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Analysis of cows' stays in a comb-type stable with an attached exercise yard using a location system

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A cubicle barn can be designed as either a longitudinal or transverse barn (comb-type stable). On a newly built dairy farm with an automatic milking system (AMS) and slatted floor, the comb barn geometry was chosen, giving the cows access to an adjoining exercise yard via five corridors. A tracking system made it possible to analyse the location of the cows. In particular, the study investigated whether certain corridors were preferred and how often the exercise yard was used. It was found that the outer corridor was used for a longer duration, although, unlike the other corridors, only one row of cubicles was adjacent to it and it was the furthest away from the milking system. In order to improve emission protection and animal welfare, it could be interesting to examine whether it would be advantageous to adapt the corridor widths in comb-type stables.

Keywords
Dairy cattle husbandry, barn construction, comb-type stable geometry, animal behaviour

In addition to other considerations, animal-friendly husbandry systems should facilitate movement, structure, and exposure to different climate zones (Wissenschaftlicher Beirat für Agrarpolitik beim Bundesministerium für Ernährung und Landwirtschaft 2015). In terms of floor characteristics, cattle demonstrate a preference for yielding surfaces that they can walk and lie on. The use of hard floors has been linked to adverse effects on claw health and hoof integrity (Benz 2002, Somers et al. 2003, Bergsten 2004). When a flexible rubber mat was installed on a concrete slatted floor, not only did the hoof status of the herd improve, but the activity of the cows in a dairy herd with a comb-type stable geometry and cubicle corridors only two metres wide also increased and aligned with the level of a comparison herd in a two-row loose housing area (Benz 2002). Lower-ranking and younger animals have to get out of the way and be able to satisfy their basic needs, such as feeding and drinking or lying down for a sufficient length of time (Frieten et al. 2021), with primiparous cows showing reduced lying times and extended standing times after integration (Hut et al. 2022). When assessing the dimensions of walkways and the area behind the feeding cows (feeding alley), two dairy cows should be able to pass each other unhindered (Frieten et al. 2021). In Baden-Württemberg, for example, a minimum walkway width of 2.5 metres and a minimum feeding alley width of 3.5 metres is considered to be particularly animal-friendly and is subsidised as part of the agricultural investment funding (Landesrecht BW 2023). Structuring measures such as raised feeding places with feed partition walls reduce displacement (DeVries et al. 2006, Benz et al. 2013, Zähner et al. 2020). In addition, dead ends should be avoided in stables. According to the implementation notes of the Managementhilfe Q-Wohl-BW (Benz et al. 2021), a dead end is a stable area that is at least five metres long and less than

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five metres wide (net area without cubicle and without elevated feedstalls) with no alternative routes. Cubicles do not count as alternative routes, unless the structural design allows the animals to pass through them without danger. However, experimentally restricted walking areas had no demonstrable effects on stress parameters in dairy cows in studies by Krämer et al. (2017). Exercise yards offer additional opportunities for movement (Simon et al. 2018, Simon et al. 2020) and climatic stimuli in equal fashion (Frieten et al. 2021).

Exercise yards are used by cows for about an hour a day (van Caenegem et al. 1997, Schrade et al. 2010). The relative time spent by the animals in an attached exercise yard that is spatially separate from the barn is on average 4 to 10 %. With an average of 32 to 35 %, the time spent by the animals in the integrated exercise yard is significantly higher because it is used as a functional area for structural reasons (Schrade et al. 2010). Observations in exercise yards with not roofed cubicles and feeding places showed that the feeding places were used for about a third of the time spent in the exercise yard, and the cubicles for a quarter (Benz et al. 2024).

New manure removal technology and automatic milking systems (AMS) enable barn floor plans to be designed without taking into account the usual manure removal axes (Itkin 2010). In the comb-type stable, the cubicles are at right angles to the feed axis, in contrast to the parallel arrangement in a longitudinal stable (Eilers 2014). A comb-type stable offers particularly short distances for the cows and the additional hygienic advantage that, with solid-surface walkways, excrement does not have to be removed over the entire length of the stable (Itkin 2010). In terms of combining environmental and animal protection, the aim when building a stable today is to keep the proportion of soiled surfaces low in order to limit ammonia emissions (Umweltbundesamt 2021).

So far, there has been a lack of research regarding the behaviour of dairy cows in a comb-type stable. The aim of the pilot study presented here was to describe the use of different functional areas by cows in a comb-type stable.

Material and Methods

The study farm was located in southern Baden-Württemberg in the Lake Constance district. It expanded its dairy herd from 96 to 180 cows in 2019. For this purpose, the dairy cow barn with AMS built in 2010 was extended with a new barn building for 72 lactating cows, 12 fresh milkers, dry cows, a calving area and another AMS. Both automatic milking systems from the company Lely were based on free cow traffic. The herd of 180 lactating cows had access to a shared exercise yard between the two barn buildings with additional feeding places at a stitch feed table with feeding belt. The newly built barn was designed with a comb-style stable geometry and slatted floor with deformable rubber mats. Elevated rubber mat cubicles were installed in the cubicle area, consisting of four opposing rows with a total of 18 cubicles each. Five three-metre-wide cross corridors with exercise yard access were created, with the corridor adjacent to the AMS also serving as a waiting area. The new building was given a seven-metre-wide membrane light ridge, in which a foil over a round arch construction provides diffuse light entry (Figure 1).

Figure 1: Study farm in the Lake Constance district in Baden-Württemberg, Germany with newly built dairy cow barn with membrane light ridge in comb barn (© B. Benz)

The feeding areas were built with elevated feedstalls, feeding place dividers and headlock feeding gates. The new stable had 50 feeding places and a further four in the waiting area of the AMS. There were a total of 28 feeding places on each side of the exercise yard, six of which were roofed, while the remaining feeding places only had a roofed feed conveyor. Fresh feed was unloaded every morning at 8 a.m. on the feeding table in the stable and at the feeding conveyor in the exercise yard. Around midday, hay was fed on the feeding table in the stable, where fresh feed was also provided in the evening. The cows received an enhanced basic feed ration (30.9 kg grass silage, 7.7 kg corn silage, 2.2 kg energy mix with 70% corn and 30% barley, 1.3 kg protein mix, 0.8 kg grass cobs, 0.5 kg each of molasses and hay, 0.7 kg corn gluten, 0.4 kg dried beet pulp, 0.3 kg corn kernels and mineral feed) and additional concentrates at the automatic milking system. The feed pusher robot operated for the first time at 10 a.m. after the feed was unloaded and then pushed the feed every hour.

The observed sub-herd was comprised of an average of 65 lactating Holstein cows (approximately 85%) and Simmental cows (approximately 15%), with an annual milk yield of approximately 10,100 kg of milk.

The use of a location system (SMARTBOW®, Smartbow GmbH, Weibern, Austria) recorded the location of each cow in the exercise yard and inside the comb-type stable from 25 November 2020 up to and including 7 July 2021. Twelve areas were selected for this purpose, namely the five cross corridors, the four lying areas with opposing lying boxes, the exercise yard and the feeding areas in the stables and on the exercise yard (Figure 2).

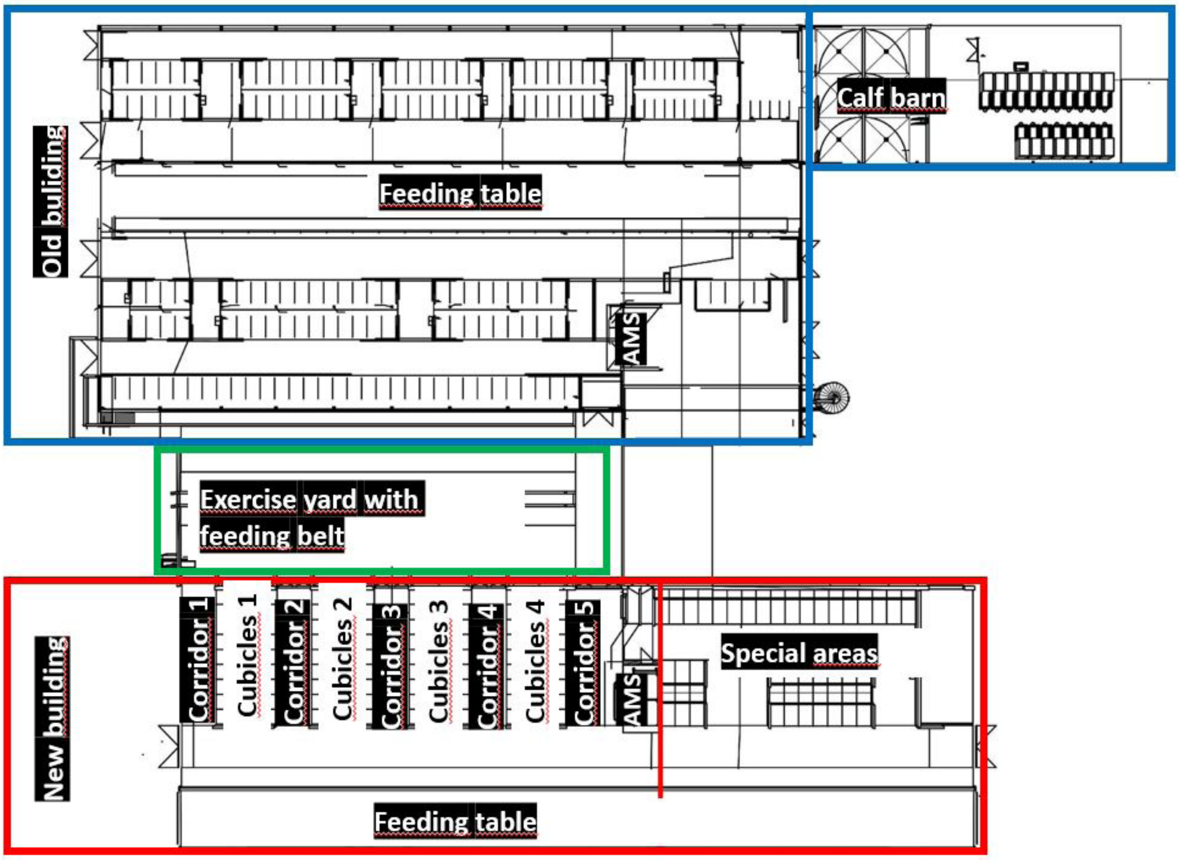

Figure 2: Barn floor plan with old building and attached calf barn (blue), exercise yard (green) and new building with special areas (red); the five corridors and four lying areas (lying areas 1 to 4) are also shown in the new building.

The acceleration sensor integrated into the ear tag recorded acceleration data every second (or every 5 or 10 seconds in the event of data overload) for transmission to a receiver as low-frequency signals (1 Hz). The position is determined according to the principles of Time Difference of Arrival (TDoA) and Angle of Arrival (AoA). The receivers (Smartbow wallpoints) permanently installed in the stables send the data in real time to a local server (Smartbow station). In their study on the validation (four-stage validation) of the Smartbow animal-tracking system, Wolfger et al. (2017) report differences of only 1.22 to 1.80 m between laser measurements and Smartbow data. The present study is based on minute values, which means that animal visits < 1 minute in duration were not recorded. The lactation number and days of lactation were known for each individual animal.

Data analysis

After calving and the resulting higher lactation number, a cow was registered as a new animal in the database. Over the entire study period, this resulted in a total of 97 individual animals in the evaluation file, although the herd only comprised 80 individuals (animals) and there was an average of 65 lactating cows in the observed herd. To calculate the total daily usage time of an area, the recorded minutes of an individual animal were summarised using the pivot function in Excel and divided by the number of days this animal spent in the herd under observation. For daily routines, all usage times in the area under consideration were summarised by time of day and divided by the number of animals registered within the respective hour. Since particular attention is paid to lower-ranking and younger animals with regard to necessary evasive distances in stables (Freiten et al. 2021), analyses were carried out taking parity into account. For this purpose, lactation numbers 1 to 3 were evaluated individually (Lac1 with n = 15, Lac2 with n= 41, Lac3 with n = 13), from the fourth lactation onwards the data were summarised (Lac4+ with n = 28). Because the exercise yard had to be closed due to snow from 9 to 20 January and from 11 to 15 February 2021, there was a period of 17 days without access to the exercise yard. During this time, the geometry of the stall changed, because without access to the yard, the cubicle corridors became dead ends. The study period with access to the exercise yard lasted from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021, and totalled 182 days.

Since the data were not normally distributed (Shapiro–Wilk test), non-parametric tests were used (Wilcoxon test for pairwise comparisons, Friedman test for group analyses) and medians, minimum and maximum values and interquartile range (IQR) were given as measures of dispersion. In multiple pairwise comparisons, the α error correction according to Bonferroni was used to adjust the significance level. The Kendall's Tau test was used for correlation analysis. The distribution of frequencies was analysed using the Chi-square test. The statistical evaluations were carried out using the program R Version 4.2.1 and the package R Commander. $p < 0.05$ was considered significant.

Results

When the animals had access to the exercise yard (wEY), they were recorded there for an average of 74 minutes (min. 7, max. 187 minutes, IQR 45 minutes) per day. In the lying area, the total daily usage time when the animals had access to the exercise yard was 624 minutes per day (min. 81, max. 892 minutes, IQR 133 minutes), whereas when they did not have access to the exercise yard (nEY), it was 678 minutes (min. 214, max. 992 minutes, IQR 127 minutes) and thus there was no difference (Wilcoxon test, p-value = 0.053). The total daily usage time of the corridors was 72 minutes on average with access to the exercise yard (min. 8, max. 163 minutes, IQR 32 minutes) and did not differ from the values without access to the exercise yard of 80 minutes (min. 11, max. 165 minutes, IQR 41 minutes, Wilcoxon test, p-value = 0.065). The time spent in the feeding area of the stables was 214 minutes (min. 22, max. 459 minutes, IQR 79 minutes) with access to an exercise yard, while it was significantly longer (289 minutes, min. 10, max. 577 minutes, IQR 87 minutes, Wilcoxon test, p-value < 0.001) (Figure 3).

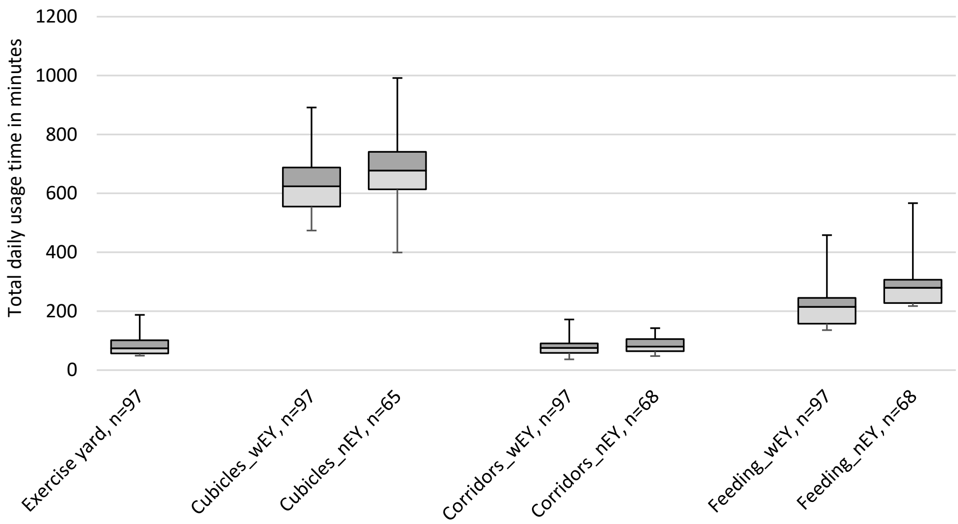

Figure 3: Total usage time of the exercise yard and lying areas, corridors and feeding area in the stables with (wEY) and without (nEY) access to the exercise yard, data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), study period without access to the exercise yard from 9 January to 20 January 2021 and from 11 February to 15 February 2021 (17 days), average herd size 65 animals

Use of the five cubicle corridors

With regard to the use of the five cubicle corridors, the average number of uses per animal and day, the individual length of stay and the total daily usage time per animal and day were of interest. The two situations with (wEY) and without (nEY) access to the exercise yard were taken into account in the analyses. On average, each cow used the cubicle corridors a total of 30.1 (wEY) or 29.0 (nEY) times per day. The cubicle corridor uses increased from corridor 1 to corridor 5, regardless of access to the exercise yard (Kendall's tau test, tau = 1, p-value = 0.017). The total time spent in corridor 5, which also served as a waiting area, was more than twice as long in both cases as in corridor 1 (wEY: 2.3, nEY: 2.1) and about four times as long as in the middle corridors 2 to 4 (wEY: 3.9, nEY: 4.0). On average, the total usage time of the cubicle corridors was 16 % lower for those with access to the exercise yard compared to those without (Table 1).

Table 1: Use of the five cubicle corridors with and without access to the exercise yard, data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), study period without access to the exercise yard from 9 January to 20 January 2021 and from 11 February to 15 February 2021 (17 days), average herd size 65 animals

Parameter	**Specification**	**With exercise yard**					**No exercise yard**				
		Corridor 1	Corridor 2	Corridor 3	Corridor 4	Corridor 5	Corridor 1	Corridor 2	Corridor 3	Corridor 4	Corridor 5
Number of uses	per animal and day	5,4	5,6	5,6	6,7	6,8	5,3	5,2	5,4	6,1	7,1
Length of stay	in minutes	2,4	1,3	1,3	1,3	4,4	3,1	1,8	1,7	1,4	4,9
Total utilisation period	per animal and day	13,2	6,9	7,7	8,3	30,0	16,5	9,3	8,4	8,1	34,5

The individual length of stay in the cubicle corridors was on average 17% shorter with access to the exercise yard than without. The shortest mean length of stay (1.3 minutes) was recorded in corridors 2 to 4 with access to the exercise yard, and the longest (4.9 minutes) in corridor 5 without access to the exercise yard. The dispersion was highest in corridor 1 without access to the exercise yard (IQR wEY/nEY corridor 1: 1.2/2.2 minutes, corridor 2: 0.8/1.1 minutes, corridor 3: 0.8/1.0 minutes, corridor 4: 0.7/1.0 minutes, corridor 5: 1.2/1.3 minutes), with corridor 1 also had the greatest range (range wEY/nEY corridor 1: 7.4/8.6 minutes, corridor 2: 2.9/7.0 minutes, corridor 3: 3.7/5.5 minutes, corridor 4: 4.2/5.4 minutes, corridor 5: 4.0/4.7 minutes) (Figure 4).

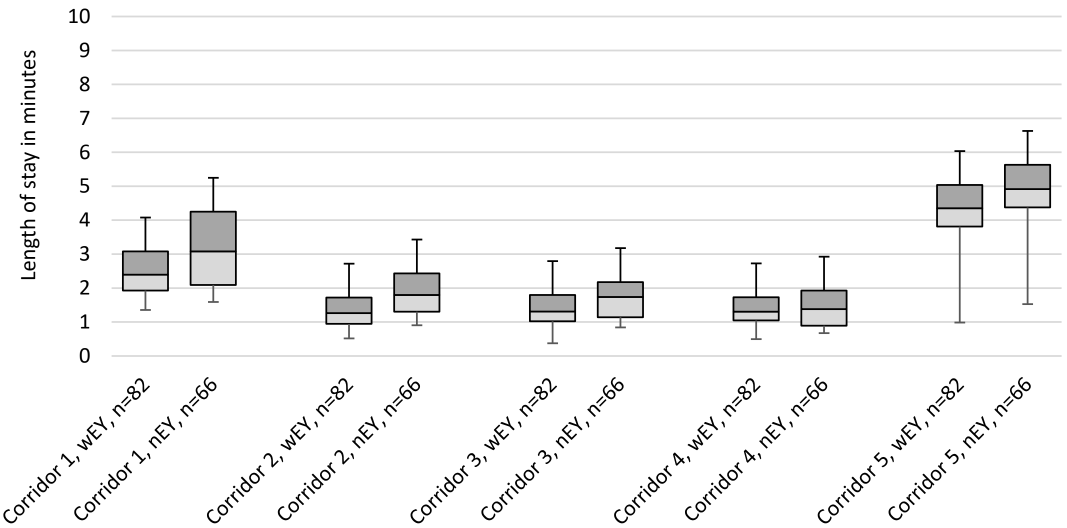

Figure 4: Length of stay in the five cubicle corridors with (wEY) and without access to the exercise yard (nEY), data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), study period without access to the exercise yard from 9 January to 20 January 2021 and from 11 February to 15 February 2021 (17 days), average herd size 65 animals

There were no differences in the number of uses between the situations with and without an exercise yard (Table 2). However, the number of times the cubicle corridor was used did differ between corridors 1, 2 and 3 and corridors 4 and 5 with and without access to the exercise yard. Furthermore, it was shown that the number of times the corridors 4 and 5 were used was significantly higher with access to the exercise yard than for the other corridors. This also applied to the situation without access to the exercise yard, with the exception of corridor 1, which did not differ from corridor 4.

Table 2: Pairwise comparisons of parameters of cubicle use, in the upper third comparison of the situations without an exercise yard and with an exercise yard, in the middle third comparison with access to the exercise yard, in the lower third comparison without access to the exercise yard, Wilcoxon test (significance level according to Bonferroni correction for multiple pairwise comparisons (with and without an exercise yard) p-value < 0.013)

Number of uses						
		with exercise yard (wEY)				
Corridor 1		**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**	
no exercise yard (nEY)	**Corridor 1**	n.s.	n.s.	n.s.	*	*
	Corridor 2		n.s.	n.s.	*	*
	Corridor 3			n.s.	*	*
	Corridor 4				n.s.	n.s.
	Corridor 5					n.s.
with exercise yard (wEY)		**Corri-dor 1**	**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**
Corridor 1			n.s.	n.s.	*	*
Corridor 2				n.s.	*	*
Corridor 3					*	*
Corridor 4						n.s.
no exercise yard (nEY)		**Corri-dor 1**	**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**
Corridor 1			n.s.	n.s.	n.s.	*
Corridor 2				n.s.	*	*
Corridor 3					*	*
Corridor 4						n.s.

Length of stay						
		with exercise yard (wEY)				
Corridor 1 **Corridor 2**		**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**		**Corri-dor 1**
no exercise yard (nEY)	**Corridor 1**	n.s.	*	*	*	*
	Corridor 2		*	*	*	*
	Corridor 3			*	n.s.	*
	Corridor 4				n.s.	*
	Corridor 5					n.s.
with exercise yard (wEY)		**Corri-dor 1**	**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**
Corridor 1			*	*	*	*
Corridor 2				*	*	*
Corridor 3					n.s.	*
Corridor 4						*
no exercise yard (nEY)		**Corri-dor 1**	**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**
Corridor 1			*	*	*	*
Corridor 2				n.s.	*	*
Corridor 3					n.s.	*
Corridor 4						*

Total utilisation period						
		with exercise yard (wEY)				
Corridor 2 **Corridor 3**		**Corri-dor 4**	**Corri-dor 5**			
no exercise yard (nEY)	**Corridor 1**	n.s.	*	*	*	*
	Corridor 2		*	n.s.	n.s.	*
	Corridor 3			n.s.	n.s.	*
	Corridor 4				n.s.	*
	Corridor 5					n.s.
with exercise yard (wEY)		**Corri-dor 1**	**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**
Corridor 1			*	*	*	*
Corridor 2				n.s.	*	*
Corridor 3					*	*
Corridor 4						*
no exercise yard (nEY)		**Corri-dor 1**	**Corri-dor 2**	**Corri-dor 3**	**Corri-dor 4**	**Corri-dor 5**
Corridor 1			*	*	*	*
Corridor 2				n.s.	n.s.	*
Corridor 3					n.s.	*
Corridor 4						*

The analysis of the length of stay showed significant differences with and without access to the exercise yard compared to all other corridors in corridors 2 and 3, where the length of stay increased without access to the exercise yard. Significant differences in the total time of use were found especially in corridors 1 and 5. The time of use with access to the exercise yard was significantly different between the corridors, except for corridors 3 and 4. The total time of use was significantly longer in corridor 1 than in corridors 2, 3 and 4. Corridor 5 had a significantly longer total time of use than all other corridors.

Parity had no influence on the proportions of corridor use, as there was no significant difference between any of the cubicle corridors (chi-square test, df=3, corridor 1: X-squared = 0.286, p-value = 0.963, corridor 2: X-squared = 1.930p-value = 0.58 7, corridor 3: X-squared = 1.167, p-value = 0.761, corridor 4: X-squared = 0.782, p-value = 0.854, corridor 5: X-squared = 0.965, p-value = 0.8098) (Figure 5).

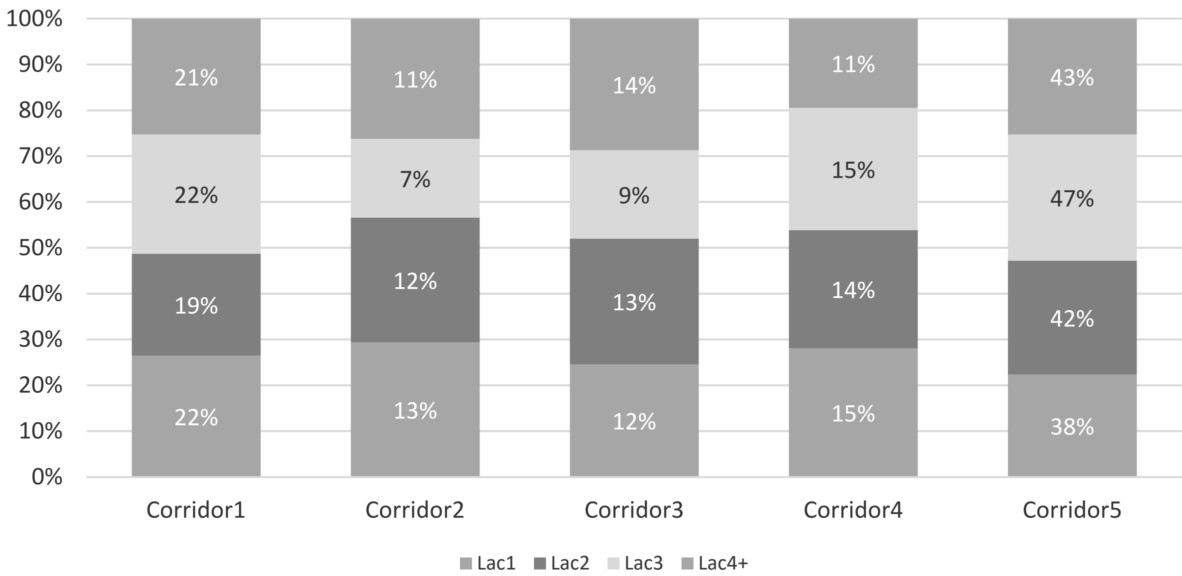

Figure 5: Relative frequency of use of the cubicle corridor by cows of different parities, data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), average herd size 65 animals

Use of the exercise yard

The total daily usage time and the duration of a single stay in the exercise yard were analysed taking into account the animal groups of different parities. There were no differences between the animal groups with regard to the total daily usage time of the exercise yard (Friedman test, p-value = 0.183) (Figure 6).

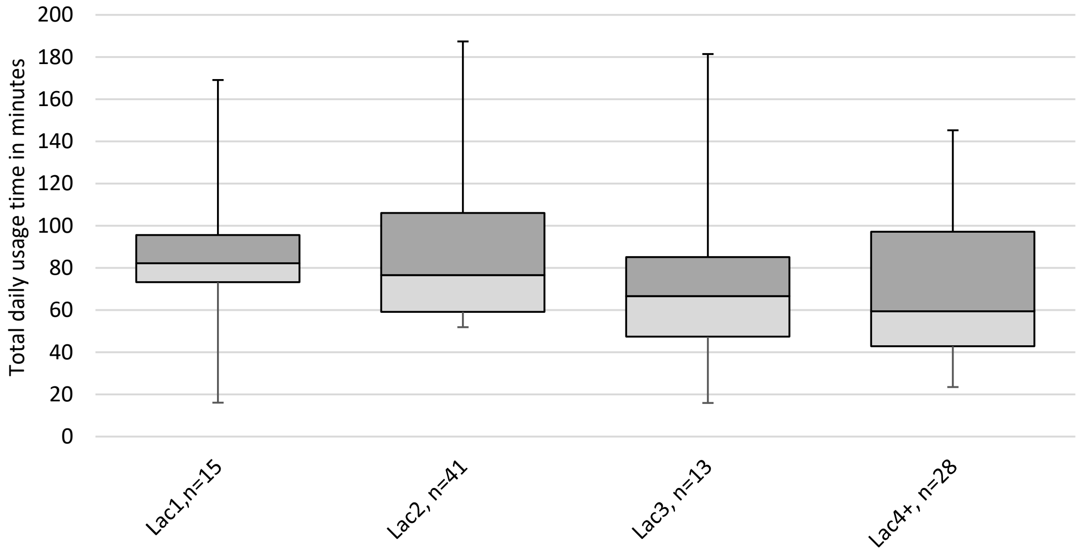

Figure 6: Total daily use of the exercise yard, categorised by parity (lactations 4+ combined from the fourth lactation onwards), data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), average herd size 65 animals

Furthermore, no correlation was found between increasing lactation number and total daily usage time (Kendall's Tau test, p-value = 0.083). It was found, however, that the individual time spent in the exercise yard differed between primiparous cows and cows in their fourth or later lactation (Wilcoxon test, p = 0.005). However, there was no correlation between the increasing number of lactations and the length of stay (Kendall's Tau test, p-value = 0.083). Primiparous cows spent an average of 9.6 minutes in the exercise yard per visit (min. 6.5, max. 16.1 minutes, IQR 4.4 minutes), while the length of stay for cows in their fourth or later lactation was 7.2 minutes on average (min. 3.7, max. 11.7 minutes, IQR 2.8 minutes). The mean duration of stay for cows in their second lactation was 8.6 minutes (min. 2.7, max. 15.1 minutes, IQR 3.7 minutes), while for cows in their third lactation it was 7.8 minutes (min. 5, max. 16.5 minutes, IQR 2.5 minutes) (Figure 7).

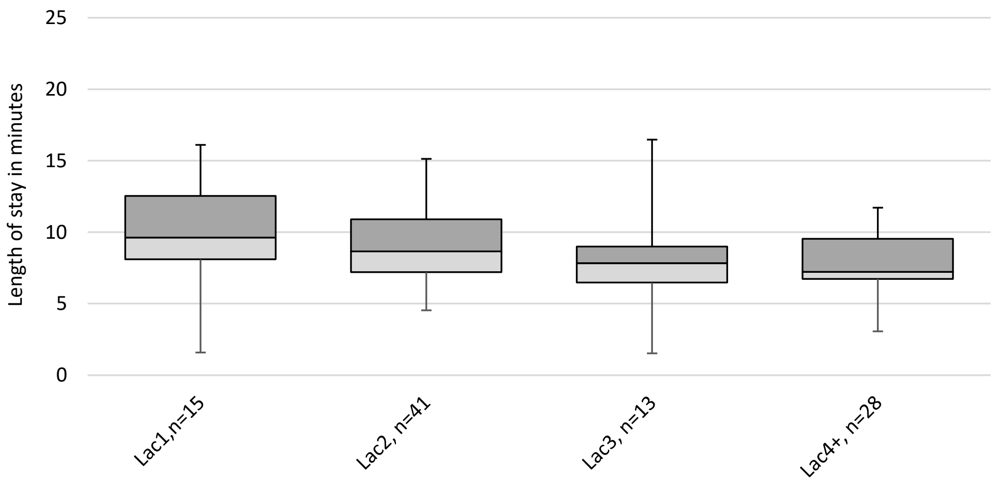

Figure 7: Daily length of stay in the exercise yard, differentiated by parity (summarised as Lac4+ from the fourth lactation onwards), data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), average herd size 65 animals

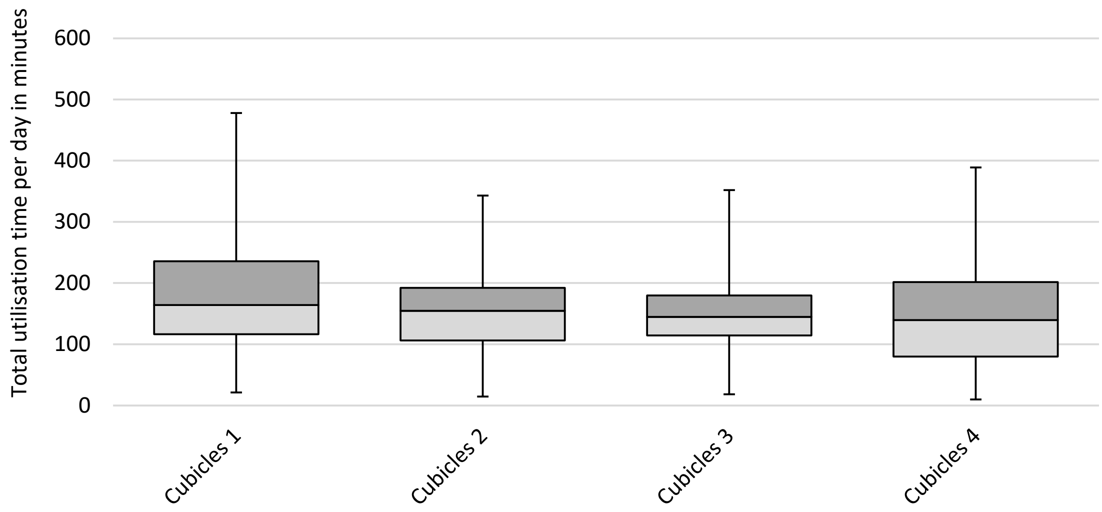

Figure 8: Total daily usage time of the four lying areas with access to the exercise yard, data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), average herd size 65 animals

Use of lying areas

The total lying time in the four lying areas did not differ between the lactation numbers, neither with (Friedman test, p-value = 0.127) (Figure 8) nor without access to the exercise yard (Friedman test, p-value = 0.244). Likewise, pairwise comparison of the total usage time of the individual lying areas between the situations with and without access to the exercise yard showed no differences (Wilcoxon test, lying area 1: p-value = 0.896 , lying area 2: p-value = 0.671, lying area 3: p-value = 0.749, lying area 4: p-value = 0.066).

Within the four lactation categories, the relative frequency of use of the four lying areas was compared. Each group used the four lying areas equally (chi-square test, df = 3, Lac1: X-squared = 1.04, p-value = 0.792; Lac2: X-squared = 0.83, p-value = 0.830, Lac3: X-squared = 0.08, p-value = 0.994, Lac4+: X-squared = 0.60, p-value = 0.897) (Figure 9).

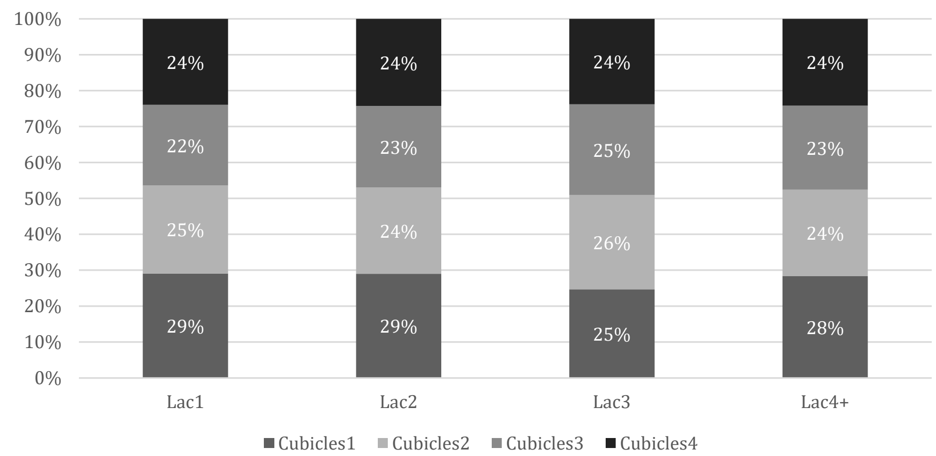

Figure 9: Relative frequency of lying area use, differentiated by parity (summarised into Lac4+ from the fourth lactation), data basis: study period with access to the exercise yard from 25 November 2020 to 5 January 2021 and from 18 February to 7 July 2021 (182 days), average herd size 65 animals

Use of the exercise yard and feeding places in the exercise yard under different climate conditions

In order to assess the potential impact of climatic conditions, two distinct periods with varying external temperatures were examined. The first, spanning a week in March, had an average temperature of 7.4 °C, while the second, spanning a week in June, had an average temperature of 19.4 °C (both measured at 2 p. m). In March, not all the animals in the herd were present in the exercise yard during the seven-day evaluation period. However, a total of 54 animals were observed, while in June, a comparable number, 53, were present. The duration of individual stays recorded within an hour was 7.2 minutes in March (minimum 3.9, maximum 16.1 minutes) and 9.1 minutes in June (minimum 5.9, maximum 13.6 minutes). No significant difference was found between the data sets using the Wilcoxon test (p-value = 0.16). In March, the longest durations of stay in the exercise yard were observed between 10 a.m. and 5 p. m. In contrast, in June, the maximum values were reached between 5 and 8 p.m. and between 10 and At 12 p.m., the maximum length of stay during the day was observed at 3 p. m. in March (16.1 minutes) and at 6 p.m. in June (13.6 minutes) (Figure 10).

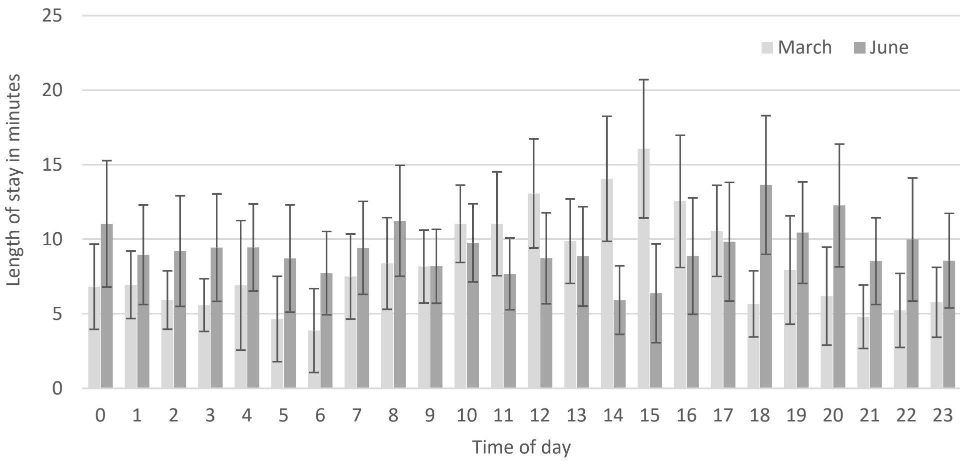

Figure 10: Daily duration of stay in the exercise yard over the course of the day within one week in March and in June, data basis March week 1.3.-7.3.2021 with average temperature (2 p.m.) 7.4 °C, June week 15.6.-21.6.2021 with average temperature (2 p.m.) 19.4 °C, March: 54 cows, June: 53 cows

Discussion

Due to the comb-like barn design, there were five cubicle corridors leading to the exercise yard on the dairy farm, with corridor 5 also serving as a waiting and exit area from the AMS. This explains the significantly longer total usage time of corridor 5. However, corridor 1 was also used for longer than the corridors in between. Corridor 1 was located at the edge of the stable and served as access to only one row of cubicles in lying area 1, although it was not possible to analyse which cubicle corridor was used for lying area 1. Since this lying area was not used more than lying areas 2 and 3, the cows either used corridor 1 more often to access the exercise yard or to get a good overview of the barn (retreat area), which resulted in the higher lengths of stay. Corridors 2, 3 and 4 each offered access to cubicles on both sides. Without access to the exercise yard, the animals did not use the corridors less often. The parameters for the use of cubicle corridors, when the corridors became dead ends due to the temporary closure of the exercise yard, changed only slightly. It can therefore be assumed that these corridors were mainly used to reach the cubicles. This is also supported by the fact that the total time spent in the lying areas remained unchanged with and without access to the exercise yard. The cubicles on the farm in the study were designed as elevated cubicles with comfortable rubber mats and promised a high level of comfort (Weary et al. 2000, Tucker et al. 2003, Tucker et al. 2019), so that unrestricted use can be assumed. However, it was noticeable that the range of lengths of stay in the corridors without access to the exercise yard was wider in corridors 1 to 4 than in those with access to the exercise yard. Presumably, the temporary dead ends were not very restrictive overall and offered sufficient alternative options because, at 3 metres wide, they exceeded the minimum requirement of 2.5 metres (Landesrecht BW 2023) and were thus generously dimensioned. It should also be noted that all walking areas in the stables were equipped with rubber flooring, which provides the animals with a non-slip and at the same time hoof-friendly surface and also makes turning easier (Benz 2002). Even with only two-metre-wide walkways with dead ends, a deformable rubber flooring in a comb-type stable resulted in comparable animal activity to that in a two-row stable (Benz 2002). The Managementhilfe Q-Wohl-BW (Benz et al. 2021) also suggests rubber mats to compensate for limited dimensions in the stable.

The frequency of corridor use increased with increasing proximity to the AMS. Corridor 5, which also served as a waiting area for the AMS, was used most intensively. It was not relevant which parity the cows were in when using the corridors. It was therefore not the case, for example, that lower-ranking cows favoured a particular corridor. Due to the need to minimise polluted areas in cattle stables in order to protect emissions and maintain animal welfare (Umweltbundesamt 2021), this study raises the question of whether corridor widths in comb-type stables could be reviewed and adapted. This question could be investigated under controlled conditions in further studies. This is supported by the fact that the geometry of the comb-style stable could become more important in the future, because the structural and technical implementation will be easier due to flexible mobile manure removal technology (Itkin 2010) and automatic milking.

With an average of 74 minutes of total daily use of the exercise yard, the values were slightly higher than the daily residence time determined by Schrade et al. (2020) on attached exercise yards. However, it should be taken into account that there was a feed supply, so that the exercise yard design is similar to an integrated exercise yard, which is used more intensively (Schrade et al. 2020) because a functional area is integrated. However, it was noticeable that the exercise yard was used longer per stay by primiparous cows than by cows in at least their fourth lactation. One possible explanation for this could be that the exercise yard offered a good overview and escape routes and therefore cows of lower parity spent more time there. However, the total utilisation time of the primiparous cows was not significantly higher. This would be obvious, as primiparous cows have a larger time budget available due to the shorter lying times after integration (Hut et al. 2022) and need an escape route (Frieten et al. 2021).

Not all cows in the herd used the exercise yard during the two weeks in March and June, but only about 85 % of the herd. This aspect could not be analysed in depth, but could be the subject of further research with animal-specific recording of exercise yard use. The higher outside temperatures in June would have led us to expect a lower level of exercise yard utilisation than in March, but the opposite was actually the case. There may have been some shading of the exercise yard, which was sheltered between the old and new stables. In March, roughly in line with Caenegem et al. (2017), the maximum use of the exercise yard took place between 9:00 and 16:00 or 18:00.

Conclusions

A comb-type stable offers the possibility of creating several access points to an adjoining exercise yard, depending on the number of corridors. The outer of five corridors at the edge was used somewhat less frequently in the study presented, but with longer stays in each case, resulting in a total utilisation time that was about twice as long. However, the different corridor usages had no effect on the utilisation of the four lying areas. The temporary closure of the exercise yard with the resulting dead ends only slightly changed the animal behaviour. In order to improve housing systems with regard to current animal welfare and environmental protection requirements, it would appear to make sense to further investigate alley widths in comb-type stables.

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