Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar
http://dx.doi.org/10.5424/sjar/2013114-3834

Spanish Journal of Agricultural Research 2013 11(4): 1028-1035
ISSN: 1695-971-X
eISSN: 2171-9292

The effect of breed in a hot environment on some welfare indicators in feedlot cattle

S. Dikmen*

Department of Animal Science. Faculty of Veterinary Medicine. Uludag Universiy. 16059 Bursa, Turkey

Abstract

Heat stress has an important effect on the welfare of livestock and causes significant changes in biological functions. This study was carried out to investigate the behavioral differences of Brown Swiss (BS) and Holstein (H) feedlot cattle reared in a hot environment. All of the cattle were housed in a semi-open feedlot barn. The individual behavioral response variables measured were feeding, drinking, rumination, standing, resting, locomotor activity and elimination (urinating and defecating). For each animal, behavioral observations were recorded at 10 min intervals for 1 h starting at 06:00, 10:00, 13:00, 16:00, 20:00 and 23:00 h. The effect of breed, time of the day and hour of observation and the interactions of these factors were included in the model. The data were analyzed using the PROC GLM procedure in SAS. There were significant interactions between breed and time of observation for rumination ($p < 0.001$), standing ($p < 0.001$), resting ($p < 0.01$), time of feeding and locomotor activities ($p < 0.05$). Overall, feeding behavior was greater for BS cattle ($p < 0.05$). Resting behavior was greater for H ($p < 0.01$) and was primarily observed late at night (23:00 h). The observed effects of breed on behavior within the observation times from 06:00 to 23:00 h were significant ($p < 0.05$ and $p < 0.001$) except for the hour of observation beginning at 10:00 h ($p > 0.05$). BS cattle exhibited more frequent standing behavior at 13:00 h, whereas H cattle exhibited more frequent standing behavior at 16:00 h ($p < 0.01$). The welfare of male H feedlot cattle was concluded to be more affected than that of male BS feedlot cattle when the ambient temperature was high (at 13:00 h).

Additional key words: behavior; cattle; heat stress; animal welfare.

Introduction

Strong social interest in animal welfare has produced important changes in European legislation regarding livestock industries. Increased production capacity makes livestock more susceptible to heat stress (Silanikove, 2000), and heat stress is one of the major factors that influences animal productivity in hot environments (Jacobsen, 1996; Silanikove, 2000; West, 2003). The effects of thermal discomfort during the summer months have become major concerns in the raising of farm animals.

The welfare of an individual animal is its state of comfort as it attempts to cope with its environment (Broom, 1986). In hot environments, animals attempt to compensate for adverse conditions by changing their behaviors, and their physiological processes change as well (Donovan *et al.*, 1998; Mader *et al.*, 2001). It is important to investigate the types and degrees of these changes in farm animals. Knowledge of breed-specific behavioral changes may help to improve the welfare of cattle in hot environments. It is well documented that heat stress has a negative effect on the performance of feedlot cattle (Mitlöhner *et al.*, 2002) in that it supresses animals' appetite and decreases feed intake (Hahn, 1999). In addition, several behavioral changes occur in response to heat stress, including decreases in activity, changes in feeding behavior (Brown-Brandl *et al.*, 2006), and animal spending more time standing (Silanikove, 2000). Several authors have reported that standing behavior increases in dairy cattle (Purwanto *et al.*, 1994; Lin *et al.*, 1998; Cook *et al.*, 2007), feedlot heifers (Brown-Brandl *et al.*, 2006) and in beef cattle (McDaniel & Roark, 1956; Zahner *et al.*, 2004) in

* Corresponding author: serdal@uludag.edu.tr
Received: 10-12-12. Accepted: 26-09-13.

Abbreviations used: BS (Brown Swiss); GLM (generalized linear model); H (Holstein); LWG (liveweight gain); THI (temperature humidity index).

response to heat stress. A change in standing behavior can be considered a sign of heat stres for feedlot cattle in hot environments.

Some physical responses to heat stress in cattle are breed specific (Hammond *et al*., 1998). Under heat stress, body temperature regulation varies depending on the breed (Silanikove, 2000; Dikmen *et al*., 2008). Differences in thermoregulation mechanisms of *Bos taurus* and *Bos indicus* cattle have been observed (Hammond *et al*., 1998). Under the same environmental conditions, *B. taurus* cattle are more sensitive than their *B. indicus* counterparts. On the other hand, the resistance to thermal stress varies within a breed (Ravagnolo & Misztal, 2000). The degree of a breed's susceptibility to heat stress may modify animal behaviors, which may help to mitigate the effects of heat stress.

Very little comparative information is available on the daily behavioral patterns of different breeds in response to thermal discomfort. A hypothesis was formulated that the differences in heat tolerance among breeds may result in differences in their behaviors in hot environments. The objective of this study was to investigate the differences in the behaviors of male Brown Swiss and Holstein feedlot cattle in response to thermal discomfort.

Material and methods

This study was carried out at the experimental feedlot of the University of Uludag's Faculty of Veterinary Medicine's research farm in the Bursa province in the northwest of Turkey. The research farm is located at Gorukle, Bursa, at 40°14' N and 28° 52' E in the eastern Marmara region. In this region, animals are exposed to high temperatures for 3-4 months annually (between May and September). The average recorded temperature and humidity at this location during the 4-week observation were 23.2 ± 0.5°C and 57.8 ± 2.2%, respectively, at 07:00 h; 31.7 ± 0.3°C and 37.6 ± 0.7%, respectively, at 14:00 h; 24.2 ± 0.3°C and 55.8±1.5%, respectively, at 21:00 h (Fig. 1). The ambient temperature and humidity were recorded at a height of 2 m inside the semi-open feedlot using an Extech Hygro/ Thermometer Model 445715 (Extech Instruments Ltd., MA, USA). The maximum and minimum ambient temperatures and humidity were determined for a 24-h period (Fig. 1) and were used to calculate temperature-humidity index (THI) values. The following equation was used to calculate the THI values (NRC, 1971):

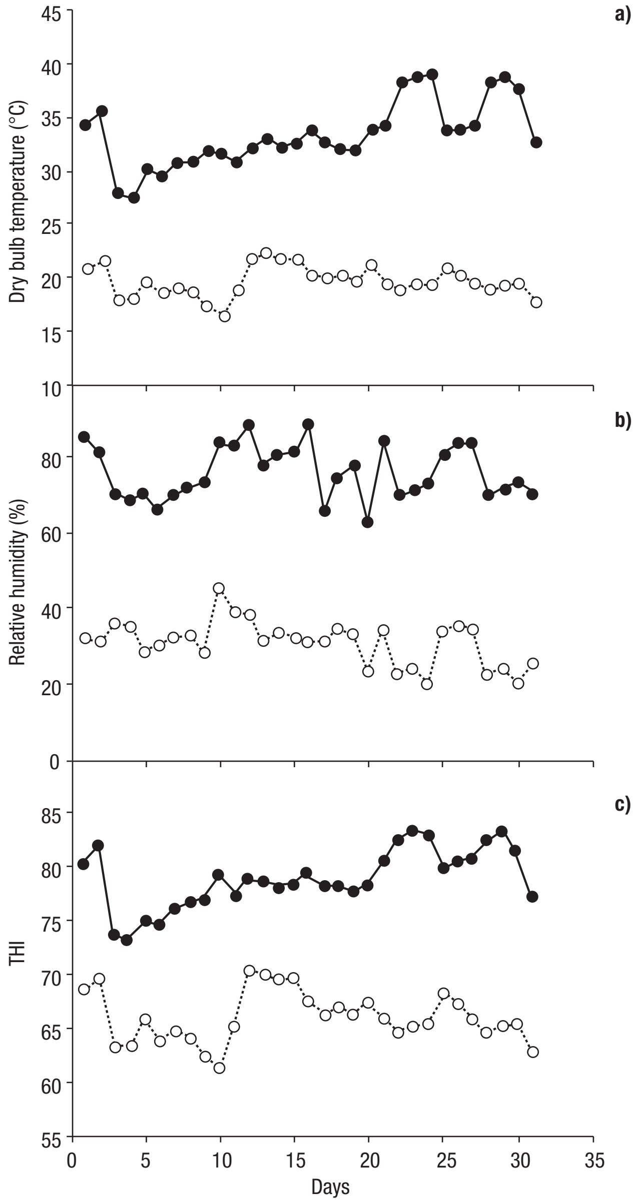

Figure 1. Daily averages of maximum (solid circle) and minimum (empty circle) a) temperature (°C), b) humidity (%) and c) temperature-humidity index (THI) during the study.

$$THI = [1.8T + 32] - [(0.55 - 0.0055\,RH)] \cdot [1.8T - 26.8)]$$

where T = the dry bulb temperature (°C) and RH = the relative humidity (%).

Animals and housing

The animals were housed in a semi-open feedlot barn. The experiment was conducted in accordance with the "Guide for the Care and Use of Agricultural

Animals in Research and Teaching" (FASS, 1999) and the ASAB/ABS guidelines for the use of animals in research. The University of Uludag's Faculty of Veterinary Medicine's Animal Care and Use Committee also approved this study. Sixteen randomly selected male Brown Swiss (BS) (566 ± 27 kg) and Holstein (H) (567 ± 27 kg) cattle were allocated into four pens according to their breed. The coat color of the Holstein cattle was half black and half white. At the time of the experiment, all of the animals were 17-18 months old. Within each main group (BS and H), the animals were assigned to one of the four replicates (n = 4 in each pen). The number of animals in each replicate was determined in the manner described by Mitlöhner *et al*. (2001). Each replicate was housed in a separate nearby pen. The pens were adjacent to one another, and all pens were oriented in the direction opposite that of the main work flow of the farm. The longitudinal axis of the feedlot had a north-south orientation. The pen floor was made of concrete with a space allowance of 15 m^2 per animal and a total area of 60 m^2 for each replicate within the main group. Half of the pen area was covered with a concrete roof, and the ceiling height was 3-m above the ground. The pens were adjacent to each other and were separated by iron fencing. No fan or any other cooling system was used during the experiment. All cattle were fed ad libitum with a concentrated feed in pellet form containing 12% crude protein and 11.5 MJ kg^{-1} energy and including chopped wheat straw as roughage. The wheat straw was not processed and was top-dressed with the concentrated feed. All of the animals had free access to water during the experiment. The animals were fed twice daily (at 06:00 and 15:00 h), and feed consumption for the animals was limited to 10 kg of the concentrated feed per head and per day. The live weights of the cattle were determined using a Baster scale with a precision of ± 100 g (Baster, Izmir, Turkey). At the beginning of experiment, the amount of daylight was 16 h 22 min. During the night, artificial light was used between 21:00 and 05:00 hours. Supplementary lighting was provided by one 20-W incandescent lamp placed 2.5 m above the ground under the roof in each pen (60 m^2).

The live weights of the animals were measured every month from May to August. The live weight gain (LWG) for each breed was determined for three periods; May to June, June to July and July to August. None of the bulls monitored in this experiment had any illness before or during the experiment.

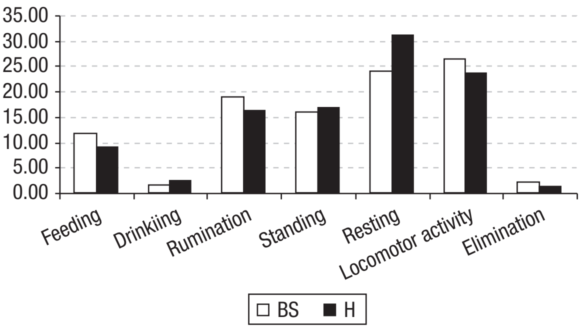

Figure 2. Percentage count for 1 h observation of daily activities of Brown Swiss (BS) and Holstein (H) cattle (%).

Behaviors

A scan sampling technique was used to monitor the behavior of animals (Mitlöhner *et al*., 2001). For each cattle, behavioral observations were recorded at 10 min intervals (Mitlöhner *et al*., 2001, 2002) for 1 h at 06:00, 10:00, 13:00, 16:00, 20:00 and 23:00. All of the animals were monitored for 12 days. All behaviors shown in Figs. 2-3 were pooled by breed. All animals in the pens were numbered, and their individual behaviors were recorded according to these numbers. The individual behaviors recorded were feeding, ruminating, drinking, standing, resting, locomotor activity and elimination. Feeding was defined to be the animal's head over or in the bunk, and drinking was defined to be the animal's head over or in the water trough. Ruminating was defined to be the act of rumination either standing or resting. Standing was considered to be an inactive upright posture (no locomotion) and without any movement, whereas resting was defined as body contact with the ground. Locomotor activity was defined as any change of body location within the pen. Urinating and defecating were considered as eliminative behavior.

Statistical analysis

The method described by Mitlöhner *et al*. (2001), was used to analyze the behavioral data. Prior to general linear model (GLM) analysis, an arcsine-square root transformation was performed on behavioral data to achieve normal distribution. The data were analyzed with using PROC GLM procedure of Statistical Analysis System (SAS version 9.1; SAS Institute, Inc., Cary NC). The change of THI between the observation days and the difference of liveweight between breeds

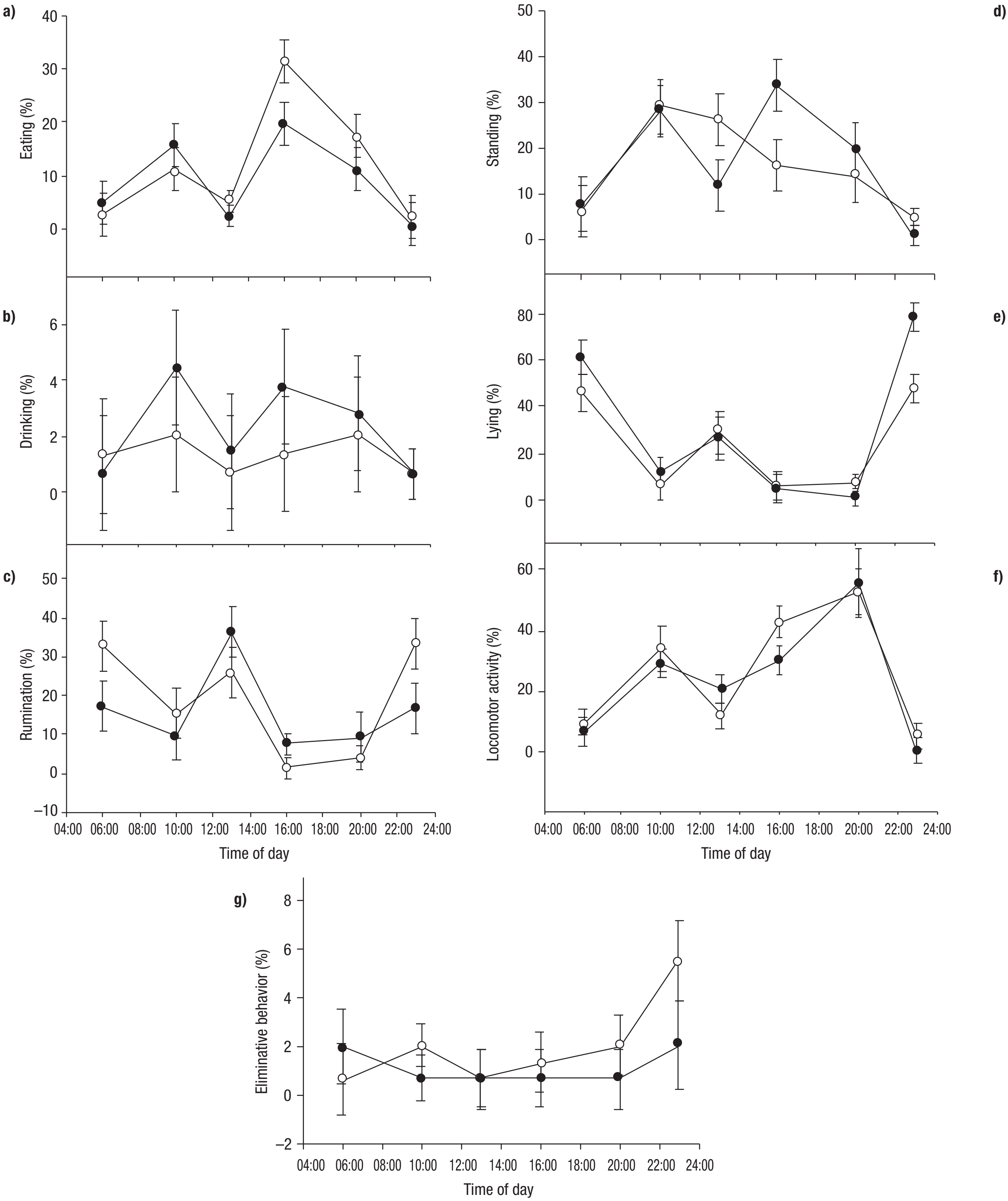

Figure 3. Means and standard errors for percentages of feeding (a), drinking (b), rumination (c), standing (d), resting (e), locomotor activity (f) and eliminative (g) behaviors of Brown Swiss (open circles) and Holstein (closed circles) cattle during the observation hours.

were similar ($p > 0.05$) and were not included in the model. Final model included the effects of animal, day, observation time (06:00, 10:00, 13:00, 16:00, 20:00 and 23:00h), breed (BS and H), replicate and all interactions. And the error term was considered to be animal within breed. Data concerning mean live weight and LWG of breeds and the effects of breed, period and breed by period interaction were analyzed by using PROC MIXED procedure of SAS, and animal within breed was the random effect. A probability of $p < 0.05$ was considered significant.

Results

Environmental conditions (dry-bulb temperature, humidity and THI) are shown in Fig. 1. During the experiment, maximum THI (estimated using maximum dry bulb temperature and minimum RH), minimum THI (estimated using minimum dry bulb temperature and maximum RH) and mean THI (estimated using mean dry bulb temperature and RH) were found to be 79 ± 0.4, 66.6 ± 0.4 and 74.4 ± 0.4, respectively. These environmental conditions show that moderate heat stress conditions occurred during the study.

Initial mean live weight of BS and H cattle were 566 ± 27 kg and 567 ± 27 kg, respectively ($p > 0.05$). The differences of live weight and LWG from May to August among breeds were not significant ($p > 0.05$). But the effect of the period was found highly significant as expected ($p < 0.001$). Daily behaviors of feedlot cattle are presented in Table 1 and Figs. 2-3. Overall (Fig. 2), the BS cattle exhibited more frequent feeding behavior ($p < 0.05$), and the H cattle exhibited more frequent resting behavior ($p < 0.01$) (Table 1). The difference in the other behaviors were not significant ($p > 0.05$). The H cattle exhibited 30.4% more resting behavior ($p < 0.01$) primarily during the cool times of the day (23:00 h) and 23.5% less feeding behavior ($p < 0.05$) than the BS cattle. A comparison of the observation hours showed that the BS cattle exhibited more ruminating behavior early in the morning (06:00 h) and late in the day (23:00 h, $p < 0.01$), but when the ambient temperature was higher, the BS cattle exhibi-

Table 1. Behaviors (%) of Brown Swiss (BS) and Holstein (H) cattle

Hour	Group	Feeding	Drinking	Rumination	Standing	Resting	Locomotion	Other	p^x
06:00	BS	2.68	1.34	32.89	6.04	46.31	10.07	0.67	*
	H	4.79	0.68	17.12	7.53	60.96	6.85	2.05	
		NS	NS	**	NS	NS	NS	NS	
10:00	BS	11.11	2.08	15.28	29.17	6.25	34.03	2.08	NS
	H	15.56	4.44	9.63	28.15	11.85	29.63	0.74	
		NS	NS	NS	NS	NS	NS	NS	
13:00	BS	5.07	0.72	26.09	26.09	28.99	12.32	0.72	*
	H	2.22	1.48	36.30	11.85	26.67	20.74	0.74	
		NS	NS	NS	**	NS	NS	NS	
16:00	BS	31.47	1.40	1.40	16.08	5.59	42.66	1.40	***
	H	19.55	3.76	7.52	33.83	4.51	30.08	0.75	
		*	NS	*	**	NS	*	NS	
20:00	BS	17.36	2.08	4.17	13.89	7.64	52.78	2.08	**
	H	11.27	2.82	9.15	19.72	0.70	55.63	0.70	
		NS	NS	NS	NS	**	NS	NS	
23:00	BS	2.08	0.69	33.33	4.86	47.92	5.56	5.56	***
	H	0.70	0.70	16.78	0.70	78.32	0.70	2.10	
		NS	NS	**	*	**	*	NS	
Pooled	BS	11.60[a]	1.39	18.91	15.89	23.90[a]	26.22	2.09	**
	H	8.87[b]	2.28	16.07	16.67	31.18[b]	23.74	1.20	
p^y		*	NS	***	***	**	*	NS	

p values: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.0001$. NS: non-significant. [x]: p values show the differences of group by behavior within the observation hour. [y]: p values show the differences of group by time within the behavior type. [a,b]: Values with different superscripts in the same column differ statistically ($p < 005$).

ted less ruminating behavior than the H cattle (16:00 h, $p < 0.05$). The BS cattle consumed more feed than the H cattle in general and at 16:00 h ($p < 0.05$). The frequency of resting behavior was greater for both breeds at 23:00 h and was greater for BS cattle at 20:00 h. The change in feeding behavior during the day was found to be significant ($p < 0.05$). No significant difference in overall standing behavior was detected, but the change in this behavior during the day was significant ($p < 0.001$), with the H cattle exhibiting more standing behavior at 16:00 h ($p < 0.01$) than the BS cattle. The locomotor activities of the two breeds were not significantly different overall, but during the day they were different ($p < 0.05$), with the BS cattle exhibiting more locomotor activity at 16:00 and 23:00 h ($p < 0.05$).

Discussion

Ruvuna *et al*. (1986) reported that Brown Swiss grow as quickly as Holstein, which is consistent with the findings of this study. There was no significant effect of breed or of the interaction of breed and observation time on growth ($p > 0.05$), but the effect of observation time was found to be highly significant as expected ($p < 0.001$). Body weight and LWG are related to metabolic body size (Kadzere *et al*., 2002) which is also a measure of metabolic heat production. According to Kadzere *et al*. (2002), cattle with similar body weights produce similar amounts of internal heat that needs to be dissipated. Given that the feed offered (amount and type) to the groups and the barn related factors (*i.e.* pen, workers, feed source) were the same throughout the experiment, the significant effect of observation time on the behaviors observed might be the result of the animals' responses to heat stress (Mitlöhner, 2000) of the level of the average THI (74.4 ± 0.4) during the study suggests that all of the animals were under moderate heat stress (West, 2003).

During the experiment, the ambient temperature and THI exceeded the upper critical levels for cattle (Brown-Brandl *et al*., 2006; Bohmanova *et al*, 2007; Dikmen & Hansen, 2009). Several authors have reported increases in standing behavior in dairy cattle (Purwanto *et al*., 1994; Lin *et al*., 1998; Cook *et al*., 2007) and beef cattle (McDaniel & Roark, 1956; Eigenberg *et al*., 2005) in response to heat stress. This increase in standing behavior is bleived to be due to the animal's attempting to maximize wind exposure and evaporation (Mitlöhner, 2000). Overall, the two breeds considered in this study, exhibited similar changes in their standing behavior, which suggest similar responses to heat stress (Zahner *et al*., 2004; Brown-Brandl *et al*., 2006). However, the standing behavior of the two breeds during the day was different ($p < 0.001$). During the day, the BS cattle exhibited more standing behavior than the H cattle at 13:00 h ($p < 0.05$) and less at 16:00 h ($p < 0.01$). These difference in standing behavior between the two breeds may be the result of differences in their adaptation to heat stress. It has been reported that behavior change is the most cost-effective response to a stressor because it simply alleviates the effects of the stressor by avoiding it (Mitlöhner, 2000). Therefore, the change in standing behavior for the BS cattle may be helpful in regulating their body temperature via convection and radiation. Similarly, the rumination behavior of the BS cattle was greater than that of the H cattle early in the day and late at night (06:00 and 23:00 h) ($p < 0.01$), and was lower in the middle of the day (13:00 h) ($p < 0.05$) (Fig. 3). The changes observed in the feeding behavior of the two breeds during the day were significant ($p < 0.05$). These changes might be the result of the effect of the higher ambient temperature (31.7 ± 0.3^{o}C) and THI during the day time (14:00 h) (Holter *et al*., 1996; West, 2003). Less frequent feeding has been reported to be one of the first symptoms of heat stress in cattle (Mitlöhner, 2000). Feeding frequency is highly correlated with body temperature, which is related to the thermostatic control of feed intake (Eigenberg *et al*., 1994). The difference in rumination behavior between the breeds could be the result of the changes in their behaviors in response to changes in the environmental stressors. Beede & Collier (1986) and Brown-Brandl *et al*. (2006) have reported that rumination is altered or depressed when cows are under heat stress or dehydration. The change in this behavior for the BS cattle could be a sign of their body temperature regulation.

Correa-Calderón *et al*. (2004) have reported that Brown Swiss cattle are better able to regulate their body temperature than Holstein cattle. Based on the observed changes in their behaviors, we have concluded that BS cattle can tolerate the effects of thermal stress better than H cattle (Correa-Calderón *et al*., 2004). The H cattle exhibited more resting behavior, but they tended to rest more at night (23:00 h) ($p < 0.01$) while the BS cattle rested more only at 20:00 h ($p < 0.01$) (Fig. 3). The greater frequencies of resting behavior for the H cattle late at night and early in the morning and their greater frequency of standing behavior at 16:00 h could be due to heat stress felt during the day. The locomotor activity of the BS cattle was greater at 16:00 h. At this time of the day, they tend to take advantage of access to feed and water, which could be the reason for the increase in locomotor activity. The agonistic behaviors of both breeds were greater at 20:00 h, which could be the reason for the observed increases in locomotor activity during this time. The overall feeding frequency of BS cattle was greater than the H cattle, which could be a sign of better heat tolerance of this breed, given that heat stress increases body temperature and this increase causes a significant decrease in feeding frequency (Eigenberg *et al*., 1994; Mitlöhner, 2000). The increased amount of feeding behavior for both breeds at 10:00 and 16:00 h could be a result of feeding time at the farm. The BS cattle tended to eat more during the day than the H cattle (Fig. 3). The less frequent locomotor activity, less frequent feeding behavior, and more frequent standing behavior of the H cattle at 16:00 could be due to the greater susceptibility of this breed to heat stress at this time of day. These changes in the behaviors of the H cattle could also be due to interruption of their welfare (Zahner *et al*., 2004; Cook *et al*., 2007). Zoa-Mboe *et al*. (1989) and Dikmen *et al*. (2008) have reported that the effects of heat stress are greater at 15:00 h, which might explain the increase in standing behavior of the H cattle at 16:00 h.

Prolonged high ambient temperatures can impair the ability of cattle to dissipate body heat to the environment (Kadzere *et al*., 2002). Environmental modifications such as water applications and shade provision can help in cooling the animals. The results of this study can be used to make better decisions about how to manage cattle in hot environments. Modifications to management systems may result in better welfare and greater productivity for these breeds.

The effects of heat stress on fattening performance is also related to dry matter intake, which decreases when the ambient temperature exceeds 25-26°C (Eigenberg *et al*., 2005; Gaughan *et al*., 2008). The decreased eating frequency of H cattle during the day time might be an effort to compensate for the effects of heat stress (Holt *et al*., 1999).

The results of this study suggest that BS cattle exhibit fewer signs of heat stress than H cattle under the same environmental conditions. This difference might be the result of changes in their behaviors during the day time. The differences in the behaviors of BS and H cattle are likely to be more obvious in hot, humid environments because of the latter's less effective use of sensible heat loss mechanisms (Kadzere *et al*., 2002).

In summary, the findings of this study indicate that the behaviors of BS cattle change in response to increased ambient temperature during the daytime and that BS cattle exhibited fewer signs of heat stress than H cattle in a hot environment. These results suggest that in a hot environment, different cattle breeds regulate their behaviors in different ways and to different degrees in response to changes in environmental conditions. Identification of possible differences in these behaviors under different conditions could help in assessing the levels of heat stress in different breeds. Changes in environmental conditions were found to cause significant changes in the behaviors of male BS feedlot cattle. Providing an efficient cooling system between 13:00 and 16:00 h and changing the feeding time or restricting feeding during the day might be useful in decreasing heat stress and related behavior changes during the daytime, with a resulting increase in the animals' welfare.

Acknowledgements

The author is thankful to Dr. Bilgehan Y. Dikmen from Uludag University Agricultural Faculty, for her great assistance and help in the improvement of the manuscript. The author is also thankful to the farm crew at the research farm of the Uludag University, Faculty of Veterinary Medicine, for their excellent support.

References

Beede DK, Collier RJ, 1986. Potential nutritional strategies for intensively managed cattle during thermal stress. J Anim Sci 62: 543-554.

Bohmanova J, Misztal I, Cole JB, 2007. Temperature-humidity indices as indicators of milk production losses due to heat stress. J Dairy Sci 90: 1947-1956.

Broom DM, 1986. Indicators of poor welfare. Brit Vet J 142: 524-526.

Brown-Brandl TM, Nienaber JA, Eigenberg RA, Mader TL, Morrow JL, Dailey JW, 2006. Comparison of heat tolerance of feedlot heifers of different breeds. Livest Prod Sci 105: 19-26.

Cook NB, Mentink RL, Bennett TB, Burgi K, 2007. The effect of heat stress and lameness on time budgets of lactating dairy cows. J Dairy Sci 90: 1674-1682.

Correa-Calderón A, Armstrong A, Ray D, DeNise S, Enns M, Howison C, 2004. Thermoregulatory responses of

Holstein and Brown Swiss heat stressed dairy cows to two different cooling systems. Int J Biometeorol 48: 142-148.

Dikmen S, Hansen PJ, 2009. Is the temperature-humidity index (THI) the best indicator of heat stres in lactating dairy cows in a subtropical environment. J Dairy Sci 92: 109-116.

Dikmen S, Alava E, Pontes E, Fear JM, Dikmen BY, Olson TA, Hansen PJ, 2008. Differences in thermoregulatory ability between slick-haired and wild-type lactating Holstein cows in response to acute heat stress. J Dairy Sci 91: 3395-3402.

Donovan GA, Dohoo JR, Montgomery DM, Bennett FL, 1998. Calf and disease factors affecting growth in female Holstein calves in Florida, USA. Prev Vet Med 33: 1-10.

Eigenberg RA, Hahn GL, Nienaber JA, 1994. Control of eating activity based on energetics for finishing swine under thermal stress. Proc 13th Symposium on Energy Metabolism of Farm Animals. Mojacar, Spain. European Association for Animal Production (EAAP) 76: 351-355.

Eigenberg RA, Brown-Brandl TM, Nienaber JA, Hahn GL, 2005. Dynamic response indicators of heat stress in shaded and non-shaded feedlot cattle, Part 2: Predictive relationships. Biosys Eng 91: 111-118.

FASS, 1999. Guide for the care and use of agricultural animals in agricultural research and teaching, 1st rev ed. Federation of Animal Sciences Societies, Savoy, IL, USA.

Gaughan JB, Mader TL, Holt SM, Lisle A, 2008. A new heat load index for feedlot cattle. J Anim Sci 86: 226-234.

Hahn GL, 1999. Dynamic responses of cattle to thermal heat loads. J Anim Sci 77(Suppl 2): 10-20.

Hammond AC, Chase Jr CC, Bowers EJ, Olson TA, Randel RD, 1998. Heat tolerance in Tuli, Senepol, Brahmansired F1 Angus heifers in Florida. J Anim Sci 76: 1568-1577.

Holt SM, Mader TL, Gaughan JB, Lisle A, Scott TL, 1999. Limit feeding feedlot cattle during the summer. Asian Austral J Anim Sci 13(Suppl C): 329-332.

Holter JB, West JW, McGilliard ML, Pell AN, 1996. Predicting ad libitum dry matter intake and yields of Jersey cows. J Dairy Sci 79: 912-921.

Jacobsen KL (ed), 1996. The well-being of dairy cows in hot and humid climates. II. Reducing stress. Compendium of continues education in practical veterinary, Vol 18. Veterinary Learning Systems, Trenton, NJ, USA. pp: S242-S254.

Kadzere CT, Murphy MR, Silanikove N, Maltz E, 2002. Heat stress in lactating dairy cows: a review. Livest Prod Sci 77: 59-91.

Lin JC, Moss BR, Koon JL, Flood CA, Rowe S, Martin JR, Brady B, Degraves F, Smith RC, 1998. Effect of sprinkling over the feed area and misting free stalls on milk production. The Professional Animal Scientist 14: 102-107.

Mader TL, Hungerford LL, Nienaber JA, Buhman MJ, Davis MS, Hahn GL, Cerkoney WM, Holt SM, 2001. Heat stress mortality in midwest feedlots. J Anim Sci 79(Suppl 2): 2.

McDaniel AH, Roark CB, 1956. Performance and grazing habits of Hereford and Aberdeen – Angus cows and calves on improved pastures as related to types of shade. J Anim Sci 15: 59-63.

Mitlöhner FM, 2000. Behavioral and environmental management of feedlot cattle. PhD thesis, Texas Tech University, USA.

Mitlöhner FM, Morrow-Tesch JL, Wilson SC, Dailey JW, McGlone JJ, 2001. Behavioral sampling techniques for feedlot cattle. J Anim Sci 79: 1189-1193.

Mitlöhner FM, Galyean ML, McGlone JJ, 2002. Shade effects on performance, carcass traits, physiology, and behavior of heat-stressed feedlot heifers. J Anim Sci 80: 2043-2050.

NRC, 1971. A guide to environmental research on animals. Natl Acad Sci, Washington, DC.

Purwanto BP, Harada M, Yamamoto S, 1994. Effect of environmental temperature on heat production and its energy cost for thermoregulation in dairy heifers. Afr J Anim Sci 7: 179-182.

Ravagnolo O, Misztal I, 2000. Genetic component of heat stress in dairy cattle, parameter estimation. J Dairy Sci 83: 2126-2130.

Ruvuna F, McDaniel BT, McDowell RE, Johnson Jr JC, Hollon BT, Brandt GW, 1986. Growth and reproduction characteristics of purebred and crossbred dairy cattle in first lactation. J Dairy Sci 69: 782-793.

Silanikove N, 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants. Livest Prod Sci 67: 1-18.

West JW, 2003. Effects of heat-stress on production in dairy cattle. J Dairy Sci 86: 2131-2144.

Zahner M, Schrader L, Hauser R, Keck M, Langhans W, Wechsler B, 2004. The influence of climatic conditions on physiological and behavioural parameter in dairy cows kept in pen stables. Anim Sci 78: 139-147.

Zoa-Mboe A, Head HH, Bachman KC, Baccari Jr. F, Wilcox CJ, 1989. Effects of bovine somatotropin on milk yield and composition, dry matter intake, and some physiological functions of Holstein cows during heat stress. J Dairy Sci 72: 907-916.