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Observations on the location and excretion behaviour of cows in a structured exercise yard

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Approximately 30% of ammonia emissions from cattle farming originate from livestock buildings and their functional areas, particularly from unclean walking areas. The implementation of exercise yards to enhance animal welfare results in an increase in the proportion of emission-active areas. A novel approach to harmonising the competing objectives of animal welfare and environmental protection with regard to ammonia emissions is the structuring of exercise yards with elevated rubber mat cubicles, thereby reducing the proportion of emission-active areas.

In this study, the behaviour of a lactating herd was recorded over the course of a year using an animal tracking system. The real-time localisation of the animals enabled the analysis of their use of the various functional areas of the structured exercise yard. The results demonstrated that the cows utilised the exercise yard for a mean duration of 2.3 hours per day. 32% of animals spent time in the elevated rubber mat cubicles, 27% in the cross corridors and 25% in the feeding areas. Additionally, the excretion behaviour of dairy cows in the exercise yard was observed directly. It was found that approximately 70% of urine excretion occurred in the feeding alley alone.

Keywords
Dairy cow, exercise yard, excrements

The exercise yard serves to improve animal welfare, yet simultaneously increases the active emission surface area, which in turn increases ammonia emissions (Umweltbundesamt 2021). It is therefore of the utmost importance to clean the exercise yard on a regular basis and to promptly transport the excrement to covered outdoor storage areas. Cattle eliminate diffusely and, in contrast to urine, faeces can be excreted while walking, eating, lying down, standing and standing up. In order to urinate, the dairy cow must stop all other activities for this period (Philips 2002). The average interval between two urinations is 98 minutes (Shepherd et al. 2017). Defecation occurs approximately 12 times a day. As defecation typically takes place in a standing position, the cubicles in loose housing are designed in such a way that the faeces fall into the alley as far as possible. In particular, when cattle stand up after lying down, there is an increased amount of faeces and urine. If faeces are deposited while the animal is lying down, the lying area can become contaminated (Foris et al. 2021; Draganova et al. 2015; Phillips, 2002). Richter (2006) found that 70% of faeces are defecated in the feeding alley.

It is generally recommended that the feeding of cows should not be disturbed by the manure removal technique within the first two hours after feed presentation (Buck et al. 2012). However, the conflicting goals of maximising alley hygiene can be addressed by the use of elevated feed stalls,

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which allow a high manure removal frequency with feed intake undisturbed by sliders (Benz et al. 2014). Zähner et al. (2019) demonstrated that elevated feed stalls with twelve manure removal cycles per day resulted in 8% reduction in ammonia emissions during the summer, a 19% reduction during the autumn, and a 16% reduction during the winter. According to estimates by Christ and Benz (2020), combined structural and technical ammonia reduction techniques, such as elevated feed stalls with feeding place dividers and emission-reducing walking surface designs as well as elevated rubber mat cubicles on the not roofed exercise yard area, are suitable for compensating for the additional emissions caused by exercise yards.

In a study conducted by Van Caenegem and Krötzl Messerli (2017), it was found that cows utilize an exercise yard for approximately half of the time they are not engaged in activities such as eating or milking. In relation to the daily time budget, this equates to 5% of the herd on average. The use of the exercise yard varies depending on the amount of space available; with less space (3.6 m^2/animal), utilisation was around a third lower than with more space (15.1 m^2/animal). Regardless of the available space, the utilisation of the exercise yard is more intensive during sunny autumn and winter days. In general, 70 to 80% of exercise yard use occurs during daylight hours between 9 am and 4 pm. In an experimental trial, Smid et al. (2019) provided 12 lactating cows with more than 100 lactation days with access to a 144 m^2 (12 m^2/animal) littered exercise yard. In summer, the animals utilised the exercise area for lying down 54% of the time, whereas in winter this figure was only 5%. In summer, the cows spent an average of 25% of the day outside, in contrast to only 3.3% in winter. In particular, during summer nights between 20:00 and 06:00, the animals spent an average of 50% of their time outdoors. During the summer months, the animals spend a significantly reduced amount of time outdoors between the hours of 6 a.m. and 8 p.m. This is in order to avoid the sun's rays.

Charlton et al. (2013) observed a higher motivation of cows to use the pasture at night. Kismul et al. (2019) compare the behaviour of automatically milked cows that have access at night to either a pasture or a paddock with 100 m^2 per cow, 228 m (paddock) and 228 to 338 m (pasture) away from the barn. Feeding differs fundamentally between the two groups. In the case of access to pasture, grass silage is offered restrictively for 12 hours during the day and in the case of access to the paddock, grass silage is offered ad libitum for 24 hours a day in the barn. The authors report that the cows only use the pasture 33% of the time during the 12-hour "night" period (3.9 hours) and predominantly during the first three hours between 6 and 9 pm. Of this time, they spend 8% lying down (19 minutes) and graze for 85% of the effective grazing time of 2.47 hours, while the group with access to the outdoor run is outside on average 25% of the time (3.08 hours) and lies down for 32% of this time (59 minutes). Both groups therefore spend a large proportion of their time indoors, without utilising the offer of outdoor access at night. The low utilisation of pasture with restrictive feeding in the barn results in a lower milk yield. The authors conclude that it is important to offer feed in the barn even when there is access to pasture at night in order to avoid losses in performance.

Schrade et al. (2010) found that only a few animals are in the exercise yard after milking or feeding. Between 4 and 10% of a herd spend time in a separate exercise yard, whereas in an integrated exercise yard the utilisation is 32 to 35% due to the adjacent and with cubicles taken into account (Schrade et al. 2010). Even in large exercise yards with an area of 15.1 m^2 per cow, little movement is observed with an average daily distance of only 100 metres; with 3.6 m^2 per cow, this is only 40 metres per day (Van Caenegem and Krötzl Messerli 2017). The cows spend the majority of their time in the exercise yard with no recognisable activity or ruminating, totalling around one hour per day.

Animals, material and methods

The animals in this study were a Fleckvieh herd with an average annual yield of 11,200 kg of milk per cow. In the 6-row cubicle barn, there were 144 deep bedded cubicles for the lactating herd with access to the exercise yard. The fresh milkers and the selection area were not observed. All cubicles were arranged opposite each other, 1.25 m wide and 2.6 m long. The barn had two external feeding tables. All feeding places were built as elevated feeding stalls with feeding place dividers at every second feeding place. The feeding alleys were 2.5 m wide, plus 1.55 m long feeding stalls, resulting in a total width of 4.05 m. Feeding alleys and elevated feeding places were covered with rubber pads both in the barn and in the exercise yard. The walking surfaces had a 3% cross slope to the urine collection drain in order to separate faeces and urine more quickly and thus achieve a reduction in ammonia emissions. The walkways between the cubicles were 3 meters wide. The cows were milked using three automatic milking systems.

The adjoining exercise yard was structured with a total of 18 not roofed elevated rubber mat cubicles and two covered feeding areas. It was also equipped with a water trough and two automatic cow brushes. There was no cross passage at the end of the barn (Figure 1).

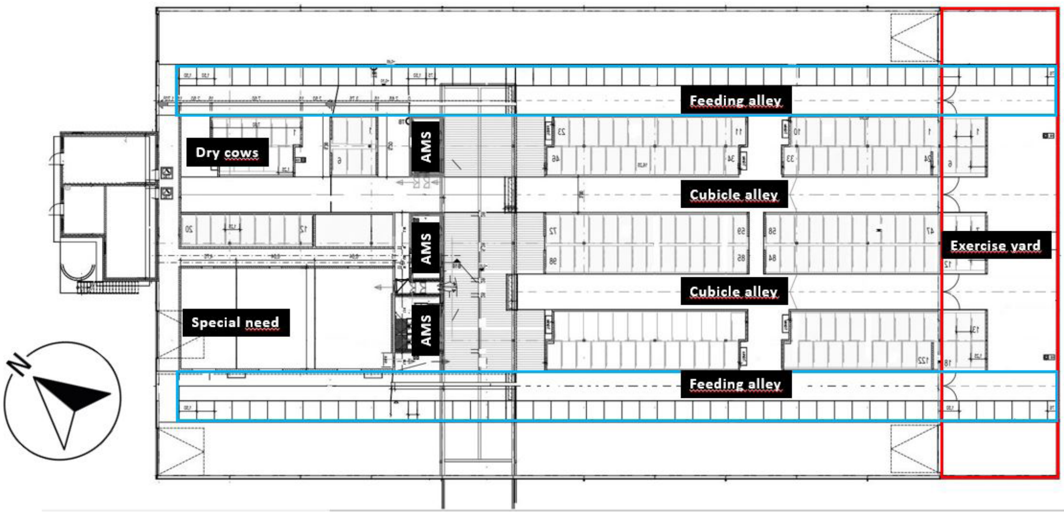


Figure 1: Floor plan of the barn on the study farm (the adjoining exercise yard is on the right and is framed in red; the feeding alleys are also marked with a blue frame)

The area of the exercise yard was 295 m^2. Without elevated feeding places and elevated rubber mat cubicles, there was 201 m^2 of pure exercise area. The manure was removed from the alleys in the barn and the exercise yard every two hours using stationary reversible scraper valves, while the cross corridors were cleaned manually in the morning and evening (Figure 2).

Figure 2: Structured exercise yard of the test farm with manure removal axles and turning flap turn scrapers

Real-time localisation

Between October 2021 and September 2022, a tracking system (SMARTBOW®, Smartbow GmbH, Weibern, Austria) was used to record the whereabouts of each individual cow in the barn (control) and in the exercise yard as well as in ten individual areas of the structured exercise yard (Figure 3).

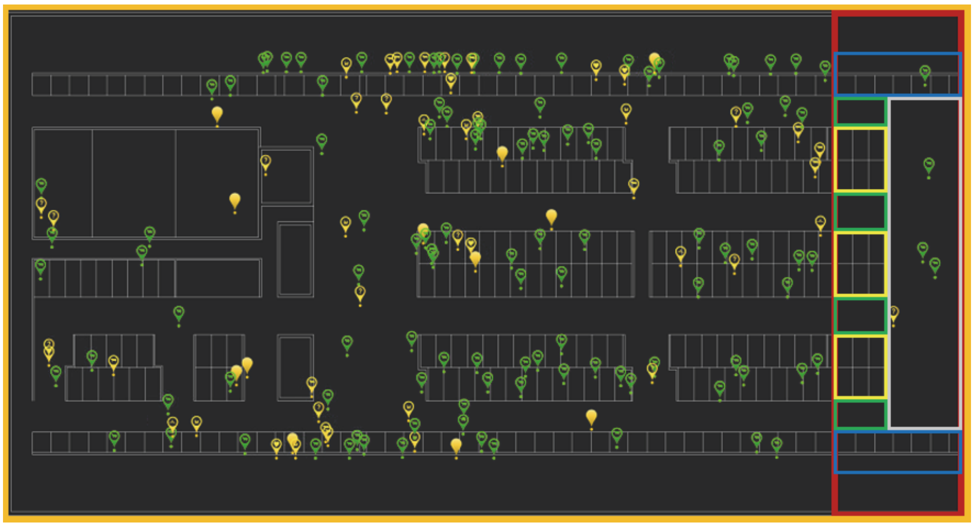


Figure 3: Stable floor plan with the colour-coded recording locations in the exercise yard: yellow = three elevated rubber mat cubicle areas; blue = east (top) and west (bottom) feeding areas; green = east (top) and west (bottom) feeding alleys and two cubicle alleys; grey = outside cross alley. Inconspicuous cows were shown in green by the system, conspicuous cows were highlighted in yellow.

The Smartbow ear tag has an integrated acceleration sensor for recording cow and rumination activity. This records the acceleration data every second (in the event of data overload at 5 or 10 second intervals) and sends the low-frequency signals (1 Hz) to a receiver. The location is detected using the

Time Difference of Arrival (TDoA) and Angle of Arrival (AoA) principles. The receivers permanently installed in the barn (Smartbow Wallpoints) sent the data in real time to a local server (Smartbow Station). In their study on the validation (four validation steps) of the Smartbow system, Wolfger et al. (2017) cite differences of only 1.22 to 1.80 m between laser measurements and the Smartbow data for the location of the animals. On our test farm, the recording accuracy was checked using daily totals of the residence times of individual cows in the localisations, which was 98%. For evaluation reasons, there were stays of less than one minute within the study presented, which were rounded down to zero due to the amount of data. This meant that if a cow changed recording area and spent less than a minute in the new area, there was a gap. Due to the 10 different recording areas, the stays <1 minute totalled 11.8% of the total time spent in the exercise yard. All data was summarised into hourly values, which meant that over 900,000 pieces of information were available per month for all areas and animals. The calculation of the duration of animal stays in the individual sectors was always based on 144 cows with access to the exercise yard. This means that the duration of a stay in a sector in the exercise yard of all cows was totalled and divided by the constant number of 144 cows. Due to group changes, an average of 155 individual cows were registered in the exercise yard, whereby it was not possible to take into account the individual days a cow spent in the exercise yard due to the amount of data.

The outside temperatures were only recorded every quarter of an hour between 31 March 2022 and 25 July 2022 using a stationary weather station (Vantage Pro2, Davis Instruments, Hayward, USA). The weather station was mounted in the centre of the exercise yard at a height of six meters above the ground and recorded solar radiation, precipitation, temperature and humidity. In addition, data from the barn climate software of the test company (SBE, Lock Antriebstechnik GmbH, Ertingen) was available.

Direct observation of elimination behaviour

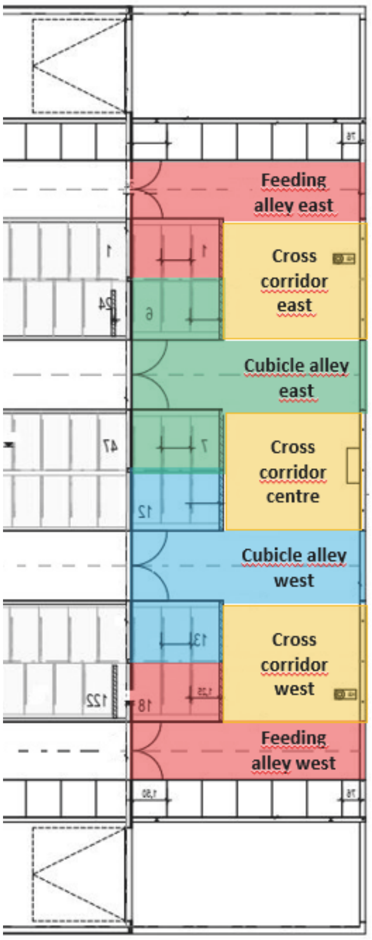
The shedding of faeces and urine was directly observed in the not roofed exercise yard over a total of two twelve-hour periods from 7 a.m. to 7 p.m., whereby the observation times were divided over eight days (Table 1).

Table 1: Periods of direct observations of elimination behaviour

date	Time of day	Number of hours	Precipitation and average temperatures
23.9.2021	10:00 to 15:00	5	No precipitation, 15°C
27.9.2021	15:00 to 19:00	4	No precipitation, 18°C
30.9.2021	7:00 to 10:00 a.m.	3	No precipitation, 7°C
3.10.2021	7:00 to 10:00 a.m.	3	No precipitation, 10°C
6.10.2021	15:00 to 18:00	3	No precipitation, 11°C
8.10.2021	10:00 to 12:00	2	No precipitation, 14°C
17.10.2021	12:00 to 15:00	3	No precipitation, 12°C
18.10.2021	18:00 to 19:00	1	No precipitation, 8°C
	Total	24	

During the observations on elimination behaviour, temperatures averaged 12°C (between 7°C and 18°C) and there was no precipitation. The run yard area was divided into seven sectors for the observations. The reason for this division, which deviated from the recording locations of the animal location, was the fact that soiling caused by excrement from cows using the elevated rubber mat cubicles ended up in the adjacent walking area of the cubicle or feeding alley. This was taken into account by dividing the area into seven recording locations instead of ten. In this way, areas of roughly comparable size were also created in the walking area sectors where the time of defecation or urination was recorded (Table 2).

Table 2: Division of the exercise yard into sectors for the direct observations on elimination behaviour, elevated cublicles and feeding places are not included in the area data



Sectors on the exercise yard	Designation	Size of the exercise yard (without cubicles)	Equipment
	Feeding alley east	30 m^2	3 elevated rubber mat cubicles, access to 18 feedings places
	Feedings alley west	30 m^2	3 elevated rubber mat cubicles, access to 18 feedings places
	Cubicle alley east	30 m^2	6 elevated rubber mat cubicles
	Cubicle alley west	30 m^2	6 elevated rubber mat cubicles
	Cross corridor east	27 m^2	Cow brush
	Cross corridor centre	27 m^2	Water trough
	Cross corridor west	27 m^2	Cow brush

Data analysis

The data basis for animal localisation based on 12 monthly mean values or 24-hour mean values for daily courses was not normally distributed, which was tested using the Shapiro Wilk test. Differences between groups were performed using the Friedman test and medians and maximum and minimum values were reported. Standard deviation (SD) and coefficient of variation (CV) were added to the arithmetic mean. Pairwise comparisons of frequencies were analysed using the binomial test. The Kendall's tau test was used to test for correlation. The statistical analyses were carried out using the program R version 4.2.1 and the package R Commander. Significant was defined as p < 0.05, very significant from p < 0.01 and highly significant from p < 0.001.

The study was notified to the responsible regional council as an animal experiment in accordance with Section 8a (1) No. 2 TierSchG No. LAZ 03/20 A.

Results

Animal stays in the exercise yard

On average, the cows spent 140.6 minutes a day in the exercise yard for 2.3 hours (SD = 13.8 minutes, CV = 10.2). The cows spent 34.6 minutes (SD = 3.7 minutes, VK = 9.3) in the feeding areas, 4.6 minutes (SD = 1.0 minutes, VK = 4.8) in the two feeding alleys, 44.9 minutes (SD = 4.7 minutes, VK = 4.8) in the 18 elevated rubber mat cubicles, 9 minutes (SD = 4.7 minutes, `VK = 9.6), the two cubicle alleys with 2.4 minutes (SD = 0.3 minutes, VK = 7.9) and the cross corridors with 37.7 minutes (SD = 7.0 minutes, VK = 5.4). With an average of 11.8 minutes (SD = 1.1 minutes, CV = 14.6), 11.8% of the animal stays in the exercise yard had a duration of <1 minute and were not taken into account (Figure 4).

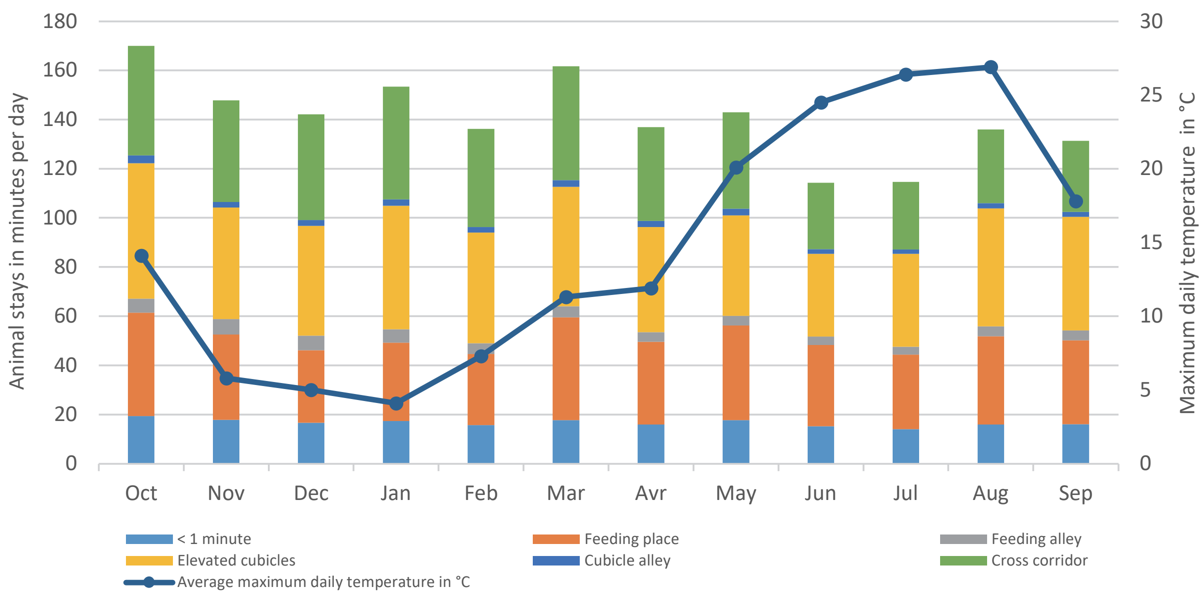


Figure 4: Duration of stays in the individual sectors in the structured exercise yard, data basis: October 2021 to September 2022, location system data, east and west feeding areas, east and west cubicle alleys and east, centre and west cross alleys combined into a total of 5 sectors, the maximum daily temperature is plotted on the secondary axis as an average of the maximum values in the month

On average, 32% of the time a cow spent in the exercise yard was spent in the elevated rubber mat cubicles, 27% in the cross corridors and 25% in the feeding areas. The number of stays in the cubicle corridors was 2% and in the feeding corridors 3%. There were highly significant differences between the individual sectors (chi-squared test, X-squared = 45.889, df = 4, p-value < 0.001), but no significant differences between the frequencies of stays in the high boxes, in the cross corridor or in the feeding areas (chi-squared test, X-squared = 0.87059, df = 2, p-value = 0.647). There was also no difference between cubicle alleys and feeding alleys (binomial test, p = 0.289).

There was no correlation between the mean daily maximum temperature of a month and the mean percentage of time the animals spent in the exercise yard (Kendall's tau test, z = 20, p-value = 0.086, tau = -0.04).

The average duration of a cow's stay in the exercise yard was 15.7 minutes (median, max. 22.2 minutes, min. 10.2 minutes). The longest mean duration of a residence event was observed in March 2022 between 9 and 10 a.m., the shortest in July 2022 between 11 and 12 a.m. The mean duration of a stay event differed highly significantly between the months (Friedman test, $p < 0.001$). Three months were summarised for clarity. In July to September, the average duration of a stay event was higher at night than during the day, while the opposite was true in the months of October to December and January to March (Figure 5).

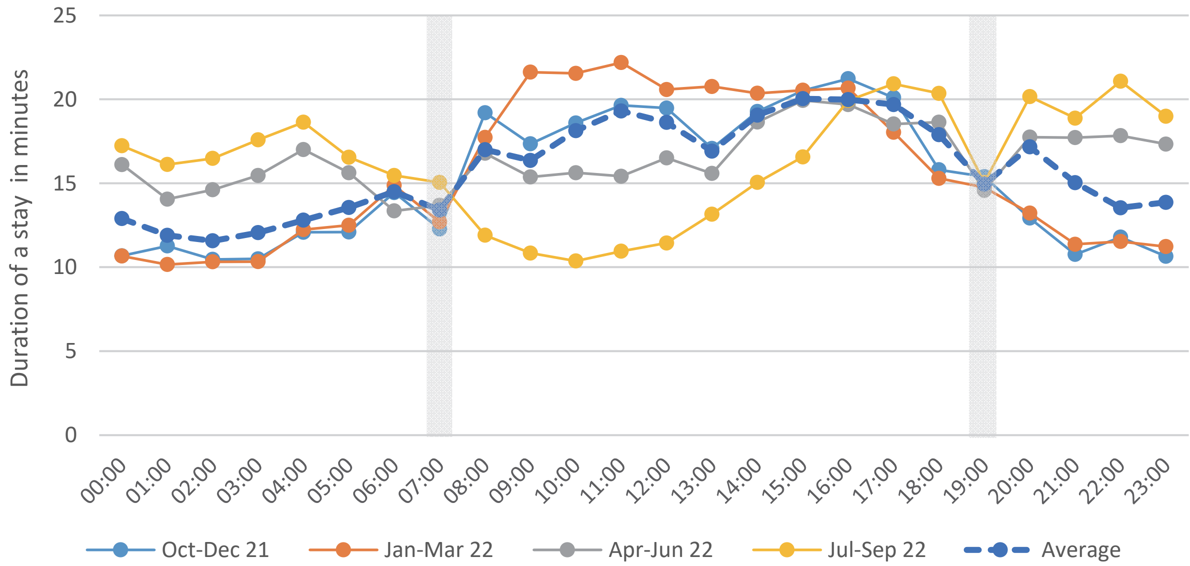


Figure 5: Duration of a stay in the exercise yard, shown over the course of the day, summarised for three months. Feeding times are highlighted in grey. Data basis: Tracking system data, 144 animals with exercise yard access, recording period October 2021 to September 2022

There were highly significant differences between the twelve months with regard to the number of cows registered in the exercise yard within one hour (Friedman test, $p < 0.001$). A maximum of 56% of the animals (81 animals) were registered with access to the exercise yard. The monthly average was 48% (69 animals) and the minimum was 23% (34 animals). The highest hourly value was reached on 18 October 2022 between 17:00 and 18:00 with 98 recorded animal visits (68% of animals with access to the exercise yard).

The maximum duration of a stay event was on average 21 minutes (median) over the entire observation period, with the highest value in March (24.8 minutes between 9:00 and 10:00) and the lowest in November (19.6 minutes between 6:00 and 7:00). The mean proportion of the herd that was in the exercise yard within an hour and the mean duration of an animal's stay resulted in a mean number of animals in the exercise yard of 9.7% (SD = 5.7%, CV = 58.6) of the herd. If the largest proportion of the herd was in the exercise yard during the course of the day, then the maximum duration of a stay was also in the highest range (Figure 6).

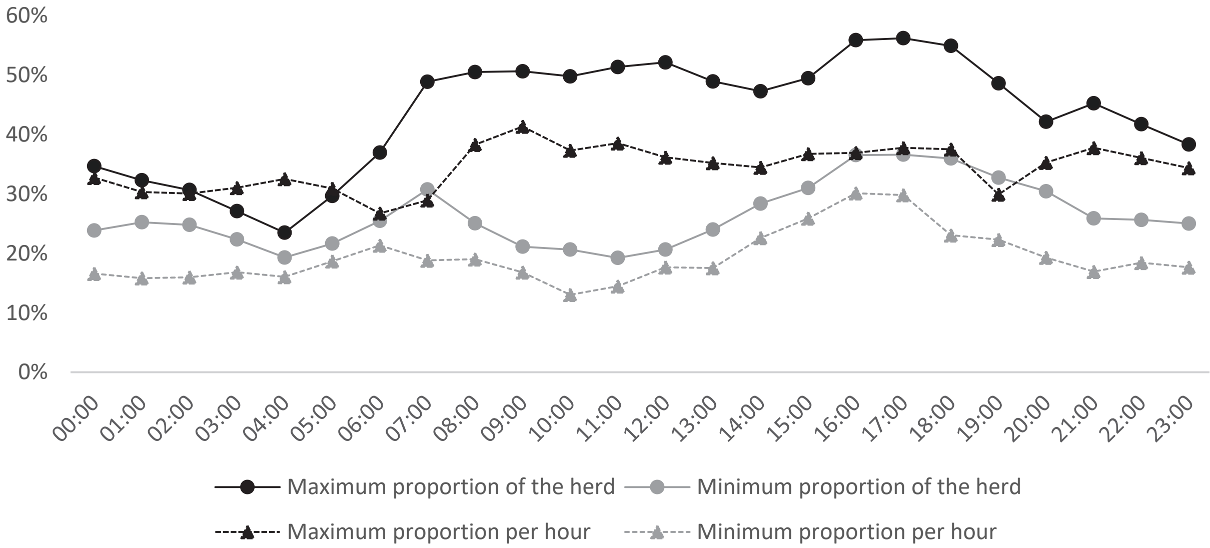


Figure 6: Daily course of the maximum/minimum herd proportions in the exercise yard and their maximum/minimum proportions per hour, data basis: October 2021 to September 2022, Tracking system data

A further analysis focused on the utilisation of the elevated rubber mat cubicles in the exercise yard. The 18 not roofed rubber mat cubicles were each used for an average of 6 hours per day (max. 7.1 hours in October 2021, min. 4.3 hours in June 2022). All cows were analysed according to the duration of a stay per visit in the cubicle. At 34%, highly significant short stays of >1 to 3 minutes were recorded most frequently (chi-square test, n = 6, z = 24, p-value < 0.001), while there were no differences between the other durations of stay (chi-square test, n = 5, z = 2.9, p-value = 0.568) (Figure 7).

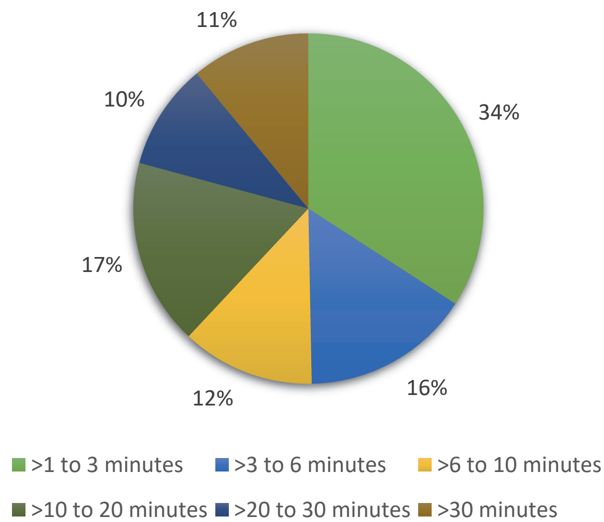


Figure 7: Proportion of animal stays in the 18 elevated rubber mat cubicles in the exercise yard according to their duration (6 non-linear categories, animal stays < 1 minute are not included), data basis: 12 months with a total of 83,895 observations

Elimination behaviour

During the 24 hours of direct observation, which was divided into eight observation days and carried out twice between 7 am and 7 pm, a total of 158 faeces and 108 urine samples were observed in the exercise yard every 12 hours (Table 3).

Table 3: Mean distribution of excretions in the period 7 am to 7 pm (12 hours) in the sectors of the structured exercise yard, data basis: direct observation over a total of 2x12 hours spread over eight observation days, 144 animals with access to the exercise yard

Excretion	Section of exercise yard	Feeding alley east	Feeding alley west	Cubicle alley east	Cubicle alley west	Cross corridor east	Cross corridor centre	Cross corridor west	total
Faeces	Number	55	34	19,5	11,5	18	13	7	158
	Proportion in %	35	22	12	7	11	8	4	100
Urine	Number	45	31	13	10	4	7	1	109
	Proportion in %	42	28	12	9	3	6	1	100

The majority of excretions took place with comparable frequency in the feeding alley (faeces 56%, urine 70%, binomial test, p-value = 0.247). The proportion of faeces (20%) and urine (21%) was also similar in the corridor (binomial test, p-value = 1). Significantly more faeces (24%) than urine (10%) was recorded in the transverse corridor (binomial test, p-value = 0.024).

The number of faeces and urine excretions was similar over the observed daily period, with faeces being defecated more frequently than urine (binomial test, p = 0.003). During the course of the day, the lowest amount of faeces and urine was passed between 1 and 2 pm (Figure 8).

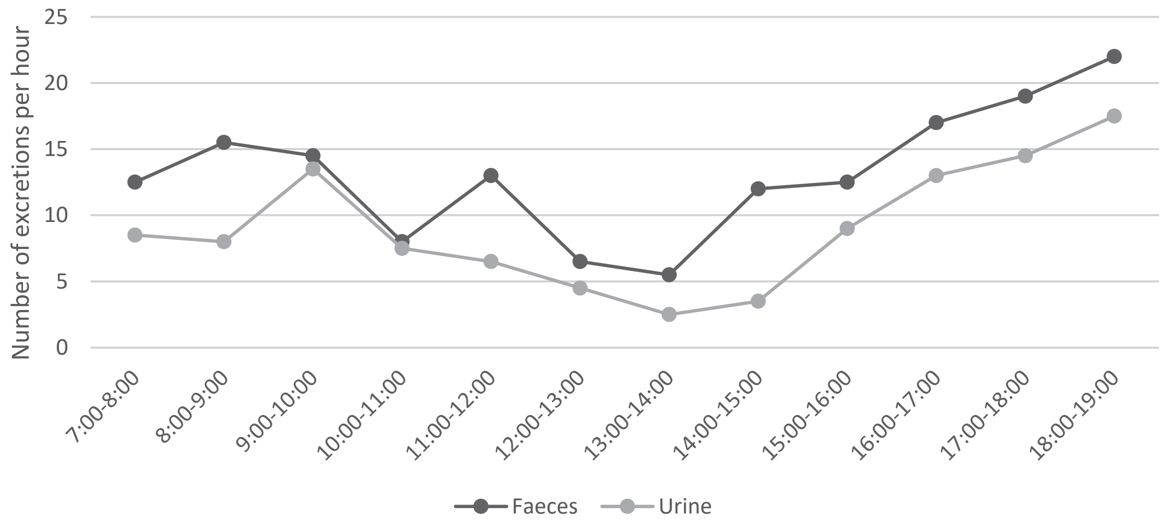


Figure 8: Excretions over the course of the day, data based on direct observations over a total of 2x12 hours, 144 animals with access to the exercise yard

Discussion

The present study showed that the cows spent an average of just over two hours a day in the exercise yard, in contrast to the values determined by Van Caenegem and Krötzl Messerli (2017). There, an average of one hour was measured in the exercise yard and the maximum values of over 90 minutes on sunny autumn and winter days were also at a lower level. The focus of Van Caenegem and Krötzl Messerli (2017) was on the comparison of different types of space, taking climatic influences into account. The authors concluded that the utilisation of exercise yards depends less on the space available than on weather influences. An in-depth analysis taking weather data into account was not possible within the scope of the study. However, it was analysed whether average daily temperatures correlate with time spent in the exercise yard. No correlation was found between the maximum daily temperature and the time spent in the exercise yard. The result is only roughly indicative, as the analysis only included the average maximum daily temperatures of a month, which were compared with the monthly average values of daily exercise yard use.

The cows spent between 10 and 22 minutes per visit in the exercise yard. On average, the longest time spent in the yard was observed in March and the shortest in July. In winter, there was an opposite pattern compared to the summer months in terms of the duration of the individual stay events. In summer, the animals spent more time in the exercise yard at night than during the day, while in winter the duration of time spent in the exercise yard during the day was longer than in summer. It should be noted that neither the shift due to summertime nor the feeding times were taken into account in the analyses. However, it can be assumed that these factors did not significantly influence the results.

The average number of animals in the exercise yard was calculated based on the total number of cows registered in the exercise yard within one hour divided by their average duration of a stay. At just under 10%, the result fits in well with the data from Schrade et al. (2010). The authors state 4 to 10% of a herd in an attached exercise yard and 32 to 35% in an integrated exercise yard, including the use of the accessible cubicles. The space available in the exercise yard in the present study was significantly less than in the Swiss studies (Van Caenegem and Krötzl Messerli 2017, Schrade et al. 2010). Van Caenegem and Krötzl Messerli (2017) analysed available space of between 3.6 and 15. m^2/animal, while the study by Schrade et al. (2010) was based on 2.4 to 3.4 m^2/GV. The Baden-Württemberg agricultural investment subsidy requires at least 1.5 m^2 of not roofed area for each animal in the herd (Infodienst Landwirtschaft – Ernährung – Ländlicher Raum Baden-Württemberg 2023). On the farm under investigation, the exercise yard area was 2.05 m^2 per cow with access to the exercise yard. The infrastructure in the exercise yard appears to be more important than the available exercise yard area per cow. While the animals in the studies by Van Caenegem and Krötzl Messerli (2017) and in one of two barn concepts in the study by Schrade et al. (2010) only had an open area at their disposal, the second barn concept by Schrade et al. (2010) had access to a row of cubicles, which explains the significantly higher proportion of animals. On the structured exercise yard of the study farm, there was access to two times 13 feeding places and three times six not roofed elevated rubber mat cubicles. There was no difference in the frequency of use of the elevated rubber mat cubicles (32%), cross corridors (28%) and feeding areas (24%) in the exercise yard, and it can be concluded that the cows were evenly distributed over the available space. Furthermore, the results suggest that the structure of the exercise yard made it attractive for the cows and that this explains the higher utilisation, both in terms of total daily usage time and herd proportion, compared to the studies by Van Caenegem and Krötzl Messerli (2017) and Schrade et al. (2010). The fact that around a third of the animals spent time in the cross corridor of the exercise yard was recorded could be explained by the presence of water troughs and cleaning brushes. It is possible that the present study slightly underestimates the proportion of the herd in the exercise yard, as this was calculated by dividing the sum of all durations of stay by the number of animals with access to the exercise yard (144). This did not take into account the fact that individual animals could be selected for treatment for a short time and then not have access to the exercise yard, nor that the actual number of animals fluctuated somewhat due to group changes. However, it can be assumed that over the long study period totalling 365 days and the overall high number of animals, no relevant distortion of the results was caused by this systematic methodological error. When a large proportion of the herd was in the exercise yard, the individual stay events were particularly long. This observation suggests that the exercise yard was used intensively under attractive conditions, even when many animals were already there. However, the question of whether the structure of the exercise yard has an influence on its utilisation cannot be answered conclusively due to the lack of comparative possibilities in this study under practical conditions.

Van Caenegem and Krötzl Messerli (2017) found that 70% of all exercise yard visits took place during the day between 9 am and 4 pm, and on sunny autumn days this figure was as high as 81%. This finding is consistent with the maximum number of animals and the maximum duration of a stay event between the feeding times (7 a.m. and 7 p.m.) of our own analysis and also with the observations of Kismul et al. (2019), according to which night-time access to open-air runs was only rarely used.

As an elevated cubicle in the exercise yard was used for an average of just under 6 hours a day, with a maximum of 7 hours, it can be assumed that the capacity of elevated rubber mat cubicles was sufficient for the animals. There were deep bedded cubicles for all animals in the barn, so there was an animal to cubicle ratio of 1:1, which was merely supplemented by the not roofed elevated cubicle in the exercise yard. Due to the short duration of elevated rubber mat cubicle use in the exercise yard, with only 11% of uses lasting more than 30 minutes, it can be assumed that the cows preferred to stand in the elevated rubber mat cubicles rather than lie down. It can be assumed that the animals, which according to Van Caenegem and Krötzl Messerli (2017) are predominantly inactive in the exercise yard and chew the cud 37% of the time, found a suitable sheltered retreat in the elevated cubicle in the exercise yard. There are still research gaps with regard to the proportion and arrangement of structure in exercise yards, which the study presented cannot clarify under practical conditions due to a lack of comparative possibilities.

The faeces and urine output in the exercise yard was concentrated in the feeding alley. Around 70% of the urine and 56% of the faeces were observed there, which confirms the data from Richter (2006). It should be noted, however, that although a total of 24 hours was observed, this observation period was divided into two 12-hour periods during the day for reasons of practicability and therefore did not cover the night. It is therefore only possible to make a statement on the distribution of faeces in the observed areas, but not on the absolute amount of faeces and urine output in a structured exercise yard. As there were more cows in the exercise yard during the day than at night, it cannot be assumed that the observation period falsifies the result. Less faeces and urine were observed at midday between 1 and 2 pm. It is possible that there was a correlation with the main rest periods, but this was not analysed.

In order to keep ammonia emissions low, frequent manure removal intervals are also required in addition to urine-draining structures on the surfaces of the alleyways (Schrade et al. 2010; Umweltbundesamt 2021). The fact that manure was mainly eliminated in the feeding alley emphasises the importance of the design of this area. If feeding areas are designed as raised platforms, the cows are not disturbed by the manure removal technology. If necessary, this could even further increase the manure removal frequency at times of high manure/urine production, which in the present study would be between 5 and 7 pm. However, if the cows are standing on a level feeding alley to eat, it is recommended to pause the manure removal technique within two hours of feeding (Buck et al. 2012). Overall, it can be concluded that the possible structural and technical measures for reducing ammonia emissions can be assumed to be highly effective in the feeding alley with 70% urine output. In future, intelligently controlled manure removal technology should take into account the respective manure production, which presumably varies with the slightly fluctuating animal stays at different times of the year. Although 24% of the faeces were observed on the crossways, only 10% of the urine output, which is largely responsible for ammonia formation, was observed. From an emissions reduction perspective, therefore, no prioritisation of reduction measures can be derived. As the animals spend a third of their time in the exercise yard in the elevated rubber mat cubicles, it would make sense to design as much of the exercise yard as possible with elevated rubber mat cubicles in order to minimise the number of crossways that need to be cleaned. This is already supported in Baden-Württemberg as part of the SIUK funding programme (Spezifische Investitionen zum Umwelt- und Klimaschutz) (Infodienst Landwirtschaft – Ernährung – Ländlicher Raum Baden-Württemberg 2023). In Caenegen et al. (1997), the main observed behaviour of cows in the exercise yard was standing without visible activity (47%), followed by rumination (39%). These behaviours can be performed well in elevated rubber mat cubicles if their control systems allow standing. The design and position of the neck control is largely responsible for this (Benz et al. 2020). As the elevated rubber mat cubicles reduce the soiled floor space, emission-reducing floor designs outside the feeding alley could be dispensed with for economic reasons.

Provided that the existing observations on the distribution of faeces and urine excretion and the time and location of dairy cows in a structured exercise yard were confirmed by further research, it would be possible to re-evaluate the emissions of an attached exercise yard structured with not roofed elevated rubber mat cubicles and feeding places.

Conclusions and outlook

The structured exercise yard with 18 not roofed elevated rubber mat cubicles and 26 additional feeding places was used by the 144 cows in the herd with access to the exercise yard for around 2.3 hours a day in this study. The cows were distributed fairly evenly between the functional areas of elevated rubber mat cubicles, cross corridors and feeding areas. Each elevated rubber mat cubicle was used for a total of just under 6 hours a day, presumably generally for standing rather than lying down. From the elimination behaviour in the exercise yard, it can be deduced that the priority for NH_3 mitigation measures should be placed on the feeding alley with the highest faeces and urine output. Further studies on different exercise yard designs could help to assess the emission potential of exercise yards more accurately.

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