DOI: 10.1590/1809-6891v24e-73923E

Ciência Animal Brasileira
Brazilian Animal Science

e-ISSN 1809-6891

Section: Animal science
Research article

Behavioral changes in dairy calves raised in outdoor holding pens with alternative roofing

Alterações comportamentais de bezerras criadas em bezerreiros tropicais com cobertura alternativa

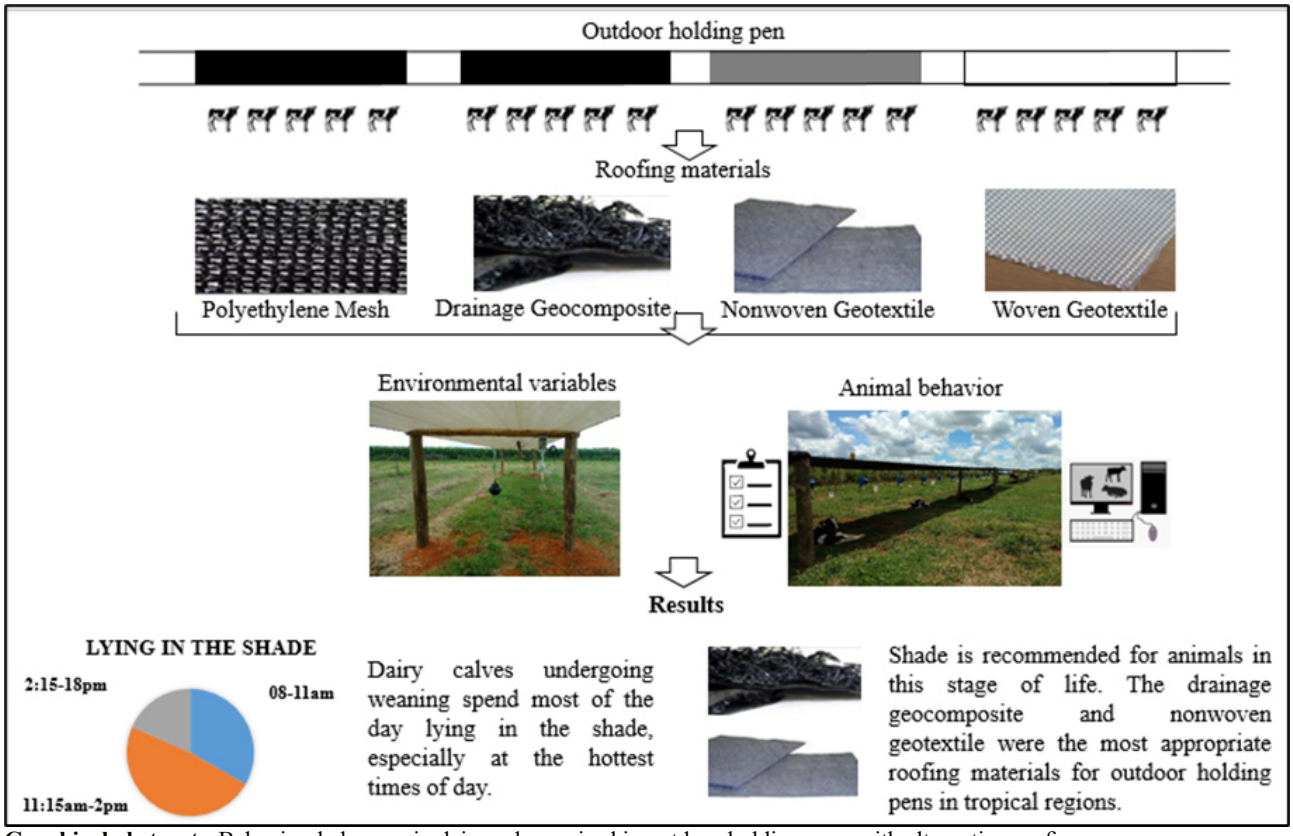
Jéssica Caetano Dias Campos[1*], Roberta Passini[1], Lainny Jordana Martins Pereira e Sousa[1], Alliny das Graças Amaral[1]

[1]Universidade Estadual de Goiás (UEG), Anápolis, Goiás, Brazil
[*]Corresponding author: jessicacaetano5@hotmail.com

Abstract
This study assessed the behavior of dairy calves raised in outdoor holding pens covered with different geosynthetics. Twenty crossbred (Girolando, Jersey and Holstein) dairy calves undergoing weaning were used, with an average initial live weight of 40.6 Kg. A completely randomized block design was used, with a 4 x 3 factorial scheme and 5 repetitions. The roofing materials were polyethylene mesh, drainage geocomposite, nonwoven geotextile and woven geotextile, representing the first factor, and assessment times (8 to 11 a.m., 11:15 a.m. to 2 p.m. and 2:15 to 6 p.m.) the second factor. Environmental variables were analyzed, and the following heat stress indices calculated: black globe-humidity index (BGHI) and equivalent temperature. The average BGHI and equivalent temperature were 79 and 26, respectively. Walking behavior differed between treatments ($P<0.05$) and was more frequent in the woven geotextile treatment. The most frequent behavior observed throughout the day was lying in the shade (53%), demonstrating the importance of providing artificial shading during this stage of life. When compared to polyethylene mesh, the drainage geocomposite and nonwoven geotextile were better suited to providing shade for dairy calves undergoing weaning in tropical regions.
Keywords: cattle; heat stress; ethogram; shading; geotextile.

Resumo
O trabalho avaliou o comportamento de bezerras leiteiras, criadas em bezerreiros de modelo tropical, contendo diferentes geossintéticos como material de cobertura. Foram avaliadas 20 fêmeas Girolando, Jersey e Holandesa com peso inicial médio de 40,6 Kg durante a fase de aleitamento. O delineamento experimental foi de blocos casualizados completos, em arranjo fatorial 4 x 3 com 5 repetições. Os materiais de cobertura foram: malha de polietileno, geocomposto drenante, geotêxtil não-tecido e geotêxtil tecido foram o primeiro fator e os períodos do dia (08 às 11, 11:15 às 14 e 14:15 às 18 horas) foram o segundo fator. Foram avaliadas as variáveis ambientais e calculados os índices de conforto térmico: índice de temperatura do globo negro e umidade e índice de temperatura equivalente. As médias do índice de temperatura do globo negro e índice de temperatura equivalente foram 79 e 26, respectivamente. O comportamento andando diferiu entre tratamentos ($P<0,05$), sendo mais frequente no tratamento geotêxtil tecido. A frequência comportamental mais observada ao longo do dia foi deitada à sombra (53%) deixando evidente a importância da disponibilização de sombreamento artificial para essa fase de vida. Os materiais de cobertura geossintéticos Geodrenante e Geotêxtil não-tecido, comparados à malha de polietileno, foram os mais apropriados para a utilização como sombreamento em regiões de clima tropical para bezerras em fase de aleitamento.
Palavras-chave: bovinos; estresse térmico; etograma; sombreamento; geotêxtil.

Received: September 1, 2022. Accepted: October 27, 2022. Published: January 13, 2023.



Graphical abstract - Behavioral changes in dairy calves raised in outdoor holding pens with alternative roofing

1. Introduction

Brazil is a large country, with a climate classified according to the characteristics of each of its biomes. The Central West region contains the country's largest biome, the Cerrado, classified as Aw (wet tropical) under the Köppen classification system, with well-defined periods of drought and rainfall[1]. Given the sensitivity of dairy calves to solar radiation levels, high temperatures and relative humidity, local climate conditions must be considered when raising these animals, since these variables can affect their growth and future production. The Southern and Central regions of Goiás contain the largest combined dairy-producing area in the state[2], known for its thermal fluctuations and weather changes, which can directly affect dairy cows.

Rearing calves in individual holding pens with no physical contact with conspecifics can change their original behavioral habits of zootechnical interest, as can the effects of local weather conditions, resulting in physiological and behavioral consequences that may compromise their well-being [3]. Observing animal behavior contributes to understanding their needs in terms of animal husbandry facilities and how these conditions affect their welfare, in order to improve milk production in the herd. The results can be used to suggest changes in the cattle raising system, its facilities and the materials used.

In milk production systems, calves are used as replacement stock and represent the future composition of the herd. From an early age, calves need adequate nutritional, hygiene and environmental conditions to fully express their genetic potential and natural behavior. One of the most effective ways of ascertaining whether an animal is experiencing heat stress is by observing its behavior [4], since animals respond by changing their behavioral patterns, such as typical posture and activity, including movement and food and water intake [5].

In some cases, behavioral changes are the only visual sign of stress or well-being in certain environments [6]. There is a need for sustainable production systems that use alternative materials and/or waste from other activities to safeguard animal welfare. One of the roofing materials with potential in shading is geosynthetics, flat sheets manufactured from natural, synthetic or polymeric materials [7].

In order to better understand the behavior of dairy calves exposed to Cerrado conditions in Goiás state, this study investigated three geosynthetics used as roofing for outdoor holding pens.

2. Material and methods

The study was conducted at the Calf Weaning Center of Fazenda Piracanjuba-Pró-Campo, located at Km 48 of the GO-020 Highway in the Zona Rural district of Bela Vista, Goiás state (GO), Brazil (16°58'22" S and 48°57'12" W, altitude of 803 meters). Climate in the region is classified as Aw (wet tropical, with a rainy summer and dry winter) according to the Köppen classification system. As described by Campos, Passini and Nascimento [8], average annual temperature and rainfall are 23.1°C and 1,355 mm. The study was carried out in summer, from February 26-28 to March 2-3, 2017. Data obtained from the weather station on the property during the study period are shown in Figure 1.

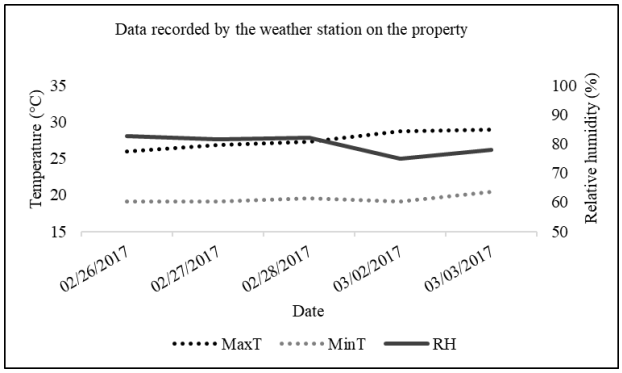


Figure 1. Maximum and minimum temperature and average relative humidity recorded by the weather station on the rural property during the study period.

The project was approved by the Animal Ethics Committee (CEUA) of Goiás State University on June 12, 2017, under protocol number 002/2017. Twenty crossbred (Girolando, Jersey and Holstein) dairy calves were used, with an average initial weight of 40.6 Kg during weaning, which ended at 90 days old [8].

A completely randomized block design was used (animal age difference of 0 ± 5 days), as described by Campos, Passini and Nascimento [8], in a 4 x 3 factorial scheme, with 5 repetitions. The roofing materials were polyethylene mesh, drainage geocomposite, nonwoven geotextile and woven geotextile, representing the first factor, and times of day (8 to 11 a.m., 11:15 a.m. to 2 p.m. and 2:15 to 6 p.m.) the second factor. The polyethylene mesh (PEM) was black and 1.60 mm thick, the drainage geocomposite (DGEO) black and 11 mm thick, the nonwoven geotextile (NWGT) grey and 1.80 mm thick, and the woven geotextile (WGT) white and 0.40 mm thick. All the roofing materials provided 80% UV protection.

The 4 North-South facing [8] covered holding pens (1 per treatment) were 19 m long, 2 m wide and 1.55 m high, installed 3 meters apart in a pasture planted with *Cynodon dactylon* cv. Vaquero. Each pen housed five calves whose collars were attached to a wire rope close the ground, allowing them to move freely in a 12 m straight line [8]. The animals had access to shade throughout the day as well as a covered trough and buckets of fresh water and milk (Figure 2).

Figure 2. Calves in outdoor holding pens covered with geosynthetics material as shading.

Their diet consisted of milk replacer, water and concentrated feed, as described by Campos, Passini and Nascimento [8]. The milk replacer was offered in individual buckets, twice a day, in the morning (8:30 a.m.) and afternoon (3:30 p.m.), totaling 6 liters a day. Water was provided *ad libitum* and the amount of feed was adjusted in accordance with daily consumption.

In order to characterize the microclimate inside the pens, a microstation data logger (HOBO ONSET® H21-002) was installed in the geometric center of each pen, 1.5 m above the ground. Each device was equipped with three (S-THB-M002) sensors to measure dry and wet bulb and black globe temperature, recorded every 5 minutes throughout the study period [8].

Wind speed data (W) were obtained daily from a weather station on the property. Environmental variables were analyzed, and the following heat stress indices calculated: black globe-humidity index (BGHI) and equivalent temperature (ET) [8]. Dew point temperature (DPT) and enthalpy (H) values were obtained using Grapsi® computer software, developed by Melo et al. [10].

BGHI was calculated using equation 1, proposed by Buffington [10]:

$$BGHI = BGT + 0.36DPT + 41.5 \quad (1)$$

where: BGT = black globe temperature (°C); DPT = dew point temperature (°C).

Equivalent temperature (ET) was calculated using equation 2, developed by Baêta [12]:

$$ET = 27.88 - 0{,}456t + 0.00100754t^2 - 0.4905rh + 0.00088rh^2 + 1.1507w - 0.126447w^2 + 0.0019876trh - 0.046313tw \quad (2)$$

where: t = dry bulb temperature, °C; rh = relative humidity, %; w = wind speed, m s^{-1}.

Behavior was assessed on 5 non-consecutive days, preferably with no cloud cover. In accordance with Perissinotto [13], there was a seven-day adjustment period to familiarize the animals with the site, contact with people and daily management practices, after which observation for data collection began.

The method used for behavioral observation was focal sampling, whereby four observers were each responsible for assessing five animals within a treatment every 15 minutes, from 8 a.m. to 6 p.m., in line with Mac-Lean [14].

The frequency of different behaviors was measured using an ethogram to record postural (standing or lying down) and activity-related data: eating (EAT), drinking (DRI), walking (WLK), standing ruminating in the sun (SRSUN), standing ruminating in the shade (SRSHD), lying ruminating in the sun (LRSUN), lying ruminating in the shade (LRSHD), standing in the sun (SSUN), standing in the shade (SSHD), lying in the sun (LSUN), lying in the shade (LSHD), interacting with the trough (INTR), foraging in the sun (FSUN) and foraging in the shade (FSHD).

The data were submitted to analysis of variance using SisVar 5.6 software® [15]. When significant, the environmental variables were compared by the Scott-Knott test at 1% and the behavioral variables using Tukey's test at 5% significance. The statistical model included the effects of the treatment, assessment times and treatment x assessment time interaction. Data on the frequency of different behaviors were submitted to square root transformation.

3. Results and discussion

According to the data collected by the weather station on the property during the study period, the average minimum and maximum temperature, relative humidity and wind speed were 19.4 and 27.6 °C, 80 % and 1.3 m/s^{-1}, respectively, with total rainfall of 113.3mm. The results of the environmental variables analyzed are shown in Figure 3. There was no significant difference in dry bulb temperature (P>0.01), but black globe temperature and relative humidity differed between treatments (P<0.01).

Average temperature and black globe temperature were 26.6 and 29.6 °C, respectively. According to Baêta and Souza [16], the ideal temperature for young calves is between 18 and 21°C, while Mota [17] considers black globe temperatures between 7 and 26°C comfortable. In the present study, the holding pens covered with alternative materials did not provide comfortable conditions for the calves, with black and dry bulb temperatures exceeding the ranges proposed by Baêta and Souza [16] and Mota [17].

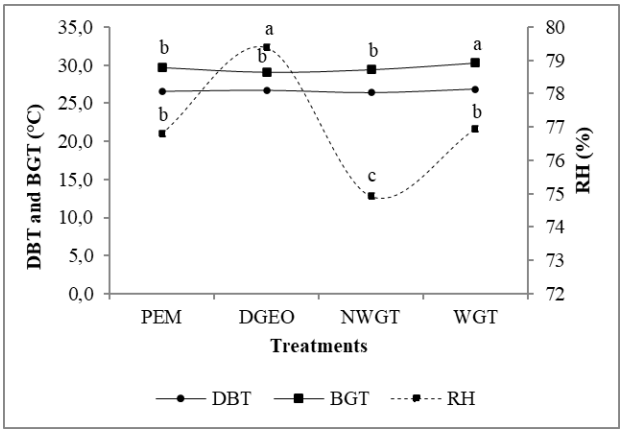


Figure 3. Average values for dry bulb temperature (DBT, °C), black globe temperature (BGT, °C) and relative humidity (RH, %) for the treatments.

The 80% UV resistant materials were unable to minimize the effects of the local temperature. However, given the climate conditions in the region, uncovered pens would result in greater physiological and behavioral effects. In accordance with Campos, Passini and Nascimento [8], the PEM and NWGT treatments produced the highest respiratory rates (68.44 and 70.08 min^{-1}, respectively) and rectal temperature (39°C), while the lowest (60.31 breaths min^{-1} and 38.9°C) were recorded in DGEO.

In a study by Campos, Passini and Nascimento [8], these two physiological variables showed a similar pattern throughout the experiment, with lower values in the morning that gradually increased through midday and peaked in the afternoon, followed by a gradual decline that helped the animals cool down and reach homeothermy during assessment.

Average relative humidity in the present study was 77 %, exceeding the ideal range of 50 to 70% [16] and demonstrating that none of the roofing materials safeguarded the thermal comfort of the animals within this range. Assessment time had an effect (P<0.01) on dry (C°) and black globe temperature (°C) and relative humidity (%) (Table 1).

Table 1. Average values for dry bulb temperature (DBT, °C), black globe temperature (BGT, °C) and relative humidity (RH, %) in the morning and afternoon.

	Assessment time				
	1	2	3		
Variable	**8-11 a.m.**	**11:15 a.m.-2 p.m.**	**2:15-6 p.m.**	**Mean**	**Prob.F**
DBT	26.8b	28.2a	25.3 c	26.65	0.0001
BGT	29.8 b	32.2 a	27.6c	29.63	0.0001
RH	79 a	70 b	80 a	77.02	0.0001

Means followed by different letters in the row differ according to the Scott-Knott (P<0.01)

Temperature follows a daily cycle, peaking in the early afternoon and dropping to a minimum in the early hours of the morning, whereas the opposite occurs for relative humidity, as shown in Table 1. These thermal fluctuations and amplitudes directly affect animal physiology, making it important to investigate holding facilities that minimize these effects and ensure the well-being of livestock.

The highest temperatures were recorded in the second time period, accompanied by the lowest RH. Although this period was the most stressful for the calves and exhibited the highest DBT and BGT values, considering an RH of 70%, it was still the closest to ideal values [16]. On the other hand, RH did not differ in periods 1 and 3, even when temperatures fluctuated as expected throughout the day. In animals exposed to a combination of high temperatures and relative humidity, these variables can cause physiological changes, requiring energy expenditure to maintain homeostasis [18]. The heat stress observed in our study with young calves could impact udder development, delaying puberty and compromising their reproductive status.

For animals reared in the field, the skin temperature (ST) of different parts of the body varies depending on the time of day (morning-afternoon). In a previous study, Campos, Passini and Nascimento [8] recorded the highest average ST in the cannon area (31.75 °C) between 8 and 10 a.m. under WGT roofing, and the lowest (30.15° C) under the DGEO covering. Calves housed in the DGEO-covered pen exhibited the best results for the physiological variables when compared to the other roofing materials assessed [8].

The performance of the materials tested was unsatisfactory in terms of ensuring the well-being of the calves. No effect was observed for treatment-assessment time interaction for DBT, BGT and RH ($P>0.05$) or between treatments for the thermal comfort indices BGHI and ET ($P<0.05$). Mean BGHI values in the PEM, DGEO, NWGT and WGT treatments were 79, 78, 79 and 79, respectively. According to Baêta [12], a BGHI up to 74 indicates thermal comfort; 74 to 78 the need for caution; 79 to 84 danger; and above 84 an emergency situation.

The overall mean BGHI in the summer season studied was 79, indicative of a need for caution. In the present study, none of the roofing materials used provided thermal comfort, potentially affecting the physiological, behavioral and milk-producing aspects of the calves. Heat stress can affect the mammary glands, with a decrease in epithelial cells compromising udder development and affecting the immune system and making the animal vulnerable to infectious diseases, such as primiparous females with mastitis caused by streptococci, coliforms, and other diseases [19]. ET values above 27 indicate stress in dairy cows; in our study, the average ET across all the treatments was 26. According to the data in Figure 4, the assessment times exhibited an effect ($P<0.01$) on thermal comfort indices.

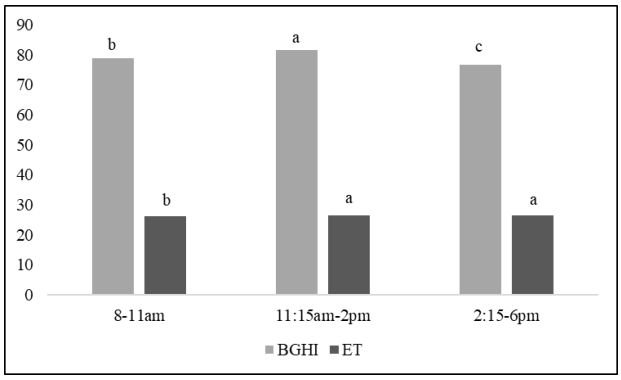


Figure 4. Average black globe-humidity index (BGHI) and equivalent temperature (ET) values for the different assessment times.

For the indices assessed, period 1 was the least stressful for the animals, since the temperature tends to be mild at this time, increasing gradually throughout the day. During this time, activities that produce more metabolic heat, such as walking and eating, tend to increase. Period 2 was the most uncomfortable for the calves, with a BGHI of 81 characterizing danger [16] and ET of 27 indicating discomfort [12]. As a result, the calves consumed less feed and searched for shade, remaining idle in an attempt to reduce energy expenditure.

Although individual pens can prevent the animals from expressing their natural behavior, they are still able to lie down, stand and walk a few steps. Changes in behavioral habits associated with an uncomfortable environment, as observed in our study, may explain the frequency of the behaviors observed. The treatments only exhibited an effect ($P<0.05$) for walking. Animals under the DGEO roofing walked the least (2.63%), followed by those in the PEM (3.02%), NWGT (5.46%) and WGT (5.46%). Analysis of the results showed that only a short time was spent walking, influenced by the unfavorable climate variables [19] during the data collection period, associated with the roofing materials used on the pens studied. The fact that the calves housed under the DGEO cover walked less compared to those in the remaining treatments may be related to environmental variables since this material produced the lowest BGT values, ensuring their well-being.

Average for the other behaviors studied were as follows: eating (EAT, 24.07%), drinking (DRI, 5.56%), lying ruminating in the sun (LRSUN, 17.93%), lying ruminating in the shade (LRSHD, 12.05%), standing in the sun (SSUN, 12.30%), standing in the shade (SSHD, 15.36%), lying in the sun (LSUN, 12.38%), lying in the shade (LSHD, 10.54%), interacting with the trough

(INTR, 17.62%), foraging in the sun (FSUN, 18.28%) and foraging in the shade (FSHD, 20.14%). The assessment times had an effect (P<0.05) on all the behaviors observed (Figure 5), except for LSHD, as shown in Figure 6.

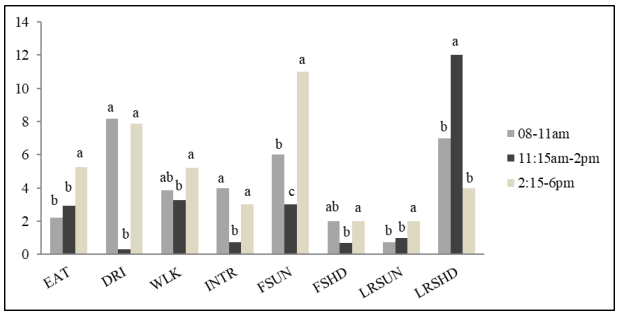


Figure 5. Average frequencies for behaviors observed in dairy calves raised in outdoor holding pens on Piracanjuba farm in Goiás state. Eating (EAT), drinking (DRI), walking (WLK), interacting with the trough (INTR), foraging in the sun (FSUN), foraging in the shade (FSHD), lying ruminating in the sun (LRSUN), lying ruminating in the shade (LRSHD).

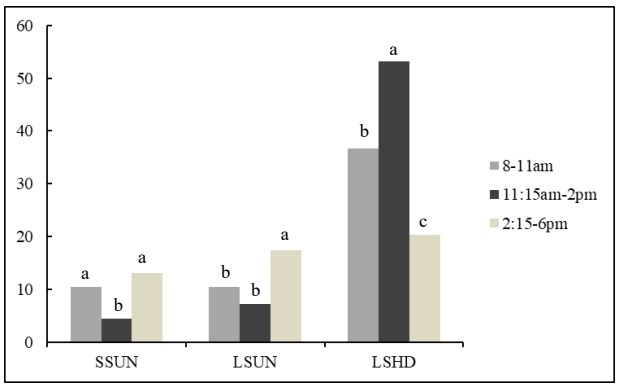


Figure 6. Average frequencies for behaviors observed in dairy calves raised in outdoor holding pens on Piracanjuba farm in Goiás state. SSUN: standing in the sun; LSUN: lying in the sun, LSHD: lying in the shade.

Significant statistical differences (P<0.05) were observed for eating, drinking, walking, lying ruminating in the sun and shade, lying in the sun and shade, interacting with the trough and foraging in the sun and shade at the different assessment times, as shown in Figures 5 and 6. Eating (5.2%) and foraging in the sun (10.6%) were more frequent between 2:15 and 6 p.m., when feed was supplied, and the most frequent behavior during this time was standing in the sun (13.1%), all of which are related to searching for and consuming food. These behaviors were also accompanied by the lowest DBT, BGT and BGHI values, indicating that the milder environmental conditions may have favored food-related activity.

The ingestion behavior of animals varies according to environmental, food and animal characteristics. Predetermined feeding times tend to influence the occurrence of peak ingestion activities [21], which are generally concentrated immediately after feed is supplied. Our results corroborate those of Miotto [21], who assessed the behavior of young bulls and observed greater feeding activity after feed was provided, from 8 to 11 a.m. and 2 to 5 p.m., when they were encouraged to consume fresh food. The highest values for drinking were recorded between 8 and 11 a.m. (8.1%) and 2:15 and 6 p.m. (7.9%). Miotto [21] also observed increased searching for water from 2 to 5 p.m., justified by the higher temperatures and greater food consumption in this time period.

In the present study, liquid was offered twice a day between 8 and 9 a.m. and 4 and 5 p.m., with animals spending more time drinking during feeding periods. The habit of searching for water depends on feeding time, the physiological condition of the animal, amount of dry matter consumed, physical makeup of the diet, water availability and quality, temperature of the water supplied and ambient temperature [22].

Walking was more frequent between 2:15 and 6 p.m., followed by 8 to 11 a.m., likely because more time was spent foraging. The calves walked less during the hottest time of the day (11:15 a.m. to 2 p.m.), lying ruminating in the shade and lying in the shade being the most frequent behaviors observed, at 11.7 and 53.2%, respectively.

The animals reduced their activity at the hottest times of day and sought shelter, lying in the pens under the shade provided by the roofing. This habit of lying down can increase or reduce the contact surface so that heat flows from the animal into the environment or vice-versa, behavior that occurs at temperatures above 30 °C [23]. According to Tripon [24], walking behavior in animals may also be related to the availability of forage in the environment, prompting them to move more often and for longer in order to select food during grazing seasons.

Lying ruminating in the sun was more frequent (2.2%) between 2:15 and 6 p.m. due to the milder climate conditions as the evening approaches, which may have influenced food consumption. Oliveira [25] reported that rumination is affected by feeding activity and occurs after food ingestion when the animal is resting. Time spent lying down is related to the rearing environment, including the type of holding pen, the comfort it provides, and climate factors, among others. There is also a strong association between lying down and ruminating.

The most frequent behaviors during the hottest period of the day (11:15 a.m. to 2 p.m.) were Lying ruminating in the sun and lying in the shade, with the latter occupying more than half (53.2%) of the daily observation time (10 hours). According to Muller [26], ruminating while lying down may indicate a clean holding pen or environment, or shade-seeking behavior at the hottest time of day.

Standing in the sun and lying in the sun were more common between 2:15 and 6 p.m. Kovács [27] reported that animals tend to remain standing to maximize heat loss through convection. As such, the calves in our study may have done so to regulate their body temperature or while waiting for food, which was supplied during this time period. On the other hand, the milder temperatures mean they may have taken the opportunity to rest in the sun.

Interacting with the trough was greater from 8 to 11 a.m. and 2:15 to 6 p.m., possibly because they were waiting for milk, which was supplied in the morning (8 to 9 a.m.) and afternoon (4 to 5 p.m.), demonstrating their conditioning to feeding times and preference for milk during this stage of life. Foraging in the shade was more frequently observed in the morning (1.8%) and afternoon (2.1%). According to Pinheiro [28], animals forage or graze largely in the early morning or late afternoon, staying in the shade at the hottest times of day, which is consistent with the results obtained in the present study.

Our findings also corroborate those of Melo [29], who studied the forage intake of cattle and observed more grazing in the early morning and late afternoon. The most frequent behavior observed throughout the day in our study was lying in the shade, regardless of the time, highlighting the importance of providing shade for animals raised in individual pens. Analysis of interaction between the treatments and assessment times indicated an effect for ($P<0.05$) for drinking, walking, lying ruminating in the sun, standing in the sun and the shade and interacting with the trough, as shown in Table 2.

Table 2. Average behavioral frequencies for treatment-assessment time interaction.

		Treatments					
Behavior	**Time**	**PEM**	**DGEO**	**NWGT**	**WGT**	**C.V. (%)**	**F value**
DRI	2:15-6 p.m.	6.75 b	7.00 b	9.00 a	8.75 a	9.33	0.0153
WLK	11:15 a.m.-2 p.m.	2.33 ab	0.33 b	5.67 a	4.67 a	27.05	0.0011
LRSUN	2:15-6 p.m.	4.00 a	1.00 b	2.50 ab	1.25 b	30.02	0.0138
SSUN	8-11 a.m.	14.46 a	8.31 ab	7.38 b	11.69 ab	19.79	0.0421
SSHD	8-11 a.m.	3.69 b	12.92 a	8.92 ab	14.15 a	22.13	0.0016
INTR	8-11 a.m.	5.85 a	2.46 b	4.62 ab	1.85 b	25.02	0.0064

Means followed by different letters in the rows differ according to Tukey's test ($P<0.05$). Drinking (DRI), Walking (WLK), Lying ruminating in the sun (LRSUN), Standing in the sun (SSUN), Standing in the shade (SSHD), Interacting with the trough (INTR).

Between 2:15 and 6 p.m., drinking was more common in the NWGT and WGT treatments, possibly because temperatures were higher in relation to PEM and DGEO. Similarly, walking was also more frequent in these same treatments but at the hottest time of day (11:15 a.m. to 2 p.m.), which may be due to discomfort as a resulting of the roofing materials used. On the other hand, lying ruminating in the sun was greater in the PEM and NWGT treatments in the afternoon. Standing in the sun and shade differed between treatments in the morning, but no pattern was observed in relation to the different roofing materials studied. Interacting with the trough was also more common in the morning, particularly in treatment PEM and NWGT. Animals seek favorable conditions according to their temporary needs and preferences [30]. Their behavior is guided by environmental changes, especially temperature, by also by hormonal and metabolic changes, learning aspects, conditioning and momentary physiological factors, such as physiological needs, hunger and thirst.

4. Conclusion

When compared to polyethylene mesh, the drainage geocomposite and nonwoven geotextile were better suited to providing shade, resulting in lower temperatures and BGHI values. The different roofing materials only affected the walking behavior of the dairy calves, which was greater when the white woven geotextile cover was used. All the behaviors studied were affected by the time of day, in accordance with the physiological needs of the animals. The most frequent behavior throughout the day was lying in the shade, demonstrating the importance of providing shade for dairy calves undergoing weaning raised in outdoor holding pens in tropical regions.

Conflicts of interest

None to declare.

Author contributions

Conceptualization: J.C.D. Campos e R. Passini. *Data curation:* J.C.D. Campos e L.J.M. Pereira e Sousa. *Formal analysis:* J.C.D. Campos e R. Passini. *Acquisition of financing:* R. Passini e A.D.G. Amaral. *Project management:* J.C.D. Campos e R. Passini. *Investigation:* J.C.D. Campos e L.J.M. Pereira e Sousa. *Methodology:* J.C.D. Campos e R. Passini. *Resources:* R. Passini e A.D.G. Amaral. *Writing (original draft):* J.C.D. Campos e R. Passini. *Writing (review and editing):* J.C.D. Campos e A.D.G. Amaral. *Software:* J.C.D. Campos.

Supervision: R. Passini. *Validation:* R. Passini. *Visualization:* J.C.D. Campos e A.D.G. Amaral.

Acknowledgments

The authors are grateful to the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) – Funding code 001 and the team at the Calf Weaning Center of Fazenda Piracanjuba-Pró-Campo in Bela Vista, Goiás state, Brazil.

References

1. Espinoza GW, Azevedo LGD,Jarreta Junior M. O clima da região dos Cerrados em relação a agricultura. Folhetos, Embrapa Cerrados. 1982. 36p. Available from: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/98805/1/cirtec-09.pdf

2. Ferreira GCVM, Iziara F, Couto VRM. Pecuária em goiás: análise da distribuição espacial e produtiva. Revista Eletrônica do PRODEMA. [Internet]. 2019;13(2):21-39. Available from: http://www.revistarede.ufc.br/rede/article/view/579

3. Fernandes TA, Costa PT, Farias GD, Vaz RZ, Silveira IDB, Moreira SM, Silveira RF. Características comportamentais dos bovinos: Influencias da domesticação e da interação homem-animal. REDVET-Revista Electrónica de Veterinária.[Internet].2017;18:1-29. Available from: https://www.researchgate.net/publication/322011075_Caracteristicas_comportamentais_dos_bovinos_Influencias_da_domesticacao_e_da_interacao_homem-animal_-_Cattle_behavioral_characteristics_Influences_of_domestication_and_human-animal_interaction

4. Almeida GLP, Pandorfi H, Barbosa SBP, Pereira DF, Guiselini C, Almeida GAP. Comportamento, produção e qualidade do leite de vacas Holandês-Gir com climatização no curral. Revista Brasileira de Engenharia Agrícola e Ambiental. [Internet].2013;17(8):892–899. Available from: https://doi.org/10.1590/S1415-43662013000800014

5. Delfino LJB, Souza BB, Rosangela MN, Silva WW. Influência bioclimatológica sobre os parâmetros hematológicos de bovinos leiteiros. Agropecuária Cientifica no Semiárido. [Internet]. 2012;8(2):08-15. Available from: http://revistas.ufcg.edu.br/acsa/index.php/ACSA/article/view/171/pdf

6. Vilela RA, Leme TMC, Titto CG, Neto PF, Pereira AMF, Balieiro JCC, Titto EAL. Respostas fisiológicas e comportamentais de vacas holandesas mantidas em sistema adiabático evaporativo. Pesquisa Veterinária Brasileira. [Internet].2013;33(11):1379-1384. Available from: https://www.scielo.br/j/pvb/a/xnBdkbRxttyRVRPKWyF8WwF/?lang=pt&format=pdf

7. Oliveira LA, Viana PMF, Santos DCR, Reis EF. Uso de geossintéticos como reforço em estradas não pavimentadas. Revista Engenharia Agrícola. [Internet].2016;36(3):546-557. Available from: https://www.scielo.br/j/eagri/a/bqpStPRs8rBc5tkDYwxVKqc/?lang=pt&format=pdf

8. Campos JDC, Passini R, Nascimento KFMD. Thermography and physiology of stress in dairy calves in outdoor holding pens covered with geosynthetics. Revista Brasileira de Engenharia Agrícola e Ambiental. [Internet].2021;25(11):787-793.

Available from: https://www.scielo.br/j/rbeaa/a/8gfkvF6prts35PrpH3ZtbLJ/?lang=en

9. Climate-Data.org. Clima Bela Vista de Goiás.[Internet].2020. [Acesso em: 21 Jun. 2020]. Available from: http://pt.climate-data.org/location/43439/

10.Melo EC, Lopes DC, Corrêa PC. GRAPSI-Programa computacional para cálculo das propriedades psicométricas do ar. Engenharia na Agricultura. [Internet].2004;12(2):145-154. Available from: https://www.researchgate.net/profile/Evandro-Melo-2/publication/284415565_GRAPSI_-_Programa_computacional_para_o_calculo_das_propriedades_psicrometricas_do_ar/links/5deeb3684585159aa470f500/GRAPSI-Programa-computacional-para-o-calculo-das-propriedades-psicrometricas-do-ar.pdf

11.Buffington DE, Collazo-Arocho A, Canton GH, Pitt D, Thatcher WW, Collier RJ. Black globe humidity index as a comfort equation for dairy cows. American SocietyofAgriculturalEnginneers. [Internet].1981;24(3):711-714. Available from: https://elibrary.asabe.org/abstract.asp?aid=34325

12.Baêta FC, Shanklin MD, Jonhson HD, Meador NF. Equivalent Temperatura Index At Temperatura Agove The Thermoneutral For Lactating Dairy Cows. American Society of Agricultural Engineers.[Internet].1987;22p.Available from: https://agris.fao.org/agris-search/search.do?recordID=US8853966

13. Perissinotto M, Moura DJ, Cruz VF, Souza SRLD, Lima KAOD, Mendes AS. Conforto térmico de bovinos leiteiros confinados em clima subtropical e mediterrâneo pela análise de parâmetros fisiológicos utilizando a teoria dos conjuntos fuzzy. Revista Ciência Rural.[Internet].2009;39(5):1492-1498.Available from: https://doi.org/10.1590/S0103-84782009005000094

14.Mac-Lean PAB, Barbosa OR, Jobim CC, Gasparino E, Santos GT, Faria LAN. Sombra artificial e método de fornecimento de concentrado no comportamento e desempenho de bezerros desmamados. Acta Scientiarum, Animal Sciences. [Internet].2011;33(4):409-415.Available from: https://doi.org/10.4025/actascianimsci.v33i4.10672

15.Ferreira DF. Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia. [Internet]. 2014;35(6):1039-1042. Available from: https://doi.org/10.1590/S1413-70542011000600001

16.Baêta FC, Souza CF. Ambiência em edificações rurais: Conforto animal. 2.ed. Viçosa: EDUFV, 2010. 269p.

17.Mota FS. Climatologia zootécnica: Pelotas: UFPEL, 2001. 104p.

18.Barros PC, Oliveira V, Chambó ED, Souza LC. Aspectos práticos da termorregulação em suínos. Revista Eletrônica Nutritime. [Internet].2010;7:1248-1253. Available from: https://nutritime.com.br/artigo-114-aspectos-praticos-da-termorregulacao-em-suinos/

19.Pragna P, Archana PR, Aleena J, Sejian V, Krishnan G, Bagath M, Manimaran A, Beena V, Kurien EK, Varma G, Bhatta R. Heat stress and dairy cow: Impact on both milk yield and composition, Review Article. International Journal of Dairy Science. [Internet]. 2017;12(1):1-11. Available from: https://docsdrive.com/pdfs/academicjournals/ijds/2017/1-11.pdf

20.Ratnakaran AP, Sejian V, Sanjo Jose V, Vaswani S, Bagath M. Krishnan G, Beena V, Devi, PI, Varma G, Bhatta R. Behavioral responses to livestock adaptation to heat stress challenges. Asian Journal of Animal Science. [Internet].2017;11:1-13. Available from: https://www.researchgate.net/publication/313548685_Behavioral_Responses_to_Livestock_Adaptation_to_Heat_Stress_Challenges

21.Miotto FRC, Neiva JNM, Restle J, Falcão AJS, Castro KJ, Maciel RP. Comportamento ingestivo de tourinhos alimentados com dietas contendo níveis de gérmen de milho integral. Revista Ciência Animal Brasileira. [Internet].2014;15(1):45-54. Available from: https://doi.org/10.5216/cab.v15i1.24627

22.National Research Council - NRC. Nutrient requeriments of dairy cattle. 7.rev.ed. Washinton, D.C. 2001. 381p.

23.Purwanto BP, Nakamasu F, Yamamoto S. Effect of environmental temperatures on heat production in dairy heifers differing in feed intake level. Asian Australasian Journal of Animal Science- AJAS. [Internet].1993;6(2):275-279. Available from: https://www.animbiosci.org/journal/view.php?doi=10.5713/ajas.1993.275

24.Tripon I, Cziszter LT, Bura M, Sossidou EN. Effects of seasonal and climate variations on calves' thermal comfort and behavior. International Journal of Biometeorology.[Internet].2013;58:1471-1478. Available from: https://www.researchgate.net/publication/258060939_Effects_of_seasonal_and_climate_variations_on_calves'_thermal_comfort_and_behaviour

25.Oliveira PTL, Turco SHN, Araújo GGL, Voltolini TV, Menezes DR, Silva TGF. Comportamento ingestivo e parâmetros fisiológicos de bovinos Sindi alimentados com teores crescentes de feno de erva-sal. Revista Brasileira de Ciências Agrárias. [Internet]. 2012;7(1):180-188. Available from: https://doi.org/10.5039/agraria.v7i1a914

26.Muller M, Silva RWSM, Mielke LF. Efeitos de diferentes instalações sobre o comportamento ingestivo de bezerros da raça holandesa. Revista da 9ª. Jornada de Pós-Graduação e Pesquisa Congrega Urcamp. [Internet].2011; 10p. Available from:https://docplayer.com.br/86832098-Efeito-de-diferentes-instalacoes-sobre-o-comportamento-ingestivo-de-bezerros-da-raca-holandesa-1.html

27.Kovács L, Kézer FL, Ruff F, Szenci O, Jurkovich V. Association between human and animal thermal confort indices and physiological heat stress indicators in dairy calves. Environmental Research. [Internet].2018;166:108-111.Available from: https://doi.org/10.1016/j.envres.2018.05.036

28.Pinheiro AC, Saraiva EP, Saraiva CAS, Fonseca VFC, Almeida MEV, Santos SGC, Amorim MLCM, Neto PJR. Características anatomofisiológicas de adaptação de bovinos leiteiros ao ambiente tropical. Revista Técnico- Científica Agrícola – AGROTEC. [Internet]. 2015;36(1):280-293. Available from: https://www.researchgate.net/publication/334635304_Caracteristicas_anatomofisiologicas_de_adaptacao_de_bovinos_leiteiros_ao_ambiente_tropical

29. Melo JC, Alexandrino E, Paula Neto JJ, Rezende JM, Silva AAM, Silva DV, Oliveira AKR. Comportamento ingestivo de bovinos em capim-piatã sob lotação intermitente em resposta a distintas alturas de entrada. Revista Brasileira de Saúde e Produção Animal. [Internet].2016;17(3):385-400. Available from: https://doi.org/10.1590/S1519-99402016000300006

30.Ferreira LCB, Machado Filho LCP, Hotzel MJ, Alves AA, Barcellos AO. Respostas fisiológicas e comportamentais de bovinos a diferentes ofertas de sombra. Cadernos de Agroecologia. [Internet].2014;9(2):1-14. Available from: https://revistas.aba-agroecologia.org.br/cad/article/view/15843