Agrociencia

GRAZING BEHAVIOR OF NEW ZEALAND HOLSTEIN COWS WITH ACCESS TO SHADE

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Citation: Ortiz-Texon M, Ramírez-Valverde R, Ortega-Cerrilla ME, Améndola-Saavedra L, Burgueño-Ferreira JA, Améndola-Massiotti RD. 2022. Grazing behavior of New Zeland Holstein cows with access to shade. **Agrociencia.** https://doi.org/10.47163/agrociencia.v56i8.2446

Editor in Chief:
Dr. Fernando C. Gómez Merino

Received: September 10, 2021.
Approved: December 01, 2022.
Published in Agrociencia:
January 11, 2023.

ABSTRACT

Access to shade decreases heat stress of grazing dairy cows, but may reduce their grazing time. It was hypothesized that access to shade would alter grazing behavior of New Zealand Holstein cows. The objective was to evaluate the distribution of time use of cows with and without access to shade in a temperate sub-humid climate with summer rainfall, where the mean annual temperature varies between 12 (January) and 18 °C (May). During the warm (May) and cool (October) seasons of 2017, two lots of nine lactating New Zealand Holstein cows grazed in two treatments, with (S) and without (NS) shade access. Behavior was recorded every 10 min for 5 d per period. The response variables were: grazing times; rumination standing, prostrate and total; resting standing, prostrate and total. The data were classified as diurnal (07:00 to 19:00 h) and nocturnal (19:00 to 07:00 h); the former were grouped into four shifts according to Temperature and Humidity Index (TIH) and solar radiation. It was analyzed with a general linear model and the MIXED procedure. In the warm season (19 °C. precipitation of 44.3 mm) cows with access to shade grazed 16 % less time ($p \leq 0.05$) in the shifts of higher THI and solar radiation, being higher the percentage of shade use. During the cool season (16 °C, precipitation 62.0 mm) at times of higher THI (71.0) and solar radiation (880.5 Wm^{-2}) S cows ruminated standing 44 % longer ($p \leq 0.05$), with total rumination time 30.7 % longer ($p \leq 0.05$) than NS; the latter rested standing 22.5 % longer ($p \leq 0.05$). Access to shade modified the behavior of New Zealand Holstein cows grazing in the temperate climate of Mexico.

Keywords: solar radiation, THI, artificial shade, Mexico, dairy cow.

INTRODUCTION

There is a growing societal interest, in Germany, for example, in animal welfare of livestock species, aimed at improvements in production systems to minimize environmental aspects with negative effects on animal welfare (Schütz *et al.*, 2018).

In dairy cows, exposure to elevated environmental temperature, solar radiation and humidity can induce discomfort and heat stress - i.e., imbalance between production and metabolic heat dissipation (Das *et al*., 2016) - and thus reduce their welfare and productive performance (Moretti *et al*., 2017). Heat stress is defined as the sum of forces external to the animal that causes an increase in body temperature and elicits a physiological response (Polsky and von Keyserlingk, 2017).

The Temperature and Humidity Index (THI) is used as a measure of thermal comfort in dairy cows (Polsky and von Keyserlingk, 2017), in which solar radiation plays an important role (Schütz *et al*., 2014). Dairy cow behavior can be used to directly assess heat stress and comfort, as heat stressed cows modify their grazing behavior (Vizzotto *et al*., 2015) and reduce their physical activity such as walking or ruminating (Das *et al*., 2016). Likewise, to improve body heat dissipation, they increase standing rumination and resting time at the expense of prostration time, which is critical for dairy cow comfort (Tucker *et al*., 2008).

Van laer *et al*. (2014) warn that in cattle production in temperate climates it is largely unknown whether cows suffer discomfort caused by environmental conditions, or whether action is required to prevent such discomfort; although Rees *et al.* (2016) and Moretti *et al*. (2017) argue that, even in temperate conditions, cows can exhibit moderate heat stress. In temperate climates, shade is not often provided to grazing cows (Van laer *et al*., 2015b; Veissier *et al*., 2018). In these climatic conditions, providing shade to dairy cows can be a resource to mitigate the effects of weather conditions, which allows them to modify their grazing behavior and increase their resting time during the hottest hours (Palacio *et al*., 2015; Vizzotto *et al*., 2015). Therefore, in this study it was hypothesized that access to shade would modify the behavior of dairy cows, and the objective was to evaluate changes in grazing time, rumination and rest of lactating New Zealand Holstein cows, with or without shade, during two contrasting times of the year in a temperate zone of Mexico.

MATERIALS AND METHODS

The research was conducted in two stages during 2017, the first in May, which is the warmest season at the experimental site, and the second in October, a cooler season coinciding with autumn. The study took place at the Grazing Module of the Universidad Autónoma Chapingo (19° 29’ N, 98° 54’ W, altitude 2240 m). The site’s climate is temperate sub-humid, with 644.8 mm of mean annual precipitation and a summer rainfall regime; the mean annual temperature fluctuates between 11.2 (January) and 17.9 °C (May) (Garcia, 2004).

In the experiment, treatments S (with access to shade) and NS (without access to shade) were evaluated. Eighteen lactating New Zealand Holstein cows were distributed in two groups of nine based on live weight, days in milk and age, by stratified randomization; these groups were then randomized among treatments. In May, NS cows had an initial weight of 481± 20 kg, an initial milk production of 21.9 ± 1.5 L d^{-1}, and were 125 ± 24 days in milk; S cows had an initial weight of 485 ± 17 kg, an initial milk production of 23.0 ± 1.8 L d^{-1}, and were 102 ± 28 days in milk. In October, the cows had an initial weight of 523.9 ± 19.8 kg and an initial milk production of 15.98 ± 0.77 L d^{-1}, a productive decrease that corresponded to the advance of lactation. The proportion of skin colors was not quantified, but the predominant skin color was black, which is a racial characteristic.

The cows were managed in rotational grazing in five paddocks of, on average, 0.54 ha of mixed alfalfa (*Medicago sativa* L.) and orchard grass (*Dactylis glomerata* L.) pastures that had an average of 5 days of grazing and 30 days of rest. The paddocks were rectangles of 36 m by 150 m divided in half; groups of cows entered from opposite sides of the paddock. Daily grazing area was defined as a function of forage mass and a daily allowance determined by a total dry matter (DM) intake target of 3 % of live weight and a grazing efficiency target (above 5 cm) of 70 % in May and 80 % in October. Additionally, the cows received supplemental feeding with 2.7 kg DM d^{-1} of commercial concentrate and corn silage (2.1 kg DM d^{-1} in May and 2.7 kg DM d^{-1} in October); the daily amount of supplement was divided in two and supplied after each milking (which occurred between 6:30 and 08:00, and between 15:30 and 17:00).

The artificial shade structures, placed at one end of the S area, were constructed with 80% shade netting supported by steel tubes according to the design proposed by Higgins *et al*. (2011). Four mobile structures of 4 x 4 m and 2.6 m high each were used; the drinking trough was placed 2 m from the shade. Shade availability per cow was 7.11 m^2, a value within the range recommended by Higgins *et al.* (2011) for grazing dairy cows and 53 % higher than that used by Palacio *et al.* (2015). In May, the average climatic conditions between 10:00 and 19:00 without shade were THI 73.5 and radiation 921 W m^{-2}, while under the shade structure the values were 71.7 and 226 W m^{-2}. In October, the values without shade were THI 68.8 and radiation 700 W m^{-2}, and 67.9, 177 W m^{-2} under the shade structure.

Cow behavior was recorded during five days in May and five days in October in 24 h cycles, being the second days of occupation (grazing) of five different paddocks in each season; in this way, the average distance between both lots during the measurement days was 105 m. The duration of the experimental phases was five weeks in both seasons. The activities were recorded by six observers (trained for one month prior to data collection) every ten minutes, using the sweep method suggested by Pullin *et al.* (2017) and recommended by Bateson and Martin (2021). Each cow was assigned a number that was painted on both flanks to facilitate identification from a distance. For the recording of nocturnal activities, the observers used pocket lamps that they turned on exclusively at the time of data collection. Observers worked in pairs in three-hour shifts, with each member of the pair recording activities in one of the treatments.

Recording of activities related to grazing behavior included whether the cow was grazing, ruminating standing or prostrate, or resting (no jaw movements) standing or prostrate (Sheahan *et al*., 2013); in addition, it was recorded whether the cow was in or out of shade. The cow was considered to be a) grazing if with her head down she took a mouthful or walked in search of a next feeding station; b) ruminating if she made chewing movements without fresh forage in her mouth; c) lying down if her flank was in contact with the ground and standing otherwise.

Solar radiation, temperature and relative humidity were measured in and out of the shade with a solar meter (Amprobe® SOLAR-100 Solar Power, Glottertal, Germany) and a thermo-hygrometer (Amprobe® THWD-5, Glottertal, Germany). The THI was calculated for 11:00, 15:00 and 17:00 h according to Schütz *et al.* (2014) and Palacio *et al.* (2015) (Equation 1).

$$ITH = (1.8\ x\ T + 32) - ((0{:}55 - 0{:}\ 0055\ x\ RH)\ x\ (1.8\ x\ T - 26\ ) \quad (1)$$

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

Statistical analysis

For analysis purposes, observations were divided into daytime (from 07:00 to 19:00 h) and nighttime (from 19:00 to 07:00 h). Based on solar radiation and the THI, the daytime period was divided into four shifts: T1 (07:00-10:00), T2 (10:00-13:00), T3 (13:00-16:00) and T4 (16:00-19:00).

To determine changes in shade access, a general linear model analysis was performed using the MIXED procedure (SAS Institute Inc., 2017). The model included the fixed effects of shift, day, their interaction, and the random effect of cow; for the analysis of the day and night periods, the effect of period, day and their interaction was included. Comparison of means was performed by Tukey's test with $p \leq 0.05$.

For the analysis of the behaviors recorded in the sweep samplings, the time spent on each behavior per cow was summed to obtain the total time in each period, assuming that each record was representative of the activity performed in the time elapsed since the previous record (Penning y Rutter, 2004). Then, the average of each activity in each treatment, was calculated for shifts T2, T3 and T4, day, night and total periods. Sweep sampling was selected based on widely validated methods for recording animal behavior (Pullin *et al*., 2017; Bateson and Martin, 2021). Likewise, intervals between observations of up to 15 min have been shown to representatively capture the behavior of grazing cattle (e. g., Améndola *et al*., 2019). The dependent variables were grazing time, standing rumination, prostrate rumination, total rumination, standing rest, prostrate rest and total rest. The analysis was performed with the GLM procedure (SAS Institute Inc., 2017), for shifts T2, T3 and T4, the model included the effect of treatment, shift, treatment x shift interaction, and day, as well as the inclusion of THI and solar radiation as covariates. The covariates were included separately and both together in the model, the significance of the effects was analyzed and the percentage reduction in the sum of squares when including the covariates was calculated. For the diurnal, nocturnal and total periods, the model included the day and treatment effect and its interaction. The means of the treatments were obtained with the LSMEANS instruction and their comparison was performed with PDIFF.

RESULTS AND DISCUSSION

Weather conditions

Solar radiation and THI during shifts T2, T3 and T4 in the two stages showed wide variations among the three shifts, as well as among days (Figure 1). For both climatic variables, high values were recorded in May at T3, while in October solar radiation at T2 and T3 was apparently similar. High values of solar radiation during May were present on days 3 and 4, while THI values at T3 during the 5 experimental days were higher than 72, a reference value for mild heat stress in dairy cattle (Polsky and von Keyserlingk, 2017). In October, elevated radiation levels were present at T2 on days 1 and 2, while the THI exceeded 72 on days 1 and 5 during T3.

Access to shade

In both stages there were differences ($p \leq 0.05$) in shade access by cows due to the effect of period, shift and day, as well as their interaction for the four-day shifts (Table 1). Access to shade was not different ($p > 0.05$) between daytime and nighttime periods in May; however, the time cows spent employing the shade resource was greater ($p \leq 0.05$) during T3 than in the other shifts.

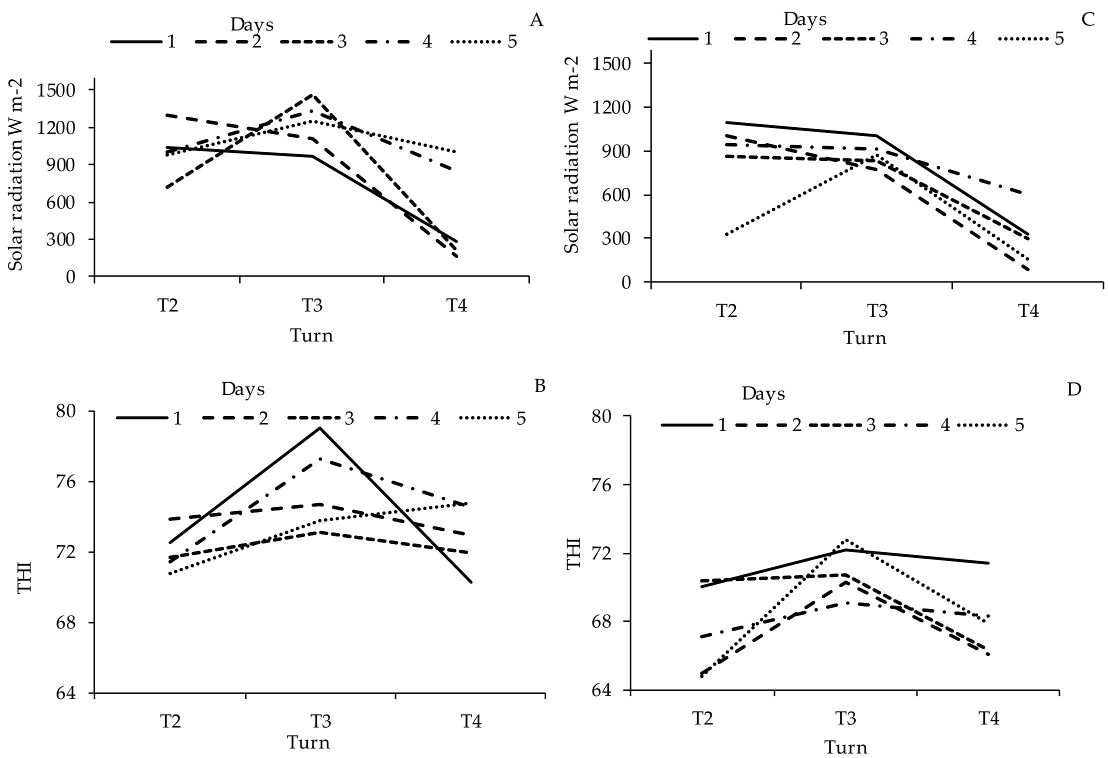

Figure 1. Solar radiation and THI calculated for different day shifts during the evaluation (5 d) of the behavior of grazing dairy cows in May (A and B) and October (C and D).

Table 1. Shade use (min) by grazing dairy cows during the evaluation days in different periods and shifts of the day in May and October.

May	Day 1	2	3	4	5	Mean, period or shift	EE	Significance level: Period or shift	Day	Period or shift x day
T1	0 c	0 c	0 c	0 c	2.2 c	0.4	4.87	≤ 0.0001	0.0013	≤ 0.0012
T2	11.1 c	3.3 c	2.2 c	1.1 c	13.3 bc	6.2				
T3	37.8 a	7.8 c	21.1 abc	31.1 ab	42.2 a	28				
T4	1.11 c	14.1 bc	0 c	2.2 c	12.2 bc	6				
Mean	12.5	6.4	5.8	8.6	17.5					
Diurnal	50 b	25.6 b	23.3 b	34.4 b	70 b	40.7	22.39	0.3891	≤ 0.0001	≤ 0.0001
Nocturnal	193.3 a	0 b	54.4 b	4.4 b	10 b	52.4				
Mean	121.7	12.8	38.9	19.4	40					
October										
T1	2.2 d	17.8 cd	2.2 d	1.1 d	6.7 d	6	6.74	≤ 0.0001	≤ 0.0001	≤ 0.0001
T2	23.3 bcd	40 bc	25.6 bcd	10 cd	5.6 d	20.9				
T3	32.2 bdc	36.7 bc	8.9 cd	45.5 b	81.1 a	40.9				
T4	10 cd	32.2 bcd	8.9 cd	30 bcd	13.3 cd	18.9				
Mean	17	31.7	11.4	21.7	26.7					
Diurnal	67.8 b	126.7 b	45.6 b	87.8 b	106.7 b	86.9	43.7	0.0071	0.0004	0.0051
Nocturnal	163.3 ab	157.8 ab	36.7 b	273.3 a	74.4 b	141.1				
Mean	115.6	142.2	41.1	180.6	90.6					

T1: (7:00–10:00); T2: (10:00–13:00); T3: (13:00–16:00); T4: (16:00–19:00). Period or Shift x Day means followed by similar indices are not different (p > 0.05). EE: Standard error.

Dairy cows accessed the shade structure equally in both seasons. Changes in shade access across shifts between seasons may be due to changes in the THI and solar radiation (Figure 1). In May, both variables presented the highest values in T3, which exceeded the critical THI value of 72. In October, the greatest access to shade during the diurnal period occurred during T3, which matched the highest values of solar radiation between 1000 and 1500 Wm^{-2}. The incidence of the THI and solar radiation, when included as covariates together, improves the fit of the models (Tables 2 and 3). This indicates that shade is an important resource for cows when THI values and radiation barely exceed the thermal comfort limit defined by Armstrong (1994). These results coincide with the reports of different authors; on the one hand, Palacio *et al.* (2015) report that cows are in comfort with THI values below 70. On the other hand, it has been consistently shown that in temperate climates, radiation affects access to shade; cows access shade to a greater extent when the effect of protection against solar radiation is greater (Tucker *et al*., 2008).

In our study, New Zealand Holstein cows made use of the shade structure equally in both phases and to a greater extent in the night period. The cows had a period of one month of habituation to the shade structure, and also made use of the structure during the first day of evaluation. These facts, coupled with the nocturnal use of the structure, indicate that they were accustomed to using the shade structure. The greater use of the shade structure during night periods in both months suggests the presence of factors other than access to shade *per se*; however, the variables taken into account in this study were not sufficient to explain the preference of cows to use the shade structure as shelter during the night.

Grazing behavior

In May, there was treatment effect ($p \leq 0.05$) on grazing time (Table 2), and in all activities there was shift effect ($p \leq 0.05$); however, in no activity there were day and treatment-by-shift interaction effects ($p > 0.05$). For all variables, solar radiation and THI jointly explained the highest percentage of the sum of squares of the shift effect.

Table 2. Significance levels of grazing behavior for cows with and without access to shade for T2, T3 and T4 shifts in May.

Variable	Statistical†	Treat¶	Percentage SC	Shift	Percentage SC	Treat x Shift	Day
Grazing	*p*	0.0320		≤ .0001		0.1509	0.7374
	THI	0.0707	27.4	≤ .0001	13.3		
	Rad	0.9951	99.9	0.0002	37.4		
	THI+Rad§	0.9998	100	0.0004	40.3		
Rumination standing	*p*	0.2088		≤ .0001		0.3160	0.6878
	THI			≤ .0001	0.5		
	Rad			≤ .0001	41.1		
	THI+Rad			0.0002	42.1		
Rumination postrate	*p*	0.8968		0.0003		0.9809	0.730
	THI			0.0005	4.4		
	Rad			0.0007	13.6		
	THI+Rad			0.0023	28.7		
Rumination total	*p*	0.1470		≤ .0001		0.2155	0.9115
	THI			≤ .0001	0		
	Rad			≤ .0001	34.1		
	THI+Rad			≤ .0001	37.8		
Rest standing	*p*	0.4721		0.0020		0.92410	0.8062
	THI			0.0067	20.5		
	Rad			0.1391	74.3		
	THI+Rad			0.1883	77.5		
Rest postrate	*p*	0.8929		0.0017		0.2547	0.3083
	THI			0.0029	5.1		
	Rad			0.0276	48.9		
	THI+Rad			0.0333	48.9		
Rest Total	*p*	0.5494		≤ .0001		0.4219	0.6538
	THI			≤ .0001	13.3		
	Rad			0.0027	65.4		
	THI+Rad			0.0042	66.6		

p †Significance level and percent reduction in the sum of squares (SC) explained by the inclusion of the THI and radiation covariates; ¶: Treatment.

For grazing time, THI was linked to 27.4 % of the sum of squares of the treatment effect, and radiation to 99.9 %, while for the shift effect they explained 13.3 and 37.4 %, respectively.

These results evidence the importance of including solar radiation levels along with THI, as indicators of heat stress-related welfare deterioration risks in grazing dairy cows (Veissier *et al*., 2018). In October there was effect ($p \leq 0.05$) of treatment (Table 3) for standing rumination, total rumination, and standing rest; in addition there was shift effect for all variables. For standing rumination, total rumination, standing rest and total rest, radiation explained the highest percentage of the sum of squares of the shift effect, whereas, for prostrate rumination, prostrate rest and grazing, the highest proportion was associated with THI. In the sum of squares of the treatment effect, the

Table 3. Significance levels of grazing behavior for cows with and without access to shade for T2, T3 and T4 shifts in October.

Variable	Statistical†	Treat¶	Percentage SC	Shift	Percentage SC	Treat x Shift	Day
Grazing	*p*	0.8120		≤ 0.0001		0.4529	0.7230
	THI			0.0082	58.6		
	Rad			0.0002	13.8		
	THI+Rad			0.0068	56.4		
Rumination standing	*p*	0.0185		0.0048		0.6138	0.5123
	THI	0.0406	23.6	0.0125	18.1		
	Rad	0.0711	43.9	0.2138	76.1		
	THI+Rad	0.0545	34.4	0.1685	71.6		
Rumination postrate	*p*	0.4412		0.0445		0.5475	0.5639
	THI			0.1986	49.6		
	Rad			0.0125	0		
	THI+Rad			0.0976	31.4		
Rumination total	*p*	0.0626		0.0300		0.8388	0.3432
	THI	0.1021	20.4	0.0403	4.6		
	Rad	0.0315	0	0.9069	97.8		
	THI+Rad	0.0230	0	0.6447	90.1		
Rest standing	*p*	0.0658		≤ .0001		0.4071	0.0727
	THI	0.0927	12.9	0.0002	15.7		
	Rad	0.0352	0	0.0006	36.1		
	THI+Rad	0.0311	0	0.0008	37.6		
Rest postrate	*p*	0.6970		0.0100		0.3929	0.1103
	THI			0.0320	27.3		
	Rad			0.0113	2.3		
	THI+Rad			0.1106	55.4		
Rest total	*p*	0.0570		≤ .0001		0.7532	0.1337
	THI	0.1047	25.9	0.0001	2.3		
	Rad	0.1352	39.1	0.0030	50.3		
	THI+Rad	0.1083	27.3	0.0031	49.1		

p †Significance level and percent reduction in the sum of squares (SC) explained by the inclusion of the THI and radiation covariates; ¶: Treatment.

THI explained 23.6, 20.4 and 12.9 % for standing rumination, total rest and standing rest. Although October is considered a cool time of the year, these results indicate that the levels of THI and solar radiation during that month may cause changes in the behavior of dairy cows in the presence of shade.

In May, S cows showed 16 % less grazing time per shift (67.5 vs. 80.5 min ± 3.92; $p \leq 0.05$) (Table 4). Access to shade did not modify ($p > 0.05$) rumination times (standing or prostrate and total) or resting times (standing or prostrate, and total). S cows modified their grazing time during the day; this decrease was mainly related to solar radiation; in addition, access to shade increased when radiation was higher, indicating that cows preferred to access the resource rather than spend their time grazing. In agreement with our study, Kendall *et al.* (2006) also reported decreased grazing in shaded cows in New Zealand's temperate climate.

In the present study, night grazing time was not different ($p > 0.05$) between cows with or without access to shade (Figure 2). Since they received supplementation, it is likely that S cows did not need to compensate for the reduced daytime grazing time. These may be due to availability of high quality forage since, in the same pastures with the same type of animals, Améndola-Massiotti *et al.* (2018) reported 25 % crude protein and 40 % acid detergent fiber, on average, for both times of the year. This good forage composition may have been linked to the fact that the cows, having acquired sufficient

Table 4. Least squares means for grazing behavior variables (min) in cows with or without access to shade during different shifts of the day in May.

Effect	Grazing	Rumination standing	Laid rumination	Total rumination	Standing rest	Laid rest	Total rest
Treatment							
NS	80.5 a	37.8	9.3	47.2	18.3	6.4	24.7
S	67.7 b	40.0	9.7	54.7	20.4	6.1	26.6
EE	3.9 2	3.91	1.99	3.54	2.07	1.53	2.15
Shift							
T2	74.2 b	56.6 a	17.2 a	73.9 a	19.4 a	7.7 a	27.1 b
T3	51.7 c	55.2 a	11.2 a	66.4 a	26.8 a	11.1 a	37.9 a
T4	96.4 a	12.4 b	0.1b	12.2 b	11.9 b	0.1 b	12 c
EE	4.81	4.79	2.44	4.33	2.54	1.88	2.63
Treatment x Shift							
T2NS	87.5	47.1	16.7	63.7	18.6	5.5	24.1
T2S	60.9	66.2	17.8	84	20.2	9.8	30.0
T3NS	51.1	55.8	11.1	66.8	26.2	13.5	39.7
T3S	52.2	54.7	11.3	66.1	27.3	8.7	36.0
T4NS	102.8	10.6	0.2	10.9	10.0	0.2	10.2
T4S	90.0	14.2	0.0	14.2	13.7	0.0	13.7
EE	10.79	10.9	5.45	9.56	5.72	4.34	6.01

NS: cows without shade; S: cows with shade; T2: (10:00–13:00); T3: (13:00–16:00); T4: (16:00–19:00). Means with different literal within column are different ($p \leq 0.05$); EE: Standard error.

nutrients and reduced their hunger drive, did not spend more time grazing instead of resting in the shade.

In contrast, in October (Table 5), access to shade did not affect ($p > 0.05$) times spent grazing, prostrate ruminating, prostrate resting and total resting during the hours of highest THI and solar radiation. At that time, S cows had 44 % more rumination time while standing (46.4 *vs*. 32.2 min ± 4.01 per shift; $p \le 0.05$) and 30.7 % more total rumination time (51.5 *vs*. 39.4 min ± 4.58 per period; $p \le 0.05$), and 22.5 % less time in standing rest (29.3 *vs*. 37.8 min ± 3.25 per period; $p \le 0.05$). At this time, S cows

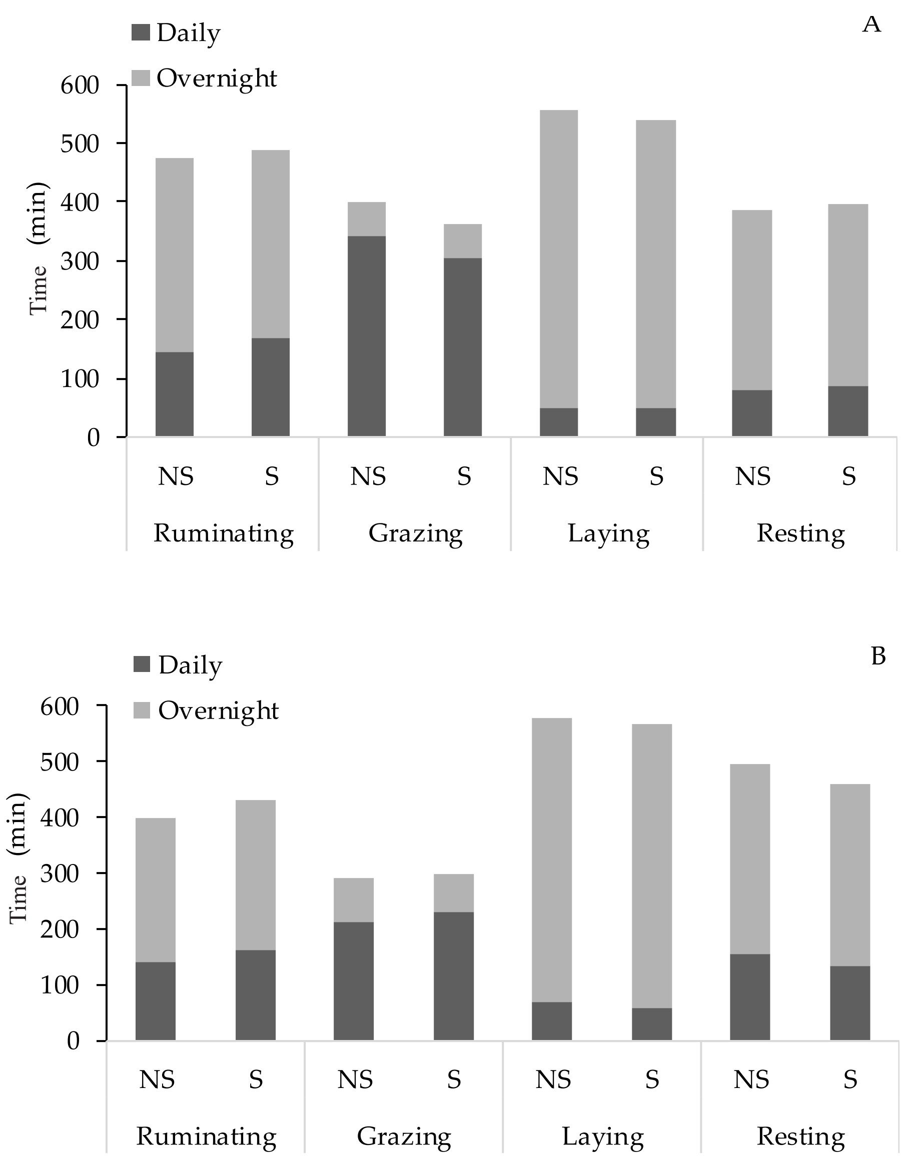

Figure 2. Behavior of grazing cows during the day and night periods of cows without (NS) and with access to shade(S) during May (A) and October (B).

Table 5. Least squares means for grazing behavior variables (min) in cows with or without access to shade during different shifts of the day in October.

Effect	Grazing	Rumination standing	Laid rumination	Total rumination	Standing rest	Laid rest	Total rest
Treatment							
NS	56.4	32.2 b	7.2	39.4 b	37.8 a	7.9	45.8
S	57.5	46.4	5.1	51.5 a	29.3 b	6.8	36.07
EE	3.06	4.01	1.84	4.58	3.25	1.96	3.69
Shift							
T2	68.7 a	40.9 a	9.9 a	50.9 a	38.9 a	13.9 a	52.8 a
T3	39.2 b	51.1 a	1.4	52.5 a	45.7 a	2.6 b	48.3 a
T4	62.9 a	25.8 b	7.1 ab	32.8 b	16.0 b	5.6 b	21.6 b
EE	3.75	4.91	2.26	5.62	3.98	2.4	4.53
Treatment x Shift							
T2NS	66.5	37.7	9.6	47.3	44.1	12.4	56.5
T2S	70.9	44.2	10.2	54.4	33.8	15.3	49.1
T3NS	36.2	42.8	1.8	44.6	53.2	2.5	55.7
T3S	42.2	59.3	1.1	60.4	38.2	2.7	40.9
T4NS	66.4	16.1	10.1	26.2	16.3	8.8	25.1
T4S	59.3	35.5	4.0	39.6	15.8	2.4	18.2
EE	5.55	6.75	3.18	7.51	5.39	3.41	5.86

NS: cows without shade; S: cows with shade; T2: (10:00–13:00); T3: (13:00–16:00); T4: (16:00–19:00). Means with different literal within column are different ($p \leq 0.05$); EE: Standard error.

ruminated longer than NS cows during the hours of highest THI and solar radiation, and also spent more time in this activity while standing. These results match those of Vizzotto *et al.* (2015), in which cows preferred to ruminate standing while under shade. The explanation for these behaviors lies in the fact that, as reported by Nordlund *et al.* (2019), the standing position represents an advantage in terms of body heat dissipation. The shorter total rumination time in NS cows coincides with that reported by Moretti *et al*. (2017), however, is surprising because the lack of difference in grazing time allows the assumption that there must have been no difference in forage intake.

In October, NS cows had a longer standing rest time, which was due to changes in THI. According to Wang *et al.* (2018), by standing, cows increase the body surface area exposed to the wind and thus increase the amount of convective heat loss. In this study, differences in standing rest time were observed during the day shifts with the highest THI and solar radiation in October. This result is in agreement with Herbut and Angrecka (2018), who found that the time of cows in lying position decreased 21 %, going from THI of 68 for 3 h to THI greater than 68 for more than 12 h.

In October, access to shade did not change the time the cows spent grazing, a situation also reported by Schütz *et al.* (2014). In the present study, during the 24-h period in both periods, there were no differences in the time spent ruminating, resting, and lying prostrate between S and NS cows (Figure 2). The fact that the amount of time cows spent grazing, ruminating, resting, or lying down in the total 24 h was not different between groups, is an indicator that the level of stress was not severe enough to maintain changes in behavior across days. The severity of heat stress depends on day and night conditions. If the ambient temperature is below 21 °C for at least 3 h during the night, the cow can dissipate the heat gained during the day (Igono *et al*., 1992). In this study, in both experimental stages, the night temperature was lower than 21 °C for more than 3 h, while the minimum temperature was 10.7 and 8 °C in May and October, respectively. This is why the cows must have been able to dissipate during the night some of the heat gained during the day.

Heat stress-induced behavioral changes can negatively impact emotional state in dairy cows (Polsky and von Keyserlingk, 2017). In this study, shade was effective in attenuating the effects on dairy cows of daytime weather conditions, although their behavioral changes did not necessarily indicate a heat stress situation as they may be the result of compensatory mechanisms, as indicated by Alves *et al.* (2017).

CONCLUSIONS

Solar radiation levels were needed along with THI to explain behavioral changes in New Zealand Holstein cows. Between 10:00 and 19:00 in the warm season (May) the Temperature and Humidity Index (THI) and solar radiation in the temperate conditions of this study affected the time spent by these cows in grazing, ruminating and resting; in the cool season (October) the situation was similar except that THI and solar radiation did not affect the time spent in ruminating. The time cows remained in the shade increased with increases in THI and solar radiation in those hours.

These changes did not necessarily indicate a heat stress situation as they may be the result of a compensatory mechanism. Shade proved beneficial in facilitating the use of these compensatory mechanisms by cows during the day; furthermore, the preference of New Zealand Holstein dairy cows for nocturnal shelter was evident in this study.

ACKNOWLEDGMENTS

To the Consejo Nacional de Ciencia y Tecnología (CONACyT) for the financial support provided during the first author's doctoral studies.

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