Time budgets of dairy cows in a cow-calf contact system with automatic milking

Teresa Johansson

Independent project • (30 hp)
Swedish University of Agricultural Sciences, SLU
Department of Animal Nutrition and Management
Master's in animal science
Uppsala 2021

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Tidsbudget för mjölkkor i ett ko-kalv system med automatisk mjölkning

Teresa Johansson

Supervisor:	**Mikaela Lindberg, Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management**
Examiner:	Sigrid Agenäs, Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management

Credits:	30 hp
Level:	A2E – Master thesis
Course title:	Master thesis in Animal Science
Course code:	EX0870
Programme/education:	Master's in Animal Science
Course coordinating dept:	Department of Animal Nutrition and Management
Place of publication:	Uppsala
Year of publication:	2021

Keywords: Dairy cows, Time budget, AMS, Cow-calf contact

Swedish University of Agricultural Sciences

Faculty of Veterinary Medicine and Animal Science

Department of Animal Nutrition and Management

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Abstract

Time budgets of dairy cattle are useful to determine the amount of time the cows can allocate to all the behaviours throughout the day. In an automatic milking system (AMS), time budgets are of interest as the individuals are able to choose how to spend the majority of their time, besides the time in the milking robot, and can be used to ensure adequate amounts of time are spent on essential behaviours, such as lying and eating. Keeping the calf together with the cow after parturition is also gaining interest in the dairy industry and from consumers' point of view. Earlier research, without calves' present, has shown that the cows time budget; how much time they place on different activities, such as eating, resting, and waiting their turn for the milking robot, can in some cases be quite strained. Thus, the aim of this study was to determine how the addition of calves into a loose housing system with AMS impacts the time budgets of dairy cows.

The study included a literature review, a time budget study, and analysis of data collected from the Swedish livestock research center, Lövsta SLU in Uppsala. The study included 40 cow calf pairs, of the Swedish Red Breed and Holstein, housed in an AMS at Lövsta. The cow-calf pairs were divided into the treatment group, cow calf contact post parturition and the control group, separation post parturition.

The results of the study showed that there was a significant difference between the treatment and control group in the time spent on the behaviours: eating roughage, eating concentrates, waiting at the AMS, standing in a free stall, and lying in a stall. Other factors, such as differences in the lactation the cow was in, the breed of the cow, and the period of the study also had an effect on the time spent on certain behaviours.

While there were differences seen in the amount of time spent on some of the behaviours, both the treatment group and control group were able to perform essential behaviours, lying and eating for adequate amounts of time for their well-being and production. Thus, from our results having the calves present in the loose housing system with an AMS is feasible for farmers. However, more research in the area needs to be done to further investigate the impacts of having cow-calf contact systems on both the dam and the calves.

Sammanfattning

Tidsbudgeten för mjölkkor i lösdrift är viktig för att skatta hur mycket tid korna har att utföra olika beteenden under dygnet. I ett automatiskt mjölkningssystem (AMS) är tidsbudgeten särskilt av intresse eftersom individerna kan välja hur de ska spendera merparten av sin tid, förutom tiden i mjölkningsroboten. Tidsbudgeten kan därför användas för att säkerställa att tillräcklig tid spenderas på väsentliga beteenden, som att ligga och vila och att äta. Att hålla kalven tillsammans med kon under mjölkperioden har fått ökad uppmärksamhet både från mejeriindustrin och från konsumenter. Tidigare forskning i AMS utan kalvar, har visat att kornas tidsbudget, dvs. hur mycket tid de lägger på olika aktiviteter som att äta, vila och vänta på sin tur till mjölkningsroboten, i vissa fall kan vara ganska ansträngd. Syftet med denna studie var därför att undersöka hur tillägget av kalvar i ett lösdriftsystem med AMS påverkar mjölkkornas tidsbudget.

Studien omfattade en litteraturstudie, en tidsbudgetstudie och analys av data som samlats in från nötstallet vid Lövsta lantbruksforskning, SLU i Uppsala. Studien omfattade 40 ko-kalvpar, av den svenska röda rasen (SRB) och Holstein, inhysta i ett stall med AMS på Lövsta. Ko-kalvparen delades in i två behandlingsgrupper; ko-kalvkontakt efter kalvning och kontrollgruppen; separerad efter kalvning.

Resultaten från studien visade att det fanns en signifikant skillnad mellan behandlings- och kontrollgruppen i tid som spenderades på vissa beteenden: äta grovfoder, äta kraftfoder, stå i väntfålla till AMS, stå i ett liggbås och ligga ner i ett liggbås. Andra faktorer såsom skillnader beroende på laktation, ras och period påverkade också den tid som spenderades på vissa beteenden.

Även om det fanns skillnader i hur mycket tid som spenderades på en del av beteendena, kan man anse att både behandlingsgruppen och kontrollgruppen utförde väsentliga beteenden såsom att ligga och vila och äta i tillräcklig omfattning för deras välbefinnande och produktion. Således visar våra resultat på att det är möjligt för lantbrukare att ha kalvarna tillsammans med korna i lösdrift med AMS. Mer forskning inom området behöver dock göras både på kor och kalvar för att ytterligare undersöka effekterna av att ha dem tillsammans i ett system för mjölkproduktion.

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Introduction

Time budgets of dairy cows in loose housing systems can be defined as the allocation of behaviours over a 24-hour period, such as lying, feeding, socializing, drinking, and milking. The cow has little control over the time spent in milking facilities as this is largely decided by the management. However, the rest of the day can be voluntarily divided between the different behaviours when in a loose housing system. It has been noted that time is a limited resource for the dairy cow (Løvendahl and Munksgaard 2016) with different factors causing time constraints (Helmreich *et al.* 2014) in the day-to-day behaviours. Some factors that can affect the time budget, are external factors, i.e. housing and management (Gomez and Cooke 2010); as well as internal factors, i.e. lactation and milk yield (Løvendahl and Munksgaard 2016). The time budget of a dairy cow is valuable as it allows insight to whether the cow is performing essential activities, such as lying and eating, for adequate amounts daily. These behaviours are crucial to the well-being and production of the dairy cow (Helmreich *et al.* 2014).

Another factor that could have an impact on the dairy cow time budget is the presence of her calf. There has been growing interest from the public, dairy farmers, and researchers to keep dairy calves with their dams throughout the rearing period (Ventura *et al.* 2013). Traditionally, in dairy farming the calves are removed from the dam within a few hours or days however, this can be seen as unnatural and potentially negative for the welfare of both the dam and her calf. There have been several reasons cited for the immediate separation of the dam and the calf, such as control over milk consumption (Flower and Weary 2001) leading to higher profits for the farmer, reduced disease transmission (Edwards and Broom 1982), decreased distress at separation (Ventura *et al.* 2013) as the development of a bond is prevented.

Conversely, as more research is done regarding cow calf contact there have also been a number of positives found in regard to later separation. Including, faster growth rate in the calf (Bach *et al.* 2009), less oral stereotypies (de Passillé and Rushen 2006), ability to perform natural behaviours such as suckling and maternal behaviours (Fröberg and Lidfors 2009), and advantages in social behaviour (Flower and Weary 2001) leading to less fearful interactions when introduced to new conspecifics. A limitation to these studies however is their duration, as they are typically relatively short term. Studies on keeping the calf with the dam throughout the suckling period ranged in duration with the calves kept with the dams one day, four days (Weary and Chua 2000), up to two weeks (Flower and Weary 2001), and at most two months (Fröberg and Lidfors 2009). Therefore, the long-term effects are still unclear. While there is research available on the impact of cow-calf contact on the calves, there is a lack of information regarding this systems impact on the dam and her daily time budget.

Dairy cows will perform maternal behaviours when given the opportunity to do so (von Keyserlingk and Weary 2007, Jensen 2011). Thus, suggesting that allocation of behaviours throughout the day will be adjusted to perform these maternal behaviours, such as licking, nursing, and staying within proximity to the calf (Wenker *et al.* 2020) in a cow-calf contact system.

To date, the time budgets of dairy cows with cow-calf contact in an automatic milking system has not yet been investigated. Therefore, the aim of this study was to determine how the addition of the calves into the loose housing system with automatic milking would impact the time budgets of dairy cows.
The main research questions being:

- How do the time budgets of dairy cows with their calves present differ from those without their calf in a loose housing system?
- How do the time budgets of dairy cows with cow-calf contact change throughout the rearing period?

Hypothesis

We hypothesize that the overall time budgets between the dams with cow-calf contact will differ from those without cow-calf contact. It is expected that the dairy cows with cow-calf contact will use part of their time budget to interact with their calf and perform maternal behaviours, thus, an adjustment to their overall time budget will have to be made, reducing the time spent on other behaviours. However, we do not expect the behaviour of lying to differ between groups, as this is a highly prioritized behaviour and cannot be compensated for.

We also expect the time budgets to differ throughout the duration of the study. When the calves grow, less time will need to be spent on maternal behaviours. Thus, the dam will have additional time to allocate to another behaviour, likely increasing the time spent lying due to high priority.

Literature Review

The time budget of dairy cows

The amount of time spent on different behaviours throughout a 24-hour period can be referred to as an animals' time budget. In free stall systems, cows have the ability to choose how to spend the majority of their time throughout the day, except for the time spent in the milking parlour or milking robot. This remaining time is voluntarily divided between activities such as eating, drinking, resting, socializing in alleys and standing in stalls (Gomez and Cooke 2010). As well as the unavoidable amount of time spent moving between these activities.

External factors

External factors, such as the housing system and management, can have major impacts on the time budget of cattle. Systems that use automatic milking (AMS) may see that the amount of time an individual has to spend in the waiting area by the milking robot depends on her position in the social hierarchy within the herd (Lauwere *et al.* 1996). Thus, leading to long wait times for certain individuals affecting the amount of time available for other important behaviours. The type of routing system and use of one-way gates can also change the cow time budgets and the number of visits to the AMS. When testing four different routing treatments to an AMS, Lauwere *et al.* (2000) found differences across treatments in feeding behaviour after milking and overall time spent in the feeding area. The availability of free stalls can also have an impact on the amount of time lying behaviours are performed, i.e. reducing the lying time if there is competition for stalls, particularly for the subordinate animals (Winckler *et al.* 2015). As well as the availability of space in the feeding area, if there is a limited space, some cows may adjust their feeding times to avoid times when there is increased competition at the feeding area in order to prevent any aggressive interactions (Deming *et al.* 2013). Deming *et al.* (2013) also found that daily lying duration in an AMS herd was positively associated with providing more space at the feed bunk and increasing the frequency of feed push-ups. Suggesting that cows that did not have to compete for bunk space had more time to spend lying. The frequency of the feed delivery also plays a role, as a study by DeVries *et al.*, (2005) showed that when increasing the delivery frequency, dairy cows increased their daily feeding time and the distribution of feeding time throughout the day. Allowing for a more equal access to feed and fewer displacements of subordinate animals.

External factors- lying behaviour

The external factors can influence the entire time budget of the cow, and more specifically impact the time spent on the lying behaviour. It is important that the time budget of the cow allows for adequate time to lie down as this behaviour is important for maximizing production, as blood flow to the udders is reported to be higher when cows are lying down than when they are standing, thus promoting, and increasing the milk production while lying (Haley *et al.* 2000). Cow comfort and well-being is also affected by the time spent lying (Haley *et al.* 2000) and when cows do not have an adequate amount of time to lie down their welfare may be reduced (Cooper *et al.* 2008). Stall design can substantially reduce the amount of time spent lying and a lack of comfort in the housing system can result in reduced time lying and increased time spent standing idle (Haley *et al.* 2000). Furthermore, the type of bedding in the stall can impact the duration of time spent lying (Norring *et al.* 2008), with cows having a preference for softer surfaces and perhaps adjusting their lying behaviour depending upon the amount of bedding available in the stall. Cows that have been prevented from lying down a full 14 hours in an experimental setting have been shown to have reduced plasma concentration of growth hormone (Munksgaard and Løvendahl 1993), which is a hormone that is positively associated with milk yield. It has been suggested that time constraints on lying behaviour will have more severe consequences than on other behaviours, as it is not possible to compensate for lack of rest. (Munksgaard *et al.* 2005). In contrast, time spent on behaviours, such as eating, can be compensated with increased feeding speed. Thus, reduction in feeding time may not have any severe consequences while reduction in lying time may have a negative impact on the animal. This behaviour takes up a large proportion of the time budget, with Jensen *et al.* (2005) and Munksgaard *et al.* (2005) suggest that approximately 12 hours of lying time throughout each 24-hour period is optimal for dairy cows.

External factors- Feeding

Dairy cows housed indoors typically spend 4-7 hours eating in bouts of 6-12 meals per day. Allowing access to feed the majority of the day is important, as extended periods of time without access to feed will reduce intake by up to 20% (Dijkstra *et al.* 2012). The type of feed can vary across farms and influence the amount of time that a dairy cow spends eating. Nielsen *et al.* (2000) found that cows fed a low concentrate diet spent more time eating, more time ruminating while standing, and less time lying as compared to those fed the high concentrate diet. This agrees with the study by Friggens *et al.* (1998) which also found cows offered high concentrate diets had less frequent but longer visits to the feeding area and consumed more per visit than those offered the low concentrate diet. The change in feeding rate is likely due to the physical properties of the feed, such as particle size and physical structure.

Individual factors

Various studies have investigated the role of individual factors on the dairy cows' time budget. For example, time budgets can be influenced by the genetics of the cow, a study by Løvendahl and Munksgaard (2016) showed that eating time is a heritable trait that is correlated with milk yield. Cows with a higher milk yield need more time to eat a sufficient amount of feed to sustain their yield, and to do so lying time or time in the stalls is usually reduced to compensate. Similarly, when analyzing the effects of milk yield on the time budget of dairy cows in tie stalls Norring *et al.* (2012) found that high milk yield cows spent a shorter amount of time lying even when they had free access to lie down in the tie stall. Thus, suggesting that a decrease in lying time may be even more pronounced in a loose housing system where the cow must walk from the feeding area to resting areas. The stage of lactation also has an impact, lying time increases and eating time decreases as the lactation period continues (Bewley *et al.* 2010, Nielsen *et al.* 2000).

This change in lying behaviour may be related to the changes in milk yield that occur throughout lactation (Norring *et al.* 2012).

Prioritizing behaviours

When there are time constraints for the cow, some activities may be given priority over others. Munksgaard *et al.* (2005) found that when time was limited, the proportion of time spent lying increased, proportion of time spent eating and socializing remained similar, and time spent on other activities decreased. However, when time spent eating was reduced, the amount of feed intake was not always severely impacted as the cows were able to compensate by increasing the speed of consumption.

The relative motivation of cows to be milked or fed has also been studied by Prescott *et al.* (1998) with the use of different tests. Where the use of a Y-maze test allowed the dairy cows the choice to be milked or not, then to be milked or fed. The cow's attendance to the AMS was also examined. Their results indicated that the motivation to be milked was weak whether the cow was a high or low milk yielder. The level of motivation was also seen to be quite variable and was independent of the stage of lactation the cow was in. The high yielding cows also visited the robot significantly more when fed 4 kg of concentrates compared to when they received no food reward. Thus, the access to a concentrate food reward seemed to be the leading reason behind the motivation to visit the AMS. Suggesting that receiving concentrate is of a higher priority to cows than being milked.

Automatic milking systems (AMS) impact on time budget

Automatic milking systems have become much more common across Europe and North America (Wagner-Storch and Palmer 2003). There are varying reasons for farms to choose to use an AMS. Some reasons may be the flexibility in labour, milking consistency, and economic optimization i.e. the higher yielding cows can increase their milking frequency. The freedom of the cows to decide when to visit the AMS and how frequently is also viewed as an improvement of welfare for the animals (Helmreich *et al.* 2014).

Conventional parlour milking systems provide more of a structured daily routine for a dairy herd, while an AMS allows for more flexibility in milking times for individual cows (Wagner-Storch and Palmer 2003). Therefore, the type of milking system can affect the daily activities and time budgets for the cows. Previous studies have reported that with AMS, cow feeding, and milking activity is more evenly distributed across a 24-hour period (Wagner-Storch and Palmer 2003). Visits to the robot are lower during the night and early morning, with Wendel et al (2000), reporting the highest amounts of milking visits in the morning. Thus, having the ability to impact the amount of time required by the individual cow in the waiting area as several may be at the robot at the same time.

Type of traffic

Successful use of milking robots requires the cows to voluntarily go to the robot to be milked. Currently there are a few different methods to achieve this. There is the option of free cow traffic, where there are no gates between the different areas of the barn to guide the animals to the milking robot, etc. Some systems use a semi guided system with the use of guided gates, one-way gates, and a waiting area before the AMS. Others use the milk first method, where the cows must pass a selection gate that determines whether the requirement to be milked is met or not, if so, the cow is sent to the milking robot before being allowed into the feeding area. Another is the "feed first" system, where the cows enter a selection gate after feeding to determine eligibility for milking, if eligible she is sent to the milking robot, if not to the resting area.

The use of these different types of cow traffic are to ensure an adequate number of visits to the milking robot every day. However, certain types of traffic could potentially reduce the feeding time and frequency. Munksgaard *et al.* (2011) tested forced versus free traffic in an AMS, in the free traffic the cows could move freely between the stall area and the feeder area without passing through the robot, and in forced traffic the cows had to pass through the robot to reach the feeder area. It was found that the average number of visits to the robot did not differ between the types of traffic, there was also no significant difference in the duration of time lying, or time spent in the feeding area. A number of other studies have seen similar results, where large proportions in the average time budgets of cows remained similar across farms even when different cow traffic systems were implemented (Helmreich *et al.* 2014, Lexer *et al.* 2009). However, these results contrast a previous study by Bach *et al.* (2009), where the forced traffic group showed a change in the eating behaviour as compared to free traffic group where no changes were observed. Therefore, it is important to consider the type of traffic used as it may be difficult to know the effects on an AMS herd and may differ between farms.

Milking frequency

The frequency and timing of milkings, such as milkings at night, can affect the time budgets of cows on farms with automatic milking (DeVries *et al.* 2011). High yielding cows or those with high milking frequency may have more constraints on their time budgets due to more frequent milking events (Helmreich *et al.* 2014) and simply having to spend more time waiting for and in the robot. Depending on the length of the interval between each milking event, these cows may also need to visit the AMS at night, thus interfering with their nocturnal lying behaviour. While those with low milking frequency will have longer time intervals having additional time for uninterrupted lying or feeding behaviours.

Hierarchy

The social ranking of the individual within the herd can also influence the time budgets of cows in an automatic milking system. Low ranking cows may have to wait for longer to enter the AMS, resulting in a low milking frequency and potentially taking time away from other activities (Meijering *et al.* 2004). In a previous study by Munksgaard *et al.* (2010), it was found that cows spent an average of 1.5 hours per day in the waiting area of the AMS. However, there was a large individual variation with the waiting times ranging from 0.5 hours up to 3.5 hours. With the position in the hierarchy likely leading to this large range in wait time as when simulating hierarchy in three different groups, low, medium, and high ranked cows, Halachmi (2009) found that a low ranked cow waiting 68.9 minutes compared to the 10 minute wait for medium ranked cows and only 3.5 minutes for the dominant cows.

Cow-calf contact systems

Under natural conditions the dam usually remains with the calf for approximately 6-8 months when the calf is gradually weaned (Phillips, 1993). However, on most European dairy farms, the calves are separated from their mothers within the 24 hours of their birth and then fed by a bottle or bucket until 4-10 weeks of age depending on the farm (Broom and Leaver, 1978). In Sweden, it is recommended to feed the calves milk for at least 8 weeks on conventional farms, and on organic (KRAV 2021) farms calves must be fed milk until 12 weeks of age. Some herds want to be weaned at a certain age, but the overall suggestion is to wean the calves when they have reached a sufficient weight and eat an adequate amount of concentrate to ensure that the calf is prepared to survive without milk. The recommendation for how long to keep the cow together with the calf is only for a day after calving in Sweden. Thereafter it is suggested to group house the calves (Kalvportalen, 2021). There are several reasons cited for this early separation in Sweden and around the world, including economic, health and welfare impacts.

Early separation

When the calf is immediately removed, the amount of milk consumption can be more closely controlled, thus allowing the producers to sell more of the milk. The calves will still receive milk; however, it is often milk that cannot be sold or a milk replacer that is cheaper than the fresh milk (Flower and Weary 2001). However, this can vary depending on the current milk prices, occasionally feeding fresh milk can be cheaper than the alternatives. Rearing the calves away from the dams is also thought to allow for closer supervision by the farmers, as they can monitor the colostrum, milk and solid food intake by the calf. Furthermore, the transmission of disease from cow to calf may also be prevented when separated immediately (Edwards and Broom 1982). Early separation is believed by many producers to be less distressing for the cow and calf. The thought being that a longer period of contact between the dam and the offspring would lead to increased bonding (Phillip, 1993). However, research has also shown that some bonding occurs as early as the first few hours following parturition (Edwards and Broom 1982). And that as little as 5 minutes of contact with her calf immediately postpartum may be enough for a strong maternal bond to be formed (Hudson and Mullord 1977). Thus, suggesting that a bond will be formed between the cow and calf regardless of if the separation takes place early after parturition.

The emotional distress of the later separation between the dam and her calf is another concern among producers and the public (Ventura *et al.* 2013) and a reason for choosing early separation. The behavioural response can last for several days, in which the cows and calves vocalize, show increased activity, reduced play behaviour (Johnsen *et al.* 2015). However, there are weaning procedures that can be utilized to reduce the response to the separation. For example, providing a supplemental milk source during and after the nursing period to allow the calf to be less nutritionally dependent on the dam (Johnsen *et al.* 2018). Fence line separation has also been investigated, while this in itself was not seen to affect the cow behaviour, having some form of physical contact in the days subsequent to separation did reduced high-pitched vocalizations and alert behaviour in calves which are seen to be signs of distress (Johnsen *et al.* 2015).

Late separation

Benefits to keeping calves with the dam for longer have been reported in the literature in several studies. It has been reported that delayed separation results in improved weight gain for the calves, likely due to the increased milk consumption. Calves that are able to suckle from the dam are able to consume more than 10% of their body weight and grow much more rapidly than those with conventional feeding (Bach *et al.* 2009). When comparing early and late cow calf separation it was found that calves separated later gained weight more rapidly and maintained this weight advantage over early separated calves for up to 4 weeks of age (de Passillé and Rushen 2006). Not only does the milk provide the calf with growth benefits but the act of suckling does as well. Calves have been seen to have a greater degree of relaxation after a meal (Hänninen *et al.* 2008) and cross suckling and other nonnutritive oral behaviours such as licking objects are greatly reduced or eliminated among calves that are group housed if their milk consumption comes via free access to a teat (de Passillé and Rushen 2006). Depriving calves of this suckling behaviour might be a cause of stress or conflict that leads to oral stereotypies (Fröberg and Lidfors 2009).

Calves that had free access to suckle on their dam in a barn with AMS rested more, ate less solid feed, and expressed less non-nutritive oral behaviours than calves fed a milk substitute from an automatic feeder in a group pen (Fröberg and Lidfors 2009). The cows and calves also have the ability to self-regulate the frequency and duration of the suckling bouts which have been reported to range between 4 and 9 depending on the age of the calf (Fröberg and Lidfors 2009). This frequency is similar to cattle living under semi natural conditions (Reinhardt and Reinhardt 1981). Allowing for continued cow calf contact promotes natural behaviours, which is an important aspect when it comes to animal welfare (Lund 2006). In this type of system, the dam is able to perform maternal behaviours, such as nursing, forming a bond with her calf, and to ability to lick and rub her calf (Wagenaar and Langhout 2007).

Keeping the dam with her calf for longer also provides advantages for social behaviour (Flower and Weary 2001). Research has demonstrated that housing calves with their dams may allow for better development of their cognitive abilities compared to those individually housed. For example, when introducing novel feeds to dam reared calves compared to calves that were individually housed, the dam reared calves were much quicker to taste the feed and they ate more of it (Costa *et al.* 2014). Being reared by their dam has also been observed to improve calves' ability to learn as compared to those individually reared (Johnsen *et al.* 2016). Even short-term contact has been seen to have some lasting effect. Krohn *et al.* (1999) and Stěhulová *et al.* (2008) reported reduced abnormal or increased normal social behaviour weeks after having only 4 days of cow calf contact.

Another argument against cow calf contact for longer periods of time is the decrease in milk yield, and therefore profits. While there is a decrease in the amount of sellable milk during the suckling period, due to the milk consumed by the calves, some studies have found that there is no difference in milk yield after suckling in cows allowed to nurse their calves (Flower and Weary 2001, Metz 1987). Flower and Wearing (2001) compared cow-calf pairs that were separated at one day versus two weeks after birth. During the those first two weeks, the later separation cows were yielding less milk, likely due to the milk consumption by the calf. However, the milk yields after both groups were separated from the calves – days 15-150 – did not differ between the two groups. Thus, keeping the calves with the dams does not decrease the milk yield long term.

Materials and methods

Ethics

The study was carried out as a part of a larger ongoing research project at the Swedish University of Agricultural Sciences education and research center (Lövsta Lantbruksforsking, Uppsala, Sweden). All the procedures involving animals were approved by Uppsala local ethics committee (ID-No: 5.818-18138/2019). Swedish Animal Welfare Legislation was followed throughout the housing and care of the animals.

Animals

Selection of animals

The animals were enrolled during a six-week period, between September 1st and October 15th, 2020. When a pure-bred dairy calf was born, the staff noted the ID of the mother, the breed of the calf, the gender of the calf, and the BRIX- value, i.e. the measure of colostrum quality. The pair would then be randomly assigned a treatment group: separation following parturition (CON), or full cow-calf contact (TREAT).

The main factors were time, effect, and gender – with every other heifer calf kept with her mother (TREAT) and every other being separated upon detection (CON). The same procedure was used for bull calves. All the control calves received colostrum manually. Half the treatment calves, allocation rule being every other born treatment calf of each gender, received colostrum manually as well.

Animals in the study

At the end of the enrolment period there was a total of 24 heifer calves (12 treatment, 12 control) and 14 bull calves (7 treatment, 7 control). Of these, there were 14 Swedish Holstein calves (7 treatment, 7 control) and 24 Swedish Red calves (12 treatment, 12 control). The treatment calves were born on average September 23, and the control calves on average September 20. There were 11 treatment and 9 control primiparous dams, and 8 treatment and 10 control multiparous dams. The last cow-calf pair entered the study October 14th and the first cow-calf pair left the study January 18th. All cow-calf pairs were in the experiment for a 4-month period. There were additional cows housed in the AMS that were not a part of the study to simulate a realistic stocking density for the AMS, the maximum number of animals being 58. The animals were fitted with collars that are read at the selection gates, feeding tables, concentrate feeders, and the AMS. They were also equipped with IceQubes (IceRobotics Ltd, Edinburgh, UK), which monitored their activity such as lying times, and number of lying bouts.

Two of the recruited treatment group cow-calf pairs were removed before the start of the study, one due to the dam dying during E.Coli treatment, the other was euthanized due to severe lameness. Throughout the study two of the dams were moved to the sick boxes for treatment before returning to the AMS. A control cow was removed due to lameness for a few days during the first period of the study. A treatment cow was removed during period 3 due to illness.

A few days pre-partum, cows were moved to and housed in individual calving boxes. Following the calving, cows were manually milked, and with the use of a Brix refractometer (Pocket Refractometer PAL-1, ATAGO CO. Ltd, Tokyo, Japan), the quality of the colostrum was determined. If a cow had a good Brix value (>20%) i.e. good quality colostrum, no additional milk was provided to the calf. If a cow had a low Brix value (<20%), the calf was offered higher quality colostrum from the freezer. Staff checked on the cow-calf pairs frequently (every 1-2 hours) to confirm that the calf was able to suckle from the dam. While the cows were restrained during the first milking, the calves were eartagged for identification (Officiell Combi 3000 Stor and E30 Rund/Stor tappdel, OS ID Stallmästaren AB, Lidköping, Sweden) and weights were recorded. Following the first milking the cows were milked twice daily, at approximately 5:00 and 16:00. When housed in the calving box, the cow and calf were able to view the other cows and had a limited amount of physical contact with the cows in boxes adjacent. The cow-calf pairs remained in the calving boxes for around two- three days, after which they were moved to the AMS.

Housing and management

The animals were housed in a heated cubicle (free-stall) system in an insulated and ventilated barn with semi- forced feed first cow traffic system and automatic milking (DeLaval VMS^{TM}, DeLaval International AB, Tumba, Sweden). In the free stall barn, the cows had the freedom to move between the feeding area, contact area, resting area and waiting area. The feed area consisted of twenty roughage bins (Biocontrol Norway AS, Rakkestad, Norway), seven water cups, and two cow brushes (DeLaval Internation AB, Tumba, Sweden).

Calves were housed in a part of the barn that was converted to a specialized calf creep area. The calf creep was inaccessible to the adult cows. This area was bedded with wood shavings and had two concentrate feeders (DeLaval International AB, Tumba, Sweden) and two water cups. An additional lying area was accessible to the treatment cows, through a selection gate, and their calves and allowed for full cow-calf contact (CCC). The treatment and control cows both had access to cubicles with partial cow-calf contact, here auditory, visual and limited physical contact was possible via a fence. The treatment and control cows had an additional lying area with no possible cow-calf contact (see Figure 1).

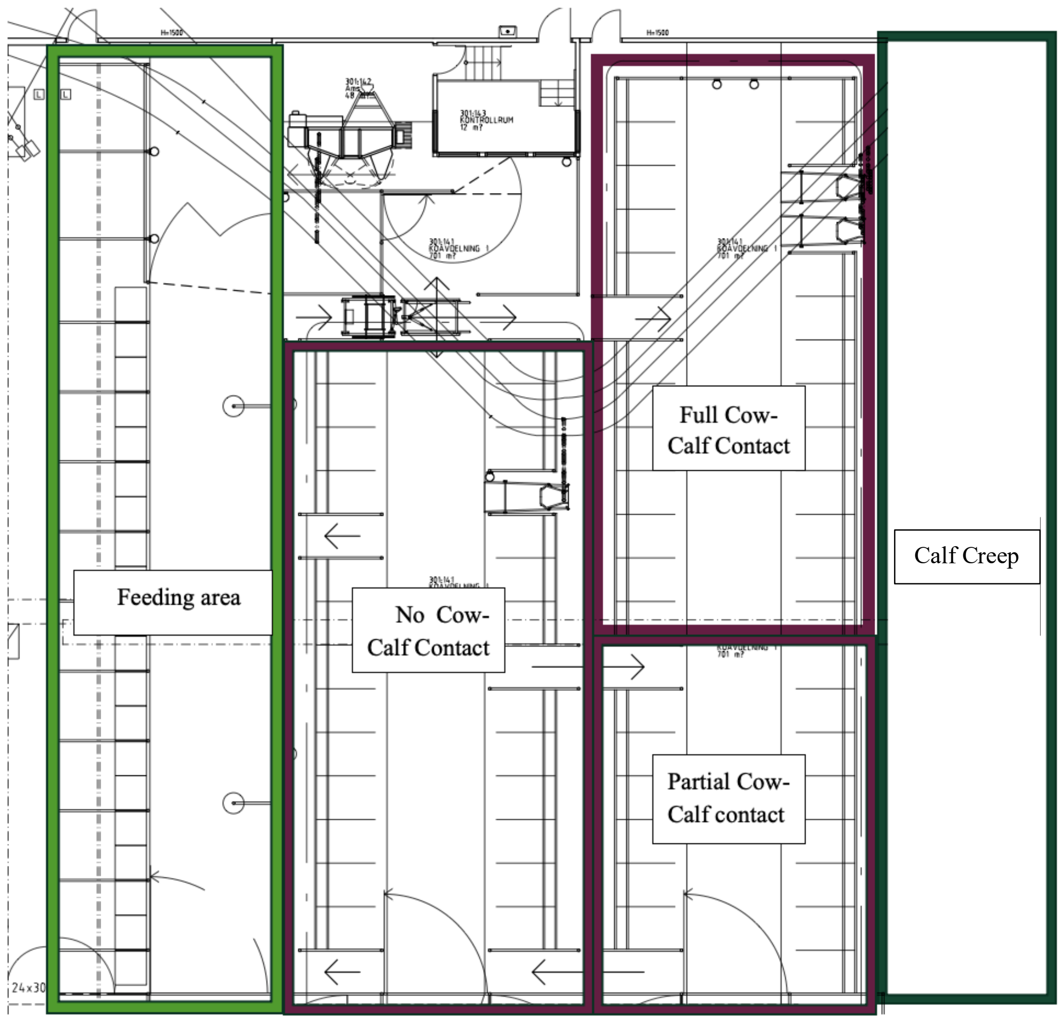

Figure 1. Overview of the AMS

The cow traffic was forced with the use of a selection gate (DeLaval smart selection gate SSG, DeLaval International AB, Tumba, Sweden), spring-loaded gates (Segregation Gate FeedSelect, GEA Farm Technologies GmbH, Bönen, Germany) and one-way gates. When exiting the feeding area, the cows passed through the selection gate. Cows were either guided to the cow calf contact area (TREAT), into the lying area (CON), or to the waiting area before the AMS if the cow was to be milked. To enter the CCC area, the cows had to push through a spring- loaded gate. There was a second spring-loaded gate to exit the CCC area, which was too heavy for the calves to push through, that led to the resting area. From this resting area, there were one-way gates that led back to the feeding area. When guided to the waiting area before the AMS, the cows voluntarily enter the milking robot, one at a time, to be milked. Once milking was completed, the cow exits the robot back into the feeding area.

Cows were milked using a robotic milking unit (VMS™, DeLaval International, Tumba, Sweden). Access to the milking unit was granted six hours after the previous milking event. If a duration of 18 hours passed without a milking event for an individual, the staff retrieved the cow and placed her in the waiting area before the AMS. The robot was accessible 24 hours daily, except for when maintenance and cleaning occurred. The milking robot milked both the treatment and control cows until they were empty. However, the control cows received a milking permit two minutes after an incomplete milking while the treatment cows did not.

The cubicles had mattresses and were scraped manually by the farm staff as often as possible to ensure dry bedding in each of the cubicles. The farm was equipped with automatic wire-driven scrapers that ran once every 30 minutes through the feeding area and once every hour through the walkways in the lying areas. The feeding tables had rubber covered scraper paths, otherwise the floors were grooved concrete paths. The AMS waiting area had slatted concrete floors. In the CCC area the automatic scrapers were initially operated manually throughout the day and turned off at night to reduce the risk of accidents. Starting November 11th, the scrapers were set to run automatically during the day, and November 23rd they were set to run automatically through the night as well. Fresh wood chips were distributed to the stalls using an automated wood chip wagon that was on rails above the AMS. This wagon was programmed to run four times daily throughout the entire barn and three additional times daily in the CCC area. The deep litter that was placed in the calf creep was provided with fresh wood chips manually as needed to maintain dry bedding.

Feeding

The cows are fed with roughage via a mixer from three different buffer tables. Salts and minerals are added to the silage once a day. The group is fed five times per day via a feed wagon that distributes the feed to a feed trough. The feed troughs are equipped with scales allowing for registration of each individual’s feed intake (Biocontrol A/S, Rakkestad Norge). Concentrates are also fed to the cows and this intake is recorded as well. There are four, automatic concentrate feeders, two in the CCC area and two in the cubicle area that all animals have access to.

Video Analysis

There were eight cameras (Samsung SNF-8010VM, Samsung Electronics Co Ltd., Seoul, South Korea) positioned above the AMS continuously recording the experimental areas. Videos were analyzed using BackupViewer (v2 1.4.6_M190708) three different periods throughout the duration of the study (Table 1). The day of the video observations the animals were marked with unique symbols with animal safe paint (Raidex Animal Marking Spray, Kruuse Animal Marking Spray) in order to distinguish individuals during video analysis. The observation periods were a total of 48 hours, with the video analysis starting at 19.00 the day the cows were marked. This was to allow several hours to pass between the marking of the animals and the video analysis to reduce the effects of the marking on their behaviour.

Table 1. Dates of the three periods throughout in the study

Period 1	05.11.2020 – 07.11.2020
Period 2	10.12.2020 – 12.12.2020
Period 3	14.01.2021 – 16.01.2021

Time budgets of the cows were determined by performing focal animal sampling of the behaviour of each cow in the experiment every 10 minutes for the 48-hour period (see Table 1 for dates). The behaviours were recorded using the ethogram (Table 2), then combined to determine the total amount of time spent on each behaviour.

Table 2. Definition of behaviours - Ethogram used during video analysis for the time budget

Behaviour – Location Trait	**Definition**
Eating in feed gates – Roughage	Head over the roughage feed trough, touching food
Eating in feed gates – Concentrates	Head over the automatic concentrate feeder
Standing – waiting to be milked	Standing in the AMS waiting area
Standing – by the brush	Body in contact with the brush
Standing – in the free stall	Two or four legs in the stall
Standing or walking – feed aisles	Standing idle or walking in the roughage feed area
Standing or walking – stall aisles	Standing idle, or walking in the free stall area
Socializing – with another cow	Any form of physical contact with another cow i.e., licking, nudging, butting
Socializing – with calf	Physical contact with the calf i.e., licking, nudging
Suckled by calf	Calf underneath back half of the cow (may be hard to see the act of suckling)
Lying in a stall	Body in contact with the floor in the stall
Drinking	Head over the water bowl
Milking	In the milking robot

Treatment cows – where they spend their time

The treatment cows were able to choose where they performed some of the behaviours included in the time budget study, such as eating in the feed gates-concentrates, standing in free a stall, standing or walking in the stall aisles, and lying in a stall. When recording these behaviours during the focal animal sampling, the location of the behaviour was recorded as well, as full cow-calf contact, partial cow-calf contact or no cow-calf contact.

Iceqube data

The IceQube data was extracted and uploaded by the farm staff weekly from each individual animals' IceTag. These files were converted from IceQube files to CSV files to allow for analysis in excel. The lying times from each of the three periods was collected, for the entirety of the three days included in each of the periods. Resulting in 72-hour average as opposed to 48-hour average collected from the video analysis. The number of lying bouts for across the three periods was also collected for each individual.

Feeding gate data

The feed trough is equipped with scales and thus records each animal's access to the feed trough and the feed intake (VMS^{TM}). We collected this data from the research facility to determine the daily feed intake during the three periods of the study. The concentrate feeders also register the current individual feeding and the amount of concentrate consumption. Data was collected for the daily concentrate intake for each individual as well.

Waiting area data

The registration of gate passages is recorded for all the animals. Therefore, we collected the data from the gate that directs the individuals into the AMS waiting area, and the data from when they enter the AMS to be milked. Using this, the time spent in the waiting area could be determined for each individual. This behaviour was also recorded in the time budget analysis, thus this data was collected for validation purposes. The data collected from the gates also contained data from more days than the time budget observations, allowing for more accurate analysis.

Statistical analysis

Time budget

All of the data was analyzed using the statistics program SAS 9.4. (SAS Institue Inc., Cary NC, USA). Prior to the analysis, the data was handled in Excel. The observations for the time budgets were summarized in excel. Where each individual's time budget was calculated as the duration of each behaviour in minutes per 24-hour period. The individual time budgets were then used to determine the treatment group and the control group average time budget for each period. Excel was also used to calculate the average amount of time and standard deviations for each activity in each of the three periods, as well as an average for all periods combined.

To analyze the time budgets, each individual cows' behaviours were counted over the 48-hour observations throughout the three periods. The values were Log10 transformed as the data was not normally distributed and the constant 1.1 was added to control for values of zero. All data were then subjected to the mixed model procedure in SAS. The model included treatment, breed, lactation, and period. All the possible interactions between the parameters were tested and then removed if shown to not be significant. The cow itself was random in the model. Effects were considered to be significant if $P < 0.05$. All LSmean values were then transformed back using antilog10 and the constant subtracted.

For the behaviours socializing with a calf or suckled by a calf, the differences between treatments could not be analyzed as only the treatment group had the possibility to perform these behaviours. Therefore, only the mean values and standard deviations were calculated, and the lactation, breed and period effects were analyzed with the LSmeans for the treatment group.

Milk yield, time in waiting area, silage intake, and concentrate intake

The data collected from the research farm was analyzed using SAS 9.4 as well. The mixed procedure was used for this data. The model included treatment, breed, lacation, and period. All the possible interactions between the parameters were tested and then removed if shown to not be significant. The cow itself was random in the model. Effects were considered to be significant if $P < 0.05$.

IceQube Data

To analyze the data collected from the Icequbes, the raw data was used find the lying duration throughout 24-hour periods. All values were Log10 transformed due to the dataset being skewed. The same mixed procedure and model were used to find significant differences as were used above for the time budget.

Treatment group – where they spend their time

To analyze the data collected regarding where the treatment cows spent their time in the AMS the glimmix procedure with a Poisson distribution was used in SAS 9.4 The model included lactation, cow, breed, location, and period. The cow was random in the model. The possible interactions between the parameters were tested and removed if shown to not be significant. Effects were considered to be significant if $P < 0.05$.

Results

Time budget results

The observations from the video analyses are presented in Table 3 as the mean time budget for the treatment group and the control group as well as the factors that were found to be significant for certain behaviours, these values are presented as the antilog of the LSMeans calculated in SAS. The average time budget for the treatment group and control group are presented below in Figure 2 and in the text for each of the three periods. The times that are presented in Figure 2 and in the text below are means ± standard deviation that were obtained during the video analysis of the time budgets.

Time feeding

The time spent feeding in the roughage gates differed between the treatment groups (Table 3). The control cows spending more time on average at the roughage gates compared to the treatment cows. Another significant factor was the period, with period 3 differing from periods 1 and 2. During period 3 the mean time at the roughage gates seen in the video analysis had increased to mean of 2.60 ±1.1 h/d for the treatment group and to 2.87 ± 1.07 h/d for the control group.

Less time was spent feeding in the concentrate feed gates where the control cows spent slightly more time at the concentrate feed gates compared with the treatment cows.

Standing in the AMS waiting area

The behaviour in the time budget with the greatest difference between the control cows and the treatment cows was the amount of time spent standing in the waiting area before the AMS (Table 3). The treatment cows spending over an hour more on average standing in the waiting area compared to the control group. There was also large individual variation in this behaviour with the minimum waiting time being 0.42 h/d and the maximum waiting time being 6.75 h/d. Figure 3 shows the waiting time throughout the three periods for both groups.

Standing in the free stall

The treatment cows spent a shorter amount of time standing in the free stall on average compared to the time spent standing in the free stall for the control cows. Cows that were in their first lactation stood in the free stalls for a mean 1.58 ± 0.68 h/d and the cows that were in later lactations spent a mean of 1.78 ± 0.76 h/d. There was also a significant difference seen for this behaviour between the third period and the first two periods, where the time standing decreased with time.

Table 3. Mean time budget results and significant factors across the three periods. Values from the antilog10 of LSmeans calculated in SAS

	Mean h/d across 3 periods		Treatment Differences	Lactation Differences	Breed Differences	Period Differences
Behaviour	Treatment	Control	P-value	P-value	P-value	P-value
Eating Roughage	2.28	2.61	**0.0037**	0.8440	0.1390	**0.0005**
Eating Concentrates	0.87	0.97	**0.0246**	0.8864	0.1284	0.2051
AMS Waiting Area	2.68	1.20	**<0.0001**	0.5646	0.3543	0.4644
Standing by the brush	0.45	0.33	0.3978	0.6944	0.1053	0.1730
Standing in a free stall	2.22	2.82	**0.0028**	**0.0019**	0.4838	**0.0016**
Stand/walking in feed aisles	1.89	1.95	0.1550	**0.0182**	**0.0452**	0.1760
Stand/walking in cubicle aisles	1.00	1.02	0.7451	0.2353	**0.0024**	0.7451
Socializing w/cow	0.03	0.09	**0.0017**	0.0713	0.8631	**0.0040**
Socializing w/calf	0.24	-	-	0.9876	0.2092	0.8692
Suckled by a calf	0.30	-	-	0.6625	0.0504	**0.00025**
Lying in a stall	11.40	12.31	**0.0072**	0.1814	0.0632	**0.0214**
Drinking	0.32	0.39	**0.0198**	0.4724	0.1000	0.1977
In AMS	0.39	0.38	0.9839	0.5370	0.7130	0.3736

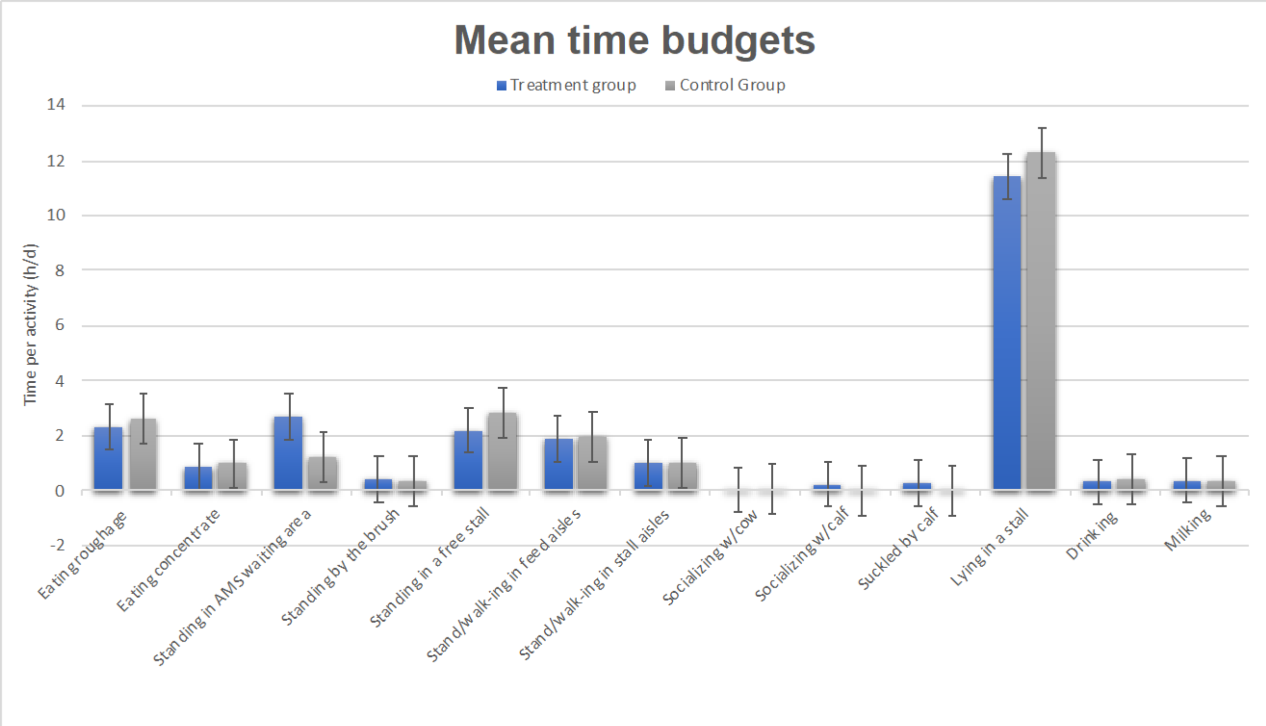

Figure 2. Summary of time budget observations, mean time budgets for both groups across all three periods with standard error bars

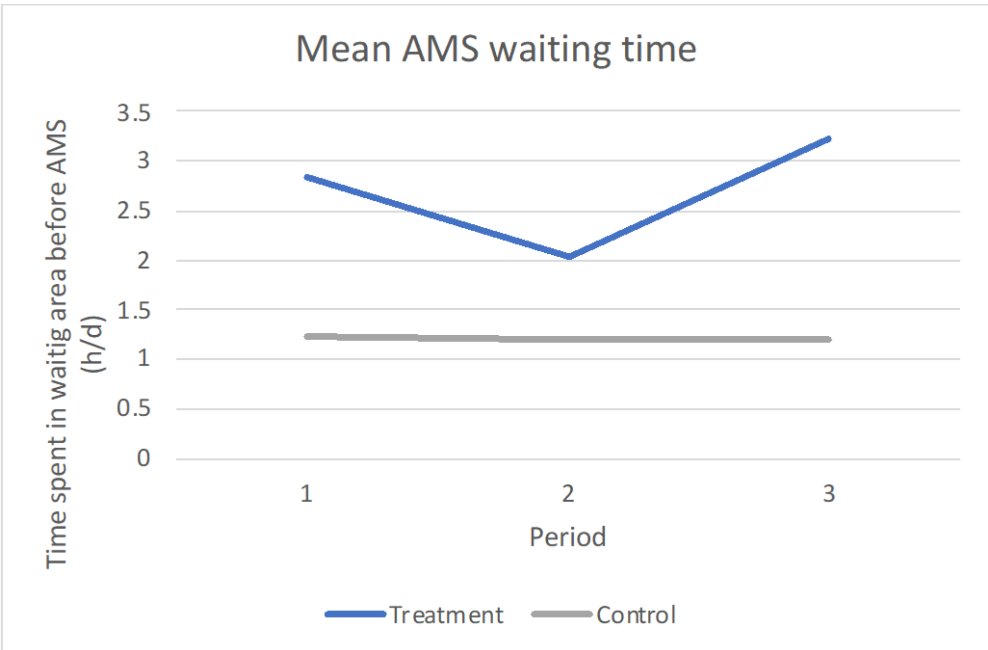

Figure 3. Mean AMS waiting time throughout the three periods, data from the video analysis

Standing and walking in the feed aisles

There was not a difference in the amount of time spent standing and/or walking in the feed aisles between the treatment groups (Table 3). Factors that were significant for this behaviour was the lactation the cow was in, and the breed of the cow. With the first lactation cows and the SRB cows spending more time on this behaviour than the late lactation animals and the Holstein cows.

Standing and walking in the cubicle aisles

The mean amount of time spent by the control cows standing and walking in the cubicle aisles did not differ from the amount of time spent by the treatment cows on this behaviour (Table 3). The only factor seen to be significant for this behaviour was the breed of the cow, where the SRB cows spent more time standing and walking.

Behaviours interacting with the calves

The treatment cows spent time both socializing with the calves and being suckled 0by the calves across all periods. The period was significant for the suckling behaviour with period 3 differing from periods 1 and 2. During period 1 the calves suckled a mean 0.36 ± 0.37 h/d, period 2 a mean of 0.33 ± 0.53 h/d and by period 3 the time suckled decreased further to a mean of 0.21 ± 0.46 h/d.

Lying behaviour

The time spent lying differed between the treatment group and control group. With the treatment cows lying for a shorter amount of time across periods. The difference spent on this behaviour was on average just under one hour across the periods. The period was also a significant factor, with periods 1 and 3 differing from one another. During period 1 the treatment cows had a mean lying time of 10.75 ± 3.31 h/d, and in period 3 this increased to a mean of 11.83 ± 2.30 h/d. There was a similar pattern for the control group, with the mean lying time in period 1 being 11.72 ± 2.66 h/d and in period 3 increasing to a mean of 12.89 ± 4.24 h/d.

Milking

There were no differences between treatment groups for the amount of time spent in the AMS. This behaviour did not differ between breeds, lactation, or the 3 periods either. The mean amount of time spent in the AMS for the treatment group was 0.39 ± 0.27 h/d and for the treatment group the mean was 0.38 ± 0.22 h/d.

Results from the data collected from the research farm

The following results are from the additional data that was collected from the research farm to either validate our time budget observations i.e. the time spent waiting at the AMS, or to gain insight into other important aspects regarding the animals, i.e. the feed intake. These results are all presented as LSMeans.

IceQube data

To confirm the lying times found during the observations for the time budgets, the data from the IceQubes was utilized. The duration of each lying bout that was recorded within the 48-hour period was combined to find the average daily lying duration for each individual during each of the three periods. The data showed similar results to what was found during the time budget observations with the IceQube data showing a significant difference in the time spent lying for the treatment group and the control group (P=0.0338). The IceQubes recorded the control group having an average lying time of 11.58 h/d and the treatment group having an average lying time of 12.36 h/d over all three periods. This was accomplished with an average of 14.5 lying bouts for the treatment group compared to 14 lying bouts for the control group. There was an interaction seen between the treatment and lactation of the cow having an effect on the number of lying bouts per 24-hr period. The interaction showed that first lactation dams with their calf present, had more lying bouts than first lactation dams in the control group. While the opposite was true for the later lactation dams, where the older cows in the treatment group had fewer lying bouts than those in the control group.

Time spent waiting for the AMS – data from selection gates

The amount of time spent on this behaviour from the time budget observations were confirmed through the use of the data from the selection gates. This data also showed a significant difference between the treatment groups (P<0.0001). The treatment group spending a mean of 3.23 h/d in the waiting area compared to the control group spending a mean of 1.99 h/d waiting (SEM = 0.6). The average amount of time spent waiting each visit to the robot was also determined. Treatment group was a significant factor here as well, with the treatment group waiting 1.77 hours each visit compared to the control group spending 1.28 hours waiting (SEM = 0.26; P < 0.0001). The lactation the cow was in was a factor for the amount of time spent waiting upon each visit to the robot. The older cows waiting for a shorter amount of time 1.24 hours per visit (SEM = 0.14), compared to the first lactation cows waiting for 1.8 hours each visit (SEM = 0.38).

Milk yield

There was a significant difference in the milk yield for the treatment group as compared to the control group (P<0.0001). The daily mean milk yield for the control cows was 37.8 kg (SEM= 0.75) and for the treatment cows the mean was 21.3 kg (SEM = 0.73). The milk yield during each visit to the robot was 8.3 kg for the control group and 15.5 kg for the treatment group. First lactation and later lactation cows also differed in their milk yield with the first lactation cows producing 25.5 kg of milk compared to the 33.6 kg milk yielded by the older cows (SEM = 0.69; SEM = 0.77; P < 0.0001). In the control group there was a significant difference in milk yields seen between the two breeds of cows (P=0.0002).

Feed intake

The feed intake did not differ between the treatment groups for the dry matter silage or the concentrates. For the dry matter intake there was no difference seen between the treatment and the control group. The control group had an average intake of 13.6 (SEM = 2.88) kg DM compared to the 13.8 (SEM= 2.91) kg DM intake by the treatment group. There was, however, an interaction seen between the treatment group and the lactation the cow was in. With a difference seen between the older cows in the control group compared to the treatment group (P=0.0106). The older control cows ate an average of 14.2 (SEM = 1.52) kg DM while the older treatment cows had an intake of 15.2 (SEM = 1.58) kg DM. There was not a significant difference between DM intake for the first lactation animals.

For the concentrates, the treatment group having a daily intake of 13. 5 kg (SEM = 2.23) compared to an intake of 13.9 kg (SEM = 2.24) for the control group. There was also no difference in concentrate intake among the different breeds or the early versus later lactation dams. However, the period of the study had a significant effect on the concentrate intake for the dairy cows ($P < 0.0001$), with a decrease in intake as the duration of the study progressed. The interaction of treatment and lactation of the cow was seen to be significant for the concentrate intake ($P = 0.0066$), with the later lactation cows from the treatment group and control groups differing in their concentrate intake. However, no difference for intake was seen between the treatment groups for the first lactation animals.

Feeding time – silage, from the Biocontrol recordings

The recordings for the time spent feeding from the silage bins show similar results to those found for the time at the roughage gates found during the time budget recordings. The time spent feeding was shown to be different between the treatment groups ($P < 0.001$) and across the periods ($P = 0.0005$). These results consistent with those found with the time budgets. Table 4 shows the eating time for the three periods and their progression across the different periods.

Table 4. LSMeans and SEM for time spent eating silage from the Biocontrol recordings

	Period 1		Period 2		Period 3	
	Treatment	Control	Treatment	Control	Treatment	Control
Eat time (h/d)	1.96	2.18	2.16	2.45	2.40	2.71
SEM	0.07	0.07	0.07	0.07	0.07	0.07

Treatment cows- where they spend their time

For certain behaviours the treatment group had the choice of where in the barn they could perform the behaviour. For example, they could spend time lying in stall in the full cow-calf contact area, the partial cow-calf contact area, or the area with no calf contact. A significant difference was seen in the amount of time the cows spent in the full CCC area compared to both the partial CCC and no CCC areas ($P<0.0001$), with the cows choosing to spend more time in the full CCC areas. There was no difference seen between the different breeds or the early versus later lactation cows. There was also no difference seen across the three periods, the cows chose to spend the most time in full CCC consistently throughout the duration of the study.

Discussion

The aim of the study was to determine whether there was a difference between the dams with cow-calf contact and the dams separated from their calves. In several of the recorded behaviours there were differences seen between the treatment groups, such as time spent eating roughage, eating concentrates, waiting for the AMS, standing in a free stall, socializing with another cow, lying in the stall and drinking. How the behaviours changed across the different periods was also investigated, and the period was found to influence several behaviours as well, such as, time spent eating roughage, standing in the free stall, socializing with another cow, suckled by a calf, and lying in the stall.

The feeding behaviour differed between treatment groups for both the time spent eating roughage and time spent eating concentrates. However, the feed intake for either silage or concentrates did not differ between groups. Munksgaard *et al.* (2005) has seen similar behaviour when evaluating responses to time constraints in dairy cows, he found that when time feeding was reduced the feed intake itself was not necessarily reduced in similar proportions. Rather the cows increased their speed of feed intake, thus the relative reduction in feed intake was less than the relative reduction in feeding time. Therefore, it is likely that the treatment cows in this study may have been compensating the reduced amount of time they spent at the feed gates by increasing the speed of feed intake.

The time spent feeding at the roughage gates also differed across the different periods of the study. With period three differing from the earlier two periods. These results differ from those found within the literature, where previous studies (Nielsen *et al.* 2000), saw a decrease in the eating time as the lactation period continued. With this decrease in eating time, increases in lying times were often seen as well. Perhaps our study saw a different pattern due to the relatively short duration spent feeding seen throughout the study as compared to others. According to Dijkstra *et al.* (2012) dairy cows that are housed indoors typically spend 4-7 hours eating per day. This being longer than what was seen for both treatment groups in this study. When combining the time spent eating roughage and concentrates, the animals in this study spent under 4 hours eating daily on average. Thus, substantially shorter durations than that seen previously in other studies, although similar eating times have been recorded at the research farm where this study was carried out. There are a number of factors that could play a role in this, perhaps the type of feed provided (Nielsen *et al.* 2000), the frequency of feed delivery, the type of traffic used, or the priorities of the animals. There could also be a difference in definitions of feeding behaviours and how the behaviour is recorded and quantified between studies. Løvendahl and Munksgaard (2016) have also seen a genetic link between the time spent eating and milk yield in dairy cows, showing that eating time is a correlated with milk yield. Perhaps this plays a role for the cows in the study, however the exact milk yield of the treatment group could not be determined since the milk intake from the calves suckling cannot be measured therefore, is not included in the overall milk yield for these dams. It was also interesting that there were no breed differences in the time spent feeding, as the Swedish Holstein is a larger breed with a higher milk yield than the Swedish Red thus, they would be expected to have a higher feed intake.

The shorter feeding time of the animals in our study is not necessarily an issue. As long as the animals have a sufficient daily intake, the dairy cows increasing their feeding speed may be a way to have time for other behaviours. Perhaps those in the control group are spending more time on this behaviour as they have less to do without a calf present to care for.

Time spent standing in the AMS waiting area differed greatly between the treatment groups. With the treatment group waiting on average 2.7 h/d versus the average of 1.21 h/d for the control group. In our study the AMS had a feed first system, where after feeding the cows did not have a choice whether they went to the AMS, rather the semi-forced gate either directed them to the waiting or to the resting area. Thus, we cannot know if the individual was aiming to feed, be milked, or go back to her calf or the resting area. Therefore, it would be interesting to investigate how a system with free cow traffic would look with cow-calf contact system. With free cow traffic, the motivation to feed or be milked could perhaps be more easily be differentiated. With the ability to see where the cow chooses to go first. The amount of time spent in the waiting area in our study was consistent with previously seen studies. In a study by Munksgaard *et al.* (2010) comparing free and forced traffic, the cows were seen to wait on average 1.5 hours per day, however there was a large individual variation seen in that study as well as in this one. The variation in waiting time likely due to the social ranking of individuals within the herd, with the higher ranked individuals passing the low ranked ones in the queue. Thus, lower ranked cows typically have to wait longer for the AMS (Meijering *et al.* 2004). Similarly, a study by Halachmi (2009) simulating hierarchy in a dairy herd, found lower ranked cows waited significantly longer than the medium ranked and dominant animals with the low ranked animals waiting 1.1 hours per day compared to only a few minutes for those with a higher rank. In this study, the ranks of the animals were not recorded, therefore it is difficult to determine if this is the reason for the difference in the waiting times for the treatment group and control group. However, there were both first lactation and later lactation cows in both groups. And according to Halachmi (2009), first lactation cows are usually of low rank, thus having them in both groups should not lead to one group being higher ranked than the other. In our study we did see this, with the first lactation animals spending more time waiting for the AMS than those in later lactations.

Perhaps the difference in waiting times could instead be due to the presence of the calves in the treatment group. The treatment cows are being suckled on throughout the day, therefore not getting as full in their udders. While the control group can only relieve their full udders with visits to the milking robot. Thus, the difference in wait time could be due to differences in the amount of motivation to be milked. The treatment group could be less motivated to reach the robot in comparison to the control group, perhaps allowing them to pass in queue while in the waiting area leading to longer waiting times. However, this speculation contradicts the findings from (Prescott *et al.* 1998) where the motivation to be milked was found to be very weak, variable and not related to the stage of lactation, therefore unlikely to be a significant reason for cows to be attracted to the AMS. The motivation to enter the AMS was more so motivated by the access to a concentrate food reward in that study. Therefore, a reason for the differences in the time spent in the waiting areas between the two groups could also be due to the availability of concentrates. The treatment group had two concentrate feeders to share among the treatment group only, while the control group had to compete with each other, the treatment group, and the filler cows to get to the concentrate feeder. Thus, they may have been more motivated by the concentrate they would receive in the AMS compared to the treatment group. However, while Prescott *et al.* (1998) suggests that feed is more motivating than being milked, that study differed greatly from ours. Firstly, in that study, the cows were taken to the Y maze to test their motivation between being milked or not, as well as being milked or receiving feed, every 3.5 hours. This is a rather short interval in which the udders may not have gotten completely full, thus the motivation to be milked may have been low regardless. As compared to our study where the dairy cows visit the robot around two times daily, thus allowing the control to get full in the udders. Secondly having the presence of calves in our study adds a new factor into the relative motivations that is hard to compare to a study that has no calves. It would be of interest to compare the relative motivations of dairy cows to interact with their calf, be milked and to feed to help understand certain results from our study.

The position of the milking robot in the barn could also have had an impact on the longer waiting times for the treatment group. The position of the robot and the waiting area before it, has the cows queueing in the direction of the feeding area. In normal circumstances when there is no calf creep this is perhaps ideal as the cows seem to be motivated to feed. However, for this study, the full cow calf contact area and calf creep are positioned behind the waiting area, and when in queue for the robot the cows are then facing away from the calves. Thus, the treatment cows would occasionally choose to stand at the edge of the waiting area looking towards the calves as opposed to getting in the robot queue. Perhaps not understanding that once they have been milked, they will be able to access the cow calf contact area once again. Therefore, likely leading to the longer waiting times for the treatment group. In a future study, facing the robot in the direction of the calves would be ideal to avoid this issue. The exact cause of these long wait times for the treatment group is an area that needs further evaluation.

Time spent socializing with other cows only accounted for minutes of the daily time budgets of the dairy cows in both treatment groups. This could be seen as a positive as it indicates that there was not necessarily any aggressive interactions between the animals. However, the amount of time spent socializing with other cows was potentially underestimated in this study due to the video analysis methodology. The behaviour of the individual was recorded every 10 minutes from a paused video. Therefore, it is possible that when a cow was socializing it was recorded as the behaviour standing/walking in the feed aisles, or stall aisles due to the difficulty of differentiating these behaviours in a still picture. In another study, with time constraints placed on the animals (Munksgaard *et al.* 2005), cows were observed maintaining the same proportion of their time spent on socializing behaviours as they did without the presence of time constraints. This indicates that social behaviour is a priority for dairy cows. Even though it is a less prioritized behaviour when compared to lying and eating. Thus, suggesting that the behaviour of socializing was perhaps overlooked throughout the time budget observations in this study. Therefore, having a better method to record this behaviour more accurately should be considered in future time budget experiments.

The amount of time spent lying in this study, 11.84 ± 3.37 h/d for all of the cows, was similar to those reported in other studies, Jensen *et al.* (2005) and Munksgaard *et al.* (2005), where they suggest that approximately 12 hours of lying time throughout each 24-hour period is optimal for dairy cows. Although the treatment group did spend less time lying then the control group, spending about an hour less lying per day across all the periods. This could have negative implications for the treatment group as this behaviour is crucial for production and well-being of the animal. Dairy cows are highly motivated to lie down, with the proportion of time spent on this behaviour increasing even when time is a limitation (Munksgaard *et al.* 2005). The shorter amount of lying time for the treatment group could be due to competition for stalls, not with other cows but with the calves. Throughout the video analysis, often there would be calves lying in the stalls instead of their calf creep area, thus reducing the amount of lying spaces for the cows. It is unclear whether the cow would attempt to displace calf if there were not any lying spaces left and this could be an area to further study and consider when using cow-calf contact systems.

Time spent lying increased as the duration of the study progressed. With both the treatment group and the control group increasing the time spent lying by over an hour daily in period 3 as compared to period 1. Other studies have reported similar findings, with the lying time increasing as the lactation period continues (Bewley *et al.* 2010). The change in lying behaviour across periods is likely due to the changes in the milk yield that occur throughout the lactation (Norring *et al.* 2012). Although in our study there was not a difference seen in the milk yield throughout the different periods. There was, however, a difference seen in the milk yield between the treatment group and the control group. These results are somewhat limiting since the milk yield was determined by the milking robot only. This gives us an idea of the differences in sellable milk throughout the suckling period between the two groups but not the amount of milk produced by each dam. Thus, from this study we cannot determine whether the prolonged cow-calf had a negative effect on milk production, and the 'losses' that are consumed by the calves should only be considered as true losses if the intake exceeds what the calf would have consumed via other methods.

The number of lying bouts per day found in this study, 14.0 bouts daily for the control group and 14.5 bouts daily for the treatment group, was slightly higher than those previously reported in the literature. Bewley *et al.* (2010) reported an average of 11 bouts daily. The difference could be due to the differences in studies, as that particular study had some animals in a parlour milking system, some cows that were over 150 days in milk while our animals were all housed in an AMS and had not yet reached 150 days in milk. This could also be due to the animals standing up more often to allow for nursing behaviour in our study. The dams with cow-calf contact would need to have more standing bouts to allow for the suckling to occur. As suckling bouts typically range from 4 to 9 times daily depending on the age of the calf (Fröberg and Lidfors 2009). The treatment cows were also observed spending less time standing in the free stall compared to the control group. This is surprising, as the treatment cows would be expected to spend more time standing to allow access to the teats for suckling behaviour by the calves. However, this could be due to suckling behaviour being recorded separately from the standing behaviours. There was also a difference in the third period compared to the first two periods in the amount of time spent standing in the free stall, with the duration decreasing as time went on. This is consistent with results seen by Løvendahl and Munksgaard (2016), where they saw that early in the lactation the cows were spending more time standing in the stalls, thus decreasing the amount of lying time, and as the lactation period progressed the opposite was true. With lying time increasing and standing in the stall decreasing. They found the stage of the cows' lactation, similarly the different periods in this study, to have a significant effect on the amount of time spent standing in the stalls.

The dams with cow-calf contact had the choice of where to spend their time in the barn and the results showed that the majority of their time was spent in the area with full cow- calf contact. This confirms findings by von Keyserlingk and Weary (2007) and Jensen (2011) that dairy cows will perform maternal behaviours when given the opportunity to do so. Spending time in the full cow-calf contact area allowed for the nursing, licking and bonding behaviours to occur between the dam and her calf. Often, the dam could be seen sharing a stall with a calf while resting and staying in close proximity to the calf. Thus, suggesting that bonds were formed between the dams and their calves. This is not surprising since as little as five minutes of contact postpartum has been enough for a strong maternal bond to be formed in a previous study (Hudson and Mullord 1977).

Another consideration when taking all the results into account is that there were additional animals housed in the system to simulate a full capacity for the AMS, on which no observations were made, and no data was collected. The presence of these animals could have impacted the behaviours of those that were included in the study. For example, if those dairy cows were dominant, this could have led to increased waiting times at the AMS. Additionally, this increased capacity may have led to more competition at the feeding areas.

Certain behaviours can perhaps be compensated for when time is constrained as seen with the feed intake. However, more research into the priorities of behaviours for dairy cattle should be investigated to optimize their time budgets and ensure that the cows have enough time for essential behaviours as well as those they have been seen to prioritize, such as socializing. Investigating the priorities when calves are added into the loose housing system would also be of interest, to further understand the priorities when housed in cow-calf contact systems and whether this differs from those housed separately from the calves. While certain behaviours were reduced in duration for the treatment group in the study i.e., lying time and eating time, none were seen to be constrained to the point of reduced well-being for the animals. In a housing system with some adjustments to ensure the best utilization of the time budget for the dairy cows, the addition of calves to a loose housing system is plausible.

Conclusion

There were differences seen in the time budgets of dairy cows with their calf present in the loose housing system with an AMS compared to the cows that were separated from their calves following parturition. In accordance with what the scientific literature currently states regarding the amount of time needed for the different behaviours in dairy cows, the results of this study suggest that all of the animals appeared to have an adequate amount of time to perform the essential behaviours throughout the day whether or not their calf was present.

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Acknowledgements

I would like to thank my supervisor, Mikaela Lindberg, for providing me with the opportunity to work on this project. I am very appreciative of all the time, support, and expertise given to me throughout the duration of the project, especially with the statistics. I would also like to thank all the staff at the Lövsta research centre where the experiment was carried out. And specifically, Gunilla Helmersson, who provided data and information regarding the study, as well as assistance at the research centre. Finally, I would like to thank my examiner, Sigrid Agenäs, for her comments and feedback that helped improve my thesis.