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Preference and usage of pasture versus free-stall housing by lactating dairy cattle

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ABSTRACT

The aim of the current study was to assess if cows preferred pasture or indoor housing, and how diurnal and environmental factors affected this preference. Lactating dairy cows (n = 5 groups, each containing 5 cows) were sequentially housed either in a free-stall barn on pasture, or given the choice between the 2 environments. Each group was tested 3 times under each condition, for a total of 21 d, to assess the effects of varying climatic conditions (outdoor temperature ranged from 9.9 to 28.2°C and daily rainfall from 0 to 65 mm/d over the course of the experiment). When provided the choice, cows spent on average (± SD) 13.0 ± 0.6 h/d on pasture, mainly at night. The time cows spent on pasture during the day decreased with the temperature-humidity index ($R^2 = 0.55$); time on pasture at night decreased with rainfall ($R^2 = 0.12$). When provided a choice, cows spent more of their lying time on pasture (69.4 ± 0.02% of the total lying time/d) than indoors in the free-stalls. Cows also spent more time in total lying down when provided a choice than when confined to pasture [0.6 h/d more lying time; standard error of the difference (SED) = 0.21 h/d] and spent even more time lying down when confined indoors (1.1 h/d more time; SED = 0.21 h/d). Cows used the indoor housing especially for feeding; feeder use peaked when cows returned from morning and afternoon milkings. However, cows with free access to pasture spent 1.0 h/d (SED = 0.09 h/d) less time eating the TMR available indoors, resulting in a decline in intake of 2.9 kg of dry matter/d (SED = 0.36 kg of dry matter/d). How cows used the indoor housing differed when cows were provided a choice; for example, cows spent a greater percentage of their time indoors at the feed alley both during the day (47% of the total time spent indoors, versus 41% for cows confined indoors, SED = 0.02%) and at night (22 vs. 5%, SED = 0.04%). In conclusion, under the housing and environmental conditions tested, cows showed a strong preference for access to pasture at night and for access to indoor housing during the day when temperature and humidity increased.

Key words: cow comfort, animal welfare, pasture, motivation

INTRODUCTION

Pasture can provide certain welfare benefits: cows have access to a more natural environment, they can perform behaviors that may be important to them such as grazing (Krohn, 1994), and cows on pasture sometimes experience a lower incidence of diseases such as mastitis (Washburn et al., 2002) and lameness (Hernandez-Mendo et al., 2007). That said, cows can also benefit from conditions provided indoors, most notably access to a high-quality diet and protection from environmental extremes (e.g., heat, cold, and wetness).

Cattle will change locations in response to the climatic conditions (e.g., Redbo et al., 2001). For example, cattle prefer to use areas protected from the wind in winter (Beaver and Olson, 1997; Senft and Rittenhouse, 1985). Similarly, cattle in hot conditions will seek shade and spend more time under shelters as temperatures increase (Blackshaw and Blackshaw, 1994; Vandenheede et al., 1995).

Generally, cattle are more affected by heat than by cold (Hemsworth et al., 1995), especially in pasture-based systems where the animals are exposed to direct sunlight. The temperature-humidity index (**THI**) is commonly used to assess thermal comfort for cattle. A THI of 72 (corresponding to 25°C and 50% relative humidity) is generally accepted as the upper threshold for lactating dairy cows, in part because milk production declines when THI exceeds this level (Igono et al., 1992; Ravagnolo et al., 2000). Depending upon the design of the indoor housing, temperature and humidity may be higher or lower than on pasture, but indoor housing provides shelter from direct sunlight and thus protects cows from the effects of radiant heating.

Although access to pasture is perceived to provide welfare benefits, very little research has measured cow preference for indoor housing versus pasture and how these preferences are related to climatic factors. In one Danish study (Krohn et al., 1992), dairy cows were pro-

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vided access to both pasture and indoor housing. Cows spent more time outdoors during the summer and cows preferred to lie down outdoors during summer nights and indoors during winter nights. Unfortunately, the study followed only a single group of 12 cows and limited the analysis to seasonal rather than daily variation in weather.

Preferences can be complex (Fraser and Mathews, 1997)—cows may prefer one environment for lying down, another for eating, and a third for socializing with herdmates. For example, a preference for indoor housing in the morning may be driven by the availability of highly palatable feed indoors at this time. Preferences may also be affected by previous experience. Thus, any study of preferences should include a wide range of behaviors likely to be important to the animal; cover the full 24-h activity cycle, ideally over several days; and ensure that all animals have at least some previous exposure to the options tested.

The aim of this study was to assess cow preferences for pasture versus indoor housing under a range of environmental conditions. Secondary aims were to 1) compare lying time when cows were restricted to indoor housing, when they were restricted to pasture, and when they were provided free choice between the 2 options; and 2) compare cow behavior, especially eating, when confined to indoor housing versus when provided free access to pasture.

MATERIALS AND METHODS

Cows and Treatments

This experiment was conducted at The University of British Columbia's Dairy Education and Research Centre in Agassiz, British Columbia, Canada. The animals were cared for according to the guidelines of the Canadian Council of Animal Care (1993).

Twenty-five lactating, pregnant, Holstein dairy cows in late lactation (266 ± 81.8 DIM, mean ± SD, range from 131 to 499 DIM) were randomly assigned to groups (n = 5 observational units). Data are reported as mean ± standard deviation; milk production (26.4 ± 3.4 L of milk/d, range from 19.5 to 31.5 L of milk/d), parity (2.5 ± 1.6, range from 1 to 6 lactations), BW (691 ± 97 kg; range from 563 to 947 kg), BCS (3.3 ± 0.5, range from 2.5 to 4; scored from 1 to 5 following Edmonson et al., 1989) and gait score (2.8 ± 0.6, range from 2 to 4; scored from 1 to 5 following Flower and Weary, 2006) did not differ among groups. No animals showed signs of illness during the study.

All cows had previous experience with both pasture and the free-stall housing. Before the experiment, all cows had been housed in a free-stall barn throughout their lactation. All cows had been kept on pasture as growing heifers and multiparous cows had also been kept on pasture during previous dry periods. To ensure that cows were acclimated to the specific housing and pasture used in this experiment, each group was housed in these test pens and pastures for 7 d before the experiment began. During this 7-d period, cows were housed in the free-stall pen between morning and evening milkings. Cows were put to pasture 2 h after the afternoon milking and brought in again just before the morning milking.

Each group was tested during a 2-d forced-choice phase when restricted to the free-stall housing, during a 2-d forced-choice phase when restricted to pasture, and during a 3-d free-choice phase when cows were allowed to choose between using indoor free-stall housing or pasture. Two of the 5 groups were tested first with the forced free-stall condition, followed by the forced pasture. The 3 other groups were tested in the opposite order. The forced phases were immediately followed by the choice phase. This 7-d cycle was repeated 3 times over the period from May 11 to July 17, 2007, to provide data for 21 d/group and to ensure that each group was tested under each condition under a range of climatic conditions. Between cycles, cows were housed indoors for a minimum of 7 d in the same pens as those used for acclimatization.

Housing, Management, and Feed Intake

Three experimental pens were used in this study. Each pen (width = 9.5 m and length = 12.3 m) contained 12 free-stalls configured in 2 rows separated by a 3.0-m alley. The width of the alley between the 6 stalls closest to the feed bunk was 3.5 m. Stalls had a base of geotextile mattress, covered with 0.1 m of washed river sand.

Individual stalls were separated by Y2K-style partitions (1.2 m wide center-to-center and 2.6 m length; Artex, Langley, British Columbia, Canada) and had a brisket board that was 1.7 m from the internal side of the curb (0.2 m height), providing a lying area of approximately 2 m^2/cow. The distance of the neck rail from the center of the mattress to the bottom of the neck rail bar was fixed at 1.25 m throughout the course of the experiment. The stalls located the furthest from the feed bunk as well as one from the row closest to the feed alley were blocked off to prevent access by cows such that 5 stalls were available for each group of 5 cows. Flooring throughout the pen (including the crossover alley) was composite rubber. Alleys were cleaned by using automatic scrapers twice daily, and the crossover alleys were scraped manually once daily.

All groups were milked twice daily, at approximately 0800 and 1500 h. Cows spent on average 30 min/milking in the holding area and milking parlor, and hence away from the pasture or home pen. When housed on pasture, cows were brought directly from the pasture to the milking parlor. During the choice phase, cows were provided free access to pasture, approximately 5 m from the barn entrance, and to a free-stall pen immediately adjacent to this entrance.

All animals were offered a TMR consisting of 39.7% corn silage, 15.8% grass silage, 29.2% concentrate mash, 7.5% alfalfa hay, and 7.7% grass hay, on a DM basis. The TMR was composed of 50% DM on average, with 16.3% CP, 38.7% NDF, and 24% ADF. Fresh feed was provided once a day at 0730 h and feed refusals were removed from the feed bins at 0700 h, before the new feed was delivered. Each pen was equipped with a validated electronic monitoring system (Insentec, Marknesse, the Netherlands; Chapinal et al., 2007) providing measures of intake and feeding time for 5 feed bins. A sixth bin provided ad libitum access to water. During the forced pasture phase, cows were kept in a free-stall pen identical to that described above for 1.5 h after each milking and provided access to the TMR.

The pasture was approximately 50:50 Festulolium (tall fescue × ryegrass cross):orchard grass and was divided into 3 plots. Water was provided via a self-filling water trough located at the edge of each plot. No shade was provided. Two of the plots were used for the forced and the choice phases, and the third used for the adaptation phase. Each group was kept on the same plot during the forced phase outdoors and the choice phase, and the 2 experimental plots were alternately used. Plots were 20 m wide × 58 m long at the start of the experiment. Each day (during the morning milking) fencing was moved to lengthen the plot by approximately 1.2 m/d, allowing cows access to fresh grass. The sward length of this fresh pasture was measured daily before animals were allowed outside, and increased from 43 to 114 cm over the course of the study.

Behavioral Measures

Six Panasonic WV-CP-470 video cameras were used to monitor the behavior of cows indoors. Each pen had 2 cameras positioned 5 m above each pen with one positioned over the feeding area and the other over the lying area. Two additional cameras (Panasonic WV-CP-470 video camera; Sentinel Ultra-zoom w/Pan 1070 outdoor video camera, Sandpiper Technologies Inc., Manteca, CA) were used to monitor when cows left for pasture. Cameras were connected to a Panasonic WJ FS 616c multiplexer and a Panasonic AG 6540 time-lapse videocassette recorder (Panasonic, Osaka, Japan). Individual cows were identified with hair dye. Red lights (wavelength approximately 650 nm) were suspended above the indoor pens to improve individual cow identification during the night hours (i.e., 2100 to 0445 h when barn lighting was off).

During the forced and choice phases, lying behavior (total lying time and number of lying bouts) was recorded for each cow using data-loggers (Tinytag Plus, Gemini Dataloggers Inc., Chichester, UK) attached to the rear leg of the cow and measured vertical and horizontal leg orientation at 1-min intervals (for details, see Huzzey et al., 2005). Loggers were attached and removed in the milking parlor during the milking immediately before and after each 7-d observational period.

During the indoor forced phase and the choice phase, behavior indoors was recorded using instantaneous sampling every 10 min for 24 h/d, providing 144 scans/d for each day of observation. Cow location and behavior in the free-stall was recorded as lying in the stall, standing with the front 2 feet in the stall, standing completely in the stall, standing in the feeding alley, or elsewhere in the pen. During the choice phase, cows were recorded as on pasture, indoors, or on the pathway between the 2 locations.

Climatic Measures

Air temperature, relative humidity, rainfall, and wind speed were recorded by the Environment Canada weather station in Agassiz. Temperature-humidity index was calculated following Ravagnolo et al. (2000): THI = (1.8T + 32) − [(0.55 − 0.0055RH) × (1.8T − 26)]; with T = air temperature (°C) and RH = relative humidity (%).

During the study, the average daily temperature was 16.5°C (±4.3°C, range from 9.9 to 28.2°C) with an average daily variation of 9.7°C (±4.0°C). Average daily precipitation was 5.4 mm (±11.4 mm, range from 0 to 65.4 mm/d). Average THI was 60.5 (±6.3, range from 49.9 to 74.6), and the average wind speed was 1.5 m/s (±0.6 m/s, range from 0.9 to 4.7 m/s). Day length varied from 15:07 (hours:minutes) to 16:14 h, with the sun rising between 0506 and 0535 h and setting between 2043 and 2121 h.

Statistical Analyses

To test the effects of climatic conditions on pasture use we calculated the time cows were on pasture during each of 45 choice days (5 groups tested sequentially over three 3-d blocks, providing 9 d/group), separately for day (0800 to 2200 h) and night (2200 to 0800 h) periods. A preliminary screening of the climatic and pasture variables was performed using the stepwise multiple regression in SAS (PROC STEPWISE; SAS version 9.1, SAS Institute Inc., Cary, NC), retaining

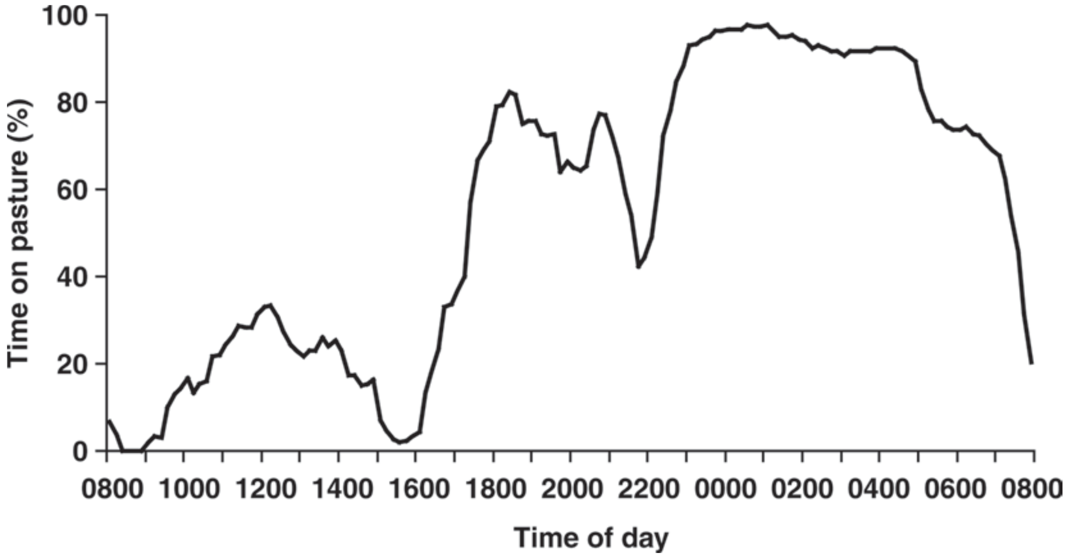

Figure 1. Mean percentage of time groups of cows (n = 5) spent on pasture when provided free choice between pasture and free-stall barn. The results are shown for 10-min intervals from 0800 h to 0750 h. Milking occurred between 0800 and 0900 h and between 1500 and 1600 h. Fresh feed was provided at 0730 h.

variables with $P < 0.05$. Only 2 climatic variables were retained: THI for daytime observations and rainfall for night time observations. The statistical significance of these factors was tested using PROC MIXED of SAS (SAS Institute Inc.), including group as a random effect in the model and testing the effect of either THI or rain (1 df) on time spent on pasture (error df = 39).

To test how cow behavior changed when kept indoors, on pasture, or provided a choice, time budget and feed intake data were averaged by group (n = 5) and phase. The time spent lying down (as measured by the data loggers) was available for the indoor, pasture, and choice phases. For this variable, the final data set consisted of 15 means and the fixed effect of phase (2 df) was tested against an error term with 9 df using PROC MIXED of SAS (SAS Institute Inc.), specifying group as a random effect in the model.

Feed intake and time budget data collected from video (time lying in stall, time standing in stall, time standing outside of the stall) were available for the forced indoors phase, and for the time cows chose to spend indoors during the choice phase, so averaging by phase and group resulted in a data set with 10 means. For those variables the fixed effect of phase (1 df) was tested against an error term with 4 df using PROC MIXED of SAS (SAS Institute Inc.), again specifying group as a random effect in the model.

Mean differences in response to treatment are provided with the standard error of the difference (**SED**). Purely descriptive measures (not intended for inferential comparisons) are cited ± standard deviation.

RESULTS

When provided the choice, groups spent on average (± SD) 13.0 ± 0.6 h/d on pasture (range 12.1 to 13.6 h/d). Use of pasture varied with time of day (Figure 1). Cows went outside less than one-third of the time between morning and evening milkings. After the evening milking, cows spent the majority of their time outside, except at around 2200 h when many cows returned briefly to the barn. Almost all of the cows stayed on pasture between 0000 and 0400 h. Some entered the barn between 0400 and 0600 h, but the majority returned only for the morning milking.

The use of pasture varied with temperature during the day and rainfall during the night; the proportion of time on pasture declined during days (0800 to 2200 h) with greater THI ($y = 1.353 - 0.016x$; $R^2 = 0.55$, n = 45, $P < 0.001$; Figure 2), and during nights (2200 to 0800 h) with greater rainfall ($y = 0.866 - 0.017x$; $R^2 = 0.12$, n = 45, $P = 0.019$).

During the choice phase, cows used the indoor housing for lying down and for feeding. Stall-use peaked during the middle of the day, with a smaller peak just before the morning milking (from 0500 to 0800 h; Figure 3A). Time at the feeder peaked when cows returned from morning and afternoon milkings and remained high during the hour after milking (Figure 3B). From 2300 to 0500 h, few cows were observed feeding indoors.

During the choice phase, cows spent most of their lying time on pasture (Figure 4) and spent 0.6 h/d more time lying down relative to when confined to pasture

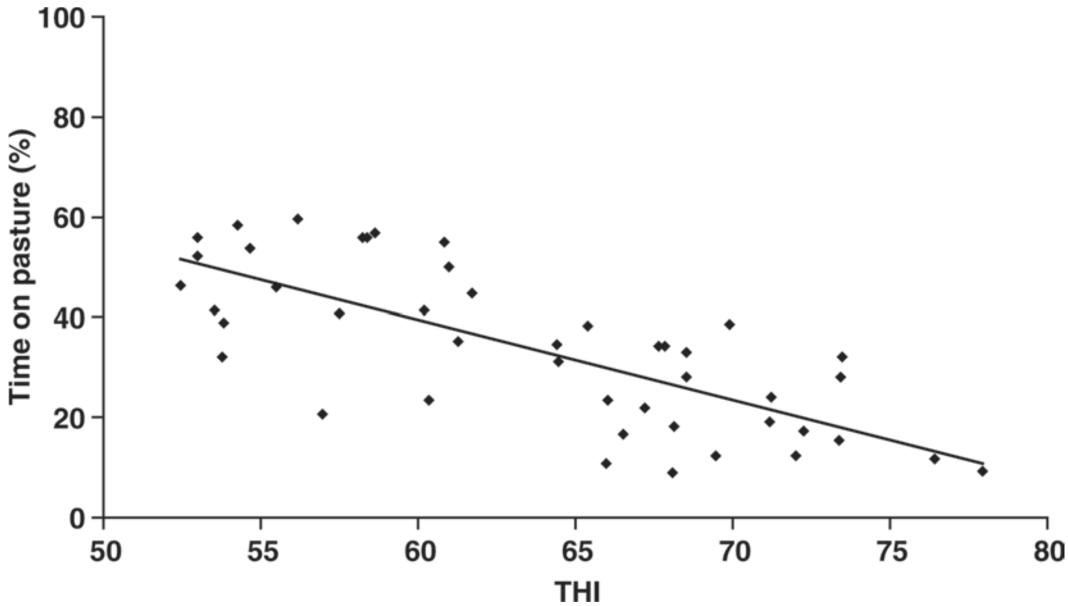

Figure 2. Mean percentage of time cows spent on pasture when provided free choice between pasture and free-stall barn. Results are shown in relation to the average temperature humidity index (THI) between 0800 and 2200 h during each day testing (n = 45 d).

(SED = 0.16 h/d; P = 0.001), and 1.0 h/d less time lying down compared with when confined indoors (SED = 0.16 h/d; P = 0.008). Total lying time was 1.6 h/d more when confined indoors than when confined to pasture (SED = 0.16 h/d; $P < 0.001$). Cows averaged 9.4 ± 2.7 lying bouts/d, with no differences between treatments. The average duration of these lying bouts was 1.29 ± 0.39 h/bout, but bouts were 0.22 h longer when cows were confined indoors versus when confined to pasture (SED = 0.07 h/d; P = 0.01), and 0.17 h longer when confined indoors versus during the choice phase (SED = 0.07 h/d; P = 0.03).

When confined indoors, cows spent on average 3.9 ± 0.8 h/d consuming the TMR, eating on average 20.4 ± 3.2 kg of DM/d. When cows had free access to pasture, time eating the TMR declined by 1.0 h/d (SED = 0.09 h/d, $P < 0.001$), and TMR intake declined by 2.9 kg of DM/d (SED = 0.36 kg of DM/d; $P < 0.001$). Thus, feeding rate was 0.8 h/d greater during the choice phase than when confined to the indoor housing.

Cows changed their use of the indoor housing during the choice phase. During the choice phase, cows spent a greater percentage of their available time at the feed alley both during the day (47% of the total time spent indoors vs. 41% for cows confined indoors, SED = 0.02%, P = 0.029) and at night (22 vs. 5%, SED = 0.04%, P = 0.015). In contrast, the percentage of time spent lying in the stalls was lower during the choice phase both during the day (33 vs. 37% for cows confined indoors, SED = 0.01%, P = 0.021) and at night (59 vs. 74%, SED = 0.06%, P = 0.072).

DISCUSSION

Cattle spent on average 46% of their time indoors when they had the choice between indoor housing and pasture. During the choice phase, cows were still required to come inside for milking; time spent on pasture would likely have been greater if this constraint was removed. Our results are similar to those of Hoffman and Self (1973) who reported that feedlot steers housed on pasture spent 47% of their time under a shelter during the summer. In contrast, Krohn et al. (1992) found that cows spent just 28% of the day indoors; this lower value might have been due to differences between the studies including the quality of indoor housing, quality of pasture, and climatic conditions.

In the present study, cows preferred the indoor environment during the day, but showed an almost exclusive preference for pasture at night. Similarly, Vandenheede et al. (1995) reported that grazing fattening bulls spent most of their time in a shelter during daylight hours, but never used it between 2200 and 0500 h. We also found a relationship between climatic factors and time spent on pasture, and Vandenheede et al. (1995) reported that rain and air temperature were both positively correlated with sheltering by cattle.

The use of shade by cattle is directly related to solar radiation (Tucker et al., 2008), as this accentuates the effect of high ambient temperatures. The fact that the cows in the present study spent a proportion of the day indoors, particularly when the THI was elevated, suggests that cows were using the indoor housing as shade. Future work should include measures of solar radiation, such as the heat load index (Gaughan et al., 2008). Moreover, future research may wish to consider how preference for pasture is affected by the availability of shade.

Cows had the lowest daily lying times when confined to pasture, showed intermediate lying times during the choice phase, and spent the most time lying down when confined indoors. This result is consistent with other work showing lower lying times on pasture (e.g., Hernandez-Mendo et al., 2007). The lower lying times on pasture may have simply been due to time spent grazing. Cows also may have found pasture more comfortable for standing and easier to transition from lying to standing. Moreover, cows forced outdoors may have preferred standing on warm days as this position may facilitate heat dissipation (Juarez et al., 2003).

When offered the choice between indoor housing and pasture, cows maintained a similar pattern of time at the feeder relative to the pattern described previously for dairy cattle housed indoors in free-stalls (i.e., peaks in feeding after the morning and evening milkings;

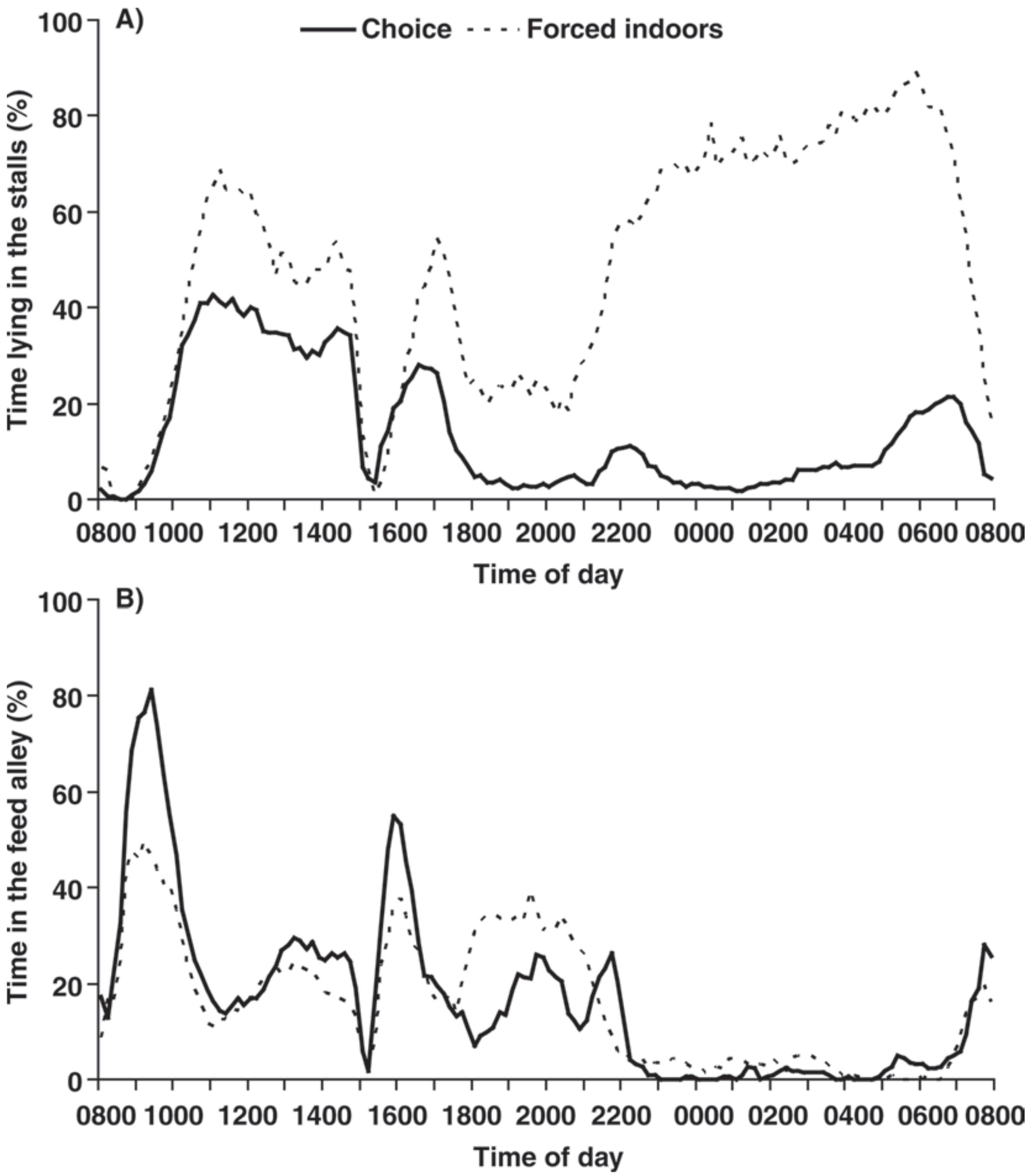

Figure 3. Mean percentage of time groups of cows (n = 5) spent lying in the free-stalls (A) or standing in the feeding alley (B) when cows were kept inside a free-stall barn or provided free choice between pasture and the free-stall barn. The results are shown for 10-min intervals from 0800 to 0750 h. Milking occurred between 0800 and 0900 h and between 1500 and 1600 h. Fresh feed was provided at 0730 h.

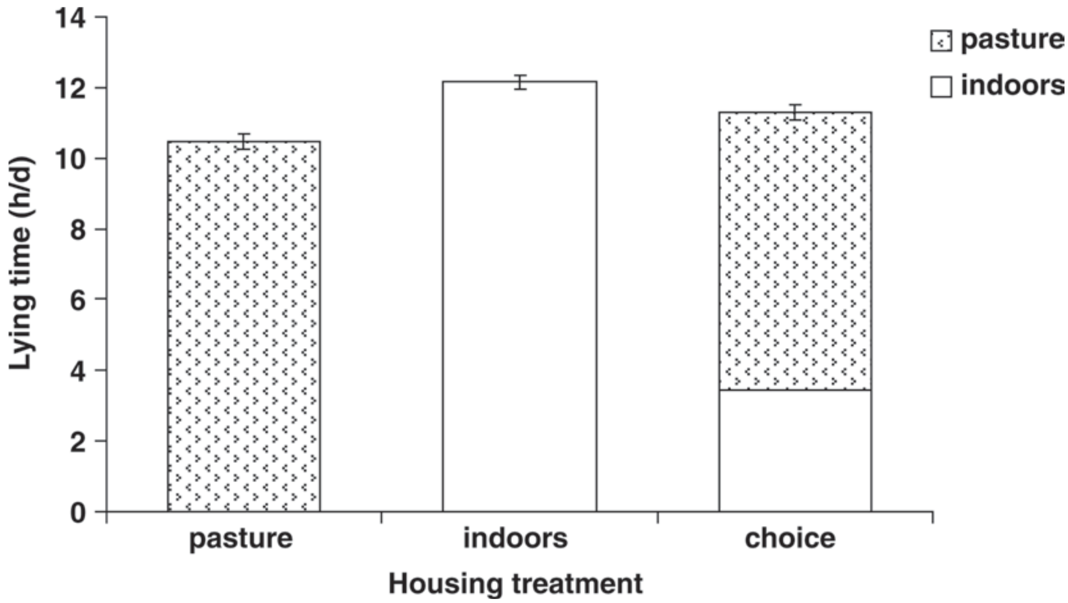

Figure 4. Mean ± SE time (h/d) groups of cows (n = 5) spent lying down when cows were kept on pasture, inside a free-stall barn, or provided free choice between the 2 options. During the choice phase, the time spent lying down in the 2 environments is shown separately.

DeVries et al., 2003). It is not clear if cows would continue this pattern if the choice phase were extended. The peaks in feeder access after milking may have been due, in part, to the experience during the forced pasture phase when cows were kept indoors to feed in the period immediately after milking.

The DMI of TMR (consumed indoors) declined by 14% when cows were given a choice compared with when they were kept indoors. Unfortunately, we were unable to quantify the amount of grass consumed while cows were provided access to pasture. Krohn et al. (1992) reported that total DMI (i.e., from pasture and TMR) remained relatively constant under similar experimental conditions, but cows varied in the ratio of grass to TMR consumed. Future work designed to test the effect of free-choice pasture on milk production should also include measures of grazing activity and grass consumption. The ratio of TMR to pasture consumed will likely vary with the relative quality of the 2 diets. The current study did not manage pasture in such a way as to optimize either grass growth or quality, and future researchers may wish to test the effects of these 2 factors.

Preference tests enable the animals to express their own priorities, allowing us to draw inferences regarding what is important to them (Dawkins, 1990) and how they trade-off conflicting motivations (Kirkden and Pajor, 2006). For example, cows in the present study may have preferred to remain indoors during the hottest hours of the day because access to shade was more important to them than any of the positive features provided by the pasture. Preference tests do not tell us how important the preference is to the animal. We do not know if the cows were highly motivated to access the preferred resource (like we would be motivated to access food after an extended period of deprivation). To answer this question, future work should measure the strength of motivation to access outdoors at night and indoors during warm, sunny weather, for example, by training cows to perform a task such as a lever push and measuring how much cows will work to access the various options.

Preferences can also be affected by previous experience. During the adaptation phase, all cows were provided with experience of both the free-stall housing and the pasture, to ensure that all animals were familiar with the 2 options. However, previous experience may have affected the results. Until the beginning of this experiment, the cows had spent their entire lactation in the barn, making this environment more familiar and potentially more attractive than might have been the case had the cows been provided equal experience. Moreover, during the adaptation phase, cows were put out on pasture only at night. Providing cows experience with the pasture during the day may have affected the preference results. Relevant to both concerns is that the majority of the cows tested actually had considerable previous experience with pasture; growing heifers and dry cows in this herd are kept on pasture during the spring, summer, and fall.

The results of the current study indicate that cows do not show an overall preference for one condition or the other; rather their preferences are conditional to time of day and environmental factors. Even these results must be interpreted in relation to the specific options provided; for example, cows may have spent more time indoors if stalls had more bedding or were better designed (Drissler et al., 2005) and may have spent more time on pasture if shade or higher energy diets were available. Indeed, this experimental approach could be used to provide insights into how both indoor and outdoor environments can be improved. One suggestion is to use this approach as a litmus test for evaluating new indoor facilities by asking how often (and under which conditions) cows choose to leave this facility for pasture; similarly the cows' perception of pasture conditions could be evaluated by measuring how often cows would choose to return to the barn.

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