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Preference and behavior of lactating dairy cows given free access to pasture at two herbage masses and two distances[1]

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ABSTRACT: A number of factors influence dairy cow preference to be indoors or at pasture. The study reported here investigated whether herbage mass and distance affects preference and if continuously housed cows exhibited behavioral and production differences compared to cows that had free access to pasture. Dairy cows (n = 16) were offered a free choice of being in cubicle housing (1.5 cubicles/cow) or at pasture with a high (3,000 ± 200 kg DM/ha) vs. low (1,800 ± 200 kg DM/ha) herbage mass. A control group (n = 16) was confined to cubicle housing for the duration of the study. Each herbage mass was offered at either a near (38 m) or far (254 m) distance in a 2 × 2 factorial crossover design to determine motivation to access pasture. Overall, dairy cows expressed a partial preference to be at pasture, spending 68.7% of their time at pasture. This was not affected ($P > 0.05$) by herbage mass. Both grass intake ($P = 0.001$) and grazing time ($P = 0.039$) was greater when cows were offered the high herbage mass. Neither total mixed ration intake ($P > 0.05$) nor milk yield ($P > 0.05$) was affected by herbage mass or distance. Additionally, no interaction existed between herbage mass and distance ($P > 0.05$). Distance affected preference: overall time on pasture was greater at the near distance ($P = 0.002$); however, nighttime use was not affected by distance ($P = 0.184$). Housed cows produced less milk than free-choice cows and this was potentially due to a combination of decreased lying time in housed cows ($P < 0.001$) and grass intake (1.22 kg/d) in free-choice cows. This study shows that herbage mass is not a major factor driving dairy cow preference for pasture, but distance does affect preference for pasture during the day. Additionally, there are clear production and welfare benefits for providing cows with a choice to be at pasture or cubicle housing over being continuously housed. Further research is necessary to quantify the effect of lying time on milk yields.

Key words: access to pasture, behavior, dairy cow, distance, herbage mass, housed

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INTRODUCTION

Dairy cows have evolved as grazers, so providing access to pasture allows the expression of natural behavior (Rutter, 2010). Modern cattle, however, have undergone genetic selection that has increased milk yield and resulted in higher nutrient requirements than their ancestors (Webster, 1996). These cattle may not be able to meet their nutritional demands through grazing alone (Fike et al., 2003). Additionally, grass growth is seasonal and climate and soil conditions often require cows to be housed for at least part of the year in some parts of the world (O'Driscoll et al., 2009). Therefore, it has been general practice to house animals over the winter, but some management practices include housing cows all year round (Haskell et al., 2006). Indoor housing provides greater control over feed intake, which helps to maintain body condition and production levels. Total mixed rations (**TMR**) are thought to facilitate a more balanced nutrient intake for lactating cows (Coppock et al., 1981), as keeping cows on pasture can result in a loss of BW and also cause a reduction in milk yield compared to continuously housed cattle (Fontaneli et al., 2005), due to the intake rate of grazed herbage being lower than can be achieved from TMR (Kolver and Muller, 1998).

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Preference testing, or giving the animal an opportunity to choose between resources, provides insight into how animals perceive their environment and is consequently a common method of assessing animal welfare (Webster, 1996). There is emerging evidence that dairy cows generally prefer to be at pasture, although a number of factors influence this preference including weather, body condition score, season, time of day, and distance to pasture (Legrand et al., 2009; Charlton et al., 2011b, 2013; Falk et al., 2012).

Herbage mass in studies assessing dairy cow preference to be at pasture has been maintained at a wide range, sometimes differing by more than 1,000 kg DM/ha throughout the study. It has been reported that manipulating herbage mass (McEvoy et al., 2009) and herbage allowance (a function of herbage mass) affects pasture DMI (Moate et al., 1999) and grazing time in dairy cows with restricted access to pasture (Perez-Ramirez et al., 2009), and because of this, herbage mass may be an important driving factor in dairy cow preference to be indoors or at pasture. The objective of the current study was to determine to what extent herbage mass influenced dairy cow preference for access to pasture and whether or not this interacted with distance to pasture.

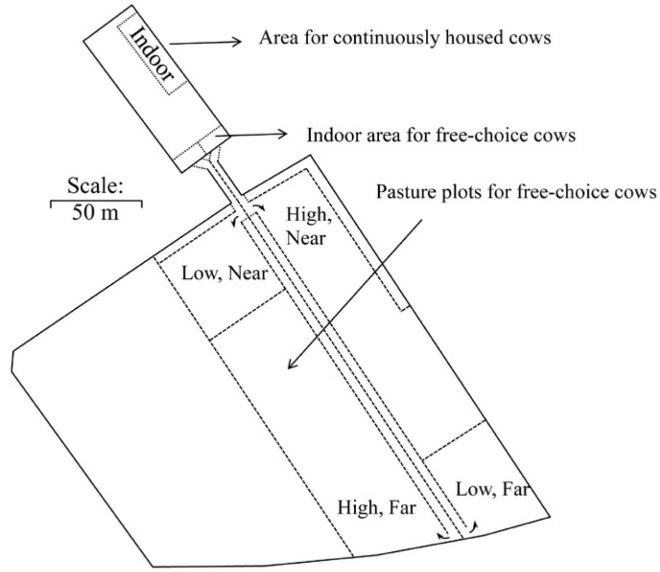

Figure 1. Plan of the experimental area showing the position of the indoor housing for the continuously housed cows and the indoor housing for cows that had free access to pasture in relation to the near pasture at 38 m from the housing (with high [3,000 ± 200 kg DM/ha] vs. low [1,800 ± 200 kg DM/ha] herbage mass) and the far pasture at 254 m from the housing (with high vs. low herbage mass).

MATERIALS AND METHODS

Ethical approval for this study was given by the Harper Adams University (**HAU**) Research Ethics Committee.

Animals and Management

Thirty-two (12 primiparous and 20 multiparous) in-calf, mid-to-late-lactation, Holstein–Friesian dairy cows that were 229 ± 82.9 (mean ± SD) days in milk (**DIM**), producing 34.1 ± 6.98 kg/d, with an average locomotion score (**LS**; Flower and Weary, 2006) of 2.19 ± 0.64 and BCS of 2.5 ± 0.35 (Edmonson et al., 1989) were chosen from the HAU dairy herd, Shropshire, UK, for this study. Sixteen animals were tested during study period A: July 16 to August 21, 2011. The second set of 16 animals was tested during study period B: August 24 to September 29, 2011. Animals were randomly allocated to 1 of 3 groups during each study period: group 1 (n = 4) and group 2 (n = 4) were given free choice to move between indoors and outdoors during the day and night except during milking (free-choice cows), and group 3 (n = 8) was continuously housed (housed cows). The groups were balanced for milk yield, DIM, BCS, and LS at the start of each period.

Study cows were milked with the main herd, and after both ante meridiem and post meridiem milkings (approximately 0430 and 1530 h), study cows were automatically separated into a holding area via an automatic segregation gate (GEA Farm Technologies, Bönen, Germany). At approximately 0645 and 1630 h, study cows in group 3 were led into their housing area, which they shared with members of the main herd that were not used as part of the experiment (611 m^2 free-stall housing; 1.5 cubicles [2.7 by 1.2 m]/cow with 3-cm thick rubber mattresses, bedded with lime ash 3 times/wk; Fig. 1) with ad libitum access to TMR (407 g/kg DM, 161 g/kg CP, and 356 g/kg NDF) from 12 electronic Roughage Intake Control (**RIC**) feed bins (1.0 by 0.9 by 0.8 m; Insentec, Marknesse, the Netherlands). Water was provided ad libitum at either end of the allotted housing area from 2 water troughs. Study cows in groups 1 and 2 were led to their indoor area where they were physically separated from the main herd (they were still able to engage in auditory, visual, and limited physical contact), which was at the end of the indoor housing facility (210 m^2 divided into 2 equal areas by a swing gate; free-stall housing; 1.5 cubicles (2.7 by 1.2 m)/cow with 3-cm thick rubber mattresses, bedded with lime ash 3 times/wk). Here, they had access to ad libitum TMR via 4 feed bins (0.7 by 0.6 by 0.4 m) placed inside 4 (1.2 by 1.4 m) Calan gate feeders (American Calan, Inc., Northwood, NH) on each side (8 Calan gates in total; 4 per group). Water was available ad libitum from 2 water troughs on each side of the swing gate. After being separated into their respective areas, gates were opened to allow cows access outside onto a track that led to the pasture (predominantly a mix of perennial ryegrass and white clover; Fig. 1) at approximately 0730 h.

The 1.8-ha field used for the study was cut for silage on May 19, 2011, and 20 kg/ha N (Lithuanian

Table 1. Group allocations to high (3,000 ± 200 kg DM/ha)/low (1,800 ± 200 kg DM/ha) herbage masses at near (38 m)/far (254 m) distances and to the continuously housed group during study period A (July 16 to August 21) and B (August 23 to September 29)

Group	Study period	Training period	Measurement period		Training period	Measurement period	
		d 1–10	d 11–15	d 16–20	d 21–27	d 28–32	d 33–37
1	A		High/near	Low/far		Low/near	High/far
2	A		Low/near	High/far		High/near	Low/far
3	A		Continuously housed			Continuously housed	
4	B		High/near	Low/far		Low/near	High/far
5	B		Low/near	High/far		High/near	Low/far
6	B		Continuously housed			Continuously housed	

Ammonium Nitrate (34.5 % N), Belarus, Lithuania) applied. Application of N was continued on a monthly basis throughout the trial. Further electrical fencing was erected to divide the study area into 4 plots (Fig. 1): high herbage mass (maintained at approximately 3,000 ± 200 kg DM/ha) at 38 m from the cubicle housing (high/near), high herbage mass at 254 m from the cubicle housing (high/far), low herbage mass (maintained at approximately 1,800 ± 200 kg DM/ha) at 38 m (low/near), and low herbage mass at 254 m (low/far). Note that herbage mass here is defined as the total mass of herbage per unit area of ground above ground level (Allen et al., 2011). The high herbage mass was chosen to provide lush pasture for cows to consume all of their feed from grass alone if they chose and the low herbage mass was chosen to allow for grazing and for use as a loafing paddock. Over the course of the experiment, herbage offered consisted of 243 g/kg DM, 122 g/kg CP, and 534 g/kg NDF on average across both allowances. Each herbage mass was offered at 2 distances to determine dairy cow motivation for access to pasture as well as to investigate whether an interaction existed between herbage mass and distance.

The high herbage mass plots were approximately 0.66 ha and the low herbage mass plots were approximately 0.22 ha. All 4 plots had self-filling water troughs. The troughs in the 0.22 ha plots straddled the fence line of the 0.66 ha plots, so cows in the high herbage plots would have access to water at both the top and bottom of the grazing area. Additionally, a back fence was installed in the high herbage mass plots to ensure a consistent herbage mass throughout the study. An electronic rising plate meter with a built in regression equation (herbage mass = [sward height (cm) × 125] + 640; F200; Farmworks, Feilding, New Zealand) was used for 2 mo before the start of the study and during the study to monitor herbage mass daily. Three weeks before the start of the study, 11 heifers were used to graze down the low herbage areas, and 60 low-yielding cows from the HAU milking herd were used to graze down the high herbage areas, to have the required herbage mass for each plot at the start of the study. Additionally, the field was topped throughout the study to maintain appropriate herbage mass. In practice, the high herbage mass plots ranged from 2,740 to 3,209 kg DM/ha, while the low herbage mass ranged from 1,634 to 2,208 kg DM/ha.

Experimental Routine

Training. Each group of cows was given a 10-d training period to ensure that each cow could access their individual feed bin via a Calan gate or RIC bin without assistance. Free-choice cows were also trained to use the indoor and pasture experimental area (described in *Animals and Management*). Free-choice cows were locked into the housing area after milking during the first 5 d, during which time they were trained to access their individual Calan bin. During the last 5 d of training, cows were herded up the track into the area of pasture they would have access to during the measurement period. They were left for 1-h intervals, approximately 3 times/d, and periodically observed and herded in and out until all cows successfully entered and exited on their own. Cows were given free access to pasture during the night. Cows were also given a 7-d retraining period to the Calan gates on the opposite side of the building (to allow them access to the remaining 2 herbage plots) in the same manner.

Measurement Period. After each training period, all groups had a 5-d measurement period where groups 1 and 2 each had access to 1 of the 4 plots while group 3 remained indoors (see Table 1). During each measurement period, groups 1 and 2 were provided with different herbage masses but were always at the same distance from the housing to remove weather effects. A Latin square was used to allocate each group to the order of low/high herbage and near/far distances (Table 1).

Measurements

Total Time Spent at Pasture or Indoors. A Voltek night vision video camera (KT&C Co. Ltd., Seoul, South Korea) connected to a digital video recorder was set up to continuously record cow movement from indoor housing to the track and onto pasture.

Manual Behavioral Observations. Observations occurred on Days 2 and 4 of each measurement period. Observations took place between 1000 to 1400 h on Day 2 and from 1800 to 2200 h on Day 4. Five-minute scan sampling was used, with location (indoors, track, or pasture), posture (lying, standing, or walking), and jaw activity (grazing, ruminating, eating TMR, drinking, and idling) recorded for each cow via manual observation (Charlton et al., 2011b).

Total Mixed Ration Intake. Access to TMR for group 1 and group 2 was controlled using Calan gates. Each cow wore a Calan collar with a transponder that only allowed access to a specific feed bin. Refusals were disposed of at 0830 h every morning and were weighed during measurement periods. A weighed amount of fresh feed was made available at approximately 0930 h daily at 105% of ad libitum intake. Feed intake (TMR) for continuously housed cows (group 3) was measured using RIC bins (Sinclair et al., 2005). Fresh feed was provided at approximately 1000 h daily at 105% of ad libitum intake, and refusals were removed 3 times/wk at approximately 0800 h.

Herbage Intake. Herbage intake was estimated using dosed *n*-alkanes as described by Mayes et al. (1986) and Dove and Mayes (2006) with the following modifications. Free-choice cows were dosed with 2 g of *n*-alkane C_{32} (dotriacontane; Minakem, Beurry-la Forêt, France) twice daily from the start of the training period to the end of the experimental period. Cows were given their dosage just after their morning milking at 0630 h and just before their afternoon milking at 1430 h. The dose was placed directly on top of the TMR inside each individual Calan bin. Each cow was watched carefully to ensure they ingested the full dosage.

At 0400, 1400, and 1800 h, naturally voided feces (100 mL) were collected from the ground from each individual cow during the last 3 d of each measurement period. In practice, at 0400 and at 1400 h, samples were collected almost immediately as cows were generally lying down and had to be disturbed to go for milking, but at the 1800 h sampling time, the sampler sometimes waited until 2000 h to collect a sample. Additionally, 3 herbage samples were collected using a circular quadrat (962 cm^2) placed randomly in sections of the plot being grazed. Samples were cut, using scissors, down to ground level. One TMR sample was collected on Day 3 of each measurement period for subsequent *n*-alkane and nutrient analysis. Samples for nutrient analysis were analyzed immediately for DM content and then ground and stored for CP and NDF analysis at a later date (see *Nutrient Analysis of Total Mixed Rations and Herbage*). Samples used for the estimation of herbage intake were stored in a freezer at –20°C and subsequently freeze-dried and ground for analysis at a later date.

Weather Conditions. A Davis Vantage PRO2 weather recorder (Davis, Hayward, CA) was used to automatically record weather conditions indoors and at pasture. Ambient temperature (°C) and relative humidity (%) were recorded indoors while ambient temperature (°C), relative humidity (%), and rainfall (mm) were recorded outdoors every 15 s for the duration of the study. The temperature–humidity index (**THI**) was calculated as THI = (1.8T + 32) – [(0.55 – 0.0055RH) × (1.8T – 26)] (NOAA, 1976), in which T = ambient temperature and RH = relative humidity.

Performance. During each experimental period, milk yield for each animal on study was recorded at each milking by an automatic recording system (GEA Farm Technologies). Body condition score and weight were recorded at the beginning, middle, and end of the study but did not fluctuate as the study period was short and therefore the probability of change was small. At the beginning and end of each study period, milk samples were taken for fat, protein, and lactose percentages and analyzed using near-infrared spectroscopy (Milkoscan Minor; Foss, Hillerød, Denmark).

Nutrient Analysis of Total Mixed Rations and Herbage. For DM determination, samples were weighed directly after collection and immediately oven dried to constant weight at 105°C. Crude protein concentration in the samples was measured by combustion using a LECO FP 528 N analyzer (Leco Corporation, St. Joseph, MI). The concentration of NDF was determined according to the method of Van Soest et al. (1991).

Statistical Design and Analysis

The experiment was a 2 × 2 factorial "within subject" crossover design (groups 1 and 2) with a separate control (group 3). All data that were not normally distributed were transformed using an arcsine transformation to improve the distribution of the data and subsequently analyzed using parametric tests (means reported are of untransformed data). Overall preference for pasture was determined using a 1-sample *t*-test: the percentage of time spent indoors and at pasture was analyzed to determine if it was significantly different from 0, 50, and 100%. Analysis of daytime behavioral activity for free-choice cows was performed using a 2-way ANOVA in GenStat (12th edition; Lawes Agricultural Trust Co. Ltd., Rothamsted, UK) to determine effects of herbage mass and distance. The model was created to find a treatment effect, a distance effect, and a treatment × distance interaction and blocked by cow group. Effects of herbage mass and distance on milk yield, milk composition, TMR intake, and herbage intake were also analyzed in

Table 2. Effect of herbage mass (3,000 ± 200 kg DM [high] or 1,800 ± 200 kg DM [low]) and distance to pasture (38 m [near] or 254 m [far]) on overall time spent at pasture, daytime and nighttime pasture use, feed intake, milk yield, and behavioral activity during daylight hours. There were no interactions between herbage mass and distance for any of the measured variables

	Herbage			Distance			
Item	High	Low	*P*-value	Near	Far	*P*-value	SEM
Time spent (over 24 h), %							
Pasture	69.1	68.3	0.888	76.4	60.9	0.022	3.96
Daytime pasture use	54.1	53.0	0.925	65.6	41.5	0.046	7.38
Nighttime pasture use	77.2	75.0	0.647	80.6	71.6	0.184	3.28
DMI and milk yield							
TMR[1] intake, kg DM	21.3	21.5	0.658	21.6	21.2	0.544	0.30
Milk yield, kg	33.1	33.8	0.474	33.6	33.4	0.850	0.64
Herbage intake, kg DM	1.6	0.8	0.001	1.4	1.0	0.030	0.03
Daytime behavioral activity, %							
Indoors	35.7	39.4	0.619	23.9	51.2	0.004	5.11
Track	10.2	12.3	0.562	2.5	20.0	<0.001	2.43
Pasture	54.1	48.3	0.564	73.7	28.8	0.001	6.82
Lying	44.2	44.2	0.985	52.4	36.3	<0.001	1.90
Standing	51.7	50.8	0.794	44.5	58.0	0.002	2.21
Walking	4.1	4.9	0.452	3.4	5.6	0.068	0.83
Eating TMR	14.8	17.8	0.190	13.0	19.6	0.013	1.56
Grazing	18.4	11.1	0.039	17.8	11.6	0.073	2.24
Drinking	1.2	1.3	0.655	0.8	1.6	0.026	0.23
Ruminating	26.5	27.5	0.565	31.0	23.0	0.001	1.24
Idling	39.2	42.3	0.395	37.3	44.1	0.086	2.52

[1]TMR = total mixed rations.

this manner. Comparisons between the behavior, feed intake, and milk yield of continuously housed cows and cows given access to pasture at both the near and far pasture were made using a 1-way ANOVA followed by a post hoc Tukey test. No effect of herbage mass was observed and because of this, the continuously housed cows were compared separately with those given access to the near pasture and the cows given access to the far pasture. Linear regressions were used to determine an effect of weather on preference. Statistical significance was set at $P \leq 0.05$.

RESULTS

Effect of Herbage Mass and Distance on 24 Hours Time Spent in Each Location, Daytime Behavioral Observations, Feed Intake, and Performance among Free-Choice Cows

Overall, cows showed a partial preference to be at pasture, spending an average of 68.7% of their time at pasture over a 24-h period. This was different from 0 ($P < 0.001$), 50 ($P < 0.001$), and 100% ($P < 0.001$). Cows spent a greater percentage of their time at pasture when it was provided at the near distance compared with the far distance ($P = 0.022$), and this was not influenced by herbage mass ($P = 0.888$; Table 2). Distance affected pasture use during the day ($P = 0.046$) but not at night ($P = 0.184$), and consequently, distance had an overall effect on pasture usage. Herbage mass did not affect daytime ($P = 0.925$) or nighttime ($P = 0.647$) pasture use. Cows that had access to the high herbage mass grazed more ($P = 0.039$) than cows that had access to the low herbage mass, and grazing time was not influenced by distance to pasture ($P = 0.073$). Distance to pasture affected posture and jaw activity as cows with access to the near pasture were observed to spend more time lying ($P < 0.001$) and ruminating ($P = 0.001$) but less time standing ($P = 0.002$), eating TMR ($P = 0.013$), and drinking ($P = 0.026$).

There were no differences in the average daily TMR consumption when offered either herbage mass ($P = 0.660$) or distance to pasture ($P = 0.546$). However, grass intake was affected by herbage mass and distance with cows having a greater intake when offered a high allowance ($P = 0.001$) and a near distance ($P = 0.030$). There were no differences in average milk yield per day when offered either herbage mass ($P = 0.474$) or distance ($P = 0.850$). No differences ($P > 0.05$) were found in milk fat, protein, or lactose content when offered either herbage mass or distance, with mean values of 388, 328, and 464 g/kg, respectively. Finally, there were no interactions between herbage mass and distance ($P > 0.05$).

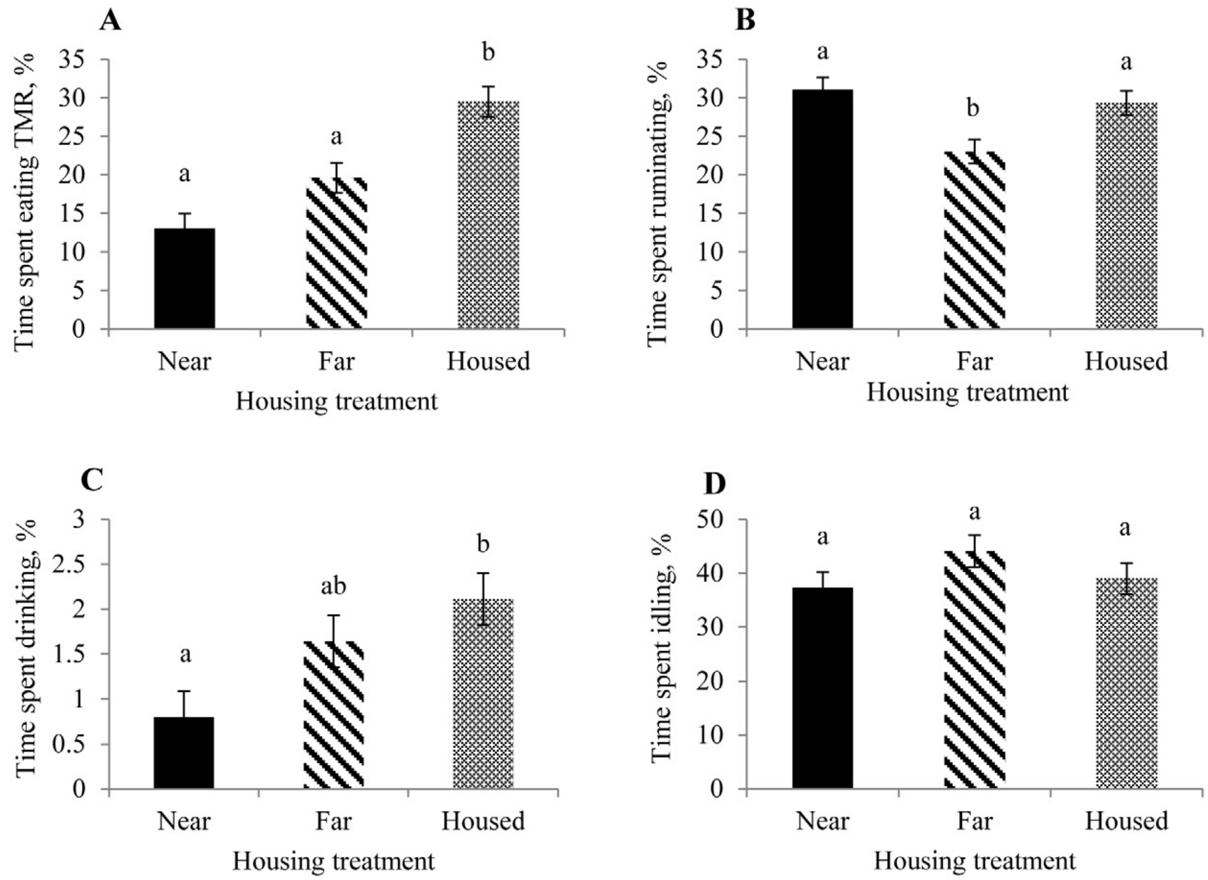

Figure 2. Jaw activity. Differences in percentage of time (mean ± SEM) spent eating total mixed rations (TMR; A), ruminating (B), drinking (C), and idling (D) between cows that were continuously housed and those given access to pasture (near and far pastures). [a,b]Significant differences ($P \leq 0.05$).

Weather

Over the course of the study the mean temperature was 16.7°C indoors (range: 10.5–22.7°C) and 15.9°C outdoors (range: 12.2–20.2°C). Indoor THI (61.6 ± 0.595; $P = 0.217$; range: 57–66) and outdoor THI (60.2 ± 0.591; $P = 0.124$; range: 56–65) had no effect on preference. Rainfall occurred on 18 out of 40 measurement days (0.04 ± 0.01 mm/d) and no effect of rainfall was found on time spent at pasture ($P = 0.451$).

Differences in Behavioral Activity (Daylight Hours), Feed Intake, and Milk Yield between Free-Choice and Housed Cows

Jaw Activity. Cows were observed to spend more time eating TMR (Fig. 2A) when continuously housed than those that had access to the near or far pasture (29.5 vs. 13.0%; $P < 0.001$, and 29.5 vs. 19.6%; $P < 0.001$, respectively). Additionally, cows were observed to spend more time ruminating (Fig. 2B) when continuously housed than those that had access to the far pasture (29.3 vs. 23.0%; $P = 0.004$) but there was no difference compared to cows that had access to the near pasture. Finally, cows at the near pasture were observed to spend less time drinking than continuously housed cows (0.840 vs. 2.11%; $P = 0.018$; Fig. 2C).

Posture. Cows were observed to spend more time lying when offered access to the near pasture compared to those that were housed (52.1 vs. 34.6%; $P < 0.001$; Fig. 3) but there was no difference between housed cows and those that had access to the far pasture (34.6 vs. 36.3%; $P > 0.05$). Additionally, cows were observed to spend more time standing when continuously housed than when given access to the near pasture (61.8 vs. 44.9%; $P < 0.001$), but there were no differences between the housed cows or those given access to the far pasture. Finally, there was no difference ($P > 0.05$) in the percentage of time spent walking.

Total Mixed Ration Intake. When comparing TMR consumption for cows that had access to the near or far pasture vs. cows that were continuously housed, no differences were found in the amount consumed (21.6 vs. 21.3 vs. 23.0 kg DM/d; $P = 0.101$).

Milk Yield. Cows that had access to the near pasture and cows that had access to the far pasture produced more milk on average per day compared to continuously housed cows (33.6 vs. 33.4 vs. 26.8 kg/d; $P < 0.001$; Fig. 4).

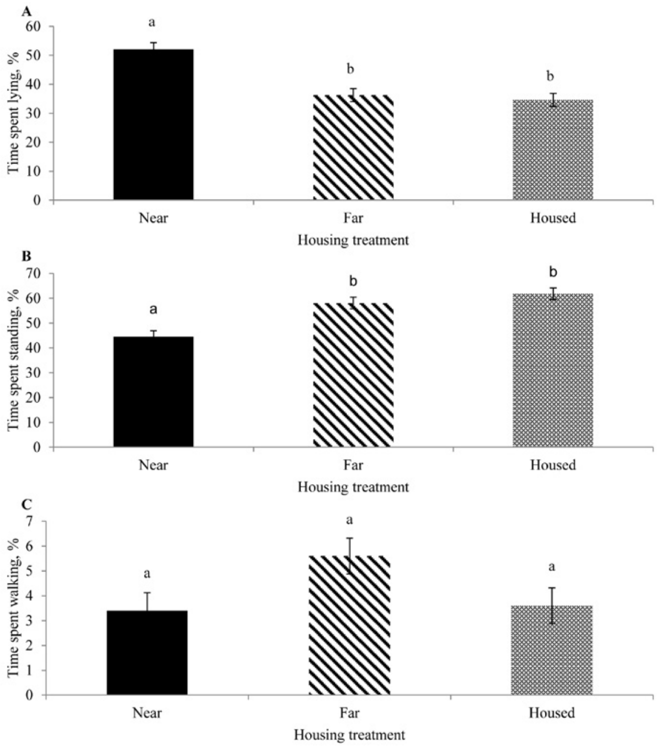

Figure 3. Posture. Differences in percentage of time (mean ± SEM) spent lying (A), standing (B), and walking (C) between cows that were continuously housed) and those given access to pasture (near and far pastures). [a,b]Significant differences ($P \leq 0.05$).

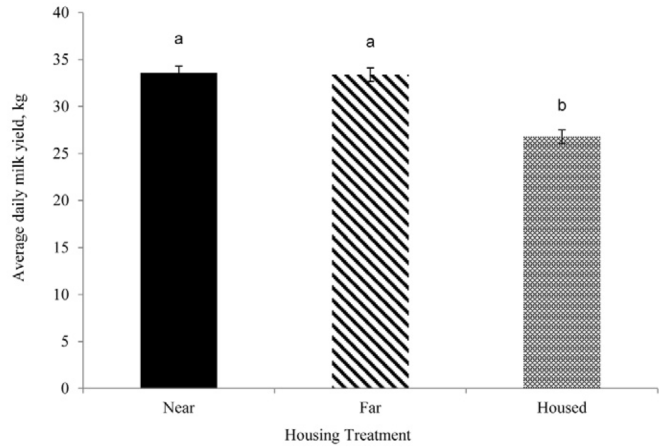

Figure 4. Differences in average daily milk yield (mean ± SEM) between cows that were continuously housed and those given access to pasture (near and far pastures). Cows at the near pasture are the same sample of cows at the far pasture. [a,b]Significant differences ($P \leq 0.05$).

DISCUSSION

Overall, cows expressed a partial preference to be at pasture, spending almost 70% of their time outside. Preference for pasture was affected by distance but not herbage mass. The overall partial preference for pasture is similar to findings reported by Krohn et al. (1992) and Charlton et al. (2011a), where dairy cows given a free choice to be indoors or at pasture during the summer spent 72 and 71% of their time outdoors, respectively. However, Charlton et al. (2011b) reported that dairy cows preferred to be indoors over 90% of the time. This difference may be due to the cows used by Charlton et al. (2011b) having had limited exposure to pasture during rearing. Falk et al. (2012) and Legrand et al. (2009) reported that cows did not show an overall partial preference to be indoors or at pasture, spending 42 and 46% of their time indoors, respectively. The lack of preference for pasture in these 2 studies may be due to the higher maximum THI values reported at pasture than in the current study, as heat stress can influence where cattle choose to spend their time (Blackshaw and Blackshaw, 1994).

Herbage mass did not influence preference under the conditions of this study and there was no interaction between herbage mass and distance to pasture. This suggests that herbage mass is not a key driving factor in dairy cow preference to be indoors or at pasture when a TMR is offered indoors. This is potentially because high yielding dairy cows (>30 kg milk/d) cannot achieve the same DMI from grazing as cows fed a TMR; they are constrained by DM per bite, bite rate, and grazing time (Kolver and Muller, 1998). Additionally, the relatively low average grass intake of 1.22 kg DM/d suggests that dairy cows were simply supplementing their TMR intake with grass rather than actively using grass as their sole means of nourishment. As it has been shown that dairy cows prefer to select their diet when given a chance, and a TMR provides a balanced nutrient intake for the average cow rather than the individual (Rutter, 2010), cows may have been using the pasture as a way to fulfill individual nutritional needs. It should be noted that paddock size may have been confounded with herbage mass (where the cows may have preferred the high herbage allowance plots simply because they were larger), but ultimately no effect of herbage allowance was found except on grazing time and herbage intake (which was expected), suggesting that there was no effect of paddock size on preference either under the conditions of this study.

Ketelaar-de Lauwere et al. (2000) reported contradictory results indicating that at lower sward heights, cows spend more time indoors. However, unlike in the current study where the temperature range outside was moderate (12.2–20.2°C), much greater temperatures were reported (18.9–32.1°C) in the study of Ketelaar-de Lauwere et al. (2000) and so it is likely that some interaction between temperature and sward height affected time spent indoors rather than sward height being the sole reason for increased time indoors. Additionally, the cows used by Ketelaar-de Lauwere et al. (2000) were in early to mid lactation vs. the mid to late lactation cows in the current study, which may have affected their motivation to be at pasture, although yield was higher in the current study.

Distance to pasture was the main factor that influenced preference, with cows spending more time at pasture when given access to the near vs. far pasture. Similar results were reported by Sporndly and Wredle (2004): when cows were given access to a near pasture (50 m), they chose to spend 68% of their time outdoors. In the current study, cows were not willing to walk the far distance to gain access to pasture during the day but were willing to do so during the night. Charlton et al. (2013) also reported that when cows had to walk a short distance (60 m) to gain access to pasture vs. farther distances (140 or 260 m), cows were prepared to walk the distance at night but not during the day, suggesting that pasture access is particularly important at night.

The intake of TMR and milk yield were not affected by herbage mass or distance to pasture, although cows did spend more time eating TMR when given access to the far pasture, possibly because they spent more time indoors during the daytime, which is typically when the majority of feeding behavior occurs (Tucker, 2009). Both TMR intake and milk yield among free-choice cows were maintained at high levels throughout the study (21.4 kg DM/d and 33.5 kg/d respectively). The ability to maintain intake and milk yield is supported by previous research that has indicated that giving cows free access to pasture is not detrimental to performance if cows are allowed ad libitum access to a TMR indoors (Chapinal et al., 2010). In contrast, the present findings are contradictory to that reported by Legrand et al. (2009), where there was a 14% decrease in TMR intake when cows were given a choice between cubicle housing and pasture. Cows in the current study produced more milk than cows used by Legrand et al. (2009; 34 vs. 26 kg/d, respectively) despite being at approximately the same lactation stage as cows in the current study, and because of this it suggests they may have had different metabolic requirements that influenced their intake behavior. Additionally, grass intake was not measured by Legrand et al. (2009), so although TMR intake may have decreased, it is not clear whether overall DMI decreased as a result of free access to pasture.

Herbage intake in the current study was affected by both herbage mass and distance. Intake was higher at the near pasture with cows consuming 0.44 kg DM/d more than when given access to the far pasture and cows consumed 0.79 kg DM/d more at the high allowance vs. the low allowance. Bargo et al. (2003) reported similar results indicating that pasture DMI increases as herbage mass increases. These results are not surprising, as grazing time was affected by herbage mass with cows spending more time grazing when offered a high allowance and a tendency existed for cows to spend more time grazing at the near distance. Contrary to these findings, Ketelaar-de Lauwere et al. (2000) reported that total time spent grazing was not influenced by sward height. This contrary result may be due to their greatest reported sward height of 14.5 cm being less than the high herbage mass offered in the current experiment, but as they did not report herbage mass or sward type, the results are difficult to compare directly.

Dairy cows spent more time grazing at the high herbage mass but they did not actually spend any more time at pasture when offered the high herbage mass. These results contradict those reported in 2 studies that examined grazing behavior in dairy cows at different herbage allowances where herbage allowance did not influence the proportion of time spent grazing (Perez-Prieto et al., 2011; Chilibroste et al., 2012). The results of the current study, however, are supported by Perez-Ramirez et al. (2009), where there was a tendency ($P = 0.067$) for the proportion of time spent grazing to increase at a high herbage allowance vs. a low herbage allowance (which would correspond to a high herbage mass vs. a low herbage mass) with cows that spent 22 h at pasture. The lack of treatment effect on grazing time reported by Chilibroste et al. (2012) and Perez-Prieto et al. (2011) could be due to their observations of grazing being over 3 different herbage allowances (low, medium, and high), and in both studies the low/medium herbage allowances offered was comparable to the high herbage mass offered in the present study. Additionally, Chilibroste et al. (2012) and Perez-Prieto et al. (2011) conducted their studies in winter in contrast to the current experiment and that of Perez-Ramirez et al. (2009), which were conducted in the summer and spring, respectively. As season influences dairy cow preference to be at pasture (Krohn et al., 1992), it may also influence the proportion of time spent grazing when dairy cows have a choice to be indoors.

Lying and ruminating time were affected by distance to pasture, with cows spending more time lying and ruminating when offered pasture at the near distance. As lying time increased as the distance to pasture decreased, this may be a function of pasture being a comfortable lying area for dairy cows. Studies have reported that pasture is a preferred substrate to lie on (Krohn et al., 1992; Ketelaar-de Lauwere et al., 2000), and this may also explain the strong preference for pasture at night reported in the current study as well as by Legrand et al. (2009), Falk et al. (2012), and Charlton et al. (2013), as the majority of lying behavior occurs during the night (Tucker, 2009). As rumination time is more frequent during periods of lying (Schirmann et al., 2012), it is logical that cows spent more time ruminating when offered the near distance as they also spent more time lying. It should be noted that both rumination and lying behavior were not recorded at night and 24-h time budgets may be different from time budgets during the day. Free-choice cows at the far pasture may have been altering their time budget during the day when compared to free-choice cows at the near pasture. Cows at the far pasture spent less time lying and subsequently less time ruminating as they spent less time at pasture during the day and spent more time indoors eating TMR. However, at night, when they actively chose to access pasture, they may have made up the difference.

Previous research has reported that Holstein–Friesian dairy cattle are particularly susceptible to heat stress (Blackshaw and Blackshaw, 1994) and are highly motivated to seek shade to reduce the negative consequences of heat stress (Shütz et al., 2008). If given a choice, dairy cows will move indoors during the day as thermal comfort decreases with increasing THI at pasture (Legrand et al., 2009; Falk et al., 2012). In the current study, the THI did not influence cow preference to be indoors or at pasture, which has also been reported by Charlton et al. (2013). Both the current study and that of Charlton et al. (2013) reported similar average values for THI at pasture (60.2 and 59.6, respectively) and the maximum THI value of 65 in the current study did not exceed the reported upper critical limit for lactating dairy cows of 72 (corresponding to 25°C and 50% relative humidity; Tucker et al., 2008). Although Legrand et al. (2009) reported a mean THI value of 60.5, which was similar to the current study, the THI range was much wider (49.9–74.6) than that of the current study (56–65), making it more likely for changes in pasture use to become apparent, and the maximum value exceeded the upper critical limit of 72. This may be why in the current study THI did not appear to affect preference for pasture. Rainfall has also been reported to affect preference (Legrand et al., 2009; Charlton et al., 2011b), but as rainfall was negligible in the current study when compared to both Charlton et al. (2011b) and Legrand et al. (2009; 0.04 vs. 0.60 vs. 5.4 mm/d), it did not influence where cows spent their time.

When comparing housed cows vs. free-choice cows, the main differences occurred when free-choice cows had access to the near pasture. Housed cows, however, spent more time eating TMR than free-choice cows at either distance but had similar daily intakes with all cows eating approximately 22 kg DM/d of TMR. This indicates that free-choice cows reallocated their time budget compared to continuously housed cows but were still able to maintain a high intake. Additionally, free-choice cows at either distance produced more milk than housed cows. This is potentially a function of both increased cow comfort when given access to pasture as well as herbage intake. The average herbage intake (kg DM/d) of 1.22 would account for about 3 kg of the 6.7 kg increase in milk yield if we assume that the ME of the grass was between 10.0 and 12.0 MJ/kg DM and that the ME of the milk is 5.2 MJ (McDonald et al., 2011). There is the potential that the rest may be accounted for by lying time. Overall lying time in free-choice cows with access to the near pasture was greater than housed cows, and there is some evidence to suggest that mammary blood flow increases during periods of lying (Metcalf et al., 1992), which may increase milk yield. Further studies are necessary, however, to quantify exactly how lying time affects milk yield. The increase in lying time among free-choice cows is a particularly interesting finding because although overall time spent lying was more than housed cows, free choice cows did not spend more time lying on pasture than indoors, a finding that was contradicted by Ketelaar-de Lauwere et al. (2000). This suggests that allowing dairy cows to have control over their environment by offering them a free choice promotes lying behavior in dairy cows, even if the majority of time is not spent lying on pasture. It is also possible that lower stress levels contributed to this increase in milk yield as agonistic encounters are more easily avoidable at pasture because of the increased inter-cow distance outdoors (Philips, 2010).

Conclusions

Herbage mass is not a driving factor in dairy cow preference for pasture, but it does influence grass intake, which, among other factors, increases milk yield. Distance affects pasture use, but only during the day, suggesting that dairy cows are more highly motivated to access pasture at night. Finally, housed cows spend less time lying down and produce less milk than cows with free access to pasture. Giving dairy cows control over their own environment seems to have both welfare and production benefits and as such should be seen as a gold standard to strive towards.

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