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Free-choice pasture access for dry cows: Effects on health, behavior, and milk production

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ABSTRACT

Allowing dairy cattle to access pasture or outdoor areas is known to be beneficial for cows' welfare and is considered important by the general public. However, in confinement-based operations with high-yielding cows, pasture access may be difficult to implement, especially for lactating animals. Providing pasture access to heifers and dry cows seems a more feasible option for most farms. The objective of this study was to investigate the effects of providing high-yielding dairy cows with free-choice pasture access during the dry period on their health, behavior, and milk production. Over the study period, a total of 78 Holstein cows were assigned to 1 of 2 treatments during the dry period (51 ± 8 d): housing with free-choice access to the pasture (PAST) or housing continuously without any access to the outdoors (CTRL). After calving, all cows from both treatments were mixed and housed continuously. To assess the effects of the treatment on cows' performance, all animals enrolled were monitored both before calving and during the first 100 d in milk of the following lactation. The behavior of all cows involved was monitored continuously during the whole observation period using collar-based sensors. All cows were inspected monthly to assess lameness, hock lesions, cleanliness, and body condition score. During the period after calving (0–100 d in milk), milk production and composition were also monitored. Results showed that free-choice pasture access affected cows' feeding behavior. Before calving, the animals in PAST spent more time feeding than in CTRL and, interestingly, this difference tended to persist for several weeks after calving. During the dry period, cows in PAST were cleaner than in CTRL but no differences in locomotion and body condition score were found between the 2 groups. Free-choice pasture access during the dry period also affected milk production during the following lactation. The cows that spent the dry period in PAST produced more milk than CTRL counterparts, particularly for the animals that calved during summer. In the current study we have found that providing free-choice pasture access during the dry period can positively affect the performance of dairy cattle and represents a desirable practice in confinement-based dairy production systems.
Key words: dairy cows, free-choice pasture access, animal welfare, milk production, animal behavior

INTRODUCTION

In the last decades, providing pasture or outdoor access to dairy cattle has become a largely debated topic (Moscovici et al., 2021; Smid et al., 2021). Even in countries that typically rely on indoor housing systems, such as the United States and Canada, consumers consider pasture access important for dairy cattle (Ventura et al., 2016). In an online engagement, Schuppli et al. (2014) found that 80.2% of US and Canadian participants think that dairy cows should have access to pasture. The study included participants that were both affiliated and unaffiliated with the dairy industry. Surveys in Europe also highlighted that consumers care about the provision of pasture access and grazing in dairy production systems (Waldrop and Roosen, 2021). In Germany, Kühl et al. (2019) reported that pasture access can improve the public perception of common husbandry systems for dairy cows. For freestall barns, the presence of pasture increased public acceptance rate from 17 to 96%.

From an animal welfare standpoint, accessing pasture or outdoor areas was consistently shown to be beneficial, especially for claw health and the expression of natural behavior (Arnott et al., 2017; Charlton and Rutter, 2017; Hund et al., 2019). Further, research showed that, when provided the opportunity, dairy cows have a partial preference for pasture and alternative types of outdoor access, which is mainly expressed at nighttime (Legrand et al., 2009; Charlton et al., 2011; Smid et al., 2018; Smid et al., 2019; Smid et al., 2020). The benefits of pasture, however, depend on several factors, particularly management and climate (Arnott et al., 2017). In pasture-based systems, or where cattle spend

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the majority of time outdoors, some animal welfare concerns arise. Depending on climate, cows at pasture can be exposed to inclement weather or heat stress (von Keyserlingk et al., 2009). It is also well known that feeding (high yielding) cows at pasture poses several challenges, mainly because pasture alone may not provide adequate nutrients and because producers have less control on diet composition (Bargo et al., 2003).

In the context of confinement-based production systems, offering cows free-choice pasture access represents a desirable solution as it allows cows to exert their own preference and combine the benefits of both housing and pasture (Charlton and Rutter, 2017; von Keyserlingk and Weary, 2017). However, pasture access may be difficult to implement, especially for lactating dairy cows that generally have high nutritional requirements and need to return frequently indoors for milking. On the one hand, providing pasture access to heifers and dry cows seems a more feasible option for most farms and is a relatively common practice in some countries (van den Pol-van Dasselaar, 2020; Smid et al., 2021). However, the lack of control over diet composition during the dry period may increase the risk of peripartum metabolic disorders (Daros et al., 2022).

The scientific knowledge about the effects of grazing dry cows (only) remains somehow sparse as, to our knowledge, most studies on pasture access in confinement-based systems focus on lactating cows. The objective of this study was to investigate the effects of providing high-yielding dairy cows with free-choice pasture access during the dry period on their health, behavior, and milk production.

MATERIALS AND METHODS

The experiment was carried out on a commercial dairy farm located in Mantua, northern Italy (45°10′11.3″ N 10°45′01.7″ E) between May 5 and December 3, 2020 (for the treatment imposed before calving). The observation of the carryover effects of the treatment (over the first 100 DIM) lasted until March 30, 2021. Ethical review and approval were waived for this study because it did not involve invasive procedure on animals (University of Florence Research Ethics Commission).

Animals and Treatments

Over the study period, a total of 78 Holstein cows were enrolled in the study using staggered enrollment (i.e., new cows added weekly). All adult cows (approx. 140 cows) and pregnant heifers present at the experimental farm during the study period were eligible for enrollment. Lactating cows after dry-off (n = 58) and heifers at <60 d before estimated calving date (n = 20) were assigned to 1 of 2 treatments, balanced for parity: housing with free-choice access to an exercise pasture (**PAST**) or housing continuously without any access to the outdoors (**CTRL**). As the study focused on providing pasture access during the dry period only, the remaining animals in the herd were excluded from the experiment. Once enrolled, the animals remained in 1 of the 2 treatment groups until calving. Mean (±SD) dry period length was 51 ± 8 d. Each animal was exposed to 1 of the 2 treatments for a minimum of 34 d before calving (maximum was 74 d before calving).

After calving, all cows from both treatments were mixed and housed continuously without any access to the outdoors. To assess the effects of the treatment on cows' performance, all animals enrolled were monitored both before calving (when the animals were exposed to different treatments) and during the first 100 DIM of the following lactation (when the animals from the 2 treatments were mixed). The cows assigned to the PAST treatment were trained to access the exercise pasture by manually moving them to the center of the paddock (after morning feeding) during the first 2 d after enrollment. All animals involved in the experiment had previous experience on pasture as growing heifers. Mature cows were housed indoors continuously throughout their previous lactations.

Feeding, Housing, and Pasture

Before calving, cows in the 2 treatments were housed in 2 adjacent straw yard pens (Figure 1). In both pens, fresh straw was added daily and the bedded pack was renovated monthly. An equal stocking rate was maintained in both pens. Cows in both pens had ad libitum access to grass hay (through a head-locking feed barrier with >1 feeding space per cow) and were fed 2.5 kg/cow per day of a commercial pelleted concentrate for dry cows (DM basis: 22.0% CP, 8.9% crude fiber, 2.9% crude fat, and 8.0% ash; as declared by the producer Maber Srl, Volta Mantovana, Italy). The concentrate was manually distributed to all cows in both pens at approximately 0800 h. Samples of the grass hay fed to the cows were collected monthly and sent to an external laboratory for chemical analysis (Table 1). During the precalving period the cows in PAST were allowed to freely access an exercise pasture (day and night) whereas the cows in CTRL always remained indoors.

The pasture was accessible to the PAST cows through a 12.5 m long and 4 m wide concrete-paved walkway (Figure 1). The pasture was established in 2019 and consisted mainly of perennial ryegrass and white clover. Although this pasture was intended mainly to provide cows with a comfortable outdoor area (exercise pasture), basic pasture management practices were em-

Table 1. Nutrient content of forages (mean ± SD) fed during the different phases of the experiment

Item	Precalving		Postcalving TMR
	Pasture	Grass hay	
DM (g/kg)	187 ± 51	920 ± 11	502 ± 61
CP (g/kg DM)	165 ± 39	82 ± 19	161 ± 27
NDF (g/kg DM)	454 ± 72	555 ± 22	324 ± 53
ADF (g/kg DM)	326 ± 45	376 ± 13	136 ± 24

ployed to maintain a healthy grass sward. The pasture area (0.75 ha) was divided into 2 grazing paddocks using an electric fence. A fresh paddock was offered to the cows on average (±SD) every 23 ± 7 d, based on grass height. Compressed grass height was measured weekly with a rising plate meter (Grasshopper, True North Technologies, Ireland) in at least 20 locations evenly spread across every paddock. During the course of the study, the average (±SD) compressed sward height was 78 ± 34 mm. Hand-plucked samples of the pasture grass were collected monthly and sent to an external laboratory for chemical analysis (Table 1).

After calving, all cows from both PAST and CTRL were mixed and housed in a single free stall pen (Figure 1). During the lactation, the cows had no access to the outdoors and were fed the same TMR ad libitum (DM basis: 17% corn silage, 21% grass silage, 8% alfalfa hay, 1% wheat straw, 29% ground corn, 9% soybean meal, 15% commercial pelleted concentrate). A sample of TMR was collected monthly and sent to an external laboratory for chemical analysis (Table 1). All cows were milked twice daily at approximately 0500 h and 1700 h in a double-8 parallel parlor.

Cow Behavior

Cow behavior was automatically recorded with a collar-based sensor system (AfiCollar, Kibbutz Afikim, Afimilk, Israel) designed to monitor dairy cattle feeding and ruminating behavior. The system returned individual daily rumination and feeding times. The functioning and the reliability of this system have been assessed in a dedicated validation study (Leso et al., 2021). To allow the cows to get used to the collar de-

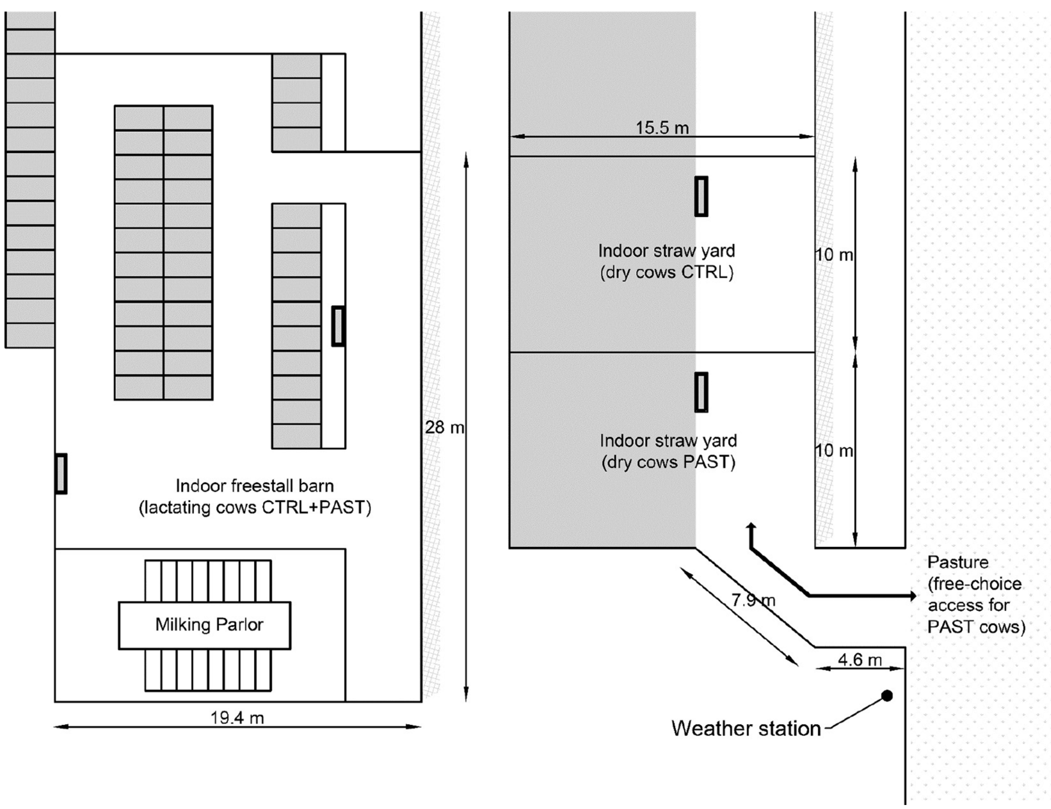

Figure 1. Experimental barn layout. Dry cows and pregnant heifers were allocated to 2 treatment groups (i.e., pens): free-choice access to pasture (PAST) or housing indoors continuously (CTRL). After calving, all cows were mixed and housed in a single pen with no access to the outdoors. Solid shaded areas represent the resting areas in straw yards and freestall pen.

Table 2. Indoor and outdoor environmental conditions (mean values, with range in parentheses) measured during the study period (May 5, 2020–Mar 30, 2021), shown separately for seasons[1]

	Outdoor		Indoor	
Season	Temperature (°C)	THI	Temperature (°C)	THI
Spring	20.4 (11.2 to 29.9)	66.6 (52.2 to 76.5)	21.5 (15.0 to 29.9)	68.4 (58.9 to 76.0)
Summer	24.4 (13.4 to 36.6)	72.2 (56.1 to 87.1)	25.5 (16.8 to 35.6)	73.9 (61.9 to 86.6)
Autumn	10.4 (−2.4 to 27.9)	50.7 (29.0 to 75.7)	13.2 (1.3 to 27.8)	55.7 (35.1 to 75.8)
Winter	5.6 (−6.0 to 22.4)	43.1 (23.5 to 67.4)	8.5 (−0.3 to 20.5)	48.2 (33.4 to 66.5)

[1]THI = temperature-humidity index.

vice, all animals were fitted with the sensor at least 14 d before being enrolled in the experiment. The behavior of all cows involved was monitored continuously during the whole observation period (from dry-off or <60 d before calving to 100 DIM).

Milk Yield and Composition

Throughout the study, milk yield of lactating cows was recorded for each cow at each milking by the automatic milk meters installed in the parlor (Afimilk MPC, Kibbutz Afikim, Afimilk, Israel). Milk fat, milk protein, SCC, and estimated 305-d milk yield were measured during monthly testing performed by the Italian Breeders Association (Associazione Italiana Allevatori, Rome, Italy). The 305-d milk yield was estimated based on ICAR guidelines (ICAR, 2020). Data from at least 3 monthly test days were obtained for each cow involved in the experiment.

Clinical Assessments

During the period before calving, all cows were inspected monthly to assess lameness, hock lesions, cleanliness, and BCS. Lameness was scored on a 5-point scale (1 = smooth and fluid movement; 5 = ability to move is severely restricted and must be vigorously encouraged to move), according to Flower and Weary (2006), as each cow was walked along a concrete floored area. Hock lesions were assessed using the 3-point system (1 = no swelling or hair loss, 2 = no swelling but hair loss, and 3 = swelling and hair loss) developed by Cornell University (2009). Cow cleanliness was assessed, according to Cook and Reinemann (2007), by measuring the degree of manure contamination on a 4-point scale (1 = clean; 4 = dirty) in 3 body areas: the udder, the lower leg, and the upper leg and flank. Body condition was scored using the 5-point system (1 = emaciated; 5 = obese; in 0.25-point increments) proposed by Elanco (Elanco Animal Health, 1996). All clinical assessments were collected by the same observer who received adequate training for all methods before the beginning of the study.

Weather Conditions

Weather conditions were recorded continuously throughout the study period using a data logging weather station (HOBO RX3000, Onset Computer Corporation, Bourne, MA) placed on the experimental site, close to the pasture (Weather station; Figure 1). The station was provided with a signal repeater (HOBOnet Repeater, Onset Computer Corporation, Bourne, MA) to allow the measurement of indoor conditions. Air temperature and air relative humidity were recorded every 5 min both indoors and outdoors. Weather data were downloaded weekly. The temperature-humidity index (**THI**) was calculated as $THI = (1.8T + 32) - [(0.55 - 0.0055RH) \times (1.8T - 26)]$ (National Oceanic and Atmospheric Administration, 1976), with T = ambient temperature (°C) and RH = relative humidity (%). Environmental conditions measured indoors and outdoors during the study period are shown in Table 2, separately for seasons.

Statistical Analysis

Data from different sources were initially processed with Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA). Three distinct dataframes were prepared for the analysis: behavior and daily milk yield data (extracted from the AfiFarm herd management software, daily values), estimated 305-d milk yield and milk composition data (obtained from Italian Breeders Association, monthly test days), and clinical assessments (monthly cow inspections). Cow data including parity, calving date, and DIM were added to all data frames by matching cow IDs and measurement timestamps. Calving date was categorized by season. Seasons were defined as: spring (from Mar 21 to June 20), summer (from June 21 to Sep 20), autumn (from Sep 21 to Dec 20), and winter (from Dec 21 to Mar 20). Parity was categorized into 2 classes: primiparous and multiparous. All data (excluding 305-d milk yield and milk composition data) were structured by week relative to calving (i.e., the week number relative to the calving date, both before and after calving). The data recorded on a daily basis (i.e., milk yield, feeding and ruminating behavior) were categorized by week to enhance interpretability of the results.

Statistical analysis was performed with R version 4.2.0. (R Foundation for Statistical Computing, Vienna, Austria). Linear mixed models were used to analyze the effect of the treatment on cow behavior, milk production, milk composition, and clinical assessments. For each response variable, a mixed effect model for repeated measures was fitted using maximum likelihood with cow as the experimental unit. The initial models included the fixed effects of treatment, week relative to calving, parity, calving season and all 2-way interactions. Week relative to calving was omitted from the initial models for 305-d milk yield and milk composition data. Cow ID entered the models as random effect and an unstructured covariance structure was chosen for all models based on the Akaike information criterion. Satterthwaite's approximation was used to calculate degrees of freedom. Behavioral data for the pre- and postcalving periods were analyzed separately. Data of SCC were statistically evaluated at a logarithmic scale (log10) to achieve normal distribution. A backward stepwise elimination procedure was used to build the final models. The main effect of treatment was forced in all models. The normality and homoscedasticity of variance were visually evaluated with residual plots. Least squares means were computed and multiple comparisons performed with the Tukey procedure. Differences were declared significant at $P < 0.05$ and tendencies were declared at $P < 0.10$. Data are presented as least squares means ± standard error unless otherwise specified.

RESULTS

Ruminating and Feeding Behavior

Ruminating and feeding times recorded before and after calving for cows in the 2 treatments are shown in Figure 2. The treatment had no effects on ruminating time neither before ($F_{1,\,73.1} = 0.02$, $P = 0.90$) nor after calving ($F_{1,\,74.7} = 0.85$, $P = 0.36$). The time spent ruminating by cows in both the treatment groups varied with week relative to calving (Figure 2) both during the pre- ($F_{8,\,3826.0} = 9.24$, $P < 0.01$) and postcalving periods ($F_{14,\,7196.6} = 37.7$, $P < 0.01$). Ruminating time in both the treatment groups decreased during the week of calving and was higher during the postcalving period compared with before calving (Figure 2). Calving season had a significant effect on the ruminating time recorded during the period before calving ($F_{2,\,72.6} = 16.1$, $P < 0.01$). Cows that calved in summer spent less time ruminating (367 ± 12.5 min/d) than those that calved in autumn (423 ± 10.9 min/d) and in winter (475 ± 14.4 min/d). However, we observed no differences among seasons in the ruminating time recorded after calving. No interactions between treatment and season were detected for ruminating time. Also, parity did not affect ruminating behavior.

Overall, cows in the PAST group (458 ± 11.1 min/d) spent more time feeding than those in CTRL (414 ± 12.1 min/d) but the effect of treatment depended on week relative to calving. A significant treatment × week relative to calving interaction was found for the period before calving ($F_{8,\,3826.9} = 2.01$, $P = 0.04$) while a tendency emerged after calving ($F_{14,\,7191.5} = 1.54$, $P = 0.09$). Cows in both treatment groups showed a similar decreasing trend in feeding time recorded during the period before calving. After calving, cows in the PAST group had higher feeding times compared with CTRL during the first 2 weeks of lactation and toward the end of the observation periods, during wk 13 and 14 after calving (Figure 2).

A treatment × calving season interaction was found for feeding time recorded during the postcalving period ($F_{2,\,69.6} = 3.76$, $P = 0.03$). The post hoc analysis showed that calving season only affected the feeding time of cows in CTRL whereas, within the PAST group, no differences among calving seasons were detected (Table 3). It was also found that CTRL cows that calved in autumn had a lower postcalving feeding time compared with cows in PAST, whereas no differences between treatment groups were detected for cows that calved in other seasons.

As opposed to ruminating behavior, parity was found to affect feeding time during both the pre- ($F_{1,\,71.9} = 4.33$, $P = 0.04$) and postcalving periods ($F_{1,\,69.6} = 17.59$, $P < 0.01$). Primiparous cows spent more time feeding than multiparous cows during the period before calving (454 ± 14.79 vs. 419 ± 8.74 min/d) as well as after calving (372 ± 13.64 vs. 306 ± 8.22 min/d). No interactions were found between treatment and parity for both the pre- and postcalving periods.

Milk Yield and Composition

For daily milk yield (Table 4), the effect of treatment depended on week relative to calving (F 13, 7126.1 =

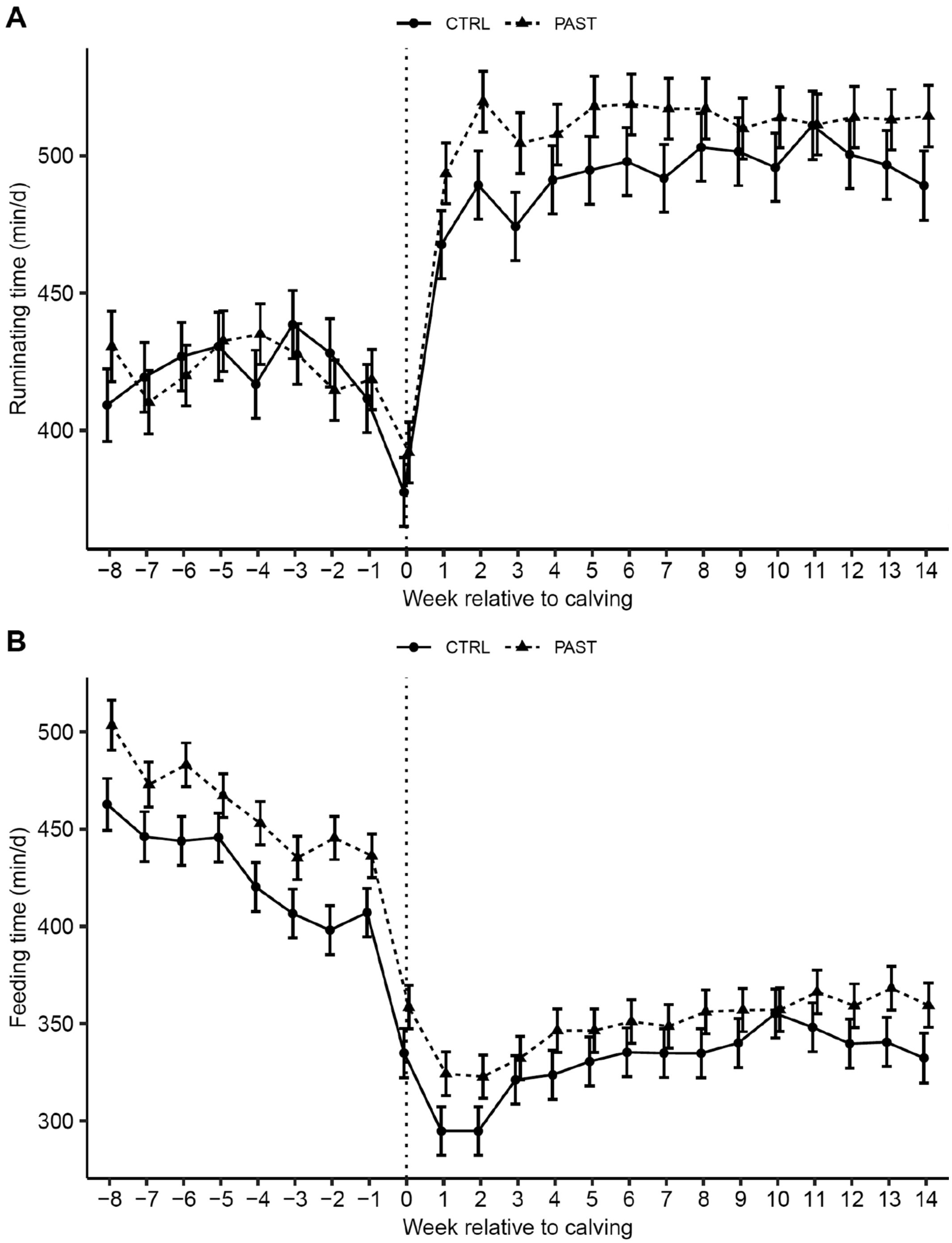

Figure 2. Average (mean ± SE) ruminating time (A) and feeding time (B) recorded before and after calving, for cows on the 2 treatments: CTRL = control, cows housed indoors continuously during the dry period; and PAST = cows housed indoors with free-choice access to pasture during the dry period. After calving, cows in both treatment groups were mixed and housed continuously in the same pen with no access to the outdoors. The vertical dashed line indicates time of calving.

266.8, $P < 0.01$). Cows in the CTRL group had a reduction in milk yield during the end of the observation period, particularly during wk 13 and 14 after calving, whereas PAST cows maintained a higher milk production (Figure 3).

Calving season affected milk yield ($F_{2,\ 69.6} = 7.11$, $P < 0.01$) and a trend indicated that calving season may have interacted with treatment ($F_{2,\ 69.6} = 2.48$, $P = 0.08$). The post hoc analysis of this interaction indicated that calving season only affected milk production

Table 3. Effect of the treatment × calving season interaction on feeding time (min/d; mean ± SE) measured during the dry period

	Treatment[1]	
Calving season	CTRL	PAST
Summer	333 ± 17.1[xy]	334 ± 18.7
Autumn	283 ± 19.5[a,x]	363 ± 11.8[b]
Winter	359 ± 19.9[y]	361 ± 19.7

[a,b]Significant differences between columns (treatment) within calving season (at $P < 0.05$).

[x,y]Significant differences among rows (calving season) within treatment (at $P < 0.05$).

[1]PAST = cows provided with free-choice pasture access; CTRL = cows housed only indoors.

of cows in CTRL (Table 5). No differences among calving seasons were found for the cows that spent the dry period in the PAST group. Further, the only significant difference between treatment groups was detected for cows that calved during summer. Parity had an effect on milk production ($F_{1,\,69.6} = 16.97$, $P < 0.01$) but did not interact with treatment. In both treatment groups, primiparous cows produced less milk than multiparous cows (34.7 ± 1.36 vs. 41.2 ± 0.82 kg/cow per day).

The cows that were in PAST during the dry period had a higher estimated 305-d yield than those in CTRL (10,124 ± 244 vs. 9,276 ± 268 kg; Table 4). Across calving seasons, winter-calving cows (10,474 ± 343 kg) had a higher 305-d yield than autumn-calving cows (9,170 ± 258 kg). Cows that calved in summer (9,455 ± 321 kg) did not differ from those that calved in the other seasons. As expected, the 305-d yield was lower for primiparous (9,204 ± 326 kg) than for multiparous cows (10,196 ± 194 kg).

During the first 14 weeks of lactation, milk fat, milk protein and SCC did not differ between treatments (Table 4). Nevertheless, it is worth noting that calving season affected milk fat ($F_{2,\,74.0} = 4.95$, $P = 0.01$) but had no effects on milk protein nor SCC. Cows that calved in summer (3.78 ± 0.12%) had a lower milk fat content than cows that calved in winter (4.34 ± 0.14%) whereas autumn-calving cows (3.96 ± 0.10%) did not differ from summer- and winter-calving cows.

Clinical Assessments: Hygiene, Hock Lesions, Locomotion, and Body Condition

Cows in PAST tended to be cleaner than cows in CTRL in all the body areas evaluated (Table 6). A main effect of treatment was found for the lower hind legs while a tendency was found for the hindquarter. Compared with multiparous cows, first-calving animals had dirtier lower hind legs (3.29 ± 0.12 vs. 2.88 ± 0.10) and dirtier hindquarter (3.17 ± 0.14 vs. 2.62 ± 0.11). The analysis of the treatment × parity interaction for udder cleanliness ($F_{1,\,34.3} = 5.59$, $P = 0.02$) indicated that treatment only affected multiparous cows, which had cleaner udder in PAST compared with CTRL (1.74 ± 0.12 vs. 2.76 ± 0.16), whereas primiparous cows did not differ (1.49 ± 0.17 vs. 1.80 ± 0.17). Cows that calved in winter (2.41 ± 0.16) had dirtier udders than those that calved both in summer (1.71 ± 0.15) and in autumn (1.72 ± 0.11).

Hock score did not differ between treatment groups (Table 6) but a significant effect of parity was detected ($F_{1,\,44.5} = 8.90$, $P = 0.01$). Primiparous cows had a lower hock score than multiparous cows (1.02 ± 0.06 vs. 1.25 ± 0.05). For the locomotion score (Table 6), a treatment x calving season interaction was detected ($F_{2,\,69.7} = 3.40$, $P = 0.04$) was found. Post hoc analysis showed a better locomotion in PAST than in CTRL only for the cows that calved in winter (1.71 ± 0.23 vs. 2.46 ± 0.26), whereas autumn- (1.57 ± 0.22 vs. 1.87 ± 0.14) and summer-calving (1.71 ± 0.22 vs. 2.09 ± 0.20) animals did not differ between treatments. Treatment had no effect on BCS (Table 6). However, parity affected BCS ($F_{1,\,76.1} = 13.8$, $P < 0.01$). Primiparous cows had higher BCS (3.76 ± 0.08 vs. 3.42 ± 0.05) than muntiparous cows.

DISCUSSION

In this study we measured the effects of allowing dairy cows to freely access an exercise pasture during the dry period. Carryover effects during the subsequent lactation were assessed by monitoring the cows for 14 weeks after calving. The treatment affected cows' be-

Table 4. Milk yield and composition (mean ± SE) measured during the first 100 DIM for cows provided with free-choice pasture access (PAST) or housed only indoors (CTRL) during the dry period

Item	CTRL	PAST	F statistic (df)	*P*-value
Milk yield (kg/cow per day)	37.0 ± 1.12	38.9 ± 1.04	1.63 (1, 69.6)	0.21
305-d milk yield (kg)	9,276 ± 268	10,124 ± 244	16.97 (1, 69.6)	0.01
Milk fat (%)	4.06 ± 0.10	3.99 ± 0.09	0.25 (1, 71.2)	0.61
Milk protein (%)	3.20 ± 0.03	3.22 ± 0.03	0.09 (1, 75.1)	0.77
SCC (1,000 cells/mL)	287 ± 101	289 ± 82	0.06 (1, 75.1)	0.81

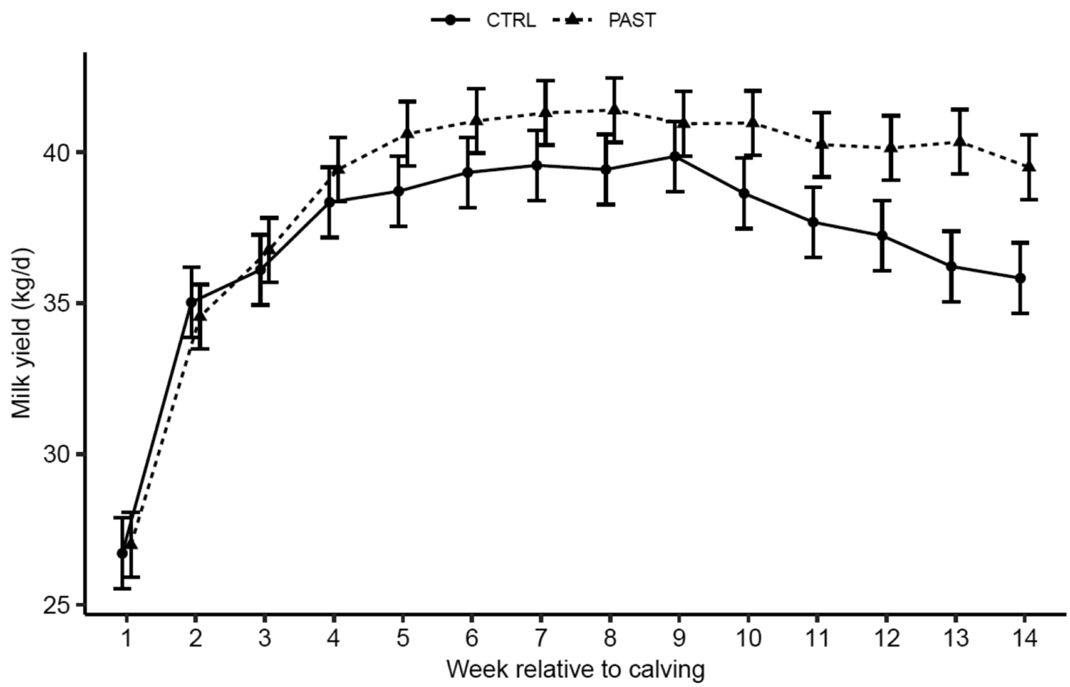

Figure 3. Average (mean ± SE) milk yield recorded during the first 14 weeks after calving, for cows on the 2 treatments: CTRL = control, cows housed indoors continuously during the dry period; and PAST = cows housed indoors with free-choice access to pasture during the dry period. After calving, cows in both treatment groups were mixed and housed continuously in the same pen with no access to the outdoors.

havior both before and after calving, particularly with regard to feeding time. The results also indicated that providing dry cows with free-choice pasture access may increase milk production in early lactation.

Cows in PAST spent more time feeding (i.e., feeding indoors + grazing outdoors) than those in CTRL. In other studies, cows on pasture have been consistently reported to spend more time feeding than cows fed indoors (Bargo et al., 2003). The main reason seems to be that, as bite mass is relatively low at pasture, grazing cows need to take a larger number of bites to achieve an adequate DMI. However, the cows involved in the current experiment had free access to both pasture and ad libitum indoor feeding so they were not forced to graze to satisfy their nutritional needs.

Table 5. Effect of the treatment × calving season interaction on milk yield (kg/cow per day; mean ± SE) measured during the first 100 DIM

	Treatment[1]	
Calving season	CTRL	PAST
Summer	$34.5 \pm 1.71^{a,x}$	39.9 ± 1.87^{b}
Autumn	33.6 ± 1.95^{x}	36.4 ± 1.19
Winter	43.1 ± 2.00^{y}	40.3 ± 1.96

[a,b]Significant differences between columns (treatment) within calving season (at $P < 0.05$).

[x,y]Significant differences among rows (calving season) within treatment (at $P < 0.05$).

[1]PAST = cows provided with free-choice pasture access; CTRL = cows housed only indoors.

The herbage analysis indicated that the fresh grass at pasture was likely to be more palatable than the hay fed indoors, which may have motivated the cows in PAST to spend additional time grazing outdoors. We also think that the longer feeding time recorded in the PAST group is likely to be related to the cows' inherited behavior. When given the opportunity, cows are naturally willing to spend time grazing (Charlton and Rutter, 2017). Allowing dairy cattle to graze outdoors is indeed perceived as a key factor to promote the expression of natural behavior and hence improve animal welfare. Further, depending on weather conditions, pasture is believed to offer the cows a more comfortable environment compared with the indoors (Arnott et al., 2017). The possibility to spend time outdoors may have encouraged some grazing activity in PAST cows even though herbage consumption was not the primary reason to access the pasture.

The higher feeding time recorded in PAST during the dry period tended to persist for several weeks after calving. This was largely unexpected as during the lactation cows in both groups were housed indoors and fed the same TMR diet. Possibly, the cows in PAST got used to spend more time eating (and grazing) during

Table 6. Clinical assessments (mean ± SE) for cows provided with free-choice pasture access (PAST) or housed only indoors (CTRL) during the dry period

Item	Treatment		F statistic (df)	*P*-value
	CTRL	PAST		
Cleanliness score[1]				
Lower leg	3.36 ± 0.12	2.82 ± 0.10	12.5 (1, 68.8)	<0.01
Upper leg and flank	3.06 ± 0.14	2.73 ± 0.11	3.69 (1, 71.7)	0.06
Udder	2.28 ± 0.12	1.61 ± 0.11	18.3 (1, 37.7)	<0.01
Hock score[2]	1.17 ± 0.06	1.10 ± 0.05	0.93 (1, 60.6)	0.34
Locomotion score[3]	2.04 ± 0.13	1.76 ± 0.12	2.58 (1, 71.8)	0.11
BCS[4]	3.66 ± 0.07	3.52 ± 0.06	3.30 (1, 103.4)	0.07

[1]Cleanliness was scored on a 4-point scale (1 = clean; 4 = dirty) in 3 body areas.

[2]Hock lesions were scored on a 3-point scale (1 = no swelling or hair loss, 2 = no swelling but hair loss, and 3 = swelling and hair loss).

[3]Locomotion was scored on a 5-point scale (1 = smooth and fluid movement; 5 = ability to move is severely restricted and must be vigorously encouraged to move).

[4]Body condition was scored using a 5-point system (1 = emaciated; 5 = obese; in 0.25-point increments).

the dry period which could have affected their time budget after calving. Free-choice pasture access may also have encouraged PAST cows to do more physical exercise. This may have resulted in more active animals that dedicated more time eating both before and after calving. Although we did not monitor metabolic disease events, the longer feeding time (and possibly a larger DMI) measured in PAST cows may also have reduced the risk of metabolic diseases associated with the negative energy balance during early lactation (Daros et al., 2022).

The results of the current study indicate that allowing cows to access pasture during the dry period can positively affect milk production during the following lactation. Interestingly, the effect of treatment on milk yield persisted for several weeks after calving. This is in line with Kok et al. (2017) who found a difference in feed intake and feeding behavior during the dry period due to a contrast in dry period length, which was still present after calving although treatment of cows was not different postcalving.

On average, the cows that spent the dry period in the PAST group had a higher peak yield and maintained a higher production than CTRL cows. The mechanisms that leaded to this relatively long-term effect on milk production are unclear and deserve further investigation. In previous studies, however, a positive association was found between feeding time and milk yield (Johnston and DeVries, 2018). The higher feeding time found in PAST cows (especially after calving) may therefore explain their higher milk yield.

Based on the differences recorded in milk yield as well as feeding behavior, cows in PAST were likely to have a higher DMI than in CTRL, both before and after calving. This is in contrast with the results reported in other studies. Previous research indicated that when (lactating) cows are provided a choice between indoor housing and pasture they maintain levels of DMI and milk yield similar to cows housed full time (Chapinal et al., 2010). Unfortunately, we did not measure DMI, which represents one on the main limitations of the current study. As the experiment was carried out in a commercial dairy farm, deploying an adequately accurate system to monitor individual DMI was not feasible.

The treatment x calving season interaction indicated that the free-choice pasture access during the dry period may have reduced the negative effects associated with summer heat stress. Compared with CTRL, the PAST cows that calved in summer did not show a reduction in milk production. During the hot period, accessing pasture may have represented a relief from heat stress for the cows in PAST. As a matter of fact, weather measurements taken during summer showed that the THI outdoors was lower than indoors. Even though the cows in PAST and CTRL were housed together after calving (with no outdoor access), the PAST cows that calved during summer produced more milk than CTRL. The benefits of the free-choice pasture access provided to PAST cows during the dry period extended on the following lactation. This is in line with the current knowledge about the effects of heat stress on dairy cows as thermal stressors occurring during the dry period are known to compromise performance of cows after calving (Polsky and von Keyserlingk, 2017; Fabris et al., 2019).

The free-choice pasture access during the dry period showed to affect milk production during the following lactation. However, the treatment did not affect milk composition and SCC. It is well known that cow hygiene during the dry period can affect mastitis risk in early lactation (Pantoja et al., 2009). Even though cows in PAST were cleaner than in CTRL, we found no difference in SCC between the 2 groups.

In literature, allowing cows to access pasture is consistently reported to improve hoof and leg health (Arnott et al., 2017; Hund et al., 2019). A recent study showed that (lactating) cows provided with a 7-wk period of free-choice pasture access had better locomotion and recovered faster from lameness than cows housed continuously (McLellan et al., 2022). Even a shorter 4-wk period on pasture was reported to improve gait scores compared with cows housed indoors (Hernandez-Mendo et al., 2007). In the current study, cows have been exposed to one of the 2 treatments during the whole dry period, which lasted 51 d on average, or 7.3 wk. According to previous research, this period should have been sufficient to observe an effect on locomotion. However, we did not find differences in hock lesions nor locomotion between PAST and CTRL. As opposed to most published studies that focused on providing free-choice pasture access to (lactating) cows housed in freestall barns, the cows in the current experiment were housed on a straw yard (during the dry period). Straw yards provide a softer and more comfortable surface for standing and lying and can reduce lameness risk compared with freestalls (Fregonesi and Leaver; 2001; Somers et al., 2005; Kester et al., 2014). This could explain why, in the current experimental conditions, the free-choice pasture access did not produce significant differences in cows' hoof and leg health.

All the cows in PAST had free-choice pasture access during the whole dry period but the actual pasture attendance of the individual animals was not monitored. During the experiment we noticed that not all of the cows in the PAST group were willing to access the pasture. It is therefore possible that, within PAST, some animals spent less time at pasture than others, which may represent a potential confounder. Therefore, for future studies that involve free-choice pasture access we recommend also including a measurement of the actual individual pasture attendance. Another limitation was that this study tested 2 groups of cows, each undergoing a separate treatment (later merged into a single group). However, cows in the same herd tend to synchronize their behavior (especially at pasture; Kilgour, 2012; Flury and Gygax, 2016), so it is unclear to what extent individuals within each treatment group represented independent datapoints. Also, further research is deserved to better understand the factors that influence individual cow preference to be indoors or at pasture.

CONCLUSIONS

Allowing dairy cows to freely access pasture during the dry period affected cows' behavior, particularly with regard to feeding time. Compared with CTRL, cows in PAST spent more time feeding during the period before calving. This difference persisted during the period after calving, when cows from both groups were continuously housed. During the dry period, the cows in PAST were cleaner than in CTRL but no differences were found in cows' hoof and leg health. In early lactation, the PAST cows had higher milk production than CTRL, which resulted in a higher estimated 305-d milk yield. The results indicate that allowing the dry cows to freely access pasture may represent a viable solution to provide outdoor access in confinement-based dairy production systems, where grazing lactating cows can be challenging.

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