

Behavioral indicators of cattle housed in different shade surfaces availability completed in dry tropical environment

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ABSTRACT

The objective was to assess the behavioral indicators of cattle housed in different shade surface availabilities under dry tropical environmental conditions carried out in the summer-autumn period. During 63 days the usual social and agonist variables were recorded in 1,040 bulls housed in 16 pens (4 replicas/treatment, 65 bulls/pen). Ambient temperature (AT) and relative humidity (RH) were recorded, and the humidity index (THI) was estimated. The shade surfaces tested were 1) conventional shade (S12%), 2) double shade (S24%), 3) shaded 100% without fans (S100), and 4) shaded 100% with fans (S100F). The average maximum value for AT, RH and THI was 38.1°C, 90.7% and 87.6 units. The shade surface influenced the proportion of animals under shade, eating, ruminating, and mounting, and decreased the proportion of animals panting. Pens S24 showed a higher proportion of animals eating and resting (quadratic component, $P=0.05$). Providing ventilation increased ($P=0.01$) 2.7 times the proportion of animals eating and decreased ($P=0.01$) 6.5 times the proportion of animals panting. At 0800h a greater proportion of animals eating and riding was observed, while from 1130h onwards the proportion of animals under shade, ruminating and resting increased. At 2:00 p.m., the highest percentage of animals were panting. It is concluded that a shaded surface of 12% of the pen area is enough to alleviate behavioral patterns in animals under high environmental heat load. Shade plus ventilation was shown to be a strategy in reducing panting and increasing the proportion of animals in feed bunks.

Keywords: Animal welfare, Behavior, Feedlot, Ruminants, THI

INTRODUCTION

Climatic conditions north of the Tropic of Cancer on both sides of the Gulf of California are characterized by persistently high ambient temperatures during summer (>36 °C) and relative humidity above 60% (CONAGUA, 2024). This results in a Temperature-Humidity Index (THI) score that exceeds the comfort limit for beef cattle (>72 units) (Harun *et al.*, 2022). In intensive finishing pens, these environmental

factors generates a stressful situation for cattle, modifying their physiology and behavior (Veissier and Boissy, 2007; Olivares *et al.*, 2013), such that the high environmental heat load negatively impacts on their productivity and welfare (Brown-Brandl *et al.*, 2005). To maintain homeothermy under conditions of high environmental heat load, cattle activate the physiological mechanism called thermal balance, which allows them to cope with these environmental contingencies (Silanikove, 2000).

In this regard, Arias *et al.* (2008) recommend using heat mitigation strategies in beef cattle exposed to ambient temperatures above 25°C through the incorporation of microclimates that help them cope with adverse climatic conditions. This strategy does not eliminate the environmental stress suffered by the cattle but rather allows them to adapt to these conditions (Mader *et al.*, 2003). The ambient heat load in cattle is influenced by ambient temperature, relative humidity, solar radiation, drinking water temperature, and pen characteristics, as well as internal factors such as cattle genotype, coat colour and type, body size and condition, health status, and degree of adaptation (Nielsen *et al.*, 2025). The use of a shade and ventilation system is an option that decreases the heat load from solar radiation and that is reflected from the ground. Sullivan *et al.* (2011) observed a decrease in panting and an increase in cattle performance and welfare when implementing the use of shade in different proportions. In this sense, Gaughan *et al.* (2010) demonstrated that cattle housed under shade maintain a lower body temperature and panting rate compared to those not shaded. They also state that dry matter intake, daily weight gain, and hot carcass weight were higher in cattle housed under shade. Valadez-Noriega *et al.* (2019), in two housing systems—one that provided shade with thermoplastic mesh and another without shade—observed that steers housed without shade remained standing mostly from 12:00 to 14:59 h, which was considered the hottest period of the day, and showed a propensity to consume feed. It was also observed that steers under shade showed a predisposition to lie down and ruminate during the same period of the day, as well as exhibiting a greater approach to the water trough. This result shows that indicators of behavioral response can be modified according to the intensity and variation of environmental conditions, helping to maintain homeostasis and showing an increase in heat load (Idris *et al.*, 2024).

Even though there is information regarding the effect of shade surfaces on cattle's behavioral aspects, it is limited under dry tropical conditions. Furthermore, preliminary studies show that the combination of mechanical ventilation with conventional shade can provide additional improvements in the performance of cattle ex-

posed to high heat loads in arid and dry climates (Correa-Calderón *et al.*, 2007). However, little information exists on this resource for dry tropical climates where relative humidity is higher. Consequently, we predict that the combination of ventilation and shade can minimize the combined negative effects of elevated ambient temperature and humidity on the behavior of cattle in feedlots. For the above reasons, the objective of this experiment was to evaluate the influence of three shade surfaces (12, 24, and 100% of the pen surface) and the use of fans in a total shade surface (100%) on the behavioral response of cattle in intensive finishing under conditions of high ambient temperature and humidity in the dry tropics.

MATERIALS AND METHODS

The research was carried out in the experimental cattle module of a Livestock Production Unit specializing in intensive meat production located in the municipality of Culiacán, Sinaloa (24°48'31.9" N; 107°23'40.6" W; 60 m.a.s.l.). The climate of the region is classified as BS1(h') w(w) (e), which is defined as semi-dry, very hot, and extreme with summer rains. The average annual temperature is 26°C with a maximum of 40.1°C and a minimum of 6.8°C, respectively. The maximum relative humidity is 96%, and the minimum is 12%, with an annual average of 63% (Faculty of Biology, 2024).

Characteristics of the Experimental Module

The experimental cattle facility consists of 16 pens, each with a surface area of 585 m² (15 m front × 39 m deep), equipped with an automatic water trough and a 15 m linear feed bunk (divided into 5 blocks of 2.5 m). The pens are oriented from east to west, so that the ground surface of all pens, regardless of the shade treatments, had access to sunlight, to a greater or lesser extent, throughout the day. This is a result of the pen's orientation and the angle of the sun at sunrise and sunset. The characteristics of the pens and their shaded surface are presented in Table 1.

Treatment Assignment

Two hundred and sixty bulls (average weight ~ 390 kg) that were fed with a total mixed finish-

Table 1. Characteristics of the Experimental Pens for Intensive Finishing Cattle According to the Shade Surface

Characteristics	Relative Shade Area/Total Pen Area			
	S12	S24	S100	S100F
Pens	4	4	4	4
Cattle housed/pen	65	65	65	65
Available space (m ²)	585	585	585	585
Available shade (m ²)	70.4	140.8	585	585
Available feeder (m)	15	15	15	15
Living space/head (m ²)	9.0	9.0	9.0	9.0
Shade/head (m ²)	1.08	2.16	9.0	9.0
Bunk space/head (m)	0.230	0.230	0.230	0.230

S12: 12% shade; S24: 24% shade; S100: 100% shade; S100F: 100% shade with fan.

ing diet (88:12 concentrate-to-forage ratio) were assigned to each of the shade surfaces, distributed in four pens of 65 bulls each, according to the following description:

Conventional shade (S12): four pens with a shaded area of 12% each, based on 11 metal sheets of 8 × 0.80 m (70.4 m²)

Double shade (S24): four pens with a shaded area of 24% each, based on 22 metal sheets of 6 × 0.80 m (140.8 m²)

Dome without fan (S100): four pens with a shaded area of 100% (15 × 39 m) without the presence of fans

Dome with fan (S100F): four pens with a shaded area of 100% (15 × 39 m), each pen with 3 industrial fans with a 6 m diameter, Big Vento brand, low speed (model BV06XA1508 Megaventilación S.A. de C.V., Guadalajara, Jalisco, Mexico)

The description of diets and the management of experimental units prior to and during the experiment, as well as the growth performance and carcass effects of the treatments presented here, were previously described by Castro-Pérez *et al.* (2020).

Recording of Ambient Temperature and Relative Humidity

Ambient temperature and relative humidity were recorded during the observational stage at the weather station installed in the Livestock Production Unit. To calculate the Temperature and Humidity Index (THI), the formula used was $THI = 0.81 \times T + RH(T - 14.40) + 46.40$ (Hahn, 1999), where T is the ambient temperature in degrees Celsius and RH is the relative humidity in percentages.

Procedure for Recording Variables

The duration of the prospective observational study was nine weeks (63 days), and it was carried out between the summer and autumn seasons for the northern hemisphere. The behavioral indicators related to animal welfare—habitual, social, and agonistic behavior of the cattle during the finishing stage—were recorded using previously designed forms. In a rotating manner, three people observed each pen for 15 minutes at each of the following times: 8:00, 11:30, and 14:30 h. First, the number of animals eating was recorded. Then, the evaluator entered the pen to count the number of cattle under the shade, resting, and ruminating. Subsequently, the frequency of panting and mounts was recorded without counting repetitions among the same cattle.

Statistical Analysis

The unit of observation was the pen (n = 16 pens), which housed 1,040 bulls, with an average weight of 463.8 ± 2.7 (SD). For the analysis, the ranges of the relative frequencies (RF) of cattle in each pen that showed one or more behavior(s) were used: under shade, eating, ruminating, mounting, resting, and/or panting. The formula $RF = a / ((a+b)) \times 100$ was used, where a is the absolute frequency of the behavior and (a+b) is the total number of cattle in each pen. The ranges were obtained using the RANK procedure (16). The effect of the shaded surface in each pen (S12, S24, S100, S100F), of the time (8:00, 11:30, 14:30), and of the shaded surface at each time was analyzed by analysis of variance. The coefficients for the linear and quadratic polynomials were estimated using the ORPOL function of the IML procedure (SAS, 2002). In addition, the con-

trast of each behavior in S100 vs. S100F was tested. A simple linear correlation analysis of the relative frequencies of each behavior on each pen surface and in general was performed. The maximum alpha value to accept a statistical difference was 0.05.

RESULTS AND DISCUSSION

Table 2 presents the values of the environmental variables recorded in the feedlot pens during the experimental period (summer-autumn, northern hemisphere).

The maximum weekly average value for ambient temperature was 38.1°C, and for relative humidity, it was 90.7%, representing a THI of 87.6 units, which oscillated between 82 and 85 units. These values show that during the experimental period, the cattle were in the categories of heat danger to emergency (THI of 80 to > 84 units), approaching the critical production limit and sometimes within that limit. This can lead to a decrease in the productivity of the cattle if appropriate mitigation measures are not established (Morgado *et al.*, 2023), a decrease in cattle productivity (Lees *et al.*, 2019), an increase in diseases through vectors (Nejash, 2018), and a modification of behavioral patterns (Idris *et al.*, 2023).

In this regard, Arias *et al.* (2008) report that in response to the increase in ambient tempera-

ture, cattle undergo physiological changes, including an increase in respiratory rate, modifications in pulse, and an increase in vasodilation, as a regulatory mechanism for homeostasis in critical conditions. With these responses, cattle are capable of maintaining a zone of thermoneutrality up to a certain level, but their productive behavior can be compromised, in addition to modifying their usual behavior to avoid the effects of excessive heat (Brown-Brandl *et al.*, 2006). The effect of the type of shade and mechanical ventilation on the behavioral indicators in beef cattle in the feedlot is shown in Table 3.

In the feedlot pens provided with total shade (S100 and S100F), 92.5% of the cattle housed in these pens remained under the shade. It is important to note that, as a result of the orientation of the pens, there was sunlight inside the pens during part of the morning and part of the afternoon, even when they were completely covered. This percentage of cattle under the shade was similar between the S100 and S100F treatments ($P > 0.05$). In this sense, these values were higher ($P < 0.01$) when compared to the S12 and S24 treatments. And between these two treatments, S24 showed a higher percentage ($P < 0.01$) compared to S12 (80.5 vs. 77.06%, respectively). These results are explained by the percentage of shade available in each pen. The 100% shade coverage prevents most cattle from having the option to choose whether or not to stay in the

Table 2. Weekly minimum, maximum, and average values of ambient temperature, relative humidity, and THI in the feedlot pens during the experimental period

Week	Ambient Temperature			Relative Humidity			THI		
	Min.	Max.	Avg.	Min.	Max	Avg.	Min.	Max.	Avg.
1	24.9	36.6	31.1	54.2	99.5	71.7	76	88	82
2	25.5	37.8	32.3	48.9	95.2	68.4	77	88	84
3	25.6	37.6	32.9	48.5	94.7	69.2	73	89	85
4	23.6	36.8	31.2	47.5	97.1	69.3	73	87	82
5	25.6	36.9	31.9	38.8	93.6	66.7	77	87	83
6	23.8	40.1	34.4	26.7	83.6	51.4	72	89	83
7	24.5	38.1	33.1	31.9	86.1	58.0	73	88	83
8	24.5	40.2	33.3	22.2	84.1	51.4	73	86	82
9	25.5	38.9	33.3	29.5	82.1	54.0	75	86	82
Overall	24.8	38.1	32.2	38.7	90.7	62.2	74.3	87.6	82.9

Min: Minimum; Max: Maximum; Prom: Average; THI: Temperature and Humidity Index

Table 3. Effect of the Type of Shade and Mechanical Ventilation on Behavioral Indicators in Beef Cattle in an Intensive Feedlot

Concept ¹	Type of Shade				SEM	P-value		S100 vs S100F
	S12	S24	S100	S100F		Linear	Quadratic	
Under shade	77.06	80.55	93.78	91.22	0.67	0.01	0.15	0.01
Eating	2.92	4.00	3.99	5.40	0.21	0.01	0.05	0.01
Ruminating	7.65	8.22	8.97	9.44	0.26	0.01	0.32	0.19
Mounts	2.12	1.40	3.58	3.33	0.20	0.01	0.01	0.36
Resting	36.30	40.25	36.86	36.07	0.73	0.09	0.01	0.45
Panting	1.47	1.09	1.03	0.16	0.09	0.01	0.29	0.01

¹Values expressed as a percentage; SEM= standard error of the mean.

shade, but it ensures greater thermal comfort. In contrast, cattle placed in pens provided with S24 have twice the available shade surface for the cattle compared to S12 (24% and 12% shade, respectively).

In the pens provided with 12 m² of shade, a lower presence of cattle eating was recorded during the observation periods (2.92%), a value lower than that recorded in the other treatments ($P < 0.01$). In this regard, no difference was observed between S100 and S24 (3.99 and 4.0%; $P > 0.05$). However, providing 100% shaded space plus the fan showed a greater proportion of cattle eating than the rest of the treatments (5.40%; $P < 0.01$). In the variable of time spent ruminating, the S100F (9.44%), S100 (8.97%), and S24 (8.22%) treatments were similar to each other ($P > 0.05$), which was higher than the value observed in S12 (7.65%; $P < 0.01$). This is attributed to the fact that in scenarios of high temperatures where environmental conditions are not optimal for their performance, cattle restrict their feeding to decrease the heat load since fermentation at the ruminal level and its subsequent digestion generate heat (Brown-Brandl *et al.*, 2006). For this reason, if ambient temperature and relative humidity conditions improve, the cattle return to this activity.

In the S100F and S100 treatments, cattle showed similar behavior with respect to mounts (3.45%; $P > 0.05$); however, they showed differences ($P < 0.01$) compared to the S12 and S24 pens, since this agonistic behavior was not observed in them. Among the main behavioral changes shown when the animal is subjected to high environmental heat load conditions is the reduction of agonistic behavior, including

mounting (Lees *et al.*, 2019). This thermoregulatory mechanism is activated in order to preserve body temperature (Silanikove, 2000). Cattle housed in pens with less available shade reduced their agonistic behavior as a physiological response to maintain homeothermy, while cattle housed in total shade both with and without a fan, exhibited this behavior.

A total of 26 cattle housed in S24 were observed in a resting position, a figure 9.5% higher than that of the cattle housed in the S110V, S100, and S12 pens (36.4%; $P < 0.01$). When the cattle have greater access to shade and feel comfortable, they increase their resting time; however, if they are less comfortable, they prefer to remain standing (Idris *et al.*, 2024).

This may explain why a greater number of cattle remained resting in the S24 pen than in the S12 pen. In the case of cattle housed in pens with a total shade surface, where there was not only more shade availability but also greater environmental comfort than in the S24 and S12 pens, a lower percentage of cattle resting can be attributed to the fact that under better environmental conditions, the cattle perform other behaviors such as food consumption and mounting.

The cattle housed in the S100F pens showed a lower panting frequency (0.16%; $P < 0.01$) compared to the cattle housed in the other pens. As a physiological mechanism for the increase in body temperature, the cattle pant to dissipate heat (Brown-Brandl *et al.*, 2006). In the case of S100F, mechanical ventilation favored the favorable environmental conditions to a greater extent by mitigating the direct effects of heat, which was manifested by the reduction in panting, since compared to pens that only have

natural ventilation, the effort of heat dispersion is less (Romo *et al.*, 2022).

Table 4 shows the behavioral indicators in relation to the time of observation in the finishing pens. As expected, at the time of highest ambient temperature, the number of cattle under the shade increased ($P < 0.01$), this being more evident in the afternoon (93.5%) than in the morning (71.5%). The cattle seek shade to mitigate the high environmental heat load, but the long-term persistence of these conditions affects the welfare and compromises the survival of cattle that are particularly sensitive to these climatic conditions (Lees *et al.*, 2020). Cattle need to be provided with conditions to meet basic needs that include the supply of water and food, time for rest, and shade in the pens, with particular reference to the meteorological conditions to which they are exposed during their stay in the feedlot (Arias and Mader, 2023). Cattle under favorable conditions of shade in the feedlot show less aggressive behavior and negative interaction with other cattle. In addition, the use of shade during intense environmental heat reduces the negative risks of high heat load (Aguilar-Quiñones *et al.*, 2022).

As the day progressed, the number of cattle ruminating increased (4.77, 9.24, and 11.43%; $P < 0.01$ for 8:00, 11:30, and 14:30 h, respectively). When cattle are resting, rumination is optimized; therefore, as resting time increases, rumination also increases. Feeding behavior and subsequent events such as rumination and resting are frequently monitored to evaluate the welfare and health status of beef cattle. This is because short-term behavioral responses to extreme climatic conditions can be critical for cattle with respect to their welfare (DelCurto-Wyffels *et al.*, 2021).

It has been observed that the expression of rumination depends on the amount of dry matter consumed associated with gastrointestinal motility. Therefore, the feeding schedule and the intensity of the heat load (e.g., above 86 THI units) at a certain time of day can negatively influence the expression of rumination, which is aggravated by insufficient shade in the feedlot (Lees *et al.*, 2020).

In the present study, it was observed that the cattle increased their resting time as the hours of the day passed. A lower percentage of animals were observed resting in the morning (24.6%; $P < 0.01$) compared to the times after the first observation of the day (11:30 and 14:30 h). However, no differences were shown between these two times ($P > 0.05$). Resting time has been associated with the welfare of cattle. In this sense, locomotor activity is of great importance in heat production, because physical exercise can significantly increase the acquisition of body heat. Given the increase in ambient temperature, the cattle suppress any activity that generates heat and therefore remain at rest during periods of high heat load.

Another way to rest is to remain standing, although postural changes may vary. By standing during the hot hours of the day, the cattle try to expose a greater proportion of their body surface to possible air movement to mitigate the negative effect of heat (Lees *et al.*, 2020). This generally occurs when the cattle's body temperature increases and they are unable to dissipate body heat adequately to maintain thermal balance because high ambient temperature, high relative humidity, and slow air movement contribute to the cattle's thermoneutral zone being exceeded in the feedlot (Wang *et al.*, 2020).

Table 4. Effect of the Time of Day on Behavioral Indicators in Beef Cattle in the Intensive Feedlot.

Concept ¹	Time			SEM	P-value	
	8:00	11:30	14:30		Linear	Quadratic
Avg. AT, °C	27.6	33.3	35.2			
Under shade	71.54	92.39	93.57	0.59	0.01	0.01
Eating	7.52	2.05	2.64	0.18	0.01	0.01
Ruminating	5.02	9.24	11.43	0.23	0.01	0.01
Mounting	4.77	2.05	1.00	0.18	0.01	0.01
Resting	25.81	42.22	44.07	0.65	0.01	0.01
Panting	0.18	1.14	1.54	0.08	0.01	0.01

¹Values expressed as percentages; AT= ambient temperature; SEM= standard error of the mean.

Table 5. Effect of Time and Type of Shade on Behavioral Indicators in Beef Cattle in the Feedlot

Time	Type of Shade	Behavioral Indicator					
		Under Shade	Eating	Ruminating	Mounts	Resting	Panting
8:00	S12	61.00	5.70	5.08	4.18	29.01	0.26
	S24	63.59	7.97	4.73	2.88	29.08	0.18
	S100	84.10	7.01	5.14	6.14	24.39	0.26
	S100F	77.43	9.41	5.13	5.90	20.76	0.02
	EEM	1.67	0.50	0.36	0.45	1.39	0.06
	L	0.01	0.01	0.57	0.01	0.01	0.06
	C	0.98	0.08	0.25	0.01	0.63	0.23
	S100 vs 100F	0.05	0.01	0.99	0.71	0.07	0.01
11:30	S12	85.57	1.09	7.50	1.66	36.97	1.86
	S24	89.41	1.42	8.41	0.83	46.67	1.30
	S100	97.48	2.14	10.11	3.08	42.01	1.27
	S100F	96.80	3.55	10.37	2.82	43.24	0.13
	EEM	0.89	0.25	0.47	0.37	1.34	0.17
	L	0.01	0.01	0.01	0.01	0.19	0.01
	C	0.11	0.37	0.37	0.01	0.01	0.38
	S100 vs S100F	0.59	0.25	0.25	0.38	0.52	0.01
14:30	S12	88.33	2.02	10.48	0.53	42.75	2.32
	S24	89.74	2.57	11.55	0.52	45.16	1.89
	S100	99.74	2.70	11.31	1.57	44.36	1.65
	S100F	99.48	3.28	12.42	1.38	44.01	0.30
	EEM	0.78	0.32	0.53	0.22	1.18	0.21
	L	0.01	0.03	0.09	0.01	0.77	0.01
	C	0.07	0.56	0.09	0.49	0.12	0.69
	S100 vs S100F	0.81	0.20	0.14	0.56	0.84	0.01

¹Values expressed as a percentage; SEM= standard error of the mean; L= linear effect; C= quadratic effect.

Mounts were observed in greater numbers in the morning (4.77%) compared to the midday and afternoon times ($P < 0.01$). At these times, agonistic activity is practically inhibited at 11:30 and 14:30 ($P > 0.05$). In the morning, conditions are more favorable for homeostasis, so some cattle exhibited this agonistic behavior during the hours when the THI value is lower. However, in response to the increase in this value, the cattle activate a thermoregulatory mechanism to maintain body temperature, reducing agonistic behavior (Brown-Brandl *et al.*, 2006; Arias *et al.*, 2008), especially when the animals are in climatic conditions outside their thermoneutral zone and establish an immediate self-preservation response, where energy is allocated to maintaining homeostasis and core body temperature (Salvin

et al., 2020).

Panting frequency varied at the three different times of day. In the morning, it was lower, followed by midday, with a maximum percentage in the afternoon (0.18, 1.14, and 1.54%, respectively; $P < 0.01$). As the ambient temperature increases, the THI value also rises with the passing hours of the day, and consequently the frequency of panting increases as a means of dissipating metabolic heat. In this way, the recording of panting cattle provides a visual evaluation of respiratory dynamics in cattle and evaluates the condition of the animal's breathing or panting (Salvin *et al.*, 2020). This is associated with the behavior of seeking shade, which can also be indicative that the cattle are uncomfortable with their thermal environment. Therefore, physical

Table 6. Correlation of Behavioral Indicators in Beef Cattle in the Intensive Feedlot.

Indicator		Eating	Ruminating	Mounts	Resting	Panting
Under shade	S12	-0.39 **	0.26 **	-0.27 **	0.24 **	0.34 **
	S24	-0.55 **	0.44 **	-0.29 **	0.43 **	0.29 **
	S100	-0.45 **	0.37 **	-0.39 **	0.42 **	0.18 **
	S100F	-0.45 **	0.41 **	-0.36 **	0.36 **	0.20 **
	Overall	-0.34 **	0.38 **	-0.17 **	0.32 **	0.13 **
Eating	S12		-0.12 **	0.26 **	-0.28 **	-0.20 **
	S24		-0.19 **	0.18 **	-0.44 **	-0.32 **
	S100		-0.21 **	0.20 **	-0.42 **	-0.18 **
	S100F		-0.33 **	0.12 **	-0.47 **	-0.03 NS
	Overall		-0.20 **	0.20 **	-0.40 **	-0.23 **
Ruminating	S12			-0.29 **	0.17 **	0.12 **
	S24			-0.39 **	0.29 **	0.15 **
	S100			-0.38 **	0.26 **	0.06 NS
	S100F			-0.39 **	0.35 **	0.01 NS
	Overall			-0.33 **	0.27 **	0.07 **
Mounts	S12				-0.40 **	-0.20 **
	S24				-0.36 **	-0.12 *
	S100				-0.48 **	-0.17 **
	S100F				-0.48 **	-0.13 *
	Overall				-0.43 **	-0.18 **
Resting	S12					0.01 NS
	S24					0.25 **
	S100					0.24 **
	S100F					0.07 NS
	Overall					0.15 **

S12=12% shade; S24=24% shade; S100=100% shade; S100F=100% shade with fans.

NS=Not significant ($P > 0.05$); *significant ($P < 0.05$); ** highly significant ($P < 0.01$)

modification of the environment is important to reduce the high heat load and increase heat dissipation. This is achieved by providing shade, which reduces the heat load from solar radiation, and the use of fans, which can improve extreme environmental conditions in the feedlot (Wang *et al.*, 2020). Slayi and Jaja (2025) indicate that intervention strategies facilitate the expression of positive behaviors in cattle and reduce discomfort during their stay in the feedlot, thus favorably impacting production indicators.

Significant interactions ($P < 0.05$) were observed for all variables due to the effect of time and type of shade (Table 5). It has been observed that in cattle housed in pens with less available

shade, behavioral patterns increase as a response to heat stress, especially during the hours of greatest exposure to high ambient temperature (Lees *et al.*, 2020). For this reason, mitigation strategies must be implemented to decrease the heat load in cattle during their stay in the feedlot. These strategies used in beef feedlots include shade structures, misters, or fans, which individually or combined can favorably impact cattle behavior (Davis *et al.*, 2022) and welfare indicators (Hagenmaier *et al.*, 2016), especially during times of high ambient temperature (Edwards-Callaway *et al.*, 2021). It has been observed that housing with less shade surface and higher ambient temperature conditions favors the presence of

more accentuated behavioral indicators such as remaining under the shade, increasing panting, decreasing rumination activity, and increasing resting time. In this regard, Sullivan *et al.* (2011) observed that the availability of shade in the beef feedlot reduced panting scores during periods of high heat loads. However, panting scores did not decrease when shade was provided during periods when the heat load was less than 86 units. For their part, Gaughan *et al.* (2010) and Blaine and Nsahlai (2011) state that panting is directly related to high heat load, which decreased when shade was provided to feedlot cattle. Recent experience confirms that determining the THI value in beef production helps quantify heat conditions and estimate the severity of heat stress based on ambient temperature and relative humidity; this tool is particularly valuable in tropical and subtropical climates (Silva-Neto *et al.*, 2025).

On the other hand, the interaction could also be expressed as the sum of favorable conditions, such as times with low temperatures and housing with more available shade surfaces or with the use of technologies such as fans in the pens, and that this contributes to comfort, an increase in food consumption, and animal welfare (Nielsen *et al.*, 2025) as a mitigation strategy. In this context, the recently proposed five-domain model is designed primarily to evaluate physical/functional disturbances, imbalances, and restrictions in behavioral expression, allowing for the identification of the specific negative effects that each disturbance, imbalance, or restriction may generate. These domains include nutrition, environment, health, and behavior, and a fifth, mental state, which together have a cumulative impact on animal welfare (Arias and Mader, 2023).

Table 6 shows the correlation of behavioral indicators. Positive correlations were observed in the variables ruminating and resting, as well as in the presentation of panting, related to the provision of shade. For example, with less available shade surface, the expression of panting increases (0.34), and with more available shade, a greater proportion of cattle rest (0.42).

CONCLUSION

High temperatures and insufficient shade negatively impact beef cattle welfare in feedlots.

In dry tropical environments ($>35^{\circ}\text{C}$, THI >74), adequate shade is vital for thermoneutrality. This study concludes that a shaded surface area of 12% is sufficient to alleviate negative behavioral patterns. Furthermore, combining shade with ventilation significantly reduces panting and increases feeding activity. To mitigate heat stress and support natural behaviors, implementing 12% shade availability and supplementary fans is recommended for intensive cattle fattening in tropical zones. The combination of shade and ventilation has been shown to reduce panting and increase the proportion of animals in feed bunks for fattening.

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