Parity and days in milk affect cubicle occupancy in dairy cows

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ABSTRACT

Modern dairy cattle farms are usually equipped with cubicle systems to provide cows with comfortable conditions for lying down and resting. Cows are free to choose any cubicle they want, but in reality, they do not distribute themselves uniformly throughout the barn. There are many factors that affect where a cow lies down, such as hierarchy of a cow, access to resources, cow traffic nearby, etc. In this study, we used real-time location system data from two commercial farms to examine patterns of cubicle occupancy in relation to parity and lactation stage. We summarized cubicle occupancy over several days and compared different areas of the barn. Our findings suggest that, in general, there was a higher occupancy of cubicles close to the feeding areas. High parity cows lay down more frequently in cubicles close to the milking area as opposed to first lactation cows that tend to occupy less busy areas of the barn. The overall conclusion is that cubicle occupancy is not uniform throughout the barn, and patterns related to parity and DIM are seen. This information can be important for future studies on spread of diseases and for management purposes.

1. Introduction

Cows spend a significant amount of their time lying down. Studies of the circadian rhythm of lactating cows show that they spend on average 11 h per day lying down (Tucker et al., 2020), but it can vary from 6 up to 16 h/day. Cows sleep for about 4 h/day with less than 1 h REM sleep (Ruckebusch, 1972; Ternman et al., 2019, 2018). The rest of the time lying down the cows drowse (Ruckebusch, 1972) or ruminate (Albright, 1993).

The diurnal time budget of cows varies depending on lactation stage and parity, which also have an effect on their resting behaviour. Cows in early-stage lactation spend more time in the feeding area and more time feeding than cows in late-stage lactation (Løvendahl and Munksgaard, 2016). The early-stage lactating cows also spend less time in the cubicle and less time lying down, compared with cows in late-stage lactation (Løvendahl and Munksgaard, 2016). Parity is also one factor effecting the lying behaviour of cows; primiparous cows have a higher number of lying bouts than multiparous cows, particularly the weeks after calving (Neave et al., 2017). Multiparous cows on the other hand, spend more time in the area close to the milking parlour (Diosdado et al., 2018).

The preference for a specific location within the barn to rest and the competition linked to it has so far been only of marginal interest. But there are some studies that indicate a preference of cows to rest in certain parts of a barn compared to other parts (Arave and Walters, 1980; Gaworski et al., 2003; Natzke et al., 1982). In a study with 48 lactating Holstein cows in a free stall system, results show a preference for cubicles close to the feed alley and for cubicles in the centre of a row (Gaworski et al., 2003). Cubicle preference may depend on their social rank where the dominant cows will be able to choose their preferred areas more easily than the low-ranking ones. By increasing the stocking density and thereby creating a higher competition for resources, Wierenga (1990) found a significant correlation between dominance value and the time spent in cubicles.

Studying lying behaviour and level of occupancy of certain resting areas in modern dairy cattle farms can potentially be of importance to animal welfare due to the animals' high motivation to lie down (Jensen et al., 2004). Given the choice between lying and eating after deprivation of both, cows prioritized the possibility to lie down (Tucker et al., 2018). They also are willing to work to get access to lying areas, for example by using push gates and push panels (Jensen et al., 2005). Furthermore, restricting the possibility to lie down has been shown to increase stress levels, such as changes to responsiveness of the

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hypothalamic pituitary- adrenal axis (Munksgaard and Simonsen, 1996) and reduced plasma growth hormone (Munksgaard and Løvendahl, 2011).

Real-time location systems (RTLS) are becoming more popular to obtain and analyse indoor positions of dairy cattle and have been used to determine social interactions between cows (Rocha et al., 2020), for early detection of disease and oestrus (Veissier et al., 2017), and to analyse behavioural patterns (Meunier et al., 2018). In this study, RTLS was used to investigate the occupancy of cubicles in different locations within the barn at two different commercial dairy farms.

1.1. Objective

The objective of this study was to use RTLS to detect patterns of cubicle occupancy of dairy cows in the barn. The effect of the parity as well as stage in lactation was investigated in relation to occupancy of cubicle. The hypotheses were: (1) some areas are occupied by the entire herd; (2) cows with higher parity will occupy areas close to milking area; (3) cows with higher parity will occupy areas close to feed bunk; (4) the lactation stage (DIM) will affect cubicle occupancy: areas close to the feeding area are primarily occupied by cows in early lactation.

2. Materials and methods

2.1. Farms

The data used in this study were collected on two commercial farms, one in Sweden (farm A) and one in the Netherlands (farm B). Both farms used the same real time location system (RTLS) that identifies position of a tag attached to each individual cow's neck collar.

Farm A had 203 milking cows (purebred and mix of Holstein Friesian and Swedish Red) in a non-insulated free-stall barn, which had a rectangular plan of 74 m × 33 m, with feeding alleys on both sides of the barn towards the outer walls (Fig. 1 and Table 1). The cows had access to 205 cubicles with mattress and fresh sawdust was added manually twice a day. The cows were kept in two separated groups where each group had access to one of the two feeding alleys. A milking system (2 × 12 GEA Euro class 800 with Dematron 75, GEA Farm Technologies, Bönen, Germany) was located inside the barn and the cows from both groups were milked twice a day and were fed concentrate according to milk production from concentrate feeders and roughage ad libitum with new feed delivered 12 times a day.

Farm B had 200 milking cows (Holstein Friesian) in a non-insulated free-stall barn with a rectangular plan of 76 m × 30 m and solid walls. The feeding alley was in the middle of the barn (Fig. 2 and Table 1). The cows had access to 267 cubicles with recycled manure solids (> 15 cm) as bedding material, the cows were kept in one group. The cows were milked at least twice a day inside the barn with two double automatic milking machines (Mlone 5-box, GEA Farm Technologies, Bönen, Germany) and were fed roughage ad libitum and concentrate from the AMS according to milk production. Roughage was delivered once a day at around 9:30, an automatic feed pusher (JUZ Moov, JOZ BV, Westwoud, the Netherlands) pushed the feed towards the cows five times a day (at 15:00, 18:15, 22:00, 02:00 and 06:15). Both farms had water troughs distributed evenly throughout the whole barn, placed at the end of the cubicle rows.

The study was conducted in accordance with the ethical guidelines published by the International Society of Applied Ethology (Sherwin et al., 2003). The authors declare that according to the Swedish animal welfare act, no ethical approval is needed for this type of study, so the research was not submitted to an Animal Ethics Committee.

2.2. Available data

Real Time Location System (RTLS) (CowView, GEA Farm Technologies, Bönen, Germany) was used to record the position of each cow
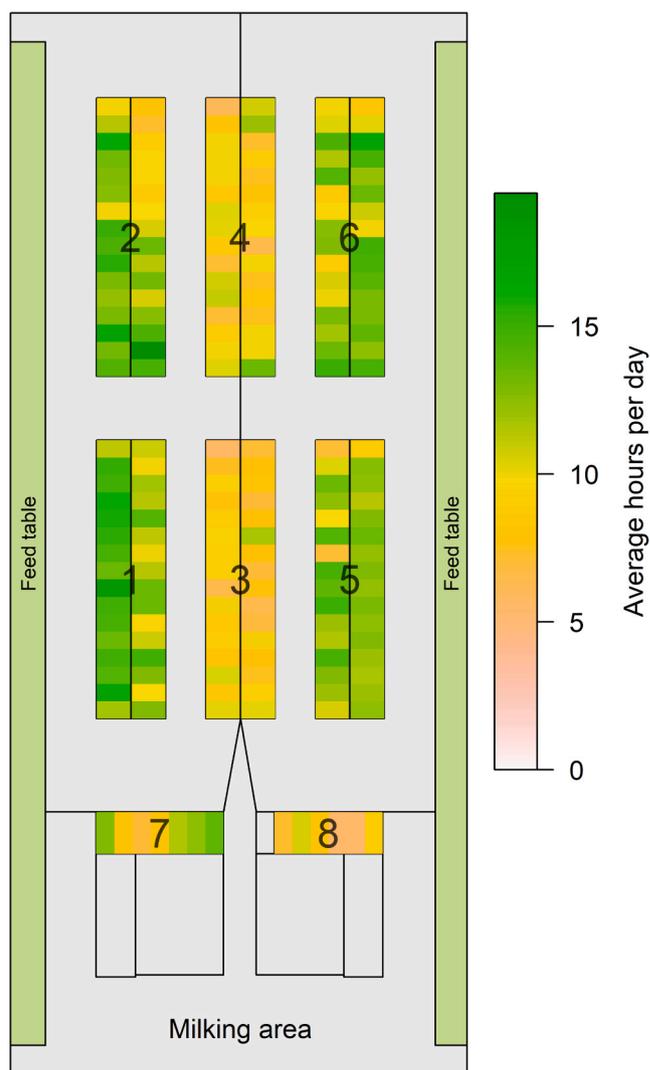

Fig. 1. Barn layout of farm A and average time each cubicle was occupied during the study period.

Table 1
Cow population on farms A and B. Days in milk (DIM) were calculated on the last day of the study.

Farm	Lactation	Early (DIM < 50)	Mid (DIM 50–149)	Late (DIM > 149)	Total
A	1	3	29	22	54
	2	14	15	39	68
	3 +	12	28	41	81
	Total	29	72	102	203
B	1	4	14	44	62
	2	10	5	23	38
	3 +	16	42	42	100
	Total	30	61	109	200

throughout the project. This system continuously recorded the position of each cow approximately every second through a triangulation using data from sensors placed in the barn and the CowView tag mounted on the top of each cow's neck collar (Sloth and Fredriksen, 2019). The system can determine each cow's position with an accuracy of 50 cm throughout the whole barn (Meunier et al., 2018). CowView data were logged on a local working station via an Ethernet connection to the CowView local server. For this paper aggregated positioning data with predicted activity (e.g. walking, eating, in-cubicle) were used. Each
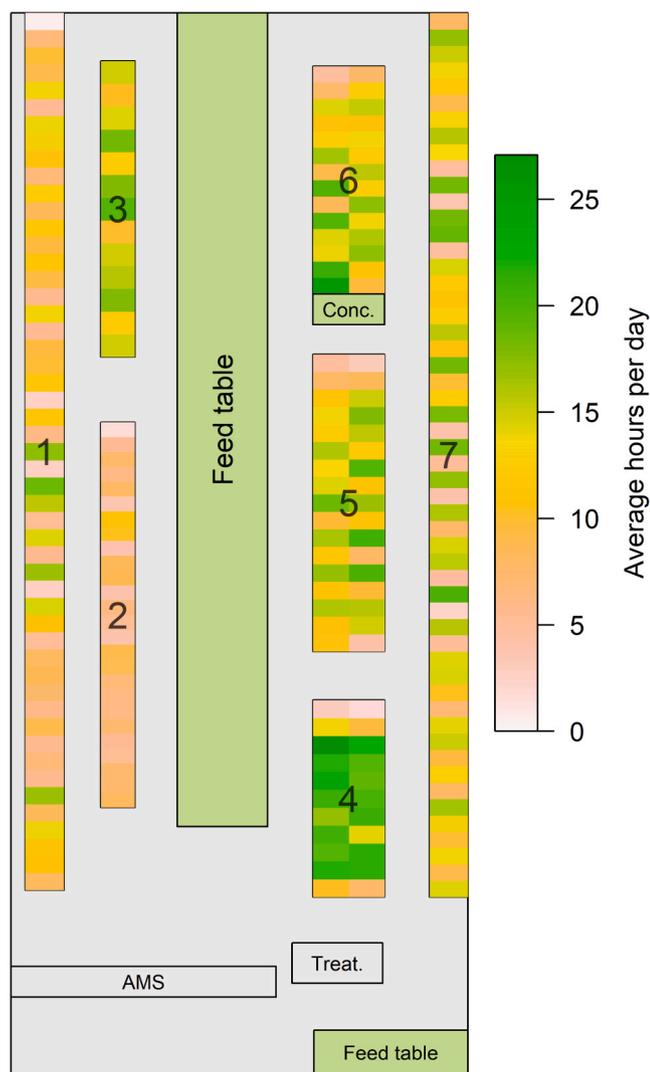
Fig. 2. Barn layout of farm B and average time each cubicle was occupied during the study period.

record provides start and end times of each specific activity, along with the corresponding coordinates. A period of 9 days, between 2 and 10 November 2020, with no missing data on both farms, was selected for this paper.

2.3. Data cleaning

The raw data were cleaned from records that belong to performance tags (tags that were specifically placed around the barn to calibrate the CowView system) and to inactive tags (tags that did not show any significant movement during the day). All remaining tags in the dataset were then linked to a corresponding cow. However, several tags could not be matched and were removed from the analysis (1 tag for 3 days on farm A and 11 tags for all 9 days on farm B). The final dataset contained 1746 and 1738 cow-day records for farms A and B, respectively.

2.4. Statistical analysis

For each cow, calculations were made for how much time it spent in a particular cubicle. To assess cubicle occupancy, lengths of these time periods for different cows were summed up resulting in the total duration each selected cubicle was occupied. Due to inaccuracies in measurements, two cows could be registered in the same cubicle at the same

time, consequently leading to an increased overall cubicle occupancy time, especially in busy areas.

Another approach was also used where the focus was on individual cows instead of particular cubicles by calculating the total time a cow or a group of cows spent in each cubicle or a group of cubicles. The study population was grouped based on lactation number (parity) and days in milk (DIM) to identify patterns of cubicle occupancy associated with these variables. Table 1 shows the number of cows in each group out of those present in the barn for at least one day between 2 and 10 November 2020. DIM was calculated on the last day of the study to account for cows dried of during the study period.

A non-parametric Wilcoxon signed-rank test (P-value = 0.05) was used to assess differences between times spent by cows in different bedding areas of the barn. At first, all cubicles were divided into several roughly equal groups of adjacent cubicles. Then, for each pair of bedding areas, two measurements of time spent in each area per cow were obtained. Different number of cubicles in bedding areas were adjusted by calculating time per one cubicle. Cows that did not spend any time in either of the chosen bedding areas were removed from this analysis to avoid problems with zero-inflation. All analyses were performed in R (R Core Team, 2020).

3. Results

3.1. General cubicle usage

Fig. 1 (farm A) and Fig. 2 (farm B) present the layout of the two barns and the average time per day each cubicle was occupied between 2 and 10 November 2020. On farm A (Fig. 1), cubicles that were closest to the feeding areas on both sides of the barn were occupied the most, while cubicles in the middle were occupied less frequently. On farm B (Fig. 2), cubicles that were close to the AMS area were occupied the least, whereas cubicles on the right-hand side of the barn were occupied the most. The same pattern for cubicles close to the feeding table from farm A was also observed on farm B, except for the cubicles close to the AMS area. Bed area 4 had the most occupied cubicles in the whole barn.

More figures related to cubicle usage of groups can be found in the Supplementary Materials.

3.2. Lactation state and parity effect

In Fig. 3 (farm A) and Fig. 4 (farm B), cows' occupancy of bedding areas depending on their parity and lactation stage are presented. To account for difference in the number of cubicles in different areas, the total time spent by each cow in all cubicles from that area were divided by the number of cubicles. Ultimately, the presented values are average time a typical cow from the specified group spent in one typical cubicle in the selected area per day.

On farm A (Fig. 3), cows in late lactation (DIM > 149) typically were moved by the farmer to the left side of the barn, but there are a few exceptions. Older cows occupied resting areas closer to the milking system (bottom of the graph), while first lactation cows occupied the more distant area of the barn.

On farm B (Fig. 4), older cows in later stages of lactation occupied cubicles close to the milking area (bed4), while first-lactation cows occupied less busy area of the barn (bed3).

3.3. Pairwise comparison of times spent in different bedding areas

Differences between times spent in cubicle by cows in different bedding areas were assessed. The summary of all pairwise comparisons between areas are presented in Fig. 5 (farm A) and Fig. 6 (farm B). This comparison visualized areas that were occupied by all cows in the barn, e.g. left side of bed1 on left side of farm A. Also, it is clearly shown that bed1 and bed2 on farm A were occupied more frequently compared to other areas. Cubicle occupancy patterns on farm B were more complex
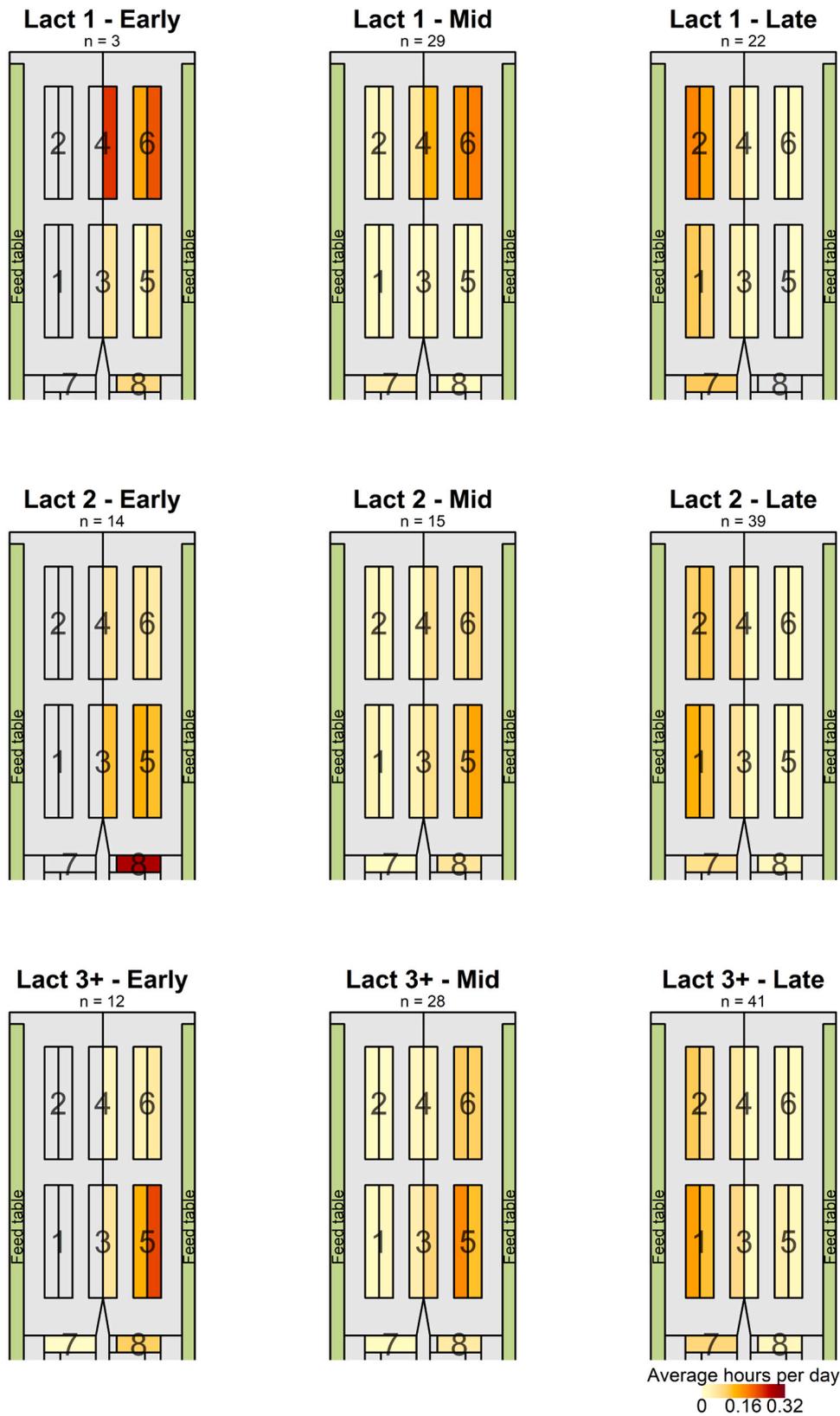
Fig. 3. Heat maps of average time in cubicle by bedding area depending on parity and lactation stage of a cow on farm A.

with bed1_top, bed2 and bed7_bottom occupied significantly less frequently than cubicles in most other areas, while bed7_top was among the most occupied areas.

Comparisons for subgroups of cows and the results can be found in the Supplementary Material.

4. Discussion

In this paper, the occupancy of cubicles from two commercial dairy farms, one in Sweden (farm A) and one in the Netherlands (farm B) were studied. Cattle management, barn layout and cubicle design are all
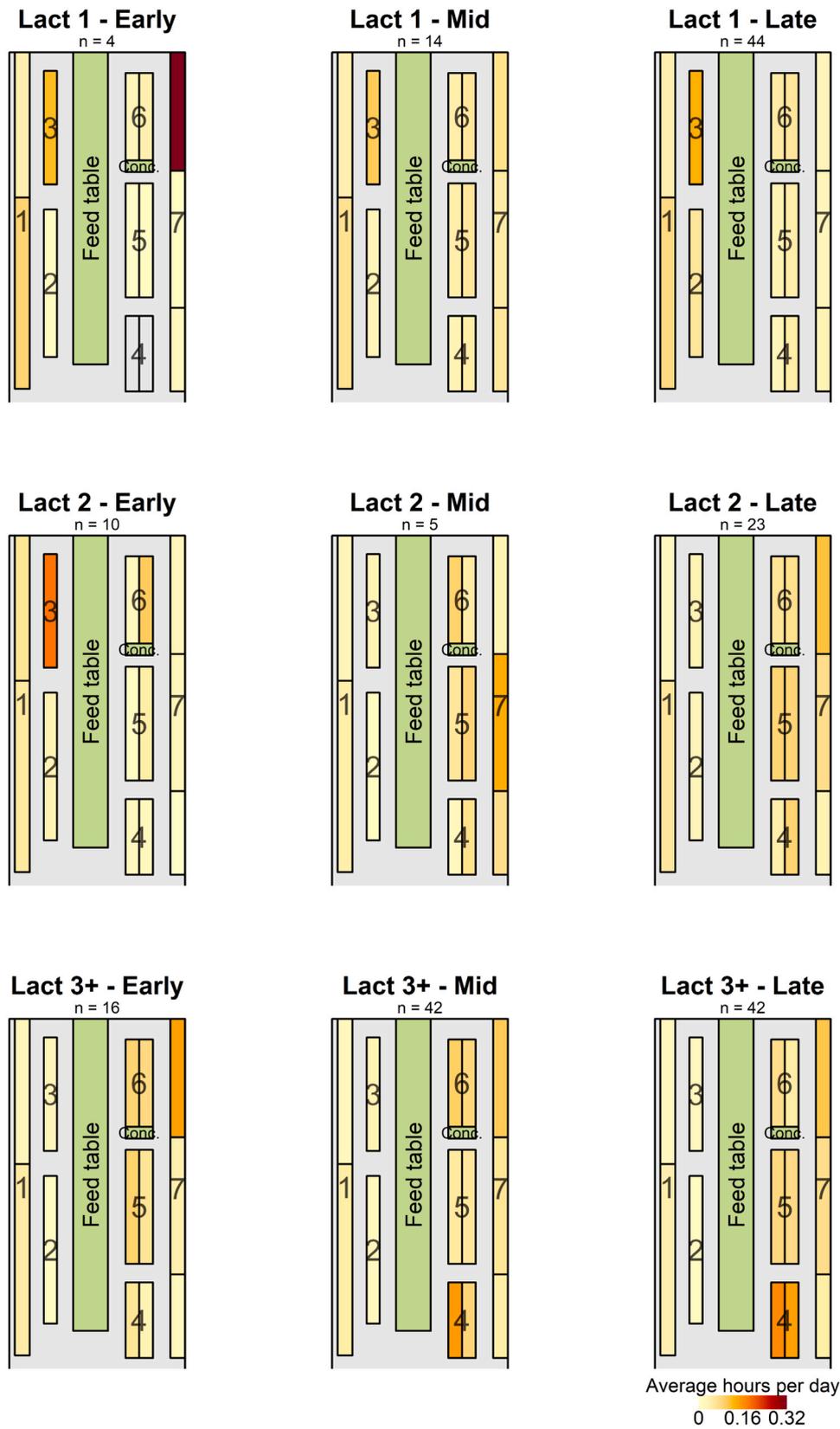
Fig. 4. Heat maps of average time in cubicle by bedding area depending on parity and lactation stage of a cow on farm B.

important factors that can affect the cubicle occupancy of dairy cows. In this study, a first step has been taken to understand the cubicle occupancy of cows, by investigating the overall cubicle occupancy on two commercial dairy herds and how it is influenced by parity and lactation stage.

The results presented in Figs. 1 and 2 show that cows are distributed non-randomly throughout the barn and that some areas have a higher cubicle occupancy than others. On farm A, cubicles that are located
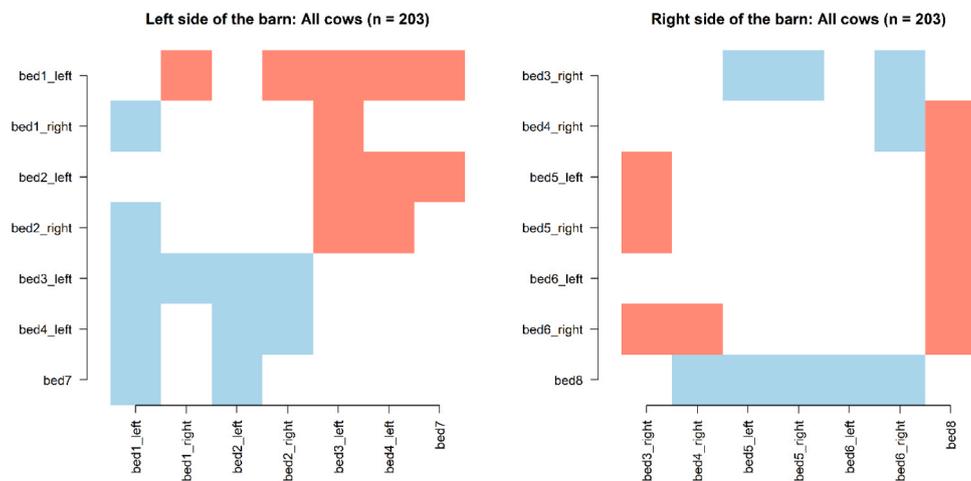
Fig. 5. Summary of comparison between times spent by all cows in different areas on farm A (See Fig. 1 for description of cubicle areas). Red indicates significantly higher (P < 0.05) time for row over column, blue significantly lower time, white no significant difference.
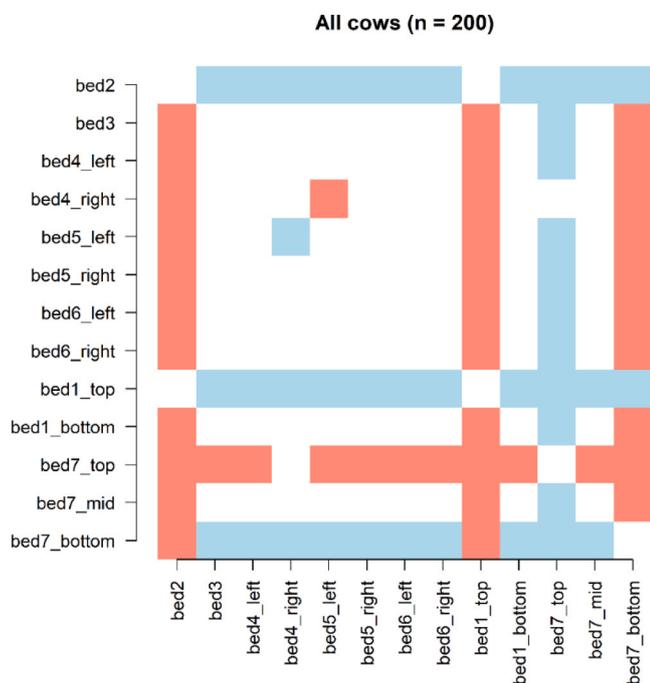

Fig. 6. Summary of comparison between times spent by all cows in different areas on farm B (See Fig. 2 for description of cubicle areas). Red indicates significantly higher (P < 0.05) time for row over column, blue significantly lower time, white no significant difference.

closest to the feeding areas on both sides of the barn had the highest occupancy. Cubicles in the middle of the barn that are located furthest from the feeding areas were occupied less frequently. This is in line with the findings of Gaworski et al. (2003), where cows occupied cubicles close to feeding area to a higher extent. The same pattern of higher occupancy close to the feeding table, could be seen on farm B, although not as clear as on farm A. These findings are also supported by the pairwise comparisons between bed areas shown in Figs. 5 and 6. The two farms differ in many aspects such as geographical location, barn layout, milking regime (milking parlour on farm A and AMS on farm B), feeding regime, bedding material and cubicle design, one group versus two groups and breeds (mix of different breeds on farm A and pure Holstein on farm B). Taken the differences and the fact that similar cubicle occupancy patterns still can be seen between the farms as described above,

it would be of interest to investigate this in future studies and to test if and how differences in management and farm design affect the level of occupancy of resting areas in a dairy herd. The RTLS used in this study provides detailed information with high precision about the movement pattern of individual cows in the herd. One limitation in this study is that the system only provides information about the position of the cow and not the actual activity that is performed. This means that it can only with certainty be said that a cow is occupying a cubicle at a specific time, but it is not possible to know if the cow is lying down or standing in the cubicle.

The detailed analysis of cubicle occupancy in groups defined by parity and lactation stage showed that these factors do affect how dairy cows occupy different areas in the barn (Figs. 3 and 4). Both parity and DIM affect behaviour patterns and time budgets of cows (Diosdado et al., 2018; Løvendahl and Munksgaard, 2016; Neave et al., 2017), which is reflected in the results of this study. Cows in early-stage lactation tend to spend more time in feeding areas and eating (Løvendahl and Munksgaard, 2016), which in this study is reflected in a higher occupancy in cubicles close to the feeding tables. Higher parity cows on both farms occupied the area of the barn closest to the milking area, which could be related to the fact that older more experienced cows can try to get a better position in the milking queue (Diosdado et al., 2018). High parity cows do have fewer and longer bouts of low activity (standing or lying) (Solano et al., 2016) and spend less time feeding (Azizi et al., 2010). This can explain the fact that this category of cows do not spread out in the barn when returning from milking and, thus, spend more time in the cubicles close to the milking area (Diosdado et al., 2018). According to Wierenga (1990) social dominance can also be a factor supporting the effect of parity on cubicle occupancy, since dominant cows can choose more freely where to rest compared to subordinates. In this study, dominance was accounted for only by parity, but it would be of interest for future studies to include other dominance traits in the analysis.

The results show how cows distribute themselves among cubicles at two different farms during a specific time period of 9 days. The findings give an indication that the occupancy of cubicles is not random and both parity and DIM seem to influence where cows rest. Several other factors may also affect the lying time and preference of specific areas of the barn, such as milking system, barn layout, bedding material and quality, lameness and stocking density (Drissler et al., 2005; Fregonesi and Leaver, 2002; Tucker et al., 2004). Temperature, light, and wind parameters were not considered in this study but their differences between areas of the barn could also influence cow behaviour.

5. Conclusion

Our results show that the cubicle occupancy is not uniform throughout the barn and a certain pattern based on parity and stage in lactation can be seen. High parity cows tend to occupy cubicles close to the milking area and there is a general higher occupancy of cubicles close to the feeding areas. This lack of random occupancy is of extreme importance when developing models of disease spread within the herd. Since the possibility to rest can have an impact on both animal welfare and production in a dairy herd, these factors are interesting to investigate further in connection to preference of cubicles in the barn and RTLS can be a helpful tool for such research. Better knowledge of cubicle occupancy patterns can be useful to design new generation of barn layouts that minimize social stress and, thus, increase animal welfare and productivity of the dairy farm.

Acknowledgements

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2021.105494.

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