BEHAVIOUR, HYGIENE, AND LAMENESS OF DAIRY COWS IN A COMPOST BARN DURING COLD SEASONS IN A SUBTROPICAL CLIMATE

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Abstract

This study aimed to assess the thermal environment, behaviour, hygiene, and lameness in dairy cows with different numbers of lactations housed in a compost-bedded pack barn system in a humid subtropical climate during autumn and winter. Between April and July 2016, behavioural and microclimatic environment assessments were conducted in a compost barn system, and hygiene and lameness assessments were performed. Crossbred cows in lactation ($n = 10$) were divided into two groups according to the number of lactations: primiparous and multiparous. Air temperature, relative humidity, and air ventilation speed were measured at 09:00, 12:00, and 15:00. The cows' hygiene and lameness were evaluated using subjective scores ranging from 1 to 4 and 1 to 5, respectively. The daytime behaviour assessment was performed as sampling 0/1, using the focal method. Primiparous cows showed a greater probability of walking ($P < 0.05$) than multiparous cows between 09:20 and 11:20, and at 15:20, and increased the water intake at 14:00. Regarding the eating behaviour and the effect of time of day within each group ($P < 0.05$), the cows ate more in the morning's early hours. The cows' hygiene scores were 1 or 2, and most cows presented scores of 1 or 2 for lameness. Our research has shown that microclimatic variables may influence the walking behaviour and water intake of primiparous cows during the hottest periods of the day, even during cold weather, in a humid subtropical climate. The dairy cows showed low hygiene and lameness scores, which indicates that the compost bar positively influenced cleanliness and locomotion comfort.

Key words: confinement, crossbred cows, thermal environment, lameness and hygiene scores

The choice of cows' environment is an important decision within dairy production because it affects animal welfare, which directly impacts productivity, milk quality, and reproduction (Bewley et al., 2017). Ensuring animal welfare on dairy farms is also particularly important due to ethics, market issues, and increasing consumer awareness of healthy dairy products.

In subtropical climate regions, many producers have opted for an alternative loose housing system for dairy cows, the compost-bedded pack barn (CB), which may have the ability to improve the longevity of dairy cows (Leso et al., 2019). In some properties, CB has been adopted to house diseased animals and those with a high degree of lameness (Costa et al., 2018) because the prevalence of lameness in this system is low (Burgstaller et al., 2016).

These results are attributed to the greater comfort of the bed area, which is deeper and softer, and the feeding track and drinkers are normally separated from the resting area by a wall or elevation step (Barberg et al., 2007). The bed must be rotated at least twice a day, between 25 and 30 cm deep, using a rotating subsoiler (Janni et al., 2007). This management is essential to avoid increased moisture and compaction and incorporate oxygen into the bed, providing an increase in the manure's aerobic decomposition and keeping the surface soft for the animals to lay, reducing risks of lameness (Astiz et al., 2014). The inner bed temperature recommended for proper composting should be between 54°C and 65°C (Janni et al., 2007) with humidity below 65% (Shane et al., 2010). A well-handled bed might keep the cows hygienic and reduce the risk of mastitis (Barberg et al., 2007; Fávero et al., 2015).

In addition to these welfare aspects, CB allows greater freedom of movement for cows to express their natural behaviour when lying down, due to the greater space per animal in the bed area (Endres and Barberg, 2007). In this system, the recommended stocking rate is approximately 9.4 m² per animal, varying according to the cows' size (minimum 7.2 m² for Holstein and 6.1 m² for Jersey; Endres, 2009). The larger space per cow in CB also contributes to a smaller number of agonistic interactions compared to that in freestall systems (Biasato et al., 2019). However, even in a low-stocking CB, factors such as age and thermal stress can trigger disputes for resources, such as space, water, and ventilation (Pilatti et al., 2019). The thermal conditions of the environment in dry and hot climates affect the behaviour and, consequently, dairy cow welfare in CB (Peixoto et al., 2019). Under these conditions, efficient ventilation systems can alleviate the discomfort of cows (Oliveira et al., 2019; Pinto et al., 2019 a).

Thus, despite some studies assessing cow behaviour in CB, few have studied the behaviour of cows in a humid subtropical climate during cold seasons (Costa et al., 2018; Pilatti et al., 2019). In this sense, we investigated whether CB's microclimate in autumn and winter may affect the behaviour of dairy cows with different numbers of lactations in a CB system in a humid subtropical climate. The objectives of this research were also to characterise the thermal environment, hygiene, and lameness of cows under CB conditions.

Material and methods

The experimental procedures were approved by the Ethics Committee on the Use of Animals of the Federal University of Technology – Paraná (CEUA-UTFPR), Paraná, Brazil, protocol no. 2015/014.

Study location

A trial was conducted between April and July 2016, on a private dairy farm located in the southwest of Paraná state, Brazil (25°43'34.20" S and 53°06'35.19" W, 556 m above sea level). The Köppen classification of the region is humid subtropical (mesothermic or Cfa), with average temperatures of -3°C to 18°C during cold months and temperatures above 22°C during hot months (Alvares et al., 2013). During the trial, the average external temperature (at the intervals of 09:00, 12:00, and 15:00) varied between 13.8°C and 20.3°C, and the relative humidity was between 67% and 89%.

Environmental and management features

The cowshed was situated on a longitudinal axis in the E–W direction, with a length of 45 m and width of 20 m. The CB's structure had a resting area (36 × 16 m) with a deep bed of wood shavings (576 m²), a feeding line with 40 feed fences and three water troughs (144 m²), and an attached milking room. The barn had a 5-m ceiling, open sides, and a skylight on the roof.

The ventilation system had seven DeLaval DF 1250 fans (DeLaval, Botkyrka, Sweden), with six paddles and an airflow capacity of 34,000 m³/h. During the experimental period, the average bed-stocking rate was 16.4 m²/animal. The bed was 35 cm deep and was stirred twice a day after each milking (between 08:00 and 09:00; 17:00 and 18:00) at 20 cm depth by a six-stem cultivator.

The barn could house 50 animals. The cows were milked twice a day (07:00 and 16:30) in a milking parlour (a 4 × 8 herringbone type) attached to the barn, and cows were fed at 08:00 and 17:00. Food was provided *ad libitum*. A total mixed ration was used (Table 1), according to the productivity level of cows. The diet was composed of corn silage (57.6%), soybean meal (11%), commercial feed defined by 20% crude protein (29%), mineral salt (1.1%), Optigen® (encapsulated urea for a controlled release of non-protein nitrogen) (0.6%), and sodium bicarbonate (0.6%).

Animal management

Between April and July 2016, 15 assessments of daytime behaviour and eight hygiene and lameness evaluations were performed. We used Holstein × Jersey cross-bred cows (n = 10) between 60 and 120 days of lactation.

The cows were divided into two groups of five animals according to the number of lactations: (1) primiparous cows, with a mean age of 2.7 years, average weight of 430 kg, and average production of 30 kg of milk/day; and (2) multiparous cows, with a mean age of 4.8 years, average of four lactations, average weight of 500 kg, and average milk yield of 32 kg/day. During the study, the 10 cows that were evaluated remained in the same environment as the other lactating cows of the property, totalling 35 animals in the CB. For the identification of the study animals, these cows received necklaces of different colours for the recognition of each animal and the corresponding group.

Table 1. Total mixed ration of cows' diet in a compost barn, during the study in cold seasons

Chemical composition	Batch 1	Batch 2
ME (Mcal/kg)	2.55	2.53
CP (%)	18.8	15.4
RDP (%)	12.4	10.8
RUP (%)	6.4	4.6
NDF (%)	31.3	38.3
ADF (%)	18.4	23.7
NFC (%)	43.8	39.4
EE (%)	2.8	2.9
Ca (%)	0.7	0.7
P (%)	0.5	0.4

Metabolizable energy (ME), crude protein (CP), rumen degradable protein (RDP), rumen-undegradable protein (RUP), neutral detergent fiber (NDF), acid detergent fiber (ADF), non-fiber carbohydrates (NFC), ether extract (EE), calcium (Ca) and phosphorus (P).

Behavioural recording

The daytime behaviour was recorded between 09:20 and 16:00. Behavioural observations were performed as sampling 0/1, using the focal method described by Broom and Fraser (2007). Each observation lasted 10 minutes, with a 30-minute interval between each observation. The observations were performed by two trained observers, who alternated between each group with each new day of observation. The behaviours were evaluated by means of the ethogram proposed by Pilatti et al. (2019), as described in Table 2.

Table 2. Behavioural ethogram and respective definitions for dairy cows (adapted from Pilatti et al., 2019)

Behaviour	Definition
Standing rest	Standing, without performing any activity
Lying rest	Lying down, without performing any activity
Standing rumination	Standing, regurgitating or rechewing food
Lying rumination	Lying down, regurgitating or rechewing food
Eating	Ingesting food from feed bins
Water intake	Ingesting water from drinking troughs
Walking	Displacement, in the rest area or feeding line

Hygiene and lameness

The assessments of hygiene and lameness were performed by two trained evaluators using subjective scores, after leaving the animals in the milking room, marching, and standing on hard and flat ground. The hygiene assessments were performed using the dirtiness score proposed by Schreiner and Ruegg (2002), which considers the udder and legs' hygiene, with a score of 1 to 4 (1 = no dirt; 2 = little dirt, 2% to 10%; 3 = moderately dirty, 10% to 30%; 4 = very dirty, more than 30%). To evaluate

lameness, we used the method described by Sprecher et al. (1997), which considers gait and alignment of the dorsum of the animal and varies from 1 to 5 (1 = normal; 2 = slightly lame; 3 = moderately lame; 4 = lame; 5 = severely lame).

Thermal variables of the environment

Air temperature (°C), relative humidity (%), and air ventilation speed (m/s) were recorded, and the temperature and humidity index (THI) was calculated. These variables were evaluated on the same days as the behaviour observations and were recorded at 3-h intervals (09:00, 12:00, and 15:00). The choice of this time interval is related to the hottest hours of the day. It is expected that more activities occur in this interval, as well as more stressful conditions, even during cold seasons. For the indoor measurements of temperature and relative humidity of the air, we used a data logger (HOBO U12-013; Onset, Bourne, MA, USA) with two external channels, with the temperature and relative humidity between -20°C and 70°C and 5% to 95%, respectively. For the air ventilation speed measurement, an ITAN-700 thermo-hygro-anemometer (Instrutemp, São Paulo, Brazil) was used with a measuring range of 0.4 to 20 m/s. The equipment, described above, were positioned at a 1.5 m height above the surface. The indoor measurements were performed manually every hour throughout the day in the geometrical centre of the barn. From this environmental data, an average was taken as the basis for the THI calculation.

The THI was calculated using the following equation described by Hahn (1999; adapted from Thom, 1995):

$$THI = Tdb + 0.36 \times Td + 41.2$$

where Tdb is the air temperature (°C) and Td is the dew point temperature (°C).

The dew point temperature was estimated using the following equation (Aguilar et al., 1986):

$$Td = Tdb - (14.55 + 0.114 \times Tdb) \times [1 - (0.01 \times RH)] - \{(2.5 + 0.007 \times Tdb) \times [1 - (0.01 \times RH)]\}^2 - (15.9 + 0.117 \times Tdb)$$

where Tdb is the air temperature (°C) and RH is the relative humidity (%).

Statistical analysis

The whole analysis was performed using a Bayesian framework; two different models were used to answer each research question. The models were similar in conception but had some particularities in terms of how we interpreted the results.

The main reason for choosing this method was based on the lower number of experimental units. According to McNeish (2016), Bayesian methods are a very appropriate and accurate means of estimation for small samples because of the use of iterative methods, such as the Gibbs sampler. This allows realization of N simulations with this limited dataset. In addition, the same author discussed other features

of this approach, such as the random parameters and fixed data, and the inclusion of prior information, which might increase the accuracy of the prediction.

The study of animal behaviour aims to examine whether an animal exhibits certain behaviour at a certain time of the day. In this case, we have a binomial response (y), which can be described by the following generalised linear mixed effects model:

$$[E(\gamma)]_{ik} = \Pi_{ik}$$

$$\text{logit}(\Pi_{ik}) = \mu\theta + u_k + \varepsilon_{ik}$$

One possible interpretation of the model is that there is an underlying score with the observed variable being:

$$y_{ik} = \begin{cases} 1 & \text{if } y_{ik}^{\bullet} > 0 \\ 0 & \text{if } y_{ik}^{\bullet} \leq 0 \end{cases}$$

Thus, the model can be rewritten as:

$$y_{ik}^{\bullet} = \mu\theta + u_k + \varepsilon_{ik}$$

where y_{ik} is the observation of the behaviour of the i -th animal on the k -th day; μ is the animal fixed effects defined as the quadratic polynomial: $\alpha + \beta x_{ik} + \gamma x_{ik}^2$; x_{ik} refers to the time of day when a certain behaviour was observed in animal x ; θ is the binary covariate for primiparous and multiparous, u_k is the random effect of the k -th day of measuring and is considered to follow normal distributions with mean zero, and standard deviations $\frac{1}{\tau}$ and ε_{ik} is the residual variance and follows a logistic distribution, which has a fixed variance of $\pi^2/3$. Because data collection occurred on several consecutive days, the day random effect must be u_k included in the model.

In summary, the information about the effect of time of day within each group (multiparous and primiparous) is described in Tables 4 and 5, considering the parameters α (first hours of the day) and β and γ (other hours throughout the day). The difference between treatments was detected when the shaded areas around the line (credibility intervals) were distant.

In the hygiene and lameness studies, the response variables are ordinal categorical scores that fall in the $j = 1 \dots J$ categories. To describe them, the following cumulative logit model was used:

$$y_{ikj}^{\bullet} = \alpha_j - \theta x_{ik} + u_k + \varepsilon_{ikj}, \quad j = 1, \dots, J-1$$

The parameter α_j refers to the cumulative logit of each category j with its own intercept and has no useful interpretation in this work. The interpretation of parameter θ is given in terms of the log of the odds ratio, and this is the main parameter for inferring the hygiene and lameness data.

In general, both models are the same as those used in Pilatti et al. (2019), and, consequently, all the prior models were defined in the same way. Model fitting was performed using R (R Development Core Team, 2019) with the package brms (Bürkner, 2018), which implements the Monte Carlo Hamiltonian algorithm.

The fitting process generated the posterior distributions of the model parameters. Subsequently, credible intervals of parameter estimates were obtained and examined. When the credible intervals of β and γ did not include zero, it was concluded that there is an effect of the time of measurement x_{ik} on the probability of the animals presenting certain behaviour. In the same way, when the credible interval of parameter θ does not include the zero, it is concluded that there is a difference between the multiparous and primiparous animals regarding the probability of these two groups showing the same behaviour.

Results

Microclimate inside the compost barn

The air temperature varied around 23°C during the day's hottest hours, initially characterising a comfortable environment. However, the maximum values reached above 32°C, indicating a harsh environment (Table 3).

The lowest relative humidity values were found in the afternoon, which was expected due to the inverse relationship with air temperature. The THI mean values ranged around 68, indicating that the cows possibly experienced mild discomfort during the trial. The maximum THI values ranged above 78, which characterised a heat stress situation. These results possibly influenced some behaviours, mainly walking behaviour and water intake, as seen below.

Dairy cows' behaviour

The walking behaviour and water intake were different ($P < 0.05$) among primiparous and multiparous cows, according to Bayesian comparisons (Figure 1 a, 1 c). However, we found the effect of time of day within each group only in the first hours of the day (expressed by the α parameter, Table 4). Primiparous cows showed a higher probability of walking than multiparous cows between 09:20 and 11:20, and at 15:20 (Figure 1 a). Regarding eating behaviour, we did not find differences between the primiparous and multiparous cows. However, we observed the effects of time of day within each group, with primiparous cows having a higher probability of eating during the early hours of the day (observed in the α parameter). There was also a difference in eating throughout the day ($P < 0.05$; observed in the β parameter) with a quadratic effect (observed by the γ parameter; Table 4), in which the highest decline in the eating probability curve was at 12:40 (Figure 1 b). Regarding the water intake behaviour, at 14:00, the water intake of primiparous was higher than that of multiparous cows ($P < 0.05$, Figure 1 c).

The probability of standing rumination was less than 20% during the entire experimental period (Figure 2 a). We observed the effects of time of day within each group

on standing and lying rumination behaviours only in the intercept α (first daily hours; Table 5 and Figure 2 b). Regarding the lying rest behaviour, the Bayesian model did not converge; thus, this behaviour was not considered in the present discussion. The probability of standing rest remained constant throughout the day, without any effect from time of day or differences between groups (Table 5 and Figure 2 c).

Table 3. Microclimatic data during the experimental period: air temperature (T), relative humidity (RH), air ventilation speed (WS) and temperature and humidity index (THI)

Time	Criteria	Variable			
		T (°C)	RH (%)	WS (m s ⁻¹)	THI
0900	Mean±SEM	18.65±0.62	71.00±0.99	0.54±0.09	65.00±0.84
	Minimum	7.65	54.00	0.00	50.00
	Maximum	28.69	91.00	5.00	78.00
1200	Mean±SEM	22.76±0.62	58.00±1.52	0.70±0.09	69.00±0.80
	Minimum	13.21	32.00	0.00	56.00
	Maximum	32.18	90.00	5.00	81.00
1500	Mean±SEM	23.03±0.60	56.00±1.71	0.77±0.09	69.00±0.81
	Minimum	14.53	24.00	0.00	57.00
	Maximum	32.92	93.00	5.60	81.00

Table 4. A posteriori daytime effect estimates of parameters (mean ± SEM and credibility intervals) of walking, eating and water intake behaviour of primiparous (treatment 1) and multiparous cows (treatment 2)

Parameter	Mean ± SEM	Percentile		Significance
		2.50%	97.50%	
1	2	3	4	5
Walking				
α (treatment 1)	-1.92288±0.74820	-3.42091	-0.48701	*
α (treatment 2)	-5.93568±2.40679	-10.73008	-1.35382	*
β (treatment 1)	-0.11947±0.20351	-0.52216	0.27503	NS
β (treatment 2)	0.69339±0.62761	-0.53343	1.93113	NS
γ (treatment 1)	0.00901±0.01246	-0.01540	0.03409	NS
γ (treatment 2)	-0.03732±0.03763	-0.11156	0.03679	NS
Eating				
α (treatment 1)	0.20991±0.49122	-0.75611	1.17281	NS
α (treatment 2)	1.21789±1.19299	-1.12806	3.53142	NS
β (treatment 1)	-0.31069±0.13833	-0.57840	-0.03005	*
β (treatment 2)	-0.48798± 0.33574	-1.14164	0.17329	NS
γ (treatment 1)	0.01807±0.00858	0.00090	0.03448	*
γ (treatment 2)	0.02458±0.02085	-0.01593	0.06522	NS

Table 4 – contd.

1	2	3	4	5
Water intake				
α (treatment 1)	-2.93765±0.82744	-4.68485	-1.45289	*
α (treatment 2)	-1.97614±2.07711	-6.08973	1.98397	NS
β (treatment 1)	0.12243±0.21440	-0.28168	0.55860	NS
β (treatment 2)	-0.27150±0.55221	-1.34103	0.80993	NS
γ (treatment 1)	-0.00286±0.01281	-0.02935	0.02175	NS
γ (treatment 2)	0.01823±0.03327	-0.04766	0.08367	NS

NS=not significant. *Statistically different based on Bayesian comparisons ($P<0.05$).

Table 5. A posteriori daytime effect estimates of parameters (mean $\pm$ SEM and credibility intervals) of standing and lying rumination and standing rest behaviour of primiparous (treatment 1) and multiparous cows (treatment 2)

Parameter	Mean $\pm$ SEM	Percentile		Significance
		2.50%	97.50%	
Standing rumination				
α (treatment 1)	-3.40326 $\pm$ 0.76370	-4.89055	-1.96541	*
α (treatment 2)	-3.40919 $\pm$ 1.88485	-7.04795	0.26315	NS
β (treatment 1)	0.27676 $\pm$ 0.19446	-0.09971	0.65580	NS
β (treatment 2)	0.23591 $\pm$ 0.48118	-0.70184	1.18147	NS
γ (treatment 1)	-0.00828 $\pm$ 0.01145	-0.03098	0.01394	NS
γ (treatment 2)	-0.00639 $\pm$ 0.02831	-0.06199	0.04814	NS
Lying rumination				
α (treatment 1)	-2.11893 $\pm$ 0.59226	-3.26663	-0.98586	*
α (treatment 2)	-1.91416 $\pm$ 1.42166	-4.74181	0.81960	NS
β (treatment 1)	0.21727 $\pm$ 0.15971	-0.08902	0.52494	NS
β (treatment 2)	0.09297 $\pm$ 0.38196	-0.64005	0.84608	NS
γ (treatment 1)	-0.01170 $\pm$ 0.00973	-0.03064	0.00707	NS
γ (treatment 2)	-0.00338 $\pm$ 0.02325	-0.04942	0.04098	NS
Standing rest				
α (treatment 1)	-0.70025 $\pm$ 0.53012	-1.74144	0.34859	NS
α (treatment 2)	-0.68609 $\pm$ 1.25711	-3.15282	1.77628	NS
β (treatment 1)	-0.07244 $\pm$ 0.14405	-0.35510	0.20649	NS
β (treatment 2)	-0.06134 $\pm$ 0.34641	-0.73819	0.61623	NS
γ (treatment 1)	0.00331 $\pm$ 0.00887	-0.01406	0.02049	NS
γ (treatment 2)	0.00131 $\pm$ 0.02145	-0.04111	0.04333	NS

NS=not significant. *Statistically different based on Bayesian comparisons ($P<0.05$).

Figure 1. Probability of occurrence of walking (a), eating (b) and water intake (c) of primiparous and multiparous cows during the daytime

Figure 2. Probability of occurrence of standing rumination (a), lying rumination (b) and standing rest (c) of primiparous and multiparous cows during the daytime

Table 6. A posteriori estimates of parameters (mean $\pm$ SEM and credibility intervals) of lameness and hygiene of primiparous and multiparous cows

Parameter	Mean ± SEM	Percentile		Significance
		2.50%	97.50%	
Lameness				
Intercept (1)	0.31±0.40	−0.46	1.11	NS
Intercept (2)	3.30±0.62	2.18	4.62	*
Treatment 2	0.80±0.46	−0.10	1.74	NS
Hygiene				
Intercept (1)	0.84±0.48	−0.06	1.85	NS
Intercept (2)	2.89±0.64	1.74	4.25	*
Intercept (3)	3.87±0.81	2.40	5.68	*
Treatment 2	0.32±0.50	−0.64	1.28	NS

Intercept (1), Intercept (2), Intercept (3) = Parameters of lameness and hygiene categorical scores; Treatment 2=multiparous cows; NS=not significant. *Statistically different based on Bayesian comparisons ($P<0.05$).

Hygiene and lameness

There was no difference ($P<0.05$) between the groups in terms of hygiene and lameness scores because the group parameter did not include zero between the credibility intervals (Table 6). Despite the groups, only scores 1 and 2 (1 = normal; 2 = slightly lame) and 1, 2, and 3 (1 = no dirt; 2 = little dirt, 2% to 10%; 3 = moderately dirty, 10% to 30%) for hygiene and lameness were scored, respectively.

Discussion

During this study, we registered daily periods with a THI above 68, which characterised uncomfortable situations for dairy cows in a compost-bedded pack barn system, in a subtropical climate during cold seasons. In addition, we found evidence of some altered behavioural patterns, mainly walking and water intake behaviours, with differences between primiparous and multiparous cows. We believe that these behaviours were possibly linked to the thermal environment, as discussed below.

Primiparous cows were more likely to walk between 09:20 and 11:20, as well as at 15:20 (Figure 1 a); however, the probability of this behaviour did not exceed 20% for both groups. This difference between cows can be attributed to the greater number of primiparous cows' activities during the time intervals in which they were observed. Another hypothesis is the group hierarchy's subordination, mainly searching for environmental resources (e.g., ventilation) because younger and lighter animals are subordinate to older cows (Sárová et al., 2013). For example, in the feeding lines, the subordinate cows may get closer to the dominant cows; however, this can result in a greater distance travelled to feed (Broom and Fraser, 2007). Thus, although a compost barn (CB) has feeding lines for all cows to feed simultaneously to prevent overcrowding, primiparous cows may have been cornered and had to walk more for

feeding, water intake, or access to other environmental resources. In a similar study in hot seasons, Pilatti et al. (2019) found no difference in walking behaviour between primiparous and multiparous cows. However, the present study found similarity in the probability of walking behaviours, which the authors found was close to 20% throughout the day. Endres and Barberg (2007) reported that cows in a CB system had the highest number of steps between 07:00 and 18:00. The authors also verified that the cows' average number of steps increased with the temperature and humidity index (THI). In this case, the average of steps was 71.6 steps/h for a THI less than 72, and 120.8 steps/h for an index ≥ 72 THI units. This increase in the number of steps may be due to the access to drinkers associated with stress and a change in behaviour associated with searching for a cooler place. This evidence was also observed in the present study when primiparous cows showed a higher water intake during the day's hottest period. Although it was expected to observe such behaviour in multiparous cows (Pilatti et al., 2019), we did not observe this in this study. A possible explanation for this is the hierarchy, with fewer resources available for primiparous than multiparous cows (proximity to fans, more fresh bedding area). A THI below 68 is classified as no risk for high-production dairy cows, 68–72 for mild discomfort, 72–75 for discomfort, 75–79 for alert, 79–84 for danger, and above 84 for emergency (Segnalini et al., 2013). According to this parameter, the present study's thermal conditions may have influenced cows' behaviour from 12:00 (THI of 65, 69, and 69 at 09:00, 12:00, and 15:00, respectively; Table 3). In a study carried out in a freestall barn during the summer period, the number of steps of confined dairy cows was negatively correlated with the THI; however, with the elevation of the THI, the long-standing of cows increased (Herbut and Angrecka, 2018; Heinicke et al., 2019). Standing for more time helps with evaporative heat loss to the environment because it exposes a greater body surface for thermolysis. This behaviour is typical of cattle under heat stress (Allen et al., 2015). The physiological and behavioural changes in heat stress may also adversely affect the body posture and time of rumination in dairy cows, due to a negative correlation between time of rumination and THI (Soriani et al., 2013; Moretti et al., 2017; Pinto et al., 2019 b).

In addition, the average THI oscillated between safe and mild discomfort. However, when we observed the maximum THI values listed in Table 3 (78, 81, and 81 at 09:00, 12:00, and 15:00, respectively), the index was between the alert and emergency classification, according to Hahn et al. (2003). According to the average THI, the cows in this study remained in comfort but had moments of light and moderate stress (when considering the THI maximum). However, it should be noted that different authors provide different THI threshold values at which heat stress begins, ranging from 68 to 74 units, with prolonged heat waves. There is also a phenomenon of the sensitivity of cows related to their increased productivity. This pattern is closely related to increased metabolism and heat release, which must be discharged into the environment (Herbut et al., 2018; Heinicke et al., 2019).

Lameness is another important factor that might affect the behaviour and health of confined cows, causing stress and pain. Cows with moderate lameness decrease feeding time and locomotor activity and remain longer in the lying position (Weigele

et al., 2018). Furthermore, due to the difficulty in raising and locomotion, moderately lame cows tend to be located further back in the line of milking, according to the same authors. The cows evaluated in this study received lameness score of 1 and 2 (1 = normal; 2 = slightly lame). This result suggests that the CB environment did not negatively affect the health of cows. Scores of lameness up to 2 (slightly lame) do not imply cow health; however, scores ≥ 3 can lead to losses in locomotion and affect reproductive aspects, such as the difficulty of identifying heat (Sprecher et al., 1997). In Brazil, a study showed that dairy farms with CB had a lower prevalence of lameness than farms with freestalls and farms that use a combination of freestall and CB (cows in transition and sick were housed in the CB; Costa et al., 2018). However, to preserve the CB health of cows regarding lameness and hoof diseases and keep the cows clean, the management and quality of the bed are essential requirements. Cows prefer soft bedding lined with dry and balanced material of sufficient quality, which is safe when getting up (Vasseur et al., 2012). The absolute frequency of the hygiene score was higher for the 1 and 2 scores (1 = no mess; 2 = little dirt, 2% to 10%), which is classified as a good indication of proper management of the bed because the moisture of the bed is a significant predictor of hygiene of cows in a CB (Eckelkamp et al., 2016). This might be explained by the higher moisture content, which resulted in bedding sticking to the legs and udders of cows. Moreover, hygiene might be associated with the bed's moisture content and related to the incidence and prevalence of subclinical mastitis in dairy cows (Fávero et al., 2015). In this trial in Brazil, the same authors reported that most cows evaluated in CB obtained 1 and 2 scores (1 = clean; 2 = slightly clean). The present study found great similarity with those results regarding cows' hygiene in a CB system.

Conclusions

During cold seasons, multiparous and primiparous cows experienced different behavioural patterns in a compost-bedded pack barn system in a subtropical climate. We found differences between these groups for walking and water intake behaviour, mainly during the afternoon. This evidence may be related to microclimatic variation, with hot periods even during the autumn and winter seasons. In this study, hygiene and lameness showed low scores, which showed suitable handling and bedding environments that kept the cows clean and without locomotion problems. These results may contribute to adopting a controlled environment programme, even during cold seasons in a subtropical climate, to provide the most suitable environment for dairy cows in different stages of lactation.

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