The effect of the shape of the waiting area on the behaviour of dairy cows in an automatic milking rotary system

Effekten av väntfållans utformning på mjölkkors beteende i system med automatiserad karusellmjölkning

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Master's Programme in Animal Science

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I denna serie publiceras olika typer av studentarbeten, bl.a. examensarbeten, vanligtvis omfattande 7,5-30 hp. Studentarbeten ingår som en obligatorisk del i olika program och syftar till att under handledning ge den studerande träning i att självständigt och på ett vetenskapligt sätt lösa en uppgift. Arbetenas innehåll, resultat och slutsatser bör således bedömas mot denna bakgrund.

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ABSTRACT

In some systems dairy cows are gathered in a waiting area (WA) prior to milking, to ensure that all cows pass through the milking unit. However, cows of low social rank might have to stand in the WA for a considerable amount of time before entering the milking unit. They may also be exposed to aggressive behaviours by cows of higher rank, which would be detrimental to their health and welfare. One of the factors which could influence the time that the cows spend in the WA and the amount of aggressive behaviours is the shape of the WA. The aim of this study was to investigate how the shape of the WA and the number of cows released towards it simultaneously affect the time that the cows spend in the WA and the frequency of aggressive behaviours. Additionally the time that the staff spent herding the cows in the different shapes of the WA was investigated. For this study 175 lactating Swedish Red and Swedish Holstein cows were used, of which 109 cows were included in all treatments. The cows were kept in 3 groups in a loose housing system with cubicles and were all milked twice daily in a DeLaval Automatic Milking Rotary (AMR^{TM}). However, only the evening milking sessions were included in the study. The experiment was divided into 6 different treatments: S50, S100, R50, R10, D50 and D10. The treatments were a combination of the shapes of the WA and a various number of cows approaching the WA at the same time. The 3 different shapes investigated were the large WA (S treatments), a reduced WA (R treatments) and a curved single file race instead of a WA (D treatments). The cows were released towards the AMR in 3 different ways; 1 group every 50 minutes (50), 10 cows every 10 minutes (10) and 2 groups simultaneously (100). The time that the cows spent in the WA was recorded for 5 to 7 days per treatment using data from a selection gate by the entrance to the WA and from the AMR system. The behaviour of the cows in the WA was recorded using video cameras and data on the frequency of aggressive behaviour was collected from 2 milking sessions per treatment. Data on the time that the staff spent herding the cows in the WA was collected from 2 milking sessions per treatment. The maximum time that the cows spent in the WA differed considerably among treatments, and ranged from 52 min in D50 to 2 h 59 min in R50. There was a significant difference between treatments ($p < 0.0001$) regarding the time that the cows spent in the WA. The cows spent more time in the large WA than in the reduced and more time in the reduced WA than in the single file race. There was a significant effect of treatment ($p < 0.01$) on the behaviours ‘pushing’ and ‘pushbutt’ (which was the frequency of ‘pushing’ and ‘butting’ combined). Regarding the behaviour ‘butting’, there was a tendency for an effect of treatment, while no significant effect of treatment was found for ‘head to head pushing’. The amount of ‘pushbutt’ was significantly ($p < 0.05$) higher in the reduced WA (R50 and R10) compared to all other treatments. This could have been an effect of low ranking cows being unable to avoid interactions with cows of higher rank due to the limited space in the WA. However, due to the limited number of observations and a number of factors affecting the cows’ behaviour, it is difficult to draw any conclusion on which shape of the WA would be preferable regarding the amount of aggressive interactions. The amount of time spent herding the cows was highest in both S treatments (49 min and 40 min in S50 and S100 respectively), while the least amount of herding time was spent in the D treatments (13 min and 10 min in D50 and D10 respectively). The maximum times and mean times spent in the WA and the herding times were shorter in the single file race compared to the other treatments. These results suggest that constructing a single file race in front of the AMR, instead of a WA, could have the potential to improve the welfare of low ranking cows around milking and minimize the negative effects of social dominance.

INTRODUCTION

Background

When cows are milked in different types of milking systems such as a conventional milking parlour, a rotary system or an automatic milking system (AMS) they are sometimes gathered in a waiting area (WA). Having a WA, where cows are held prior to milking, is a way to certify that all animals go through the milking unit (Uetake et al., 1997) and to encourage a flow of queuing cows through the milking system (Jacobs et al., 2012). However, cows of low social rank may be exposed to aggressive behaviours by higher ranking cows (Collis, 1976) and might have to stand in the WA for a long time before being able to enter the milking unit (Ketelaar-de Lauwere et al., 1996; Melin et al., 2006). Both long waiting times prior to milking and exposure to aggression are detrimental to cow health and welfare. For instance Cook and Nordlund (2009) stated that among other factors, increased milking time and more time away from the resting area negatively affect the risk of lameness in dairy cows. A cow's time budget is also negatively affected by long waiting times prior to milking and, as stated by Winter and Hillerton (1995), these long waiting times seem to be an inefficient way to spend the cow's time. If the milking time, including the time spent waiting, is reduced there will be more time for other important behaviours, for example cows that spent more time in the WA before milking compensated by spending less time eating (Uetake et al., 1997). In another study, an increased milking time resulted in a reduction in the time spent eating and lying down and a positive correlation between milk yield and eating time was found. The time spent milking and in the WA could therefore also have a negative effect on production (Gomez and Cook, 2010). The animals which are being subjected to long standing times in the WA and aggressive behaviours by other cows could have a reduced welfare considering the criteria and subcriteria for the assessment of overall welfare in farm animals used in WelfareQuality®. Some of the subcriteria, such as 'absence of prolonged thirst', 'ease of movement', 'absence of injuries' and 'expression of social behaviours' (Botreau et al., 2007) could all be compromised for cows with low rank in the situation described. It is therefore important to try to minimize the risk of long waiting times and aggressive behaviours. One of the factors which could influence the amount of time spent in the WA and the amount of aggressive behaviours is the shape of the WA.

Literature review

<u>Facility design and cattle handling</u>

When designing a barn for dairy cows it is very important to consider the behaviour of cows and how they interact with each other and the environment (Kilgour, 1978). Cattle have a wide-angle vision of approximately 330˚ due to the location of the eyes on the head, while their binocular visual field is only around 40˚ (Phillips, 2010). The narrow binocular visual field gives the cattle a poor depth perception, which explains why they are often hesitant to cross surfaces with irregularities in the floor since it could be perceived as an actual obstacle (Warriss, 1990). When driving cattle to slaughter, the use of a single file curved race, which takes advantage of their behaviour, has been suggested to improve both animal welfare and efficiency (Grandin, 1980). One advantage of the single file race, is that it only provides the cow with one possible direction. A single file race should be designed so that the cows can see far enough ahead and follow each other. If the angle is too sharp at the entrance of the race, the animals may not enter, since it looks like a dead end (Grandin, 1997). One of the purposes of having a curved instead of a straight single file race is to prevent the cattle from seeing what lies ahead until they are about to enter it, which prevents them from stopping and backing up. The other purpose is to use the fact that when a person is herding cattle, the animals tend to move in a circle around the person. A single file race for handling cattle should have solid sides to prevent the animals from being distracted by the surrounding, which might cause them to halt (Grandin, 1980). When handling cattle, a person should use the edge of the animal's flight zone (Fig. 1) to make it move in different directions. When the handler enters the animal's flight zone it will move away from the person and the animal will halt if the person exits the flight zone. To make the cattle move away calmly and not either run away or run back past the handler, the person must not step too far into the flight zone. The dimension of the flight zone is dependent on how much the cattle are used to being handled, and using the flight zone to move cows which are very used to handling can be difficult (Grandin, 1997). The animal will move forward or backwards depending on where the handler is positioned relative to the so called point of balance situated at the animals shoulder. The handler should stand behind the point of balance, to drive the animal forwards and standing in front of it will make the animal move backwards (Kilgour and Dalton, 1984). The optimal positioning for the handler to drive cattle forward is at an angle of 45-60˚ to the shoulder of the animal (Grandin, 1997).

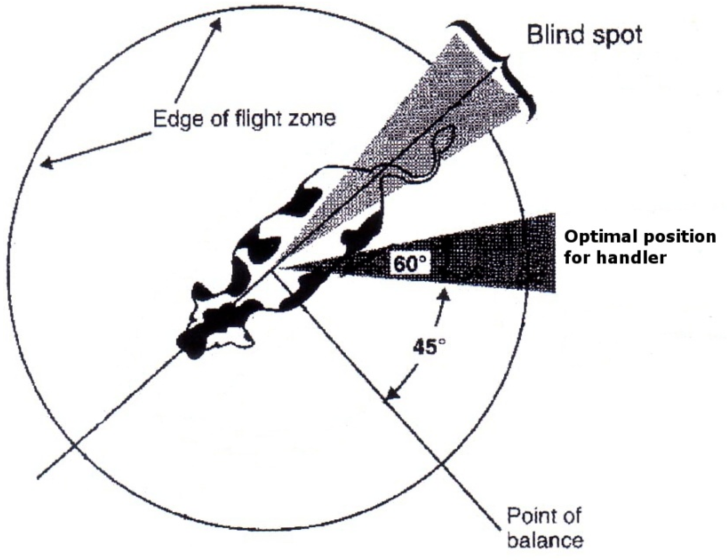

Fig. 1. The flight zone, field of vision, point of balance and handler position when herding cattle. Adapted from Grandin (1997).

An important part of the facility design and management in an AMS is the organisation of the cow traffic system. The word cow traffic refers to how different gates, such as selection gates and one-way gates, are used to guide the cows around the barn (Jacobs and Siegford, 2012). The main cow traffic systems in an AMS are forced, free and selective cow traffic. In systems with forced cow traffic the cows can only move between the resting and feeding areas by passing through the milking unit. When free cow traffic is applied the cows can move freely between the different areas of the barn. Selective cow traffic is a combination of free and forced cow traffic, where the animals can move from the resting to the feeding area through either the milking unit or a selection gate with individual recognition. When the cow has permission to be milked the selection gates do not let her through and to access the feeding area she must pass through the milking unit (Hermans et al., 2003). Later on, other cow traffic systems, such as the DeLaval feed first and milk first systems have been developed. These are intermediate between the free and selective cow traffic systems. When the feed first system is applied the cows move from the resting area to the feeding area through one-way gates. When exiting the feeding area the cows must go through a selection gate which will either guide them to the WA and milking unit or to the resting area and concentrate feeders depending on if the cow has permission to be milked or not (Forsberg, 2008). The organization of the milk first system is the same as the feed first system, with the exception that the cows enter the resting area through one-way gates and have to pass through the selection gate to be able to enter the feeding area (Rossing et al., 1997).

The behaviour of the cows is greatly affected by the organisation of the cow traffic system (Ketelaar-de Lauwere et al., 1998) and a good design of the system is crucial to be able to utilize the full capacity of an AMS (Melin et al., 2006; Svennersten-Sjaunja and Pettersson, 2008). Free cow traffic may result in an insufficient number of visits to the milking unit compared to forced cow traffic (Ketelaar-de Lauwere et al., 1998; Ketelaar-de Lauwere et al., 2000). However, in a system with free cow traffic the cows had a higher roughage intake and increased rumination time compared to forced and selective cow traffic (Melin et al., 2007). Forced cow traffic could also result in fewer meals per day and seemed to have a negative effect on low ranked cows, which spent more time in the WA and less time lying down and in the feeding area (Forsberg, 2008). Additionally, forced cow traffic may result in a higher number of non-milking visits, which decreases the capacity of the AMS (Hermans et al., 2003). When semi-forced and forced cow traffic were compared, the time that the cows spent in the feeding area was increased and the time spent standing in cubicles was reduced in the system with semi-forced cow traffic. The number of AMS visits was also more evenly distributed between cows in the semi-forced cow traffic system (Hermans et al., 2003). Hence, forced cow traffic is usually not recommended, due to possible negative effects on cow behaviour and welfare (Ketelaar-de Lauwere et al., 2000; Hermans et al., 2003; Melin et al., 2007; Forsberg, 2008).

The utilisation of a WA in front of the milking unit differs between systems. In some systems a closed WA is used where the only way out of the WA is through the milking unit (Hermans et al., 2003). In other systems an open WA is used, where the cows have the possibility to return to the resting area (Melin et al., 2006; Melin et al., 2007). There are also systems without a WA, where the selection for milking takes place in the milking unit (Stefanowska et al., 1999a) or in a selection gate located in front of the milking unit (Stefanowska et al., 1999b).

<u>Social dominance and behaviour</u>

The behaviour of one animal in a pair can be inhibited by the other, which means that the behaviour of an animal in a herd is highly dependent on its dominance status (Beilharz and Zeeb, 1982). Two main functions of a stable dominance relationship is that it can be used by the animals involved to foresee the results of agonistic interactions and that it regulates how resources within a pair of animals are distributed, thus reducing the aggression in the herd (Wierenga, 1990). A dominant animal might have been aggressive while establishing its dominance relationships within a herd, but once stable relationships are formed a dominant animal is not necessarily aggressive (Beilharz and Zeeb, 1982). However, the distribution of displacements within a pair of animals is not random and in approximately 95% of all pairs the subordinate animal showed fewer displacements than the dominant (Wierenga, 1990). Additionally, Collis (1976) found a positive correlation between the amount of initiated aggressive interactions and the animal's dominance value in a herd of 49 lactating dairy cows of similar age. However, so called contradictory displacements can sometimes also be seen, where the subordinate animal displaces the dominant. This behaviour is more common in situations of overcrowding and only accounted for 3.9 % of all displacements. It has been suggested that contradictory displacements is a result of housing and management (Wierenga, 1990).

Once formed, the dominance relationships in cattle are usually stable for a long time (Beilharz and Zeeb, 1982; Wierenga, 1990). In a study by Wierenga (1990) the dominance relationships changed in only 6.8% of all pairs of animals during 1 year, and in 23.8% of all pairs in 3 years.

Higher stocking density increases the competition for resources, which has been found to increase the frequency of agonistic interactions in dairy cows and could lead to a reduced welfare (Metz and Mekking, 1984; Fregonesi and Leaver, 2002). Also in the study by Wierenga (1990) the majority of the displacements occurred due to competition for resources.

Many different factors may influence the outcome when a dominance relationship between two animals is establishing (Beilharz and Zeeb, 1982). The existing literature on factors affecting the dominance status of an animal is somewhat contradictory. On one hand, Ketelaar-de Lauwere et al. (1996) found a positive correlation between social rank and days in milk, but found no correlation between social rank and age or parity number. On the other hand O´Connell et al. (1989) found that social rank was related to age and Phillips and Rind (2002) found a positive correlation between dominance value and both body weight and parity number. However, all cows in the study by Ketelaar-de Lauwere et al. (1996) were in their first to third lactation, which could explain why no correlation with age or parity number was found. Heifers generally have a low dominance value, but there are still a number of exceptions and it was observed that the dominance value for some cows increased over a period of 4 years, while for other cows it decreased (Wierenga, 1990). This makes it difficult to draw any conclusion on whether age and parity number affects the dominance status of a cow. There seems to be no correlation between dominance value and milk yield (Soffié et al., 1976; Ketelaar-de Lauwere et al. 1996; Phillips and Rind, 2002). Another factor that might influence a cow's dominance status in a herd is the stage of gestation, since cows in late gestation tended to avoid agonistic interactions (Beilharz and Zeeb, 1982).

The time spent in the WA and resting area is dependent on the social rank of the cow and low ranked cows were in the WA for a longer time and in the resting area for a shorter time compared to high ranked cows (Melin et al., 2006). In studies with an open WA the cows of low rank also spent more time in the WA and it happened more often that cows of low rank left the WA without being milked (Winter and Hillerton, 1995; Ketelaar-de Lauwere et al., 1996). Both Soffié et al. (1976) and Rathore (1982) have shown that cows milked in a parlour do not enter at random and that there is a consistency in the milking order over time. Phillips and Rind (2002) showed that the cow's dominance value was correlated to order of entrance to the milking parlour, where dominant cows were the first to enter the parlour.

Motivation

For an AMS or fully automated AMR to be successful and reduce labour on a farm, the cows need to attend it voluntarily. If the cows frequently have to be fetched for milking, labour will increase and part of the purpose of having an AMS will be lost. Therefore, understanding the underlying motivations of cows to enter a milking stall is important (Jacobs and Siegford, 2012). A study by Prescott et al. (1998) investigating dairy cows' motivation to be milked or fed concentrates showed a weak and variable motivation for milking and it seemed to be unrelated to stage of lactation. However, the motivation to receive concentrates was strong, and can be used to motivate cows to enter an AMS, which is often done in practice (Jacobs and Siegford, 2012; Jacobs et al., 2012). The reduced pressure on the udder by milking might be rewarding for high-yielding cows, since it was found that cows with a low milk yield entered the milking parlour later than cows with a high milk yield (Rathore, 1982). However, Prescott et al. (1998) found no difference in attendance to an AMS between high and low yielding cows and Winter and Hillerton (1995) found no correlation between milking order and milk yield in a system with an automatic milking unit.

Milking time and lameness

In a study by Munksgaard et al. (2011) the average time, that the cows in a loose housing system with an AMS, spent in the WA was 1.5 h/day and varied from 0.5 to 3.5 h/day. Additionally the cows spent 40 minutes standing in the alley leading to the WA, of which some time could be considered as time spent waiting to enter the WA when it was occupied by other cows. For the cow traffic system to be efficient and well-functioning it is crucial that roughage is available at all times (Svennersten-Sjaunja and Pettersson, 2008). The average time spent standing in the WA, in a loose housing system with an automatic milking unit, could be reduced to less than half by delivering feed 6 times per day instead of 2 times per day (Oostra et al., 2005). Additionally, the efficiency of the milking system could be reduced if cows spend more time in the WA than necessary and influence the behaviour of other cows (Stefanowska et al., 1999b; Jacobs et al., 2012).

As previously mentioned, a prolonged time in the WA can have a number of negative effects on cow health and welfare. One key factor triggering the development of claw lesions and subsequent lameness is external trauma (Cook and Nordlund, 2009) and the time spent away from the pen to be milked has been shown to increase the risk of lameness in a herd (Espejo and Endres, 2007). Applying rubber to the floor surface in the WA and alleys where the cows are walking and standing could be favourable for the cows, since it causes less wear of the claws (Cook and Nordlund, 2009; Telezhenko et al., 2009), and improves locomotion compared to concrete surfaces (Telezhenko and Bergsten, 2005).

AIM AND HYPOTHESES

The aim of this study was to investigate how the shape of the WA in front of the AMR, and the number of cows released towards it at the same time affect the time that the cows spend in the WA and the amount of aggressive behaviours performed while waiting to enter the AMR. The amount of time that the staff spent herding the cows in the different shapes of the WA was also investigated.
The research questions were as follows:

1. How are the cows' time and behaviour in the WA affected by its shape and the amount of cows released towards it at the same time?

2. How much time does the staff spend on herding the cows towards the AMR in the different shapes of the WA?

The hypotheses were:

1. The cows spend, on average, more time in the large and reduced WA than in the single file race.

2. A higher number of cows released towards the WA at the same time results in a shorter waiting time.

3. The frequency of aggressive behaviours is higher in the large and reduced WA than in the single file race.

4. The staff spend more time herding the cows towards the AMR in the large WA than in the reduced and more in the reduced WA than in the single file race.

MATERIAL AND METHODS

Animals, housing and management

This study was approved by the Ethical Committee on Animal Experiments, and was performed at the Swedish University of Agricultural Sciences' research centre for farm animals at Funbo-Lövsta in Uppsala. The experiment lasted for six weeks during the period from 14th of June until 31st of July 2012. For this study 175 lactating dairy cows of the breeds Swedish Red and Swedish Holstein were used. During the study a number of animals were added and removed from the herd, due to recent calving, drying off, illness or being relocated for another study etc., and therefore only 109 cows were included in all treatments. From the 109 cows, 76 were primiparous and 33 multiparous. Sixteen cows were in in the first to third lactation month, 33 cows were in the fourth to sixth lactation month, 44 cows were in the seventh to ninth lactation month, 15 cows were in the tenth to eleventh lactation month and 1 cow was in month fourteen or higher. The cows were kept in 3 groups, named AMR1, AMR2 and AMR3, of approximately the same size (i.e. around 50 cows/group) in a loose housing system with cubicles. Throughout the experiment the cows in all 3 groups were kept on the same pasture during the nights and indoors during the days. The animals went directly out on pasture after being milked in the evening and were taken in again for the morning milking. The cows had access to silage ad libitum and each group had access to concentrates, based on their milk production, in four DeLaval feed stations FSC400. The cows were milked twice daily at 5:00 and 16:00 in a DeLaval Automatic Milking Rotary (AMR^{TM}). AMR2 shared feeding area with a smaller group of cows which had Staphylococcus aureus infection. This smaller group had a separate resting area and were not included in this study since they were milked last and were not supposed to be mixed with the other cows. Before the start of the experiment the cows were fetched for milking, from their separate resting areas, 1 group at a time. The first group fetched was AMR3, then AMR1 and last AMR2. This order was also kept throughout the entire experiment. The floor in the WA was solid concrete and the floor in the aisle leading towards the AMR and WA had concrete slatted floors in the middle of the aisle and solid concrete on the sides. In the feeding and resting areas in AMR2 and AMR3 the floors were solid concrete while the floors in AMR1 were covered with rubber.

Automatic Milking Rotary

The Delaval Automatic Milking Rotary (AMR) which was first introduced in 2010, has a platform containing 24 stalls and 5 robotic arms and is created to handle larger group sizes of 300-800 cows (Jacobs and Siegford, 2012). It is operated manually from the inside of the rotary and can also be controlled by remote access from any computer connected to the system which is equipped with software package developed by DeLaval. The 5 robotic arms inside the rotary clean the teats (2), attach the teat cups (2) and spray the teats (1) after milking. The AMR holds still for 30 seconds per cow, to enable cows to enter and for the robots to clean, attach teat cups and spray the teats. However, the AMR is standing still for more than 30 seconds when the robots, which attach the teat, cups have difficulties finding the teats and if no cow enters it holds still for 90 seconds. During milking there was at least one person from the staff present in the AMR to, for instance, attach teat cups when the robots missed or when the cows kicked them off. However, the staff was not necessarily present in the AMR during the entire milking session.

Experimental design

The experiment was divided into 6 different treatments (Table 1), where 3 alternative shapes of the waiting area (WA) were combined with a various number of cows approaching the WA at the same time. This was done to investigate how the shape and pressure on the WA affected the cows' time and behaviour until they entered the AMR. The 3 different shapes investigated were the large (original) WA, a reduced WA and a single file race instead of a WA. The cows were released in 3 different ways towards the AMR; 1 group every 50 minutes, 10 cows every 10 minutes and 2 groups simultaneously.

Originally each treatment was planned to be performed during 5 workdays and include both morning and evening milking. This was applied during the first and second treatment except for the last day of the second treatment which only included the evening milking. Treatments 3 to 6 included 7 evening milkings per treatment, including weekends. It was assumed that it would be possible to fetch the cows from their respective resting areas for both morning and evening milking. This was a prerequisite for being able to collect data on the time that the cows spent in the WA, since they had to pass through a selection gate which was placed close to the entrance of the WA (Fig 2). However, when the cows were taken in from pasture in the morning they could not be sorted into their appropriate groups, since the selection gate could not handle such an amount of cows approaching it simultaneously. Hence, it was decided to only include evening milkings in the following four treatments.

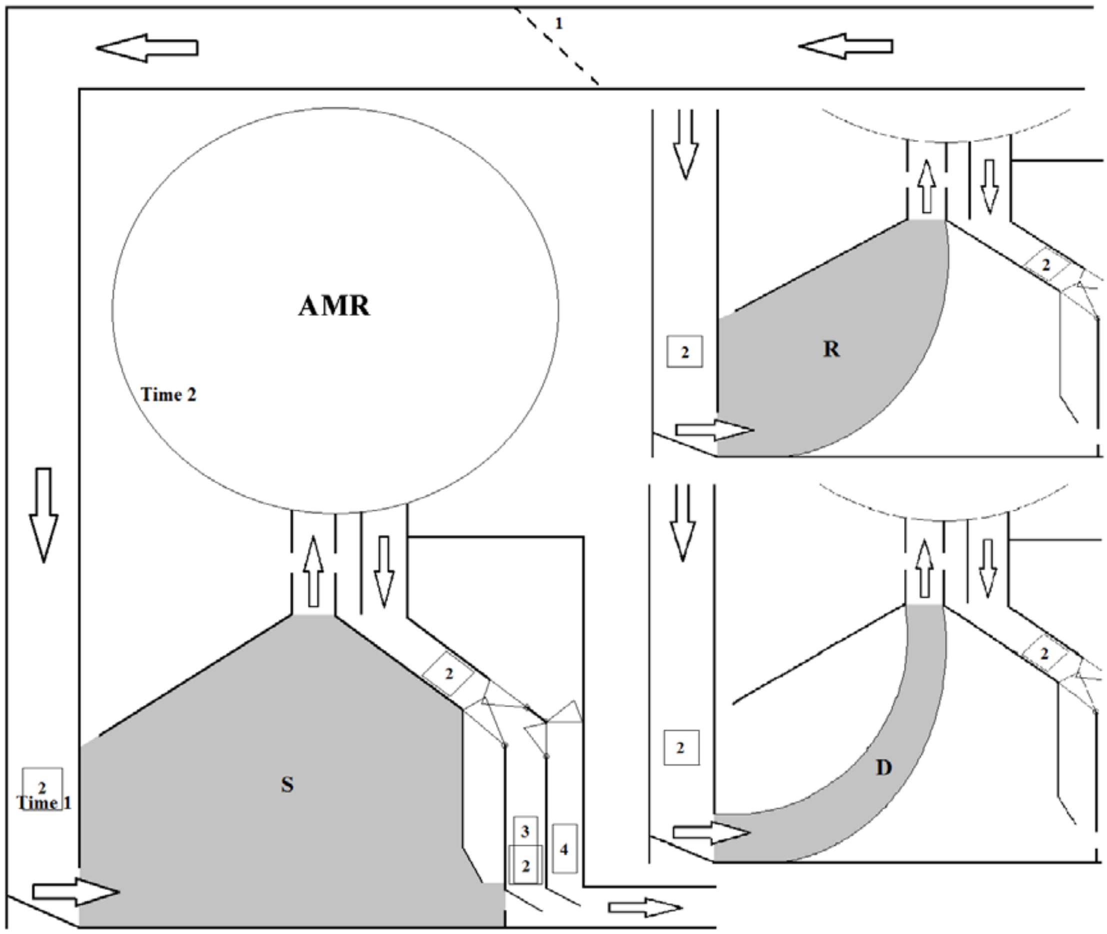

Fig. 2. The large WA (S), reduced WA (R), the single file race (D) and the surrounding of the AMR. The arrows indicate the direction of the cow traffic. The numbers represent: 1: the gate used to stop the cows when they were released ten at a time in the R10 and D10 treatments, 2: selection gates, 3: scale to weigh the cows, 4: foot bath. Gates which could be opened and closed are shown as triangles and one-way gates are shown as skewed lines. Times 1 and 2 mark where the time for entering the WA and onset of milking were registered.

The first treatment (S50) was a combination of the large (original) WA of 85 m^2 and releasing 1 group from the resting area every 50 minutes. It was calculated that 50 minutes should be enough time for most of the cows in the group to have entered the AMR before the next group was released. The second treatment (S100) was a combination of the large WA and releasing 2 groups from the resting areas at the same time. First, AMR3 and AMR1 were released and when approximately 50 cows had entered the rotary, AMR2 was released.

For the third and fourth treatments the WA was reduced to approximately half the size of the original WA (i.e. 42.5 m^2) by assembling metal gates, with particle boards attached on the inside, in a curved shape from the entrance of the WA until the entrance of the AMR (Fig 2). During the third treatment (R50) the cows were released from the resting area 1 group at a time every 50 minutes. During the fourth treatment (R10) the cows from 1 group were released into the long race leading towards the WA, which was blocked by a gate that could easily be opened and closed. Through this gate 10 cows were let out every 10 minutes. When there were less than 10 animals left by the gate in the race, the next group was released. If there were 14 animals or less left when the last cows were to be released towards the AMR, they were all let out at the same time. If there were 15 cows or more left, they were released as 2 groups with 10 cows in the first group and 5 or more cows in the second group.

For the fifth and sixth treatments a single file curved race was constructed in the WA out of different sorts of metal gates with particle boards on the inside of the race. To make the race stable and to keep the width constant along the race, 3 gates in the shape of frames were used at even distances along the race supporting the construction (Fig. 3). The race was 12 meters long and 0.85 meters wide, with an entrance of 1.85 meters. During the fifth treatment (D50) the cows were released from the resting area 1 group at a time every 50 minutes. During the sixth treatment (D10) 10 cows were released every 10 minutes as in treatment R10, with the difference that the gate in the aisle was moved backwards so that AMR3 and AMR2 were taken out into the race and then released through the gate every 10 minutes while AMR1 was released directly from the resting area, 10 animals at a time. The gate stopping the cows on their way to the WA had to be moved backwards in the aisle for the D10 treatment. This was done to ensure that there was enough room for all cows between the gate and the AMR, since fewer cows could be in the race at the same time compared to the reduced WA.

Fig. 3. Photo of the single file race, constructed out of metal gates, frames and particle boards, leading to the AMR. Photo: Isabel Dahlgren.

According to the original plan the cows were supposed to be given at least 2 days for habituation after the shape of the WA had been changed, where no data was supposed to be collected. However, since the start of the study was delayed and treatments 3 to 6 included 7 days instead of 5, the shape of the waiting area was changed on the same days as treatments 3 and 5 started.

Table 1. Order of treatments, description and number of milking sessions per treatment .

Treatment order	Treatment	Description	Number of milking sessions
1	S50	Large WA + 1 group every 50 minutes	5
2	S100	Large WA + 2 groups at the same time. When 50 cows have entered the AMR the next group is released.	5
3	R50	Reduced WA + 1 group every 50 minutes	7
4	R10	Reduced WA + 10 cows every 10 minutes	7
5	D50	Single file race + 1 group every 50 minutes	7
6	D10	Single file race + 10 cows every 10 minutes	7

To be able to finish the milking sessions within a reasonable amount of time it was sometimes necessary to herd the cows, in the aisles leading to the WA and in the WA, towards the entrance of the AMR. The instructions given to the staff regarding herding, was to herd the cows only when necessary, i.e. when no cow had entered the AMR voluntarily for a while. No specific instructions were given on how much time should pass before it would be seen as necessary to herd the cows, since it can be difficult for the person in the AMR, who sometimes also does other work in the barn during the milking, to keep track of this.

At times when there were technical problems with the AMR, the cows were milked manually. This means that the AMR stood still for shorter time for every cow since the robotic arms were inactivated and the teat cups attached manually. This affects the total milking time and the time spent in the waiting area.

Throughout the study a protocol was placed on a board close to the AMR where the staff could note down events such as claw trimming, stops in the AMR during milking, when removing or adding cows from or to the groups, manual milking in the AMR etc.

Data collection

To be able to collect data on how much time the cows spent in the different formations of the WA before entering the AMR, a DeLaval smart selection gate was placed by the entrance of the WA (Fig 2). The part of the gate that opens and closes was removed so that the selection gate was constantly open and only registered the time of passage and identity for every cow that passed through the gate. The time for onset of milking and cow identity were recorded by the AMR. From the data collected by the AMR and selection gate, the time that every cow spent in the WA could be calculated. Since the AMR did not register when a cow entered, but when the milking started, the time until the first teat cup was attached was included in the time spent in the WA. The first teat cups are usually attached on the fourth place in the AMR, but if the robots could not attach any teat cups, the onset of milking would be registered when a person attached them.

The behaviour of the cows in the WA was recorded using 4 video cameras (Monacor TVCCD-150SET), 1 directed down the aisle leading to the WA and 3 directed towards the WA from different angles. Behavioural data was collected from the videos from all 4 cameras using the software MSH-video client. The frequencies of the behaviours were recorded for 2 days per treatment using behaviour sampling with continuous recording of aggressive behaviours and mountings (Table 2).

Data on how much time was spent herding the cows in the WA was recorded from the videos from all 4 cameras in the same manner as the behaviours were recorded. No push gate was used during the study. The time for start and stop of every herding were recorded for the same 2 days per treatment which were used for the collection of behavioural data. Depending on the shape of the WA, the staffs' movement around the WA when herding the cows differed. Hence, a complex definition of herding was used to fit all treatments. When the person in the AMR was herding the cows, the time from when they left the AMR in the purpose of herding until they went into the AMR again was included in the herding time. When a person came to the WA from anywhere except the AMR, the starting time was counted from when they either started to herd the cows from the outside of the WA or when they entered the WA. When the person left the WA or started to do something else, the herding time was stopped. Not only the active herding time was included, but also the time spent outside or inside the WA, observing and waiting to see if the cows will start to walk forward.

Table 2. Ethogram of behaviours recorded and their definitions.

Behaviour	**Definition**
Pushing	Pushing the body of another cow with the head (not scratching or squeezing between two individuals). If there is 5 seconds or less between the two pushing events within the same interaction it counts as one pushing.
Butting	Giving a hard strike with the head to the body of another cow. If there is 5 seconds or less between two butting events within the same interaction it counts as one butting.
Head to head pushing	Two cows push their heads against each other. If there is 10 seconds or less between the head to head events within one interaction it counts as one head to head pushing.
Mounting	Jumping with forelegs and placing them and the rear part of the body on another cow.
Attempt to mount	Jumping with forelegs towards the body of another cow without succeeding to mount.

Statistical analysis
For the statistical analyses of behaviour of the animals and the time spent in the WA, only data from evening milkings was used.

Time in waiting area
Only the cows with at least 1 milking session in all 6 treatments were included in the analysis, which gave a total number of 109 animals. When cows passed the selection gate more than once, all passages except the first one were deleted from the dataset. The second milking during a milking session of incompletely milked cows, which were selected back to the WA, was also deleted. The observations where either the time of passing the selection gate or starting to milk was missing were excluded from the dataset. When no cow had entered the AMR for more than 16 minutes, for any reason, it was counted as a stop in the AMR. The time spent in the WA was adjusted for the cows which were there during the stop. Their total time in the WA was reduced by the total time of the stop. However, the time spent in the WA was not reduced to less than 26, 18 and 13 minutes in the S, R and D treatments respectively. These were the mean times spent in the WA during the different treatments. The data was tested for normality by treatment using the Shapiro-Wilk test. Since the results were significant for all treatments ($p < 0.1$) the time spent in the WA did not have a normal distribution and was therefore log transformed to fit the model. Thereafter, the time spent in the WA during the different treatments was analysed in Statistical Analysis System (SAS, 9.1) using the Mixed Procedure. A mixed linear model was chosen since the data consisted of repeated measurements on the same animals over time and since it can handle unbalanced data. The dependent variable, the log transformed time in the waiting area, was estimated by setting the variables treatment and group as fixed effects and animal-id as random effect.
The statistical model can be explained in the following way:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_9 x_9 + \gamma_1 z_1 + \varepsilon$$

where:
y = log transformed average of time spent in the waiting area
β_0 = intercept
$x_1 - x_6$ = treatments
$x_7 - x_9$ = groups
$\beta_1 - \beta_9$ = regression coefficients
z_1 = animal-id
γ_1 = regression coefficient
ε = residual error

Behavioural analysis
Video from 2 milkings per treatment were used for behavioural analysis. Days which would best represent a functioning evening milking without too many disturbances were chosen for analysis, which means that sometimes 2 consecutive days were chosen and sometimes there were some days in between these 2 days. All 175 animals were included in the behavioural analysis since individuals could not be recognised on the video. After the behavioural data was collected it was imported into Microsoft Excel (2010) where the frequencies of the different behaviours for each day were calculated. The frequencies of behaviours were used for the statistical analysis in SAS. The data was tested for normal distribution using the Shapiro-Wilk test. All aggressive behaviours except head to head

were normally distributed ($p > 0.1$). Since head to head could only be performed in the entrance of the single file race during the D50 and D10 treatments and was only recorded once, they were excluded from the analysis of this behaviour. When these 2 treatments were excluded, the test for normality showed that head to head also had a normal distribution. The behavioural data was then analysed using a general linear model (GLM) with the independent variables treatment, heat and total time of every milking. Heat was calculated as the sum of the frequencies of mounting and attempt to mount per milking session. At times it was difficult to distinguish if a behaviour should be recorded as pushing or butting, thus these 2 behaviours were also analysed together as pushbutt. The statistical model for analysis of the behaviours pushing, butting and pushbutt was as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_8 x_8 + \varepsilon$$

where:
y = behaviour
β_0 = intercept
$x_1 - x_6$ = treatments
x_7 = heat
x_8 = total time of milking
$\beta_1 - \beta_8$ = regression coefficients
ε = residual error

The model for the analysis of head to head was the same except that 2 of the treatments (D50 and D10) were excluded.

The time spent herding the cows during the different treatments was calculated in Excel.

RESULTS

Time in waiting area

The minimum time that a cow spent in the WA was approximately the same for all treatments. However, the maximum time differed considerably among treatments, and ranged from 52 min in D50 to 2 h 59 min in R50 (Table 3). There was no significant effect of group ($F = 0.58$, $p > 0.05$) on the time that the cows spent in the WA. However, a significant difference between treatments ($F = 172.15$, $p < 0.0001$) was found. All treatments, except S50 and S100, differed significantly from each other. The significance level was slightly lower within the R treatment. The cows spent more time in the large WA than in the reduced and more time in the reduced WA than in the race. Releasing more animals at the same time resulted in more time in the WA in the R treatments, while the effect was the opposite in the D treatments (Fig. 3). The mean number of cows in the WA for the entire milking session for all milkings during the different treatments ranged from 23 cows in S100 to 8 cows in D10. When more cows were released at the same time, the mean number of cows in the WA increased by 1 within the S, R and D treatments (Table 4).

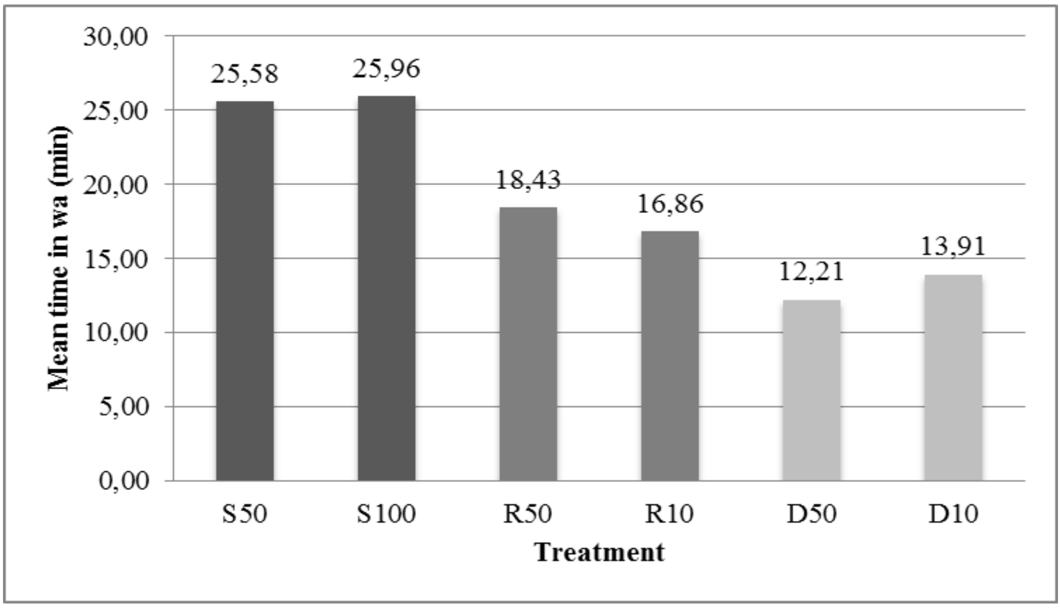

Fig 3. The time that the cows spent in the WA presented in Least Squares Means for the different treatments. n= 3827 and se=0.05. Number of cows = 109.

Table 3. Maximum and minimum time spent in the WA from all observations of cows with at least one observation in every treatment (109 cows).The times are adjusted for stops in the AMR. n=3827

Treatment	**Minimum time (hh:mm)**	**Maximum time (hh:mm)**
S50	00:02	02:57
S100	00:02	02:41
R50	00:02	02:59
R10	00:01	01:59
D50	00:02	00:52
D10	00:02	01:31

Table 4. Mean number of cows in the WA during the different treatments from observations every second minute for all milkings. Number of cows = 175.

Treatment	**Mean number of cows**
S50	22
S100	23
R50	16
R10	15
D50	9
D10	8

Aggressive behaviours

For the behaviours pushing and pushbutt there was a significant effect of both treatment and heat. There was no significant effect of the total milking time on any of the behaviours. Regarding the behaviour butting, there was a tendency for an effect of treatment and heat. No significant effect of treatment was found for head to head. However, there was a tendency towards an effect of heat (Table 5). The number of cows included in the analysis was 175. All significant effects and tendencies for an effect of heat were positive.

*Table 5. Number of observations (n) and obtained R^2, F and p-values from the statistical analysis of the frequencies of the different behaviours. Significance levels are shown within brackets, where *: ($p < 0.05$), **: ($p < 0.01$), NS: non-significant, T: tendency. Number of cows = 175.*

Behaviour	n	R^2	F-value Treatment	*p*-value Treatment	F-value Heat	*p*-value Heat
Pushing	12	0.95	9.86	0.023 (*)	29.81	0.006 (**)
Butting	12	0.92	6.12	0.052 (T)	5.50	0.079 (T)
Pushbutt	12	0.96	12.77	0.014 (*)	35.82	0.004 (**)
Head to head (D50 and D10 excluded)	8	0.97	4.16	0.20 (NS)	15.32	0.06 (T)

Pushing was performed significantly more in the R50 and R10 treatments compared to both S treatments ($p < 0.05$) and to D50 ($p < 0.01$). Pushing was also significantly higher in D10 than in D50 and S50 ($p < 0.05$). Additionally, butting was performed significantly more in R50 than in S100, D50 ($p < 0.05$) and D10 ($p < 0.01$). In D10 there was significantly less butting at the 5% level than in R10. The level of pushbutt was significantly ($p < 0.05$) higher in the R50 and R10 treatments compared to all other treatments. However, they did not differ significantly from each other (Fig 4).

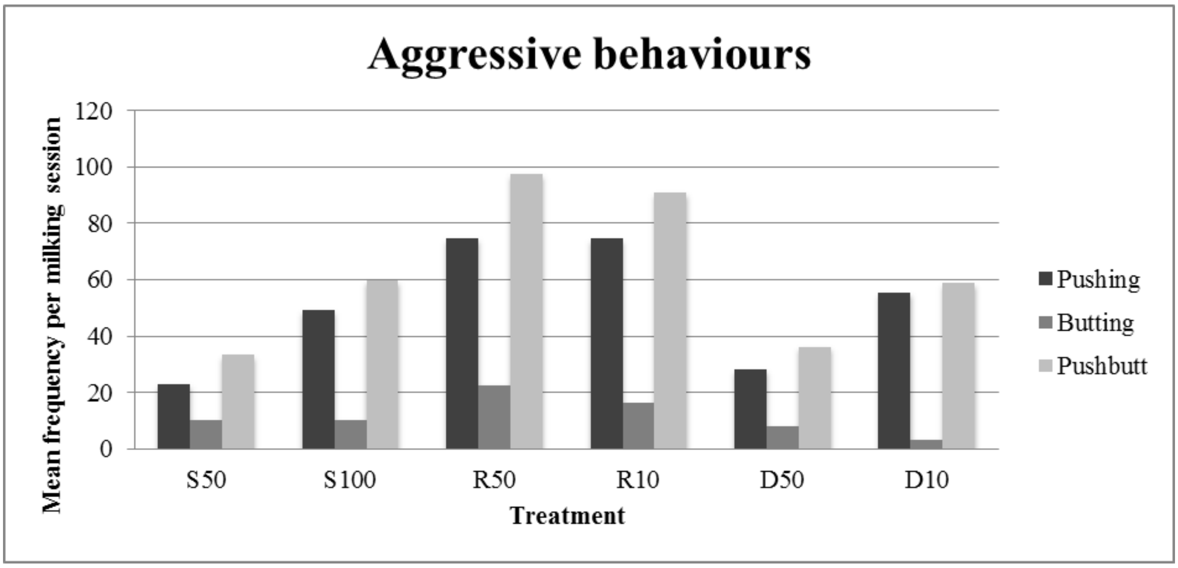

Fig 4. Frequencies of aggressive behaviours performed per milking session expressed in Least Squares Means. N = 12. Number of cows = 175.

Herding time

The time, which the staff spent herding the cows in the WA and the total time of the milking sessions, are presented in Table 6. The amount of time spent herding the cows was highest in both S treatments, while the least amount of herding time was spent in the D treatments. The total time of the milking sessions was shortest during the S100, R10 and R50 treatments, while the longest was during the S50 and D10 treatments.

Table 6. The mean time spent herding the cows in the WA during one milking session in the different treatments and the mean time of an entire milking session during the same days.

Treatment	Herding time (hh:mm:ss)	Total milking time (hh:mm:ss)
S50	0:49:09	3:22:30
S100	0:39:41	2:45:00
R50	0:23:43	2:50:00
R10	0:19:20	2:45:00
D50	0:12:55	3:05:00
D10	0:10:28	3:25:00

DISCUSSION

Time spent in the waiting area and herding time

The results of the study showed that changing the shape of the WA had a significant effect on the waiting time that the cows spent there. The waiting time spent in the single file race was reduced by approximately 50% compared to the large (S) WA, while the waiting times in the reduced WA was an intermediate between the two. Part of the explanation for this could be that the number of cows that could be in the WA at the same time differed between the shapes. Also, it should be mentioned that the time in the WA does not reflect the total waiting time since the cows also spent some time standing in the aisle prior to the selection gate. Thus, when fewer cows could be in the WA at the same time more cows could be standing in the aisle. However, the difference of mean number of cows in the WA during the entire milking was only 7 cows between the S and R treatments and between the R and D treatments. This indicates that the differences in the time spent in the WA were not merely an effect of the size of the WA.

The maximum times spent in the WA were longest in the R50 (2 h 59 min) and S50 (2 h 57 min) treatments, and shortest in the D50 (52 min) and D10 (1 h 31 min) treatments. This and the shorter mean times spent in the WA in the D treatments suggest that a single file race could minimize the negative effects of social dominance on low ranking cows around milking. The cows are forced to enter the AMR in the same order as they entered the race, which evens out the waiting time between cows. As previously mentioned, long milking times, including the time spent in the WA could have various negative effects on cow health and welfare such as an increased risk of lameness (Cook and Nordlund, 2009) and less time spent eating (Uetake et al., 1997) and lying down (Gomez and Cook, 2010).

Hence, constructing a single file race leading to the milking unit instead of a WA, could potentially improve cow health and welfare.

Within the R and D treatments there was a small but significant difference in the time spent in the WA depending on how many cows were released at the same time. This significance could be due to a high number of observations. More time was spent in the WA in R50 compared to R10, while more time was spent in D10 compared to D50. The differences were still very small (1.57 and 1.7 minutes for the R and D treatments respectively) and could have been caused by other circumstances than the number of cows released at the same time. For instance there were more technical problems with the AMR during the D50 treatment compared to the other treatment periods, which resulted in more manual milking, which in turn could result in a slightly shorter time spent in the WA.

It was hypothesized that releasing more cows at the same time would cause a higher pressure of cows moving towards the AMR, thus making the cows enter the AMR and not stand still in the WA, resulting in shorter waiting times. However, the results suggest that releasing more cows at the same time did not have such an effect. On the contrary, releasing two groups at the same time as was done in the S100 treatment did not cause a significant difference in the time spent in the WA, but could be detrimental for the cows since it would increase the time spent waiting in the aisle leading towards the WA.

The time that the cows spent in the WA, time spent herding the animals and the total milking time all reflect how well functioning and adapted the milking system and facility design are. As was hypothesized, the time spent herding the cows was highest in the S treatments, lower in the R treatments and lowest in the D treatments. However, the total milking time was longest in the S50 and D10 treatments, which also had the longest and shortest herding times respectively. One would think that less time spent herding the cows would lead to a longer total milking time. This could have been the reason for the longer milking time in D10, but does not explain the long milking time in S50. The differences in herding and milking time could also have been influenced by the person in the AMR, since they decided when to herd the cows. The shorter herding time in the D treatments could be a result of the ease with which the cows could be herded in the single file race compared to the large and reduced WA. Herding might not only be negative due to the time loss for the staff but could also affect the welfare of the cows negatively. Cows in an AMS which had to be fetched for milking showed a larger avoidance distance in a human approach test than cow which were not fetched. This indicates that fetching cows can have a negative effect on the human-animal relationship and that fetching could cause distress in some animals (Rousing et al., 2006). A good human-animal relationship is also one of the subcriteria in WelfareQuality® to assess animal welfare, and it would therefore be prefereable if the cows could be herded towards the AMR as little as possible.

In all treatments many cows tended to walk into the WA, or race, and then simply stand there without moving towards the entrance. This indicates that the cows were not motivated to enter the AMR. Hence, it would be beneficial for both staff and cows if the facility is designed to take advantage of the animals' behaviour and if the cows could be motivated to walk towards the milking unit to decrease the amount of herding. Since the motivation to be milked has been shown to be relatively low in dairy cows, giving a portion of concentrates when the cow has entered could be necessary to increase their motivation to enter the milking unit (Prescott et al., 1998). When feed was provided upon entry in a prototype of the AMR, the cow traffic into the rotary was improved and the cows were more likely to enter the rotary instead of idling (Kolbach et al., 2013). Since the cows in this study were let out on pasture after the evening milking and cows have been shown to be motivated to access pasture, especially during the nights (Charlton et al., 2013), it could be argued whether access to pasture after milking could be a motivating factor to enter the AMR. However, as previously mentioned, many of the cows in this study did not seem motivated to enter the AMR which could indicate that access to pasture after milking was not a strong motivator and that feeding concentrates upon entry might be necessary to motivate the cows to walk towards the AMR.

The single file race (D) was thought to give a better flow of animals towards the AMR, since the cows only had one direction to walk and should follow each other (Grandin, 1997). However, the race did not function as well as expected. The animals tended to halt by the entrance of the race, which could have been caused by a sharp angle and the animals could therefore not see far enough ahead, which could have made the entrance of the race seem like a dead end (Grandin, 1997). However, making the angle less sharp would have been difficult considering how the surrounding of the AMR was constructed. Another factor which could have disrupted the flow of cows towards the AMR could be the frames used to support the single file race. The cows had to step over the small metal bar on the bottom of the frames and cattle often hesitate to cross irregularities in the floor, due to their poor depth perception (Warriss, 1990). However, the cows did not seem to hesitate much before walking through the frames.

To decrease the prevalence of lameness caused by long standing times on hard surfaces, it could be beneficial to apply rubber to the floor surface in the WA and aisle leading towards it (Cook and Nordlund, 2010). However, decreasing the time spent in the WA is still more important for the health and welfare of the cows.

During the study some cows were observed standing by the entrance to the AMR for some time, pushing other cows away and not allowing any cows to enter. Since dominant cows account for the majority of displacements (Wierenga, 1990), it is not only the cow with low rank which spent a long time in the WA.

Aggressive behaviour

There was a significant effect of treatment on the behaviours pushing and pushbutt. However, there was only a tendency towards an effect of treatment on butting. As expected, the frequency of aggressive behaviours was lower in the single file race compared to the reduced WA. However it was unexpected that the frequency of aggressive behaviours would be higher in the reduced WA compared to the large WA. One explanation to why the amount of aggressive behaviours was lower in the single file race could be that a dominant cow could not displace other cows to gain access to the AMR, thus having the desired effect to lower the negative influence of social dominance on low ranked animals. Another reason could be that the number of individuals with which one cow could interact is lowest in the single file race. However, this does not explain why the frequency of aggressive behaviours was low in the large WA as well and highest in the reduced WA. One possible explanation for the high amount of aggressive behaviours performed in the reduced WA could be that low ranking cows that would normally go to a part of the WA with fewer cows to avoid agonistic interactions, could not do so in the reduced WA due to less space available. If individual cows could have been distinguished and threat and avoidance behaviours recorded, it might have given a clearer picture of the situation which could explain the distribution of aggressive behaviours among treatments. Furthermore, the data on behaviours and herding is collected from observations of 2 milking sessions per treatment and since the time spent herding the cows and the frequency of aggressive behaviours and mountings differed a lot between the days, it would have been interesting to include observations from more days if more time would have been available. A possible negative aspect of the single file race could be that, while inside the race, the cows cannot move away if they are being pushed or butted and have other cows in front of them.

Heat had a significant positive effect on pushing and pushbutt, i.e. when the frequency of mountings and attempts to mount was higher the frequency of pushing and pushbuttt was also increased. There was also a tendency for a positive effect of heat on butting and head to head pushing. This can be explained by the behavioural changes occurring during oestrus in dairy cows. The frequency of both agonistic behaviours (Sveberg et al., 2013) and sexual behaviours, such as, chin resting, mounting (Kerbrat and Disenhaus, 2004) and standing to be mounted (Palmer et al., 2010) increase during oestrus.

The high amount of aggressive behaviours found, particularly in the reduced WA could have been caused by overcrowding in the WA and competition for resources, which in this case would be space and to enter the AMR. However, since the cows’ motivation to enter the AMR seemed low, it could be discussed whether the animals value it as a resource or not. Val-Laillet and colleagues (2008) measured competitive success for access to different resources and showed that this success differed within the individual cows depending on the type of resource, which suggests that different resources are valued differently by individual cows.

Due to shortage of time no habituation periods were included in this study after the shape of the WA had been changed. This could have affected both the time that the cows spent in the WA and the behaviours and herding time. However, the lack of a habituation period might not have influenced the time spent in the WA much since each of the R and D treatments lasted for 7 days which gave a large number of observations per treatment. Regarding the behavioural observations, the original plan was to collect data from the last two days of every treatment. However, due to many technical problems with the AMR, days which would represent a normally functioning evening milking were chosen instead. The behavioural data could therefore have been more affected by the lack of a habituation period.

CONCLUSIONS

When using the single file race the maximum times and mean times spent in the WA and the herding times were shorter. These results suggest that constructing a single file race in front of the AMR, instead of a closed WA, could have the potential to improve the welfare of low ranking cows around milking and minimize the negative effects of social dominance. The results of this study could be used as a basis for further research on how the WA in an AMR system should be designed to even out and minimize the waiting times for cows and reduce the amount of herding necessary thus reducing the risk of negative effects on health and welfare. The number of cows released towards the WA at the same time had very little effect on the time that the cows spent in the WA. The results of the behavioural observations showed the highest amount of aggressive behaviours in the reduced WA. However, the results of the observations on aggressive behaviours are difficult to interpret. They could have been affected by a number of small factors other than the shape of the WA. Therefore, data including more days of observation, individual recognition and recording of subtle agonistic behaviours might be necessary to draw conclusions on which shape of the WA would be preferable regarding the amount of aggressive interactions. The results of this study reflect the situation when the AMR is used in a system where the cows are brought in groups for milking similar to a conventional parlour system. Further research is needed to understand how it would function as an automatic system with voluntary attendance.

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