Effects of providing total mixed rations indoors and on pasture on the behavior of lactating dairy cattle and their preference to be indoors or on pasture

G. L. Charlton,*† S. M. Rutter,*¹ M. East,† and L. A. Sinclair*

*Animal Science Research Centre, Harper Adams University College, Shropshire, TF10 8NB, UK

†Agriculture Department, Reaseheath College, Cheshire, CW5 6DF, UK

ABSTRACT

Grazing is considered a normal behavior for dairy cattle, although they may not be able to meet their nutritional requirements from grazing alone, and so to sustain higher yields requires access to a total mixed ration (TMR). The study aim was to provide dairy cows with access to TMR indoors and on pasture to establish influence on behavior and preference for each location. The study took place from August to November, 2009, using 36 late-lactation Holstein-Friesian dairy cows. The cows were allocated to 1 of 3 26-d study periods ($n = 12 \times 3$). Within each period the cows were further divided into a control ($n = 6$) or treatment ($n = 6$) group using a crossover design, where the cows were changed between the control and treatment group after 13 d. Treatment cows had access to TMR indoors and on pasture, whereas control cows only had access to TMR indoors. Following a.m. and p.m. milkings the cows were taken to a point equidistant between indoors and pasture and given the choice of going to pasture (1.5 ha) or to a freestall barn. Between milkings the cows had free access between the locations. Initial choice was recorded and a video camera was used to record time spent in each location. Behavior observations were recorded to establish how the cows spent their time during the day. To determine what factors influenced preference, weather conditions, milk yield, body condition score, and lameness were recorded. Initially, the cows chose indoors following milking ($96.4 \pm 0.80\%$). Overall, the cows expressed a partial preference for pasture ($71.1 \pm 1.82\%$), which was different from 100, 50, and 0%. Study period influenced preference with cows spending less time on pasture as the season progressed (86.7 vs. 68.3 vs. 58.3% for study periods 1, 2, and 3, respectively). Providing the cows with TMR outdoors did not affect pasture use, but resulted in an increase in TMR intake of 2.2 ± 0.41 kg of dry

matter/d. The cows spent more time on pasture as the temperature-humidity index indoors (55.6 ± 0.92) and outdoors (54.6 ± 0.82) increased, but rainfall and milk yield did not influence preference. Cows with lameness score >1.5 spent more time indoors (35.4 ± 4.52 vs. $25.2 \pm 2.64\%$ for cows with >1.5 vs. ≤ 1.5 lameness score, respectively). In conclusion, the cows expressed a partial preference for pasture, which was not influenced by providing TMR on pasture.

Key words: total mixed ration, preference, pasture, housing

INTRODUCTION

Dairy cattle are grazing animals, so pasture is a natural environment (Clutton-Brock, 1999). It allows the expression of normal behavior and can often be seen as a period of recovery for lame cows (Hernandez-Mendo et al., 2007; Olmos et al., 2009). Feed cost and labor were decreased when cows were on pasture (Clark and Kanneganti, 1998). Yet, when high-yielding dairy cows are only provided with pasture to graze, they may not be able to meet their nutritional demands (Fike et al., 2003), and grazing alone could compromise their freedom from hunger, and limit productivity. Fontaneli et al. (2005) reported that cows on pasture produced 19% less milk than those in confined housing, and this is often the reason dairy cows are kept indoors. When dairy cows are housed they are generally provided with a high-quality diet, which allows them to more easily meet their nutritional demands and their production potential. Indoor housing systems raise other welfare concerns. The incidence of mastitis is higher indoors (Washburn et al., 2002), natural behavior may be restricted (Boyle et al., 2008), and space allowance is often decreased. Haskell et al. (2006) found that hoof disorders and lameness were higher for cows housed indoors, compared with those on pasture.

Indoor housing provides protection from environmental conditions and studies that have offered cows a choice of where to spend their time have shown that animals spend more time indoors as the temperature

Received January 12, 2011.

Accepted March 30, 2011.

¹Corresponding author: smrutter@harper-adams.ac.uk

humidity index increases (Legrand et al., 2009), as the season progresses from summer into winter (Krohn et al., 1992), and on days when it rains (Charlton et al., 2011). Legrand et al. (2009) reported that although cows grazed on pasture, they used the indoor housing predominately for feeding, especially after morning and afternoon milking. Despite using the indoor housing for food and protection, cattle have demonstrated a preference for pasture. Krohn et al. (1992) found that during the summer months, cows spent 72% of their time on pasture. Similarly, Legrand et al. (2009) found that dairy cows had a preference for pasture during the nighttime. Pasture seems the preferred lying place for dairy cows, as they spent over 80% of their lying time on pasture when given a choice (Ketelaar-de Lauwere et al., 1999), particularly when the pasture was close (50 m) to the indoor housing (Spöndly and Wredle, 2004). In contrast to these findings, Charlton et al. (2011) reported that cows spent 91.9% of their time indoors when given a choice to be indoors or on pasture. Milk yield influenced choice, with high-yielding cows (>26.9 kg/d) spending more time indoors compared with lower yielding animals (≤ 26.9 kg/d). It was suggested that the provision of TMR indoors may have been the primary influence for the high-yielding dairy cows to spend more time indoors as they could more easily meet their nutritional demands.

The current study aimed to investigate the effect of providing dairy cattle with TMR indoors and on pasture. It was hypothesized that cows provided with access to TMR indoors and on pasture would spend more time on pasture compared with the control group with access to TMR indoors only, as cows will be able to spend their time on pasture and meet their nutritional demands from the TMR.

MATERIALS AND METHODS

Animals and Management

Thirty-six pregnant Holstein-Friesian dairy cows (8 primiparous and 28 multiparous) in late lactation (240 ± 8.46 DIM, mean $\pm$ SEM), producing between 7.3 to 45.4 kg/d, with a BCS of 3.0 ± 0.05 from the herd at Harper Adams University College, Shropshire, UK ($52^{\circ}47'N$; $2^{\circ}26'W$) were selected based on milk yield and allocated to 1 of 3 study groups ($n = 12 \times 3$). Within each group the cows were further divided into 2 groups: group 1 (treatment group; $n = 6$), which had access to TMR indoors and on pasture, and group 2 (control group; $n = 6$), which only had access to TMR indoors. Initially the cows were divided into groups using random allocation. If a significant difference existed between the milk yields of the 2 groups, they

were reselected until no significant difference occurred. Each study period lasted for 26 d, which consisted of a 7-d training period followed by a 6-d measurement period. Within each study period a crossover design was used, so on d 14 cows were rotated between treatments. Twice daily at 0430 and 1500 h the cows were taken to the milking parlor by their regular stockperson and milked through a 40-point internal rotary parlor. No concentrates were fed during milking.

The experiment was conducted between August 17 to November 6, 2009 (study period 1: August 17 to September 11, 2009; study period 2: September 14 to October 9, 2009; and study period 3: October 12 to November 6, 2009). Prior to the study the cows were housed indoors in a freestall barn from November to April and allowed access to pasture from April to October, depending on the weather conditions. Ethical approval for the study was given by the Harper Adams University College Research Ethics Committee.

Experimental Design

Following both milkings, the 12 cows were automatically separated into a holding area, using an automatic segregation gate (Westfalia Surge Ltd., Milton Keynes, UK). At approximately 0645 and 1700 h, the cows were taken from the holding area and moved to a choice point, which was equidistant (20 m) between the housing and pasture (Figure 1). At the choice point, the group of cows could choose whether to go indoors or to pasture, and their initial decision recorded. The cows were then free to move to and from each location between milkings. A Voltek night vision video camera (KT&C Co., Ltd., Seoul, South Korea) connected to a video cassette recorder (Sony SVT-124P; Sony, Tokyo, Japan) located on the pathway was used to continuously record cow movement between the housing and pasture.

Cows assigned to the treatment group had access to TMR indoors and on pasture, whereas control cows only had access to TMR indoors. The TMR indoors was available from electronic RIC feed bins (Insentec, Marknesse, the Netherlands; Jackson et al., 2004). On pasture, cows had access to the TMR through a Calan gate feeding system (American Calan, Inc., Northwood, NH). Both the treatment and control groups could graze the pasture. Prior to the study all of the cows had experience with the indoor housing and pasture.

Indoor Housing. The indoor area (206 m^2 ; freestalls; Figure 1) was part of a larger housing area and was connected to the pasture through a 4.0-m gate at the end of the barn. The indoor area had 2 passageways, both with automatic scrapers, set to run every 3 h. A 4.0-m wide passage allowed access to 12 RIC bins (1.0

Figure 1. Plan of the experimental area showing the position of the indoor housing with freestalls in relation to the pasture, the choice point [equidistant (20 m) between the indoor housing and pasture], the position of the Calan gate feeders and water trough on pasture, and the outdoor weather sensor.

$\times 0.9 \times 0.8$ m) where all of the cows had ad libitum access to a TMR (DM basis: 25% corn silage, 14% grass silage, 10% whole crop wheat, 14% caustic barley, 12% dried molasses sugar beet shreds, 12% high-protein soya, 7% rapeseed meal, 2% molasses, 2% protected fat, 1% minerals, 0.5% limestone, 0.5% urea). The chemical composition was 48.7% DM, 12.2 MJ of ME/kg of DM, 17.6% CP in DM, 30.0% NDF in DM, 18.7% starch in DM, and 7.6% sugar in DM. The cows could access feed from any of the 12 bins. A transponder attached to a collar and weigh cells located in the bins allowed individual feed intake to be measured. Fresh food was provided in the bin daily at approximately 1100 h. Feed refusals were removed from the bins every Monday and Thursday morning. The adjacent 3.7-m passageway allowed access to 18 2.7×1.2 m freestalls with 3-cm thick rubber mattresses, which were bedded with lime ash 3 times weekly. Fresh drinking water was available ad libitum from 2 $1.7 \times 0.5 \times 0.5$ m water troughs at the end of the barn, which were 6.7 m from the nearest RIC bin.

Pasture. The cows had access to a 1.5-ha field, which was fenced off using electric fencing tape (pasture; Figure 1). The grazing area consisted predominantly of a permanent mixed perennial ryegrass and white clover

sward. At the far end of the field, six 1.2×1.4 m Calan gate feeders were placed in pairs, separated by a 1.5-m gate (Calan gate feeders; Figure 1). Each pair of gates was covered with a 2.7×2.7 m high gazebo to keep the TMR dry. Cows in the treatment group could access feed from the Calan feeders using a transponder that was attached to a separate collar worn by the cows. Each cow was trained to use an individual feeder. Fresh TMR (same composition as indoors) was placed in a $0.7 \times 0.6 \times 0.4$ m feed bin at the back of each gate daily, at approximately 1100 h. To measure feed intake, refusals from the previous day were removed and weighed. At 1700 h, the feed bins were checked. If more than half of the feed had been eaten, another 10 kg of feed was added to the bin. Fresh drinking water was available ad libitum from a $1.3 \times 0.5 \times 0.5$ m water trough, situated 8.4 m from the nearest Calan gate (Figure 1).

Training the Cows. Each experimental period consisted of two 7-d training periods. During this time, the cows were trained to use the Calan gate feeders, the RIC bins, and to habituate to choosing whether to go indoors or to pasture. To train the cows to use the Calan gate feeders, the 6 treatment cows were separated from the control cows on d 1 to 4 of the training period, at approximately 1100 h (when fresh

TMR was provided). During this time, the behavior of the cows was shaped. This was achieved by opening the Calan gate as the cow approached the correct feeder. This was repeated several times until each cow was repeatedly approaching the correct gate and eating from the feeder. After this, if the cows left, the feeder the spring-loaded gate would close and lock, and the cows could then only gain access by using their transponder to open the lock, which was a solenoid operated bolt. A similar approach was used to train the cows to use the RIC bins. The cows were then observed to ensure they could successfully open the Calan gates and RIC feeders using their transponder and where eating from the feeder. All cows were successfully trained to use the Calan gates and RIC bins within 4 d.

Measurements

Manual Behavior Observations. All behavioral activities and positions were recorded for approximately 12 h/d (during the hours of daylight), every other day throughout the measurement period for the 12 cows, whether they were on pasture, indoors, or on the pathway between the locations. Manual observations of behavior occurred every 5 min during each observational period. Binoculars were used by the observer to ensure accurate identification of each cow with minimum disturbance. During each 5-min observation period the observer recorded the following activities, once for each cow: (1) location: indoors, pasture, or pathway between indoors and pasture; (2) position: lying, standing, or walking; (3) jaw activity: eating (TMR indoors or on pasture), grazing, ruminating, drinking, or idling (i.e., none of the preceding jaw activity categories); and (4) other: grooming, social interaction, investigating, estrus, play, and aggression.

Weather Conditions. Weather conditions were recorded automatically every 15 min, 24 h/d throughout the training and study period using a Davis Vantage PRO2 weather recorder (Davis Instruments Corp., Hayward, CA). Ambient temperature (°C) and relative humidity (%) were recorded indoors and ambient temperature (°C), relative humidity (%), wind speed (m/s), wind direction, and rainfall (mm) were recorded outdoors (outside weather sensors; Figure 1). 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 (%).

Performance and Lameness. Milk yield was recorded automatically for each cow at each milking by a computerized recording system (Westfalia Surge Ltd.) throughout the study and training periods.

On d 1, 13, and 26 of the study period, a BCS of 1 to 5 was assigned to each cow according to Edmonson et al. (1989). At the same time a lameness score was given to each cow, according to Flower and Weary (2006). A lameness score of 1 (smooth and fluid movement) to 5 (ability to move is severely restricted and must be vigorously encouraged to move) was given as each cow was walked along a concrete floored area. The BCS and lameness scoring at each stage were carried out by the same person at approximately 1645 h.

Sward Height. Measurements of compressed sward height were made each day at approximately 0630 h using a rising plate meter (Ashgrove Pasture Meter; Ashgrove Pastoral Products, Hamilton, NZ). The rising plate meter was placed randomly around the field 30 times in a W pattern, with 7 paces between each measurement. The measurements of compressed sward height were used to estimate the amount of herbage in the field, with kg of DM/ha calculated using the following regression equation: herbage mass (kg of DM/ha) = [sward height (cm) $\times$ 316] + 300 (Sayers et al., 2003). The field was maintained to provide between 1800 and 3000 kg of DM/ha. Throughout the study, the sward height was 7.2 ± 0.45 cm, providing $2,568 \pm 46.3$ kg of DM/ha.

Statistical Analysis

Decision from the choice point and time spent in each location was analyzed for individual cows ($n = 36$) during each 6-d study period using a 1-sample *t*-test. Percentage decision to go indoors from the choice point and time spent on pasture was analyzed to determine whether it was significantly different from 0, 50, and 100% [i.e., choice to go to pasture; indifferent (i.e., random choice); or to go indoors, respectively].

Paired *t*-tests were used to compare time budgets indoors and on pasture. Analysis of variance was used to analyze the effect of the treatment on decision at the choice point, overall time spent on pasture, pasture use during the day time and night time, the number of transitions between indoors and pasture, the consumption of TMR, and milk yield during each 6-d measurement period. The model included the effect of study period, treatment, the interaction between study period and treatment and the block of each animal. Prior to analysis the data were checked for normality using probability distribution plots. Data which were not normally distributed were transformed using a logit-transformation. All means ($\pm$ SEM) are presented as untransformed data. Linear regressions were used to determine whether a relationship existed between weather condition and animal factors and the percentage time spent indoors and on pasture. GenStat was

Table 1. Effect of treatment on time spent on pasture (% $\pm$ SEM) by dairy cows ($n = 36$), decision to go indoors from the choice point (% $\pm$ SEM), consumption of TMR (kg of DM $\pm$ SEM), behavioral activity (% $\pm$ SEM), and milk yield (kg $\pm$ SEM)

Item	Control ¹	Treatment ²	P-value
Time spent (over 24 h)			
Overall time spent on pasture (%)	70.3 $\pm$ 2.67	71.9 $\pm$ 2.49	0.298
Daytime pasture use (%)	49.8 $\pm$ 4.95	53.0 $\pm$ 4.44	0.113
Nighttime pasture use (%)	83.8 $\pm$ 1.93	84.0 $\pm$ 2.51	0.364
Transitions between indoors and pasture (n)	2.7 $\pm$ 0.19	2.6 $\pm$ 0.17	0.560
Decision at the choice point (% indoors)	96.3 $\pm$ 0.15	96.5 $\pm$ 0.12	0.867
TMR consumption and milk yield			
Consumption of TMR indoors (kg of DM)	16.7 $\pm$ 0.61	14.5 $\pm$ 0.78	<0.001
Consumption of TMR outside (kg of DM)	0.0 $\pm$ 0.00	4.4 $\pm$ 0.65	
Overall consumption of TMR (kg of DM)	16.7 $\pm$ 0.61	18.9 $\pm$ 0.57	<0.001
Milk yield (kg)	24.5 $\pm$ 1.37	24.8 $\pm$ 1.35	0.550
Behavioral activity during daylight hours (%)			
Grazing	16.1 $\pm$ 2.07	14.2 $\pm$ 1.42	0.318
Eating TMR indoors	17.7 $\pm$ 0.95	16.2 $\pm$ 1.1	0.120
Eating TMR outdoors	0.0 $\pm$ 0.00	4.6 $\pm$ 0.68	
Ruminating indoors	11.9 $\pm$ 1.85	11.1 $\pm$ 1.62	0.464
Ruminating on pasture	11.6 $\pm$ 1.18	11.9 $\pm$ 1.09	0.730
Idling indoors	19.2 $\pm$ 2.38	19.5 $\pm$ 2.16	0.834
Idling on pasture	17.6 $\pm$ 1.79	19.2 $\pm$ 1.83	0.280
Drinking indoors	1.2 $\pm$ 0.13	1.0 $\pm$ 0.09	0.024
Drinking on pasture	0.3 $\pm$ 0.07	0.4 $\pm$ 0.06	0.470

¹Cows had access to TMR indoors only.²Cows had access to TMR indoors and on pasture.

used to analyze all data (GenStat 12th edition; Lawes Agricultural Trust Co. Ltd., Rothamsted, UK).

RESULTS

Time Spent Indoors and on Pasture

The cows spent more time on pasture than indoors (71.1 $\pm$ 1.82 vs. 28.9 $\pm$ 1.82% for pasture vs. indoors, respectively) which was different from 0% ($t = 39.10$, $P < 0.001$), 50% ($t = 11.60$, $P < 0.001$), and 100% ($t = -15.89$, $P < 0.001$; Table 1). Providing the cows with TMR indoors and outdoors did not influence pasture use. The cows spent more time on pasture during the night than the day (83.9 $\pm$ 1.57 vs. 51.4 $\pm$ 3.31% time on pasture for night vs. daytime, respectively; $P < 0.001$). No difference was observed ($P > 0.05$) between the use of pasture by treatment and control cows during the daytime or night. The cows made 2.7 $\pm$ 0.13 transitions between the indoor housing and pasture (excluding the times the cows were brought indoors for morning and afternoon milking), which was not influenced by treatment. Study period had an effect on overall time spent on pasture, with cows decreasing pasture use as the study progressed (Table 2). Daytime and nighttime pasture use was influenced by the study period; pasture use during the day time (a.m. to p.m. milking) started to decrease during the second study period, whereas nighttime (p.m. to a.m. milking) pasture use only started to decrease during the third study period (Table 2).

Decision from the Choice Point

From the choice point, the cows chose to go indoors more often than they chose to go to pasture (96.4 $\pm$ 0.80 vs. 3.6 $\pm$ 0.80%, respectively), which was different from 0% ($t = 38.46$, $P < 0.001$) and 50% ($t = 18.52$, $P < 0.001$), but not different from 100% ($t = -1.43$, $P = 0.212$; Table 1). No difference was observed at the choice point for treatment or control cows. Study period influenced the decision at the choice point ($P < 0.001$), with decision to go to pasture increasing during study period 3 (Table 2).

Consumption of TMR Indoors and on Pasture

When cows had access to TMR indoors and on pasture, the overall consumption of TMR increased (Table 1). Cows receiving the control treatment ate more TMR indoors than did treatment cows. Study period influenced the amount of TMR consumed indoors and the overall consumption of TMR (kg of DM), with TMR intake increasing as the study progressed (Table 2). An interaction existed between the treatment and study period ($P = 0.024$), with control cows increasing DMI in study period 3. The total consumption of TMR (kg of DM) was influenced by milk yield ($R^2 = 0.29$, $P < 0.001$) with high-yielding dairy cows (producing >24.3 kg/d) consuming more TMR than low-yielding dairy cows (≤ 24.3 kg/d; 19.4 $\pm$ 0.60 vs. 16.2 $\pm$ 0.51 kg of DM, for high- vs. low-yielding cows, respectively).

Table 2. Effect of study period on time spent on pasture (% $\pm$ SEM) by dairy cows ($n = 36$), decision to go indoors from the choice point (% $\pm$ SEM), consumption of TMR (kg of DM $\pm$ SEM), behavioral activity (% $\pm$ SEM), and milk yield (kg $\pm$ SEM)

Item	Period 1 ¹	Period 2 ²	Period 3 ³	P-value
Time spent (over 24 h)				
Overall time spent on pasture (%)	86.7 $\pm$ 0.49	68.3 $\pm$ 2.57	58.3 $\pm$ 2.38	<0.001
Daytime pasture use (%)	82.2 $\pm$ 0.83	33.9 $\pm$ 4.90	38.2 $\pm$ 3.81	<0.001
Nighttime pasture use (%)	90.2 $\pm$ 0.46	91.9 $\pm$ 1.55	69.6 $\pm$ 2.63	<0.001
Transitions between indoors and pasture (n)	2.5 $\pm$ 0.10	2.3 $\pm$ 0.24	3.2 $\pm$ 0.36	0.064
Decision at the choice point (% indoors)	99.3 $\pm$ 0.48	99.0 $\pm$ 0.58	91.0 $\pm$ 1.87	<0.001
TMR consumption and milk yield				
Consumption of TMR indoors (kg of DM)	13.4 $\pm$ 0.67	14.0 $\pm$ 0.62	19.3 $\pm$ 0.79	<0.001
Consumption of TMR outside (kg of DM)	3.4 $\pm$ 0.83	2.8 $\pm$ 0.77	0.5 $\pm$ 0.31	<0.001
Overall consumption of TMR (kg of DM)	16.8 $\pm$ 0.81	16.8 $\pm$ 0.59	19.8 $\pm$ 0.71	0.020
Milk yield (kg)	24.6 $\pm$ 3.16	22.6 $\pm$ 1.53	27.0 $\pm$ 1.85	0.397
Behavioral activity during daylight hours (%)				
Grazing	25.7 $\pm$ 1.57	12.8 $\pm$ 1.75	7.0 $\pm$ 1.00	<0.001
Eating TMR indoors	13.8 $\pm$ 0.87	16.1 $\pm$ 1.14	21.1 $\pm$ 1.27	0.001
Eating TMR outdoors	4.2 $\pm$ 0.83	3.9 $\pm$ 0.79	0.6 $\pm$ 0.20	<0.001
Ruminating indoors	1.2 $\pm$ 0.50	14.6 $\pm$ 1.65	18.7 $\pm$ 1.90	<0.001
Ruminating on pasture	17.5 $\pm$ 0.86	8.0 $\pm$ 1.13	9.7 $\pm$ 1.29	<0.001
Idling indoors	6.1 $\pm$ 0.74	24.3 $\pm$ 2.36	27.6 $\pm$ 2.42	<0.001
Idling on pasture	27.2 $\pm$ 1.39	17.5 $\pm$ 2.13	10.4 $\pm$ 1.53	<0.001
Drinking indoors	1.0 $\pm$ 0.08	1.0 $\pm$ 0.12	1.2 $\pm$ 0.20	0.571
Drinking on pasture	0.5 $\pm$ 0.09	0.3 $\pm$ 0.08	0.2 $\pm$ 0.06	0.029

¹Study period 1 carried out from August 17 to September 11, 2009 ($n = 12$).²Study period 2 carried out from September 14 to October 9, 2009 ($n = 12$).³Study period 3 carried out from October 12 to November 6, 2009 ($n = 12$).

Behavioral Activity (During Daylight Hours)

The behavior observations revealed that during daylight hours, the cows spent 48.9% of their time indoors, 48.4% of their time on pasture, and 2.6% on the pathway between the 2 locations (Table 3). Treatment did not influence time spent eating TMR, grazing, ruminating, or drinking (Table 1). The cows spent more time eating TMR when indoors than on pasture (Table 3). Time spent drinking indoors was greater than that on pasture, but no difference was observed in idling or rumination time indoors or on pasture. Overall, eating time indoors increased with each study period and grazing time decreased (Table 2).

Of the time spent eating indoors, $32.3 \pm 1.25\%$ was in the first hour following the a.m. decision at the choice

point and $29.9 \pm 1.44\%$ in the first hour following the p.m. decision at the choice point, but this eating time decreased with study period (Figure 2). In study period 1, the cows spent longer eating and then went to pasture, whereas in study period 3 the cows spent less time eating when they first returned from milking and stayed inside.

The cows spent 52.9% of their time standing and 43.8% lying (Table 3). Time spent standing and lying was not different when indoors or on pasture. Of the 3.3% of time spent walking, more time was spent walking on pasture than indoors. The cows did not lie on the pathway between the 2 locations, but they did spend 2.1% of their time standing on the pathway and 0.5% of time walking on the pathway.

Table 3. Mean percentage ($\pm$ SEM) of time cows ($n = 36$) spent performing each behavioral activity indoors and on pasture during daylight hours when they had a choice between the 2 locations

Item	Indoors	Pasture	Overall ¹	t-value	P-value
Overall time spent (%)	48.9 $\pm$ 2.97	48.5 $\pm$ 2.93	100 $\pm$ 0.00	0.09	0.930
Eating TMR (%)	17.0 $\pm$ 0.73	2.9 $\pm$ 0.43	19.9 $\pm$ 0.71	14.68	<0.001
Grazing (%)	NA ²	15.2 $\pm$ 1.25	15.2 $\pm$ 1.25		
Ruminating (%)	11.5 $\pm$ 1.22	11.7 $\pm$ 0.80	23.6 $\pm$ 0.71	-0.13	0.895
Idling (%)	19.3 $\pm$ 1.60	18.3 $\pm$ 1.28	39.9 $\pm$ 0.85	0.35	0.730
Drinking (%)	1.1 $\pm$ 0.08	0.4 $\pm$ 0.05	1.5 $\pm$ 0.09	6.92	<0.001
Standing (%)	26.7 $\pm$ 1.14	24.1 $\pm$ 1.61	52.9 $\pm$ 1.28	1.04	0.303
Lying (%)	21.2 $\pm$ 2.38	22.6 $\pm$ 1.62	43.8 $\pm$ 1.38	-0.36	0.718
Walking (%)	1.0 $\pm$ 0.08	1.8 $\pm$ 0.16	3.3 $\pm$ 0.18	-3.83	<0.001

¹Time spent indoors, on pasture, and on the track between the 2 locations.²Not applicable.

Figure 2. The proportion ($\pm$ SEM) of indoor eating time spent eating within the first hour following milking for each study period.

Factors Affecting Preference

Throughout the study, the average temperature was 13.5°C indoors and 12.4°C outdoors (range from 6.3 to 22.4°C). The THI was 55.6 ± 0.92 indoors and 54.6 ± 0.82 outdoors. The time on pasture increased as THI increased indoors ($y = 1.5372x - 14.271$; $R^2 = 0.33$, $n = 36$ d, $P < 0.001$; Figure 3) and outdoors ($y = 1.2695x + 1.9129$, $R^2 = 0.18$, $n = 36$ d, $P = 0.012$). When the THI indoors was >55.6 , the cows spent 79.3% of their time on pasture, compared with 64.2% when the indoor THI was ≤ 55.6 . It rained on 19 of the 36 study days, but rainfall (2.1 ± 0.58 mm) did not influence preference ($P = 0.183$).

Milk yield did not influence time spent on pasture (24.3 ± 0.98 kg/d; $P = 0.743$). Although treatment cows had access to TMR indoors and on pasture, no difference existed ($P > 0.05$) in milk yield between control and treatment cows (Table 1), and milk yield did not differ between study periods (Table 2). Lactation number (2.6 ± 0.19) had no effect ($P = 0.693$) on cow preference to be indoors or on pasture. Lameness score (1.5 ± 0.09 ; range 1 to 3.5) influenced where the cows spent their time ($y = -8.474x + 84.203$, $R^2 = 0.12$, $n = 36$, $P < 0.001$); cows with a lameness score >1.5 spent more time indoors compared with those with a low lameness score (≤ 1.5). A tendency existed ($P = 0.092$) for cows with a high BCS (>3.0) to spend more time on pasture (13:33 vs. 14:02 h for low vs. high BCS, respectively) compared with cows with a low BCS (≤ 3.0). The BCS was 3.0 ± 0.05 over the study period.

DISCUSSION

The cows expressed a 71% partial preference to be on pasture, which was not influenced by providing TMR outdoors, supporting Krohn et al. (1992), who reported that cows spent 72% of their time outdoors during the summer months when given a choice. These findings are contradictory to those of Charlton et al. (2011), which showed that cows expressed a partial preference for indoors, spending over 90% of their time inside when given a choice. It is possible that the rearing of the cows and their previous experience could have influenced preference. In the study by Charlton et al. (2011), the cows had been reared indoors and had little experience of pasture before the study, whereas in the current study the cows had been reared mainly outdoors and had access to pasture during the summer months. Alternatively, the distance between indoor housing and pasture could have influenced preference, as cows in the current study had to walk 40 m between the housing and pasture, whereas in Charlton et al. (2011) 96 m separated the 2 locations. As the provision of TMR on pasture did not influence pasture use in the current study, it is possible that the short distance between indoors and pasture allowed the cows to spend time outside and return indoors to eat. Transitions between the housing and pasture (2.7) were higher in the current study than 1.8 reported in Charlton et al. (2011). The effect of rearing and distance between indoor housing and pasture on the preference of dairy cows to be indoors or on pasture requires further investigation.

Following a.m. and p.m. milkings, the cows almost always chose indoors. It is likely they chose to go indoors to eat, as they spent more than half their total eating time consuming TMR indoors following milkings. Legrand et al. (2009) found that feeding time peaked

Figure 3. Mean percentage of time cows spent outside when they had a choice to be indoors or on pasture in relation to the average daily temperature humidity index (THI).

immediately after milking. When eating, cows prefer to stand on softer surfaces, rather than concrete (Tucker et al., 2006), which would lead to the expectation that cows offered TMR while standing on concrete flooring or on pasture would choose pasture. Yet, the cows spent more time consuming TMR indoors. One explanation is the distance to the feed from the choice point, as the cows had to walk 179 m to the Calan gates and only 26 m to the RIC bins from the choice point. Previous experience of the cows may have influenced preference (Keeling and Jensen, 2002), as the cows had not eaten TMR on pasture before the study, yet they were used to eating TMR indoors.

On pasture, fresh TMR was provided daily and feed refusals from the previous day were removed, so individual feed intake could be measured. Indoors, the electronic feed bins automatically measured individual intakes, so feed refusals were removed twice per week, and on the remaining days, fresh TMR was placed on top of any remaining food. Fresh feed is a primary factor influencing feeding (DeVries and von Keyserlingk, 2005), so this practice may have affected feeding behavior. It is possible that the cows chose to eat TMR on pasture once the fresh TMR indoors was consumed.

The eating time of 4.2 h (TMR indoors, TMR on pasture, plus grazing) during the daytime supported the 4.8 h of eating time reported by Charlton et al. (2011) when cows had a choice to be indoors or on pasture, but lower than 5.3 h reported by Krohn et al. (1992). Differences in eating time between the studies may be because of the ratio of time spent eating TMR or grazing, as Krohn et al. (1992) reported 4 of 5.3 h spent grazing, which was more than double the 1.8 h in the current study. In the current study, DMI from grazing was not quantified. Control cows consumed more of the TMR indoors than did treatment cows, but when cows had access to TMR indoors and on pasture, the overall consumption of TMR increased by 11.6%. An increase in consumption may lead to an increase in milk yield; however, the length of each study period may have been insufficient to detect any significant differences in production between control and treatment cows.

Study period influenced preference and eating times, with pasture use and grazing decreasing, and eating time indoors increasing over time, supporting the finding by Krohn et al. (1992) that cows prefer indoors as the season progresses from summer to winter. Cows in study period 2 decreased daytime pasture use to less than half that of study period 1, a value that remained similarly low for study period 3. Ketelaar-de Lauwere et al. (2000) reported increased eating times when cows were offered fresh pasture, but over time eating decreased. At the beginning of study period 1, the cows

were placed on fresh pasture, but as the study was carried out during the late grazing season, the grass quality may have decreased, resulting in a decrease in pasture use and time spent grazing. Cows will often consume the majority of their feed during the daytime (Albright and Arave, 1997), and will avoid grazing areas with a low nutritious value (Hessle et al., 2008), so they may have decreased daytime pasture use as the grass quality decreased, so they could be indoors, nearer the TMR, where it may have been easier for them to reach their nutritional demands. Ketelaar-de Lauwere et al. (1999) reported that cows not offered fresh pasture started to leave the grazing area and return to the barn to feed. Nighttime pasture use was over 90% for study periods 1 and 2, but decreased by approximately 20% during study period 3, although average nighttime pasture use still remained high, with the cows spending 70% of their time outdoors during the night. Similarly, Legrand et al. (2009) observed that cows, given the choice between pasture and an indoor freestall barn, had an almost exclusive preference for pasture during the night. Ruminating and idling were influenced by the progression of the study. Cows in study period 3 spent almost 10% more time ruminating during the daytime compared with cows in study period 1. This may be explained by the cows having more available time in study period 3, as they spent 15% less time eating (TMR indoors, TMR on pasture, and grazing) than did cows in study period 1. Alternatively, the increase in rumination may be a result of cows in study period 3 consuming grass with a greater content of longer fiber with lower digestibility, as these factors are associated with decreased rumination efficiency (Teller et al., 1990), in association with the greater total DMI from the TMR.

Cardot et al. (2008) reported that DMI can affect drinking behavior and water intake of lactating dairy cows. More than 70% of water intake was during the daytime, and drinking activity was correlated with feeding and milking, which could explain why the cows in the current study expressed a preference to drink indoors. More than 60% of the cows' eating time was spent consuming TMR in the first hour following milking, so they would have been more likely to drink during this time indoors.

Lying times during the daytime were 5.3 h. Spending almost half of the observed time lying supported others (Spörndly and Wredle, 2004; Legrand et al., 2009), but no difference existed in lying times indoors or on pasture, which is contrary to findings from studies that reported that cows had a clear preference for lying on pasture, rather than indoors (Krohn et al., 1992; Ketelaar-de Lauwere et al., 2000). Spörndly and Wredle (2004) observed a large proportion of cows lying between 2300 and 0300 h. Cows in the current study

spent most of their time on pasture during the night-time, so lying time on pasture may have been higher, although observations were not carried out during the hours of darkness.

It has been suggested that cows can distinguish differences in underfoot comfort (Tucker et al., 2006) and prefer to stand more on comfortable flooring (Boyle et al., 2008). As pasture is often a softer, more comfortable surface (Hernandez-Mendo et al., 2007), it would have been expected that cows chose to stand longer on pasture rather than on concrete; however, no difference was observed between time spent standing indoors and on pasture. Walking time was higher on pasture than indoors, supporting previous findings (Charlton et al., 2011). This could be a result of the natural feeding behavior of cattle, which involves slowly walking forward (Broom and Fraser, 2007); indoors, forward movement is not necessary to find food, and eating is restricted at the feed fence.

Previous studies have reported a decrease in pasture use on rainy days (Charlton et al., 2011). Although it rained on more than half of the study days, rainfall did not influence time spent on pasture during the current study. The cows did spend more time on pasture as the THI increased. In contrast, Legrand et al. (2009) found that time on pasture decreased as the THI increased. The upper critical temperature for lactating dairy cows is 25°C (Albright and Arave, 1997) and the upper critical THI is >72 (Igono et al., 1992). In the current study, the temperature and THI remained within the comfort zone for dairy cows, which may explain why the cows were not motivated to move indoors to seek shade as the temperature increased (Schütz et al., 2008).

Lactation number and milk yield did not influence pasture use and no difference in milk yield existed between treatment groups or study groups. In contrast, Charlton et al. (2011) reported that cows with a higher milk yield spent more time indoors, possibly because of the provision of TMR indoors. A relationship also existed between lameness score and time spent indoors; cows with a lameness score above average spent more time indoors than those with a below average score. Although time on pasture can provide a period of recovery for lame cows (Hernandez-Mendo et al., 2007), and despite only 40 m between the 2 locations, lame cows may not have wanted to walk the distance from indoors to pasture with sore feet.

CONCLUSIONS

The cows expressed a 71% partial preference for pasture, which was not influenced by TMR being provided on pasture or milk yield, although the cows spent less time on pasture as the season progressed. It is pos-

sible that the short distance (40 m) between the indoor housing and pasture allowed the cows to access the pasture and return to the indoor housing to eat the TMR. Providing TMR on pasture (as well as indoors) increased total intake of TMR, but did not influence grazing time or milk yield.

ACKNOWLEDGMENTS

The authors acknowledge the cooperation of the Harper Adams University College (Shropshire, UK) farm staff, and the technical support from Giles Vince, Nicky Naylor, Michelle Midgley, David Ferguson, Fred Baker, and Alison Weekes from Harper Adams University College. We thank Moira Harris and the PhD students Andrew Watson, Chamari Palliyeguru, and Minuka Weerasinghe for helping with behavior observations and Peter Kettlewell for statistical advice (all of Harper Adams University College). This study was supported by Silcock Fellowship for Livestock Research, Harper Adams University College and Reaseheath College (Cheshire, UK).

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