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Calf or grass – What would the cow choose?

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ABSTRACT

The growing interest for keeping dairy cows with their calves for an extended period after calving is putting pressure on the scientific community to investigate the effects of cow-calf contact systems on the animals' welfare. The main aims of this study were to investigate the dairy cows' motivation for accessing their calves over a fresh pasture, and to evaluate if their motivation decreased with increasing calf age. Twenty-two Swedish Red and Swedish Holstein cow-calf pairs were enrolled at calving. The dams were housed in a robotic barn with free access to outdoor pasture, where the calves were kept during pasture season. The behaviours of the dams were recorded on three separate test days occurring every two weeks, starting when the calves were on average 10 weeks old. During test days, the calves were confined to a heavily grazed area, while the dams had free access both to the calf area and to an adjacent fresh pasture. Which of the areas the dams entered first upon returning outdoors from the barn, and what behaviours they performed in which area were registered using 10-min scan sampling during 8 h per day. The dams spent more time outdoors on Test day I (76.8±3.09%; LSMeans±SEM) compared to Day II (60.9±3.86%; P=0.006), while Day III (66.8±4.38%) did not differ from Day I (P=0.15) or Day II (P=0.55). On Test day II, they chose the calf area 54±10.05% of the times they returned to pasture, which was significantly more often than during Day I (18.2±4.96%; P=0.01), while no difference was found between Day III (37.1±9.86%) and Day I (P=0.17) or Day II (P=0.5). There was no effect of breed on total time spent outdoors, but Holstein dams tended to spend more outdoor time in the calf area (36.4±5.28%) than Swedish Red dams (24.2±3.95%; P=0.09). Upon returning outdoors, Holstein dams also chose the calf area over fresh pasture more often (46.0±7.19%) than did Swedish Red dams (25.2±6.21%; P=0.05). Primiparous cows tended to choose the calf area over fresh pasture more often (46.9±6.11%) than multiparous cows (24.5±7.25%; P=0.06). Exploratory analyses suggest that the effects of test day were more affected by the ambient weather than by the age of the calves. The study results provide some further information about factors influencing maternal motivation to reunite with their calves on pasture. However, further research is needed so that cow-calf contact systems can be designed to enable good welfare.

1. Introduction

In modern dairy farming it is common to separate cow and calf within the first 24 h of birth, after which the calves generally are housed individually during at least a part of the milk feeding period. However, previous research has shown low support for early separation among the public in multiple countries (e.g. Canada and United States, Ventura et al., 2013; Germany and United States, Busch et al., 2017; Brazil, Cardoso et al., 2017). Additionally, in Europe a recent citizen initiative opposing individual housing of dairy calves has resulted in an on-going revision of the relevant EU legislation by the European Commission (European Commission, 2021). One potential calf rearing practice that addresses both these societal concerns is keeping dairy calves together with their dams for an extended period after calving. A recent survey study identified that some dairy farms are already practicing cow-calf contact (**CCC**) in multiple European countries (Eriksson et al., 2022), and in Germany products from CCC farms are now commercially marketed under labels specifying ≥90 days cow-calf contact (Interessengemeinschaft kuhgebundene Kälberaufzucht, 2022). Since the number of farms using CCC systems is likely to increase, there is an urgent need to investigate the effects of CCC systems on animal health, welfare and production. The aims should be to ensure good welfare for

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dairy cows and calves, while at the same time addressing societal concerns and economic feasibility for farmers.

Inability of modern dairy cows to successfully care for their offspring has been raised as a concern by conventional farmers asked about their opinion of CCC (Neave et al., 2022). However, so far little research has evaluated how motivated modern dairy cows are to gain access to their calves, although one seminal paper reported that dairy cows bonded with their calf were willing to push more weight to gain access to their calves than cows that were separated from their calves directly after birth (Wenker et al., 2020). Contact with the calf and access to production pasture are non-substitute resources (*i.e.*, they do not satisfy the same behavioural need); however, choice tests can be used to assess the strength of motivation also when comparing non-substitute resources (Kirkden and Pajor, 2006). As pasture access has been shown to be a highly valuable resource for dairy cows (Charlton et al., 2013; von Keyserlingk et al., 2017), it constitutes a suitable comparator when evaluating the motivation of dairy cows. To our knowledge, there is no previously published work comparing dams' motivation for accessing their calves vs. accessing pasture.

The main aims of this study were to evaluate the dams' motivation for accessing their calves, and to assess if this motivation changed as the calves grew older. This was done by giving the dams a choice upon returning outdoors from a robotic milking barn, either to enter a heavily grazed area where their calves were housed or enter an adjacent fresh grass-clover pasture without the calves. Little is known about the time budgets of dams of dairy breed kept with calves on pasture. As such, secondary aims were to evaluate how the dam's outdoor time budgets regarding important behaviours (standing, grazing and lying) were affected over time, and to explore if there were differences in which behaviours the dams performed in the two different outdoor areas.

2. Material and methods

2.1. Animals

This study was carried out as part of a larger research project at the

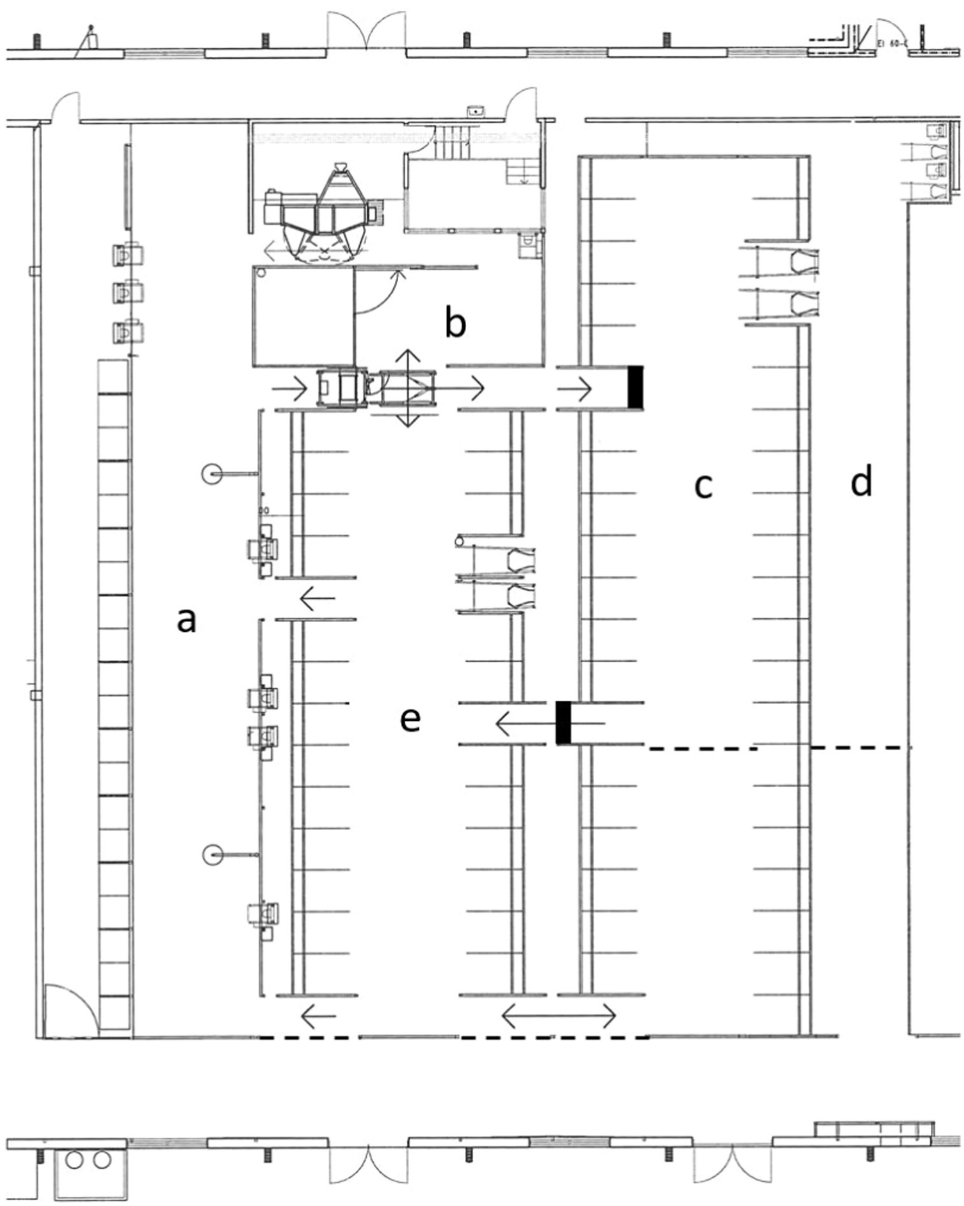

Fig. 1. The indoor robotic barn used in the study. Arrows indicate the direction of cow traffic in the barn during the indoor period, while the dashed lines represent permanently closed gates and the thick solid lines represent spring-loaded one-way gates that the dams, but not the calves, could pass. The different areas in the barn is represented with letters, where a=feeding area, b=waiting area for milking, c=contact area for dams and calves, d=calf-creep, and e=separate resting area.

Swedish Livestock Research Centre, Uppsala, Sweden. All procedures involving animals were approved by Uppsala research animal ethical committee (ID-No: 5.8.18–18138/2019). The animals were housed and cared for according to the Swedish legislation concerning cattle husbandry (SJVFS, 2019:18).

Cows pregnant with pure-bred dairy calves were enrolled at calving during a period of six weeks, between March 1 and April 15, 2020. The enrolment period was chosen to avoid large spread in calf age, in order to reduce the risk of disease transmission between calves of different age. At the end of the enrolment period, 21 dams and their offspring (17 heifer and 4 bull calves), as well as one Swedish Holstein (**SH**) foster cow with a Swedish Red (**SR**) heifer calf were included in the study. The approximately 24-hour old foster calf was introduced to the foster cow (inseminated with beef semen) within minutes after the cow had calved and her own calf had been removed. In total, 11 SH (4 primiparous, 7 multiparous) and 11 SR (8 primiparous, 3 multiparous) dams, corresponding to 10 SH and 12 SR calves were included in the study.

2.2. Housing and management

From the day when the bonded pairs left the calving pen and until May 13 the dams and their calves were kept together indoors in an automated milking system (**AMS**; Fig. 1). From May 14, when the calves were 7.6 (1.4) weeks old, the dams were allowed to walk freely between the pasture and the AMS, while the calves were housed permanently on pasture. The calves were weaned using nose-flaps on July 6, after which they were separated from the dams but kept on an adjacent pasture from July 20 to August 19, 2020.

2.2.1. Calving period

A few days before calving, dams were moved from a dry cow group box to individual calving pens from which they could see other periparturient cows. Following calving, a Brix refractometer (Pocket Refractometer PAL-1, ATAGO CO. Ltd, Tokyo, Japan) was used to determine the quality of the colostrum. If the dam had good quality colostrum (Brix values >20%), the calf was left to suckle colostrum from the dam. For dams with low quality colostrum (Brix values ≤20%), the calves were offered 3 litre of thawed good quality colostrum from a colostrum bank (n=2). The foster calf was manually fed colostrum from her own dam with a teat bottle, as the conformation of the udder interfered with suckling. The dams were milked for the first time ≤12 h of calving, but only a small amount (<2 L) was extracted to ensure that colostrum was available for the calf. Following the first milking, the dams were milked fully twice daily at approximately 5:00 and 15:30.

Dam-calf pairs were kept in the calving pen for 2.8 (0.8) days after calving, after which the dam and the calf were walked together from the calving pen to the cow-calf contact area in the AMS (Fig. 1). Once they had entered the contact area, the pairs were left to adapt to their new surroundings for a few hours. On April 17, all pairs had been moved into the AMS from the calving pens.

2.2.2. Indoor period

The indoor housing consisted of loose housing in an insulated barn with forced cow traffic AMS, where cows had to pass the feeding area before accessing the milking unit (DeLaval Feed First™; DeLaval VMS™, DeLaval International AB, Tumba, Sweden).

Within the AMS, the dams could move between the contact area where they could rest and meet their calves, a resting area separate from the calves, the feeding area and the milking unit (Fig. 1). While there were other cows housed in the AMS, they did not have access to the contact area and hence no direct contact with the calves. A selection gate (DeLaval Smart Selection Gate SSG, DeLaval International AB, Tumba, Sweden) located by the milking unit directed the enrolled dams to the contact area, while the other cows were directed into the separate resting area when exiting the feed alley. In the contact area, the dams could nurse, socially interact and rest together with their calves. The calves had access to the contact area and an adjacent calf-creep not accessible to the dams.

Dams could leave the contact area and enter the separate resting area at will, through a spring-loaded gate that the calves could not push through (Segregation Gate FeedSelect, GEA Farm Technologies GmbH, Bönen, Germany). In both the contact area and the separate resting area, the dams had access to cubicles equipped with rubber mattresses (M40R, DeLaval International AB, Tumba, Sweden), which were covered with a thin layer of wood shavings. Bedding was refreshed four to six times per day in all stalls to ensure a dry lying surface. From the separate resting area, all cows (both dams and other cows) could enter the feeding area through one-way gates. In the feeding area, they had access to roughage in twenty feed bins (stocking rate three cows per bin), water in seven water-cups, and two cow brushes. The feeding area had rubber flooring, while all other walkways were concrete.

Access to the milking unit was granted 8 h after the previous milking event; the selection gate then directed the dams into the waiting area in front of the milking robot. If the dams had not been milked for ≥18 h farm staff fetched the cows and brought them to the waiting area. The dams had access to water while standing in the waiting area, and when milking was completed they were released back into the feeding area.

2.2.3. Outdoor period

The animals were kept on grass-clover pastures when outdoors, separated by 3-wire electric fencing. The calves had access to a 190 m^2 fenced calf-creep area at all times, where they could rest, drink water from a self-filling water trough (2.0 m length) and eat concentrate from a common feed through (1.5 m length) separate from the dams. The calf-creep also contained a roofed shelter (48 m^2; PLAYMEK mobilt vindskydd, PLAYMEK, Röke, Sweden), which provided shade, a straw-bedded open lying surface and protection against harsh weather (Fig. 2).

The dams accessed the pastures via a selection gate (DeLaval Smart Selection Gate SSG, DeLaval International AB, Tumba, Sweden) located just outside the barn and a one-way spring-loaded gate (Segregation Gate FeedSelect, GEA Farm Technologies GmbH, Bönen, Germany) at the entrance to the pastures, approximately 270 m from the selection gate. The walkway was wide enough for two cows to meet and covered in finely crushed stone; heavily used parts of the walkway were covered with rubber mats. To return to the barn, the dams exited the pastures through a second spring-loaded gate and passed a one-way gate located adjacent to the selection gate by the barn. When entering the barn from pasture, the dams were first directed to the feeding area, and dams with milking permit were directed to the milking robot before they could access the resting area. After milking, the dams could choose to remain indoors or leave the barn and go back outside through the resting area at any time. Cows housed in the AMS but not enrolled in the study could also exit the building through the resting area but were directed to another pasture when passing through the outdoor selection gate and hence had no direct contact with the calves.

During the pasture season, the enrolled dams rotated between four pastures (A, B, C and D; Fig. 2). Pasture A, B and C could be accessed by both dams and calves, while pasture D was only accessible to the dams. A smaller area of pasture B (approx. 2 100 m^2) was always accessible for all animals. From this area, dams and calves could enter the available pasture (A, B or C); only one of the bigger pastures were accessible at any given time. Dams and calves spent on average 4 (1.2) days on each pasture before being moved to another, to ensure access to fresh pasture during the grazing period. Both dams and calves had access to all parts of the available pasture area, except the calf-creep to which only the calves had access. When dams had access to pasture D, the calves were kept in the smaller area of pasture B (the calf area), with no access to the larger pastures.

The dams did not have access to water on any of the pastures; however, they could drink from a self-filling water trough (2.0 m length) in the walkway directly outside pasture A (Fig. 2). Dams with ≥18 h since last milking were fetched for milking by farm staff between

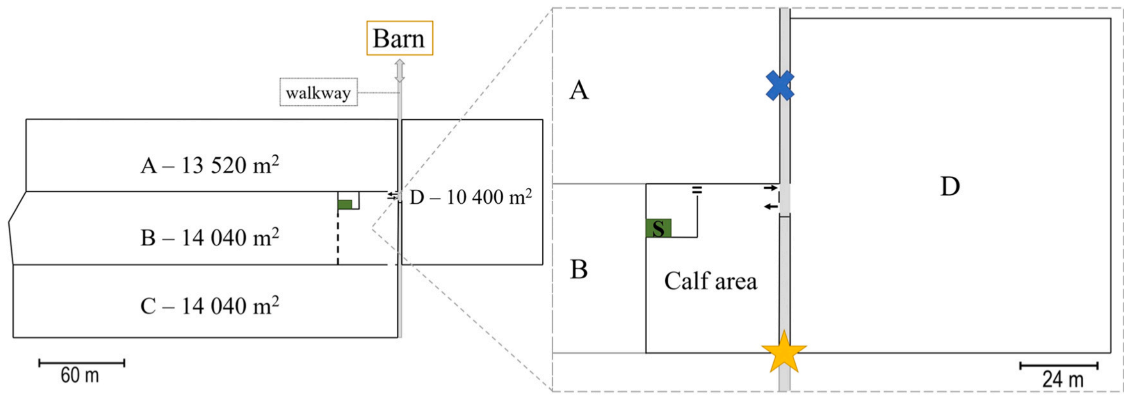

Fig. 2. Schematic illustration of the pasture areas and the walkway to the robotic barn. The dam-calf pairs were routinely rotated between three pasture areas (pasture A, B, C) during the summer, with full cow-calf contact on pasture. During our test days, the dams were instead offered pasture D, while the calves were kept on a smaller part of pasture B (enlarged section). The dams could enter either area at will, and hence needed to choose which area to enter first upon returning voluntary from the barn. ← → = spring-loaded gate and direction of opening, ═ = entrance to calf creep, S = shelter, ☆ = observer position, **X** = water trough.

05:00–06:00, 12:00–13:00 and 18:00–19:00 h. Dam-calf pairs were kept together on pasture until July 20, when the calves were 17.2 (1.4) weeks old. Weaning started two weeks earlier, when the calves were fitted with nose-flaps (QuietWean, JDA Livestock Innovations Ltd., Saskatoon, Canada) to prevent suckling.

2.3. Diet

In the indoor feeding area, the cows had access to feed bins measuring feed intake for each individual and visit (BioControl's CRFI, BioControl AS, Rakkestad, Norway). Fresh roughage was delivered four times per day (Distribution wagon FS1600, DeLaval International AB, Tumba, Sweden), during both the indoor and outdoor period. All cows could eat from all bins; however, one bin could only be accessed by one cow at a time.

During the indoor period, the dams were fed a roughage mix consisting of grass-clover and corn silage *ad libitum*. During the outdoor period, cows were fed a mix with varying proportions of grass-clover silage, corn silage and straw *ad libitum* (Table 1). Cows were also offered a mix of commercial pelleted concentrate (Komplett Norm 180, Konkret Mega 28; Lantmännen Lantbruk & Maskin, Malmö, Sweden) tailored to their individual expected daily milk yield; expected milk yield was based on the herd average milk yield for each individual's breed and parity. Maximum two kg concentrate per visit were offered in the robot at milking, while the rest was distributed in automated feeders (FSC400, DeLaval International AB, Tumba, Sweden) located in the contact area and the separate resting area. During the outdoor period, a rotational grazing strategy was implemented with the aim to provide *ad libitum* dry matter of fresh grass-clover pasture.

During the indoor period, calves had *ad libitum* access to grass-clover silage, hay and water in the calf-creep. The calves were also fed commercial pelleted calf concentrate (Idol, Lantmännen Lantbruk & Maskin, Malmö, Sweden) from two concentrate feeders (Concentrate station calves, DeLaval International AB, Tumba, Sweden) located in the calf-creep. Individual concentrate intake continued to be low during the indoor period; during the week before pasture release, the calves consumed on average 0.1 (0.5) kg concentrate per calf and day. During the outdoor period, calves had access to grass-clover pasture, commercial concentrate (Idol; Ideal, Lantmännen Lantbruk & Maskin, Malmö, Sweden) and water.

2.4. Experimental set-up

To investigate the dams' motivation for accessing their calves, pasture D (Fig. 2; enlarged section) was presented as an alternative resource on three occasions during the period dams and calves were kept together on pasture (outdoor period). Pasture D was not grazed prior to the first period and was let to regrow for 9–10 days between each period. During the three periods [each 4 (1.7) days long], dams were required to choose between access to pasture D, on the on the left side of the walkway, or the calf area, on the right side of walkway, upon returning from the barn. To enter the calf area, the dams had to walk through spring-loaded gates, while entry to pasture D was unrestricted. The spring-loaded gates were necessary, as they retained the calves on pasture whilst allowing the dams to walk freely between the barn and the outdoor areas.

2.5. Behavioural measurements

Behaviours were registered on June 3 (Test day I), June 20 (Test day II) and July 3 (Test day III) using direct observations. Test day I occurred 20 days after the start of the outdoor period, which meant that the calf area was heavily grazed already at the first test day. Behavioural registrations were always conducted on the second day the dams had access to pasture D, to reduce the risk of confounding the effect of fresh pasture with the effect of access to a novel area. Average calf age at each test day were 10.4 (1.4), 12.9 (1.4) and 14.7 (1.4) weeks, respectively.

Observations were performed for 8 h per day, spread out over five blocks (07:00–09:00, 10:00–12:00, 14:00–16:00, 17:00–18:00 and 19:00–20:00) during 13 h of the light period. Registrations were made

Table 1
Composition, nutritional properties and average individual dry matter intake of the roughage provided to the cows on each of the three days when behavioural observations occurred.

Day	DMg/*kg*	Proteing/*kg DM*	aNDFomg/*kg DM*	ME*MJ/kg DM*	G-C%	Corn%	Straw%	DMI*kg*
1	391	127	49	10.8	75	25	0	3.1
2	352	178	45	11.2	100	0	0	4.9
3	358	168	57	11.1	98	0	2	5.8

DM=Dry matter, aNDFom=amylase treated Neutral Detergent Fiber reported on an organic matter basis, ME=Metabolizable energy, G-C=Grass-clover silage, Corn=corn silage, DMI=dry matter intake by one of two observers (observer 1 on Test day I and III and observer 2 on Test day II), which were both well acquainted with the animals. The two observers jointly developed the ethogram (Table 2) and the protocol used for behavioural registrations (Supplementary Material 1); due to time constraints, inter- and intra-observer reliability was not evaluated. However, the behaviours registered were easy to observe, reducing the risk of poor between-observer agreement. Also, the animals were very familiar with both observers, reducing the risk that potential differences between test days were due to observer effects.

Behaviours were recorded using 10-min scan sampling, yielding 48 scans per cow and day. The dams were identified based on their size, coat colour and pattern, and by plastic tags (Sifferplatta, DeLaval International AB, Tumba, Sweden) attached to their collars showing their ear tag number. At every scan, the location (calf area or pasture D), and behaviour (grazing, standing, or lying) were registered. If the dam was not present outdoors, this was noted as "Out of sight". During behaviour recording, the observers was positioned in a chair in the walkway between the calf area and pasture D, as far away as possible from the gates for respective area (Fig. 2). The observers brought out equipment needed for observations (chair, protocols and binoculars) and settled in this area ≥10 min prior to the registrations started in the mornings, to reduce the risk that the dams' behaviours were affected by their presence. Between observation blocks, the observers left the outdoor area, but the equipment was left on site until the observations ended for the day.

2.6. Temperature Humidity Index

For each test day, air temperature (°Celsius) and relative humidity (**RH**) were recorded by a weather station located approximately 100 m from the pastures (LantMet, 2021). Temperature Humidity Index (**THI**) was calculated using the formula (NOAA, 1976):

$$\mathrm{THI} = {}^{\circ}\,\mathrm{Fahrenheit} - [0.55 \times (1 - \mathrm{RH})] \times ({}^{\circ}\mathrm{Fahrenheit} - 58)$$

Air temperature in °Celsius was converted to °Fahrenheit according to the formula:

$$^{\circ}\mathrm{Fahrenheit} = [^{\circ}\mathrm{Celsius} \times (9/5)] + 32$$

2.7. Statistical analysis

2.7.1. Data handling

Due to a technical error, two scans (10:40 and 10:50) are missing for all dams on Test day I. Ten cow-days (n=3 on Test day II; n=7 on Test day III) were removed from the data set, as some calves over time learned how to exit the calf area through the spring-loaded gates. As these calves could join their dams on pasture D this likely affected which area the dams were most motivated to enter upon returning outdoors, as well as their outdoor time budgets. One additional cow-day was excluded on Test day III, as one cow-calf pair was housed in an indoor sick pen while the dam was treated for interdigital phlegmon.

The proportion of time the dams spent outdoors per test day was calculated by dividing the number of observations when the dam was not Out of sight with the total number of possible observations per cow and day. The proportion of outdoor time spent in the calf area was calculated by dividing the number of observations the dams were located in the calf area with the number of observations the cows were not Out of sight per cow and day. The same strategy was used to calculate the proportion of outdoor time spent grazing and lying, respectively.

Dams were considering choosing to access the calf area first if they were registered as being in the calf area during the first or second scan after returning outdoors. This choice was made as the dams frequently spent some time drinking water outside pasture A (so they were not registered as being Out of sight) before they entered either the calf area or pasture D. The proportion of time that the dams chose the calf area over fresh pasture was then calculated by dividing the number of cow-occasions the dams entered the calf area first with the number of times they returned outdoors from the barn, per dam and test day. For dams that were already present outdoors in the beginning of an observation block, no assumption was made about what area they had entered first.

2.7.2. Statistical procedure

The probability of dams choosing to enter the calf area first upon returning outdoors was estimated by calculating the odds ratio using Proc Glimmix in SAS (SAS 9.4, SAS Institute Inc., Cary, NC, USA) with a binary data distribution and the logit link function:

$$[g(p) = \log(p/(1-p))]$$

The outcome variables proportion of observations spent outdoors and the proportion of outside observations lying down were displaying a beta distribution, while the proportion of outdoor observations spent in the calf area was displaying a gamma distribution. The proportion of observations where dams choose the calf area over fresh pasture when arriving outdoors was displaying a binary distribution. Outcome distributions were assessed visually. These outcomes were therefore analysed with generalized linear mixed models using Proc Glimmix and the log link function. As the data on proportion of observations spent grazing was normally distributed, this outcome was analysed with a generalized linear mixed model using the Proc Glimmix with a Gaussian data distribution and the identity link function.

The variable test day was used as a proxy for calf age, aligning with the study design (at each test day there was a spread in calf ages, but the increase in age between the test days was the same for all calves). Parity (parity 1 vs. 2+) and breed (SR vs. SH) were included as covariates in all models, as these factors have been suggested to influence maternal behaviours in previous research (e.g. Edwards and Broom, 1982; Loberg and Lidfors, 2001). Heterogeneity was assumed, and dam considered random effect with a first-order autoregressive covariance structure. All two-way interactions (test day×parity; test day×breed, parity×breed) were tested and excluded using stepwise backwards elimination (P>0.10). The fit of the models was evaluated by checking Generalized Chi-Square/DF and by visual inspection of the residual plots. As one of the cow-calf pair was a foster pair all analyses were run both with and without this pair. As no substantial effects on the model outputs was identified, the pair was retained in the final models.

As the weather differed between test days, average THI during the hours we observed behaviours were added as a fixed effect in exploratory models for all outcomes. These exploratory models identified signs of multicollinearity between the variables test day and THI (substantially changed estimates and increased standard errors for test day in all models), while the estimates for breed and parity were largely unaffected (Supplementary Material 2). These findings suggest that the effects of test day largely depended on the weather, rather than on the age of the calves. However, as our *a priori* hypothesis was related to the effect of calf age on the dams ́motivation to reunite with their offspring, models including test day, parity and breed will be reported below.

The results of the mixed models are presented are least squares means and standard error of means unless otherwise stated. Results were

Table 2
Behaviour definitions used in the study.

Behaviour	Description of behaviour
Grazing	Dam has the muzzle close to the ground and is performing ripping motions with the head or is chewing forage[1]
Standing	Dam standing upright with at least 3 legs on the ground[1], or in locomotion (*i.e.* walking or running)
Lying	The abdominal wall of the dam is touching the ground, with all four legs folded under the body or stretched out to the side
Out of sight	Dam is not in the calf area or on pasture D

[1] Description adapted from Pereira et al. (2020)

declared significant at P<0.05, while a tendency was assumed for probabilities P<0.1 and P≥0.05. Post hoc analyses for significant pairwise comparisons were performed using Tukey HSD tests.

3. Results

3.1. Time spent outdoors, in the calf area, grazing and lying down

Average THI differed between test days, with THI 64.8 (0.49), 73.2 (0.28) and 65.1 (0.69) for Test day I, II and III, respectively. Descriptive results showed that while all cows went outdoors on all test days for which they had pasture access (one cow was housed in an indoor sick pen with her calf on Test day III), the number of cows that were observed in the calf area differed between days. During Test day I five cows were never observed in the calf area, while the same was true for four cows during Test day III. During Test day II, all cows spent at least some time in the calf area. All cows were seen in the calf area on at least one test day, and 13 cows spent some time in the calf area on all three days. At 13.4% of the scans there was only one cow present in the calf area, with the scans (n = 142) divided between 10 different cows. On no occasion were the calves alone outdoors. At 90.1% of the scans there were dams present both in the calf area and in pasture D, while at 1.4% and 8.5% they were only present in the calf area and the pasture, respectively.

We found an effect of test day on the total time the dams spent outdoors, with the highest proportion of time outdoors on Test day I, and the lowest proportion on the hottest test day (Day II; Table 3). However, neither breed nor parity had an effect on the total time the dams were spending outdoors. Even though the total duration of time spent outdoors differed between test days, there was no differences between days in the proportion of outdoor time spent in the calf area; there was also no effect of parity on this outcome (Table 3). Interestingly, even though dams of both breeds generally spent more time on pasture D than in the calf area, SH dams tended to spend more time in the calf area compared to SR dams (Table 3). The dams spent significantly less time lying down outdoors on Test day II compared to Test day I (Table 3). In addition, test day tended to affect the time spent grazing, with the numerically highest value on Test day II (Table 3). Neither breed nor parity affected the time dams spent lying down or grazing when outdoors (Table 3).

Exploration of what behaviours (grazing, lying and standing) were performed in which area (calf area vs. pasture D) per observation hour and day are illustrated in Fig. 3. Most of observed grazing occurred on the pasture D, while the dams spent somewhat more time standing or walking in the calf area.

3.2. Choosing calf area over access to fresh pasture

As observations were divided into five blocks per test day, not all cows that spent time outdoors were observed returning from the barn, so which area they entered first could not be determined. The evaluation of which area the dams entered first was therefore based on 20 occasions performed by 16 cows for Test day I, while the corresponding values were 15 occasions and 12 cows for Test day II and 16 occasions and 12 cows on Test day III. For any one test day, no cow was observed entering the outdoor area more than two times.

For Test day II, the dams chose the calf area 54±10.1% (LSMeans ±SEM) of the times they returned outdoors, which was significantly more often than on Test day I (Table 3). This was in agreement with the results of the logistic regression, which showed lower odds for the dams choosing to enter the calf area first on Test day I compared to Test day II (Table 4). Overall, the SR dams choose the calf area 25±6.2% of the times they returned outdoors, which was significantly less often than SH dams (46±7.2%; Table 3). There were also lower odds for the SR dams to choose the calf area over fresh pasture compared to SH dams (Table 4). Primiparous dams tended to enter the calf area first more often upon returning outdoors, compared to multiparous dams (Table 3).

4. Discussion

To our knowledge, no previous studies have investigated the probability of intensively managed cows choosing to spend time with their calf over another highly attractive resource (fresh pasture). This is an important aspect to consider when developing CCC systems, at least for countries with mandatory pasture access for dairy cows.

In our study, the dams were less likely to first enter the calf area on the first test day, while they more often went directly to the calf area on the second day (with Test day III being intermediate). This result contradicts our *a priori* hypothesis, that the dams' motivation to access their calves would be the highest when the calves were young and then gradually subside with increasing calf age. As Lidfors et al. (1994) reported that the proportion of suckling bouts initiated by beef calves (and hence not through contact seeking by the dams) increased between an average calf age of 7–123 days, one possible explanation for this finding is the relative high age of the calves in our study. The calves were already 10 weeks old at the first test day and the dams' motivation to

Table 3
Least squared means±SEM are reported for the fixed effects of test day, breed and parity from generalized linear mixed models; corresponding F-values and P-values are also reported. Dams' motivation to access the outdoor area their calves were housed in, compared to accessing a fresh grass-clover pasture, was evaluated by letting them choose between the two resources upon voluntarily returning from an indoor robotic barn. The behaviours of the dams, and which area they were present in, were recorded using 10-minute scan sampling, yielding six scans per dam and hour.

	Test day					Breed				Parity			
	I	II	III	F-value	P-value	SH	SR	F-value	P-value	1	2+	F-value	P-value
Proportion of occasions dams choose calf area over fresh pasture (%)	18.2 ±4.96[a]	54.0 ±10.05[b]	37.1 ±9.86[ab]	$F_{2,22}$=5.07	0.02	46.0 ±7.19[a]	25.2 ±6.21[b]	$F_{1,19}$=4.47	0.05	46.9 ±6.11	24.5 ±7.25	$F_{1,19}$=4.24	0.06
Outdoors of total observation time (%)	76.8 ±3.09[a]	60.9 ±3.86[b]	66.8 ±4.38[ab]	$F_{2,31}$=5.58	0.009	64.0 ±3.59	72.7 ±3.36	$F_{1,19}$=2.81	0.11	71.1 ±3.13	65.8 ±3.89	$F_{1,19}$ = 1.04	0.32
In calf area when outdoors (%)	25.2 ±3.98	31.3 ±4.66	33.1 ±6.59	$F_{2,25}$=0.77	0.47	36.4 ±5.28	24.2 ±3.95	$F_{1,17}$=3.29	0.09	31.5 ±4.28	28.0 ±4.87	$F_{1,17}$ = 0.27	0.61
Grazing of total time outdoors (%)	27.9 ±2.27	33.0 ±2.44	24.7 ±2.86	$F_{2,31}$=3.09	0.06	26.1 ±2.34	31.0 ±2.38	$F_{1,19}$=1.98	0.18	29.5 ±2.18	27.6 ±2.55	$F_{1,19}$=0.28	0.60
Lying down of total time outdoors (%)	60.2 ±3.03[a]	38.1 ±3.26[b]	56.7 ±3.82[ab]	$F_{2,31}$=12.2	0.0001	48.5 ±2.75	54.8 ±2.79	$F_{1,19}$=2.40	0.14	49.4 ±2.55	53.9 ±3.02	$F_{1,19}$=1.17	0.29

SH= Swedish Holstein, SR=Swedish Red
* Superscript letters within rows and groups indicate significant differences in post hoc pairwise comparisons.

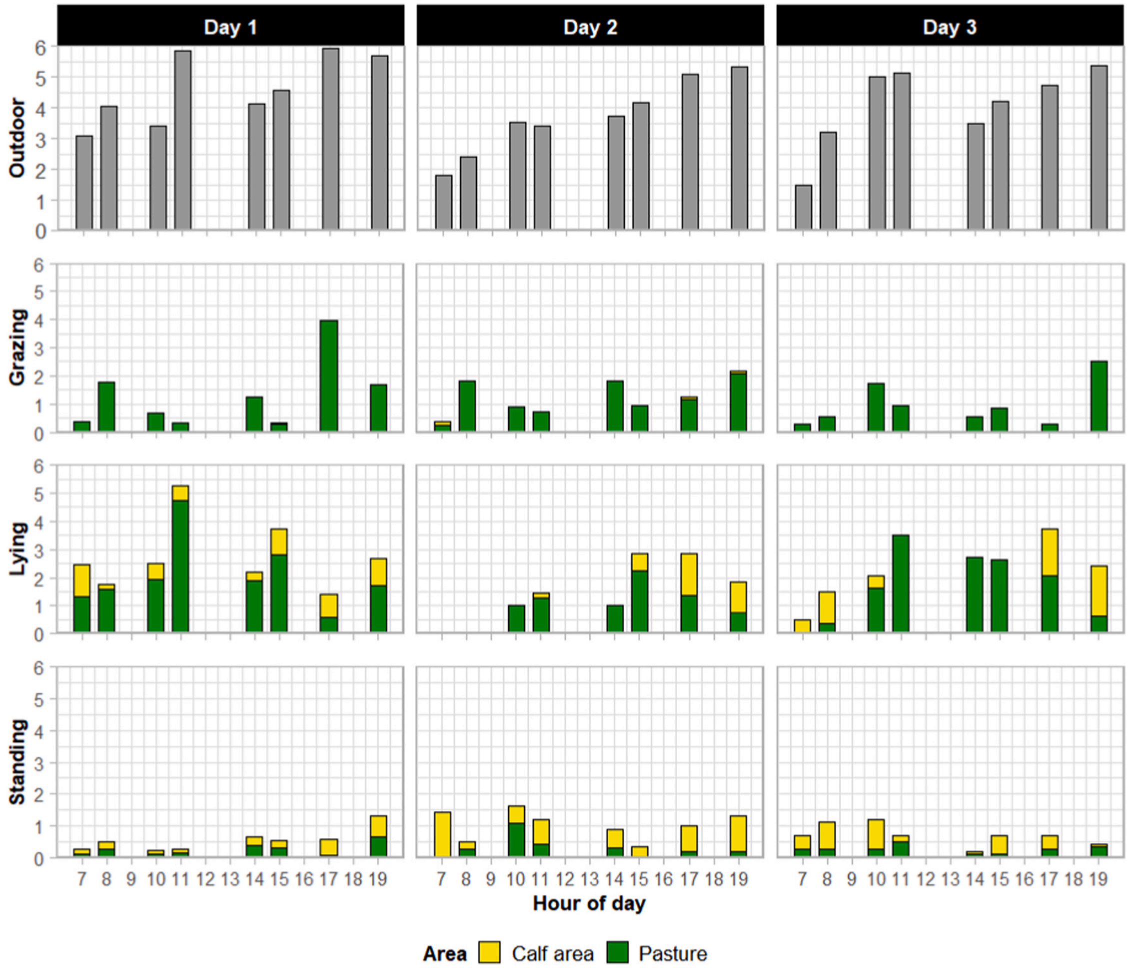

Fig. 3. The figure shows, top to bottom, the average number of scans that the dams spent outdoors (grey bars) and the average number of scans of performed behaviours by the dams depending on area (green=pasture, yellow=calf area) per observation hour. The behaviours of the dams, and which area they were present in, were recorded using 10-minute scan sampling, yielding six scans per dam and hour. Observations were performed for 8 h per test day, spread out over 13 h of the light period (07:00–09:00, 10:00–12:00, 14:00–16:00, 17:00–18:00 and 19:00–20:00).

Table 4
Comparison of likelihood of dams choosing to enter the calf area over fresh pasture as represented by the odds ratio of test day, breed and parity. Degrees of freedom (DF) and 95% confidence interval (CI) are also shown for each group. Dams' motivation to access the outdoor area their calves were housed in, compared to accessing a fresh grass-clover pasture, was evaluated by letting them choose between the two resources upon voluntarily returning from an indoor robotic barn. The behaviours of the dams, and which area they were located in, were recorded using 10-minute scan sampling, yielding six scans per dam and hour.

Group	Comparisons	Odds Ratio	DF	95% CI	
Day	I vs. II	0.189	22	0.062	0.582
	I vs. III	0.376	22	0.127	1.112
	II vs. III	1.986	22	0.567	6.957
Breed	SR vs. SH	0.394	19	0.157	0.991
Parity	1 vs. 2+	2.717	19	0.984	7.507

SH= Swedish Holstein, SR=Swedish Red

gain access to their calves would likely have been higher if the calves had been younger. The only other study testing dairy cows' motivation to access their calves that we have been able to identify (Wenker et al., 2020), reported that suckled dams were willing to push substantial weight, suggesting strong motivation to reunite with the calves. However, these motivation tests were performed when the calves were younger than 20 days.

It is also possible that the dams more often chose the pasture on the first test day due to either a particularly high motivation to graze fresh pasture early in the outdoor season (Pollock et al., 2022; Spörndly and Wredle, 2004), or because the area at this point still constituted a novel resource. Inglis et al. (2001) suggested that in an uncertain environment, animals benefit from visiting different locations to maintain updated information on potential feed sources. As the cows in our study had not previously been kept on pasture D during the current pasture season, they could have been more motivated to visit this area, compared to the already familiar calf area. To counteract some of the confounding effect of novelty, we recorded behaviours on the second day that the dams could access pasture D. This was also done to ensure that the dams were aware of the resource available in this area (*i.e.*, fresh pasture). It is worth noting that the dams did not spend more time standing idle or in locomotion on pasture D during the first test day compared to the later test days, suggesting that they did not allocate more time for exploratory behaviours on this occasion.

Even if the behaviours of the dams did not change linearly as predicted and shown in other studies the dams did alter their behaviours over the course of time, which may be an effect of the ambient temperature. On the second test day, dams spent the highest amount of time "Out of sight" (*i.e.*, inside the barn). As this was the test day with the highest THI and our exploratory analyses indicate that the effect of test day was influenced by the ambient weather, this finding is likely due to the dams performing shade-seeking behaviours to reduce heat stress

(Schütz et al., 2009; Veissier et al., 2018). Although extreme temperatures were not registered in our study, this finding suggests that dairy cows may actively avoid higher ambient temperatures even in countries with temperate climate such as Sweden. This aligns with the findings of Allen et al. (2015), who reported that dairy cows show behavioural adaptations directed at mitigating heat stress already when THI is ≥68. During Test day II, the dams also spent less of their outdoor time lying down, which has been reported as a strategy for heat stressed cattle to maximize air flow around the body and increase heat loss through convection (Kadzere et al., 2002; Schütz et al., 2009).

Contrary to Tucker et al. (2008), who reported that grazing decreased as the weather got warmer, we found that the dams spent most time grazing during the hottest test day. It is possible that the ambient temperature on this day was sufficiently high to affect lying behaviour, but too low to impact grazing. In their review, Kadzere et al. (2002) reported that feed intake of lactating dairy cattle begins to decrease around 25 °C, but that it drops substantially when the ambient temperature is higher than 30 °C. This aligns with our findings, as the temperature in the current study never was higher than 27 °C, even on the hottest test day.

Our combined results suggest that the dams were not solely choosing between access to the calf area or to pasture D, but made their choices based on their access to three locations with valuable resources – with indoor access being particularly attractive during warmer days. Choosing one resource over another indirectly imply a willingness to abandon one resource in favour for another (Kirkden and Pajor, 2006), which in our study suggests that most dams were willing to restrict their access both to fresh pasture and their calves to reduce heat stress. Cabanac (1992) argued that when the choices of animals are largely unrestricted, they will try to maximize their perception of pleasure through trade-offs between different motivations. Additionally, Boissy *el al.* (2007) suggested that when benefits outweigh the costs of acquiring a commodity, pleasure is experienced. As the dams in our study were milked in AMS and interactions with humans were limited to fetching of cows with very long milking intervals three times daily, the dams had relatively large agency to decide how to allocate their time. From our results, it seems as the dams gave up outdoor lying time during the hottest test day, while grazing time remained unchanged. Since lying down is important for dairy cows (Jensen et al., 2005; Munksgaard et al., 2005), we speculate that the dams sacrificing outdoor lying time on Test day II may have been an attempt to maximize outdoor benefits (grazing fresh pasture), while reducing heat stress (choosing to lie down in a shaded indoor environment). However, the low number of test days (only one test day with THI >68) did not allow us to evaluate this idea in the current study, and additional investigations are needed to explore this further.

On the warm Test day II the dams were also most likely to first enter the calf area upon returning outdoors, possibly because spending longer time indoors could have affected the choice the damś made when returning outdoors, by increasing the motivation to access their calves after a longer period of separation. The dams had free access to feed indoors so the increased time spent indoors on Test day II may also have resulted in higher indoor feed intake during barn visits on this test day. As such, the dams choosing to enter the calf area first could potentially have been driven more of a decreased motivation to feed than an increased motivation to access their calves. Although we could measure total daily indoor feed intake, we could not determine how much feed that were consumed during individual barn visits. As such, the study set-up did not allow us to differentiate between these two alternatives.

It also seemed like the dams were aware of the behavioural responses of the calves when they returned outdoors. Although not systematically measured, it was noted that some dams started vocalizing as soon as they entered the walkway. Sometimes their calves responded to the dams' vocalizations with increased locomotion, vocalization and mouth licking (referred to as anticipatory hyperactivity by Boissy et al., 2007). It is possible that the dams gained additional information about how urgent it was to care for the calves by observing how the calves responded, which could then be used when choosing which area to enter first. The outdoor behaviours of the dams could also be influenced by the calves. It was occasionally noted that a grazing dam left pasture D and entered the calf area after her calf started to vocalize, after which either allogrooming or suckling commenced. The sex of the offspring has been suggested to influence the amount of parental investment from the dam, with males being prioritized when the daḿs condition is good (Trivers and Willard, 1973). The uneven distribution of bull and heifer calves in the current study prevented evaluation of how calf sex would influence the likelihood of the dams choosing to enter the calf area first, and we suggest that this aspect is evaluated in future studies.

In a recent survey study in New Zealand, about 60% of the farmers that separated cows and calves shortly after calving were concerned that the selective breeding for increased milk yield had made dams of modern dairy breeds unsuitable mothers (Neave et al., 2022). Le Neindre (1989) suggested that compared to a hardy dual-purpose breed (Salers cattle), HF dams develop low social attachment to their offspring as a result of selective breeding. Based on the finding that bonded SR dams directed more attention towards their calf after the pair had been placed in separate pens with visual contact, Stěhulová et al. (2008) suggested that SR dams react stronger to separation than bonded SH dams. Further, Loberg and Lidfors (2001) investigated how SR and SH cows' respond to being introduced to foster calves at different lactation stages (d 7–200) and found that SR cows generally sniffed the calves more than the SH cows did, which was interpreted as the SR cows being more interested in the calves and this breed having a stronger tendency to show mother-young behaviours. Contrary to the above findings, we found that a higher proportion of SH dams chose to enter the calf area first when returning outdoors. They also spent slightly more time in this area than the SR dams, suggesting that the SH dams had a somewhat stronger preference for access to their calves over fresh pasture than the SR dams. However, there were substantial differences in methodology in the different studies, for example regarding the duration of time the cow-calf pairs were kept together before the tests, so the results are not directly comparable.

While previous literature has reported that dams of higher parity direct less aggression towards the offspring (dairy cattle: Edwards and Broom, 1982) and can be considered better mothers (beef cattle: Vandenheede et al., 2001), it was more common for primiparous dams to enter the calf area first upon returning outdoors in our study. A potential reason for this finding is that none of the dams previously had been kept with their offspring for more than a few hours after calving; as such, parity was not confounded with mothering experience in the current study. However, much of the previous literature has evaluated mother-young behaviours at a much lower calf age (first 6 h of life: Edwards and Broom, 1982; first 72 h of life: Vandenheede et al., 2001; first month of life: Stěhulová et al., 2013), which makes it difficult to directly compare the results.

In the current study, the dams to a larger degree left their calf outdoors in favour of the indoor environment on warm days. Additionally, during two of the three test days some of the dams were never observed in the calf area. Although the calves in our study were only partially nutritionally dependent on suckling, this is an important aspect when designing pasture based CCC systems for younger calves. Similarly to Legrand et al. (2009), the dams in our study spent more time outdoors during the evening and it is possible that all dams at some point entered the calf area during the night, even though our sampling protocol did not allow us to detect this. It is interesting to note that during our assessments there was always at least one dam present outside, even during midday on the hottest test day. While we did not see other mammals during the hours of observation, foxes were occasionally spotted on the fields during the pasture season. It is possible that the continuous outdoor presence of adult animals was aimed to deter predation (von Keyserlingk and Weary, 2007). Alternatively, this observation could indicate the presence of alloparental care (communal rearing) in *Bos* *taurus*, which was recently described in *Bos indicus* by Orihuela et al. (2021).

In contrast to Legrand et al. (2009) few dams were outdoors during the early morning, likely due to the routine of fetching cows with milking permission the hour before observations started. From the perspective of caring for the calves it might be preferable to avoid this practice during warm days, as cows were removed from the outdoors areas during a time when they likely were motivated to be there. As there may have been a lag period between fetching the dams and when they were milked, high ambient temperature after milking then could have reduced the dams ́motivation to return outdoors, resulting in long indoor visits.

Although our study set up did not allow us to evaluate the effects of walking distance between the barn and the outdoor area, it is possible that the location of the pasture and calf area (~300 m from the barn) affected the motivations of the dams. Both Spörndly and Wredle (2004) and Charlton et al. (2013) found that cows were spending less time outdoors when they had to walk longer distances (≥250 and ≥140 m, respectively) to reach the pasture. For pasture based CCC systems where the calves are kept on pasture, it may therefore be beneficial to let this group of animals graze the fields close to the barn. The motivation of the dams would likely also change if the calves were not permanently kept on pasture. It is possible that housing the calves indoors, which would be legal until 6 months of age in Sweden (SFS, 2019:66), would reduce the need for fetching dams with long milking intervals from pasture on AMS farms; we encourage further studies to evaluate this aspect. Similarly, if the calves could freely follow the dams, they would have larger agency to seek out the dam for suckling when hungry.

5. Conclusion

Although limited, this study provides some further information about the motivation of dairy cows to access their calves. Our findings indicate that the choices and behaviours of the dams on pasture are influenced by multiple competing motivations, including avoidance of high ambient temperature. However, we did not find that the dams ́ motivation to access the calves decreased as the calves got older. Further research is needed to fully understand which factors will affect maternal behaviours, so that CCC systems can be designed to facilitate good welfare for both cows and calves.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data sets presented in this study and the accompanying SAS scripts are uploaded to the Mendeley data repository and are freely available at doi: 10.17632/4mgcxr5g2b.1.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2023.106087.

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