the AMR	No feed – 1wk		1.02 ± 0.025^{a} (10.6)
	Feed – 1wk		0.81 ± 0.022^{b} (6.5)
	Feed – 3wk		0.09 ± 0.020^{b} (7.5)
	No feed – 3wk		1.12 ± 0.027^{c} (13.2)
Factor	**Treatment**		**Mean (%) ± SE Mean (%)**
Number of cows to fetch	No feed – 1wk		51.0 ± 1.63^{a}
	Feed – 1wk		38.1 ± 1.72^{b}
	Feed – 3wk		42.5 ± 1.76^{b}
	No feed – 3wk		57.2 ± 1.83^{a}
Variable	**Treatment**		**Mean (log) ± SE Mean (log) (min)**
Time spent in premilking areas	No feed – 1wk	K1	6.36 ± 0.176^{ac} (9.6)
	Feed – 1wk		5.78 ± 0.185^{b} (5.4)
	Feed – 3wk		6.09 ± 0.188^{bc} (7.4)
	No feed – 3wk		6.78 ± 0.194^{a} (14.7)
	No feed –1wk	K3	6.57 ± 0.159^{ab} (11.9)
	Feed – 1wk		6.28 ± 0.117^{a} (8.9)
	Feed – 3wk		6.42 ± 0.104^{ab} (10.2)
	No feed – 3wk		6.78 ± 0.121^{b} (14.6)