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TÜBİTAK

Research Article

Thermoregulation differs in Chinampo (*Bos taurus*) and locally born dairy cattle

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Abstract: In order to evaluate heat tolerance, physiological constants of 32 cows were measured (Chinampo: n = 12; Holstein: n = 10; Jersey: n = 10). From June to December 2006, rectal temperature and respiratory rate were recorded every Monday at 0600 and 1700 h. Holstein rectal temperature was affected by heat most, followed by Jersey, and Chinampo (the most heat-resistant). Respiratory rate of the 3 breeds was affected by climatic factors, but the Holstein and Jersey cows registered values higher than those of Chinampo cows. With a temperature-humidity index (THI) above 72 the physiological variables of all 3 breeds increased. The most heat accumulation during the day was registered in the dairy breeds. The difference in respiratory rate between morning and evening measurements was greater in Holstein and Jersey cows than in Chinampo cows. We conclude that Chinampo cows were the most tolerant to heat stress.

Key Words: Chinampo cattle, dairy cattle, heat stress, thermoregulation, rectal temperature, respiratory rate

Introduction

Measured environmental effects on the performance of cows led to the establishment of a critical mean ambient temperature (27 °C) (1) and a temperature-humidity index (THI), which considers the ambient temperature and relative humidity (2). Critical values for minimum, average, and maximum THI were reported to be 64, 72, and 76, respectively (3). THI increases as cow body temperature increases (4).

Under conditions of high temperature and relative humidity, changes in THI can be measured via rectal temperature, pulse, and respiration in European bovines (5). Natural selection, together with other factors, has resulted in some breeds with phenotypic characteristics that offset thermal effects (6); as such, some Creole phenotypes may have a particular tolerance to high ambient temperatures (7).

There are few studies, aside from those by Hammond et al. (8), that examine body temperature regulation and other physiological constants of American *Bos taurus* Creole breeds, from whose germplasm the Chinampo bovine of the Baja California Peninsula in Mexico originated. Chinampo cattle originated from Spanish bovine breeds that

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were introduced to the Baja California Peninsula during the Spanish conquest. Then, they were exposed to the local hot and dry environment for many generations and natural selection produced the Creole cattle locally known as Ganado Chinampo, a small animal that has adapted to survival under difficult nutritional and environmental conditions. Chinampo cattle are currently considered a dual-purpose genetic group. They are currently reared under an extensive pastoral system, using marginal uncultured areas that are not appropriate for specialized producing breeds.

The objectives of the present study were to measure the rectal temperature and respiratory rate in Chinampo, Holstein, and Jersey cows during summer and autumn, note the relationship between THI and the physiological variables indicated, and the cows' capacity to maintain these variables within the normal range during the day. The hypothesis was that rectal temperature and respiratory rate would respond differently to heat stress in each of the 3 breeds.

Materials and Methods

Study area

This research was carried out in an arid (desert) region of northwest Mexico, (geographical coordinates: lat 26°06´01"N, long 110º00´00"W), which is 33 m above sea level. The predominant climate according to the modified classification of Köppen is BW (H) HW (X), which is dry with most rain (averaging 195.4 mm annually) occurring in summer, some in winter, and none during the rest of the year. The study area is also very warm, with average annual temperature and humidity of 28.7 °C and 60%, respectively (9).

Experimental Protocol

For the present work 32 lactating adult cows were chosen from 3 breeds (Holstein, n = 10; Jersey, n = 10; and Chinampo, n = 12). All the animals were housed and fed in the same manner. The dairy cows were at different stages of lactation and were milked twice per day (0500 and 1700). The Chinampo cows were lactating and with calves. All animals were fed alfalfa hay and concentrate to cover their maintenance and lactation requirements.

The study was conducted for 6 months, from June to December 2006. During that period, data on ambient conditions and the animal's physiological variables were recorded every Monday at 0600 and 1700, because these were the times that corresponded to the animals' lowest and highest thermal loads. Relative humidity was recorded using a sling psychrometer (Ertco®). Dry bulb temperature was recorded using a dry bulb thermometer located adjacent to the study area. Rectal temperature measurements were made with electronic thermometers (Vet III, Advanced Animal Instruments, Williston Park, NY). Respiratory rate was measured by observing abdominal breathing movements.

THI, which expresses the equivalent temperature at 100% humidity (10), was calculated using the equation given by Kibler (11):

$$THI = 1.8 \times Ta - (1 - RH) \times (Ta - 14.3) + 32$$

in which Ta is the average ambient temperature (°C) and RH is the average percentage of relative humidity.

High production milk cows are affected when the THI is above 72, so records of response variables were classified in 2 categories (THI ≤ 72 and THI > 72), according to the criteria established by Armstrong (12).

Statistical Analysis

All analyses were performed using the general linear model and MINITAB® software (13). The general linear model included breed, month, and THI as independent variables. Dependent variables were rectal temperature and respiratory rate. The effect of breed on the dependent variables was evaluated according to each month (June to December) and THI level. Additionally, changes in THI were evaluated according to breed. The differences in physiological variables measured every Monday morning and afternoon were also analyzed according to the general linear model. Means were compared with Tukey's test (13). Statistical significance was accepted as P = 0.05.

Results

Environmental conditions during the study period

Mean maximum daily temperature was over 43 °C in June, July, and August; afterward it fell by about 4 °C per month. Mean minimum daily temperature fluctuated between 22.5 and 27.2 °C between June and October, and in November and December it fell to 18.3 and 14.3°C, respectively. The highest mean daily temperatures were registered during the months of June (37 °C) and July (37.4 °C), while there was a significant reduction in August (34.7 °C). It remained over 30 °C in September (33.9 °C) and October (31.4 °C), and declined to 26.8 °C and 20.6 °C in November and December, respectively.

Mean daily relative humidity fluctuated between 47.2% in June to 75.3% in November, and the THI varied between 64.5 in December and 81.5 in July, with values of 75.5, 80.1, 78.9, 76.4, and 70.7 in June, August, September, October, and November, respectively.

Physiological Variables in the 3 Breeds

Rectal temperature

Mean daily rectal temperatures by month (from June to December 2006) for Chinampo, Holstein, and Jersey cows appear in Table 1. In June, the lowest rectal temperature was measured in Jersey cows ($P < 0.001$), while it was similarly higher in Chinampo and Holstein cows ($P > 0.05$). Observations showed that Chinampo cows had the lowest rectal temperatures in July, September, and October ($P < 0.001$). In September, the Jersey cows had a mean value above the normal limit, although below that of the Holsteins' ($P < 0.001$).

In November the rectal temperature of Chinampo cows was lower than that of the Holstein cows ($P < 0.05$), but was similar to that of the Jersey cows ($P > 0.05$). In August and December rectal temperature did not differ between the breeds ($P > 0.05$). Generally, September was the only month in which mean rectal temperature was over the normal limit in Holstein and Jersey cows.

Respiratory rate

Respiratory rate values obtained from June to December 2006 are shown in Table 2. The respiratory rate of each breed increased between June and July. From June to November the respiratory rate was lower in Chinampo cows than in Holstein and Jersey cows ($P < 0.001$).

In the present study the highest respiratory rates were observed in Holstein and Jersey cows in September ($P < 0.001$), after which time there was a reduction until normal rates were observed in December. The abrupt increase in respiratory rates from August to September in the dairy cows is consistent with the observed increase in their rectal temperature during the same period.

Physiological responses according to two THI categories

Mean rectal temperature and respiratory rate of Chinampo, Holstein, and Jersey cows appear in Table 3, classified according to THI ≤ 72 and THI > 72. It can be seen that the physiological variables increased in all 3 breeds when THI was > 72 ($P < 0.001$).

Table 1. Effect of breed on rectal temperature in cows from June to December (mean ± SE).

Breed	Rectal temperature (°C)						
	June	July	August	September	October	November	December
Chinampo	39.1 ± .05^{a}	38.9 ± .06^{a}	39.1 ± .05^{a}	39.0 ± .06^{a}	38.3 ± .12^{a}	38.5 ± .09^{d}	38.3 ± .11^{a}
Holstein	39.3 ± .11^{a}	39.5 ± .20^{b}	39.0 ± .13^{a}	40.1 ± .13^{c}	39.3 ± .08^{b}	39.0 ± .11^{e}	38.4 ± .22^{a}
Jersey	38.7 ± .08^{b}	39.3 ± .12^{b}	38.9 ± .11^{a}	39.6 ± .11^{b}	38.9 ± .06^{b}	38.7 ± .07de	38.2 ± .11^{a}

^{a,b,c}Means within a column that have different superscripts differ significantly ($P < 0.001$).

^{d,e}Means within a column that have different superscripts differ significantly ($P < 0.05$).

Table 2. Effect of breed on respiratory rate in cows from June to December (mean ± SE).

Breed	Respiratory rate (breaths per minute)						
	June	July	August	September	October	November	December
Chinampo	45.9 ± .94[a]	49.3 ± 1.0[a]	42.6 ± 0.7[a]	43.3 ± 1.6[a]	39.0 ± 1.1[a]	36.0 ± 1.8[a]	28.9 ± 1.2[d]
Holstein	67.0 ± 2.0[b]	72.8 ± 4.8[b]	48.8 ± 1.2[b]	96.1 ± 3.9[b]	76.2 ± 3.3[b]	62.0 ± 3.5[b]	36.8 ± 4.0[e]
Jersey	65.6 ± 4.4[b]	78.7 ± 5.5[b]	52.4 ± 2.3[b]	98.1 ± 4.2[b]	83.0 ± 3.3[c]	65.4 ± 6.3[b]	33.4 ± 1.4[de]

[a,b,c]Means within a column that have different superscripts differ significantly (P < 0.001).
[d,e]Means within a column that have different superscripts differ significantly (P < 0.05).

Table 3. Effect of THI on rectal temperature and respiratory rate in Chinampo, Holstein, and Jersey cows (mean ± SE).

THI	Breed					
	Chinampo		Holstein		Jersey	
	RT	RR	RT	RR	RT	RR
≤ 72	37.9 ± .06[a]	31.4 ± 0.8[a]	38.2 ± .11[a]	51.4 ± 2.9[a]	37.8 ± .07[a]	44.0 ± 2.4[a]
> 72	38.6 ± .02[b]	42.4 ± 0.3[b]	39.1 ± .06[b]	68.1 ± 1.4[b]	38.7 ± .04[b]	68.9 ± 1.5[b]

RT: Rectal temperature (°C); RR = respiratory rate (breaths per minute).
[a,b]Means within a column that have different superscripts differ significantly (P < 0.001).

In Table 4 it is observed that the responses of the breeds to the 2 levels of THI were different. At both levels of THI, rectal temperature was greater in the Holstein cows that in the Chinampo and Jersey cows (P < 0.05), which were similar (P > 0.05). With THI ≤ 72, however, the respiratory rates of the 3 breeds were different (P < 0.05); Holsteins had a higher rate than the Jersey and Chinampo cows. With THI > 72 the respiratory rate of the dairy breeds was similar (P > 0.05), but higher than that of the Chinampo cows (P < 0.05).

Physiological responses at different times of day

Differences in rectal temperature and respiratory rate between morning and afternoon measurements appear in Table 5. It can be seen that the increases in rectal temperature in the 3 breeds were different, being greatest in the Holstein and Jersey cows (P < 0.001). Only a modest increase (5.3 ±.51) in respiratory rate of Chinampo cows was observed in the afternoon, which again made demonstrated the greater heat tolerance of the breed, which was only 33% of that registered for Holsteins and 25% of that for Jerseys (P < 0.001).

Discussion

The normal rectal temperature and respiratory rate are considered 39.5°C (14) and 36 breaths per minute (15), respectively.

The average ambient temperature from June to October was higher than *Bos taurus* cattle can tolerate and regulate via increases in respiratory rate, pulmonary ventilation, and respiratory vaporization (16). The THI that was registered from June to October was also over the critical level of comfort (THI = 72) for Holstein cattle (12).

The rectal temperature of Holstein cows was high in September, registering values 0.6 °C above the normal limit for cattle. The Jersey breed also registered average values above the normal limit (0.1 °C) in September, although lower than that of the Holsteins. This indicates that Holsteins were the least tolerant to heat stress, based on rectal temperature, followed by the Jersey and Chinampo cows (the least affected by heat stress). It is not known what mechanisms the Chinampo cattle have developed

Table 4. Rectal temperature and respiratory rate (mean ± SE) in Chinampo, Holstein, and Jersey cows according to two THI categories.

Breed	Rectal temperature (°C)		Respiratory rate[1]	
	THI ≤ 72	THI > 72	THI ≤ 72	THI > 72
Chinampo	37.98 ± 0.06[a]	38.66 ± 0.02[a]	31.46 ± 0.86[a]	42.43 ± 0.39[a]
Holstein	38.24 ± 0.11[b]	39.1 ± 0.06[b]	51.47 ± 2.93[c]	68.11 ± 1.47[b]
Jersey	37.87 ± 0.07[a]	38.76 ± 0.04[a]	44.05 ± 2.47[b]	68.93 ± 1.56[b]

[1]Breaths per minute.
[a,b,c]Means within a column that have different superscripts differ significantly ($P < 0.05$).

Table 5. Change (mean ± EE) in physiological variables in Chinampo, Holstein, and Jersey cows between morning and afternoon measurements on the same day.

Breed	Physiological variables	
	Rectal temperature (°C)	Respiratory rate[1]
Chinampo	0.78 ± .02[a]	5.3 ± .51[a]
Holstein	1.13 ± .07[b]	15.0 ± 1.9[b]
Jersey	1.01 ± .05[b]	19.6 ± 1.9[c]

[1]Breaths per minute.
[a,b,c]Means within a column that have different superscripts differ significantly ($P < 0.001$).

over more than 300 years of breeding in the arid environment (17) to exhibit the physiological behavior observed in the present study (38.3-39.1 °C). Nevertheless, acclimatization to heat stress happens when an animal, as a result of recurring or permanent exposure to a hot atmosphere, develops functional, structural, and/or behavioral qualities that improve its ability to resist heat stress (18).

It is evident that all breeds were affected by climatic factors, since the respiratory rates were above normal from June to November. Nevertheless, while there was no significant difference between the Holstein and Jersey breeds, their respiratory rates increased to above that of the Chinampo cows. It is generally accepted that genetics plays a paramount role in tolerance to heat stress. Current selection trends for milk yield reduce heat tolerance. Most of the effects of heat stress identified in dairy cattle are also present in beef cattle, albeit to a lesser extent due to the overall lower body heat produced by beef cattle (19). The respiratory rate was quite elevated between June and July in all 3 breeds, which coincided with an increase in THI. This could have reduced the effect of perspiration and increased evaporation through the respiratory tract as an additional thermoregulatory response (20).

Cattle increase their respiratory rate, pulmonary ventilation, and respiratory vaporization when the ambient temperature increases, but when it reached 26.7 °C those mechanisms in *Bos taurus* were not capable of dissipating all the excess heat (16).

The rectal temperatures observed in the present study are higher than those reported by Bouraoui et al. (21) for Holstein cows exposed to a THI between 68 and 78. They are close to those obtained at a THI of 80 in Brazil for the same breed kept in the shade (22).

When Holstein (H), Brahman (B), H × B, H × Boran, and H × Tuli steers were exposed to an average THI < 77, which is close to what prevailed in June, October, November, and December during the present study, Gaughan et al. (23) obtained respiratory rates of 68, 33, 48, 50, and 55 breaths per minute, respectively.

The values for Holstein steers in that study coincide with those obtained in the present study, and the respiratory rates that were recorded for Brahman and Holstein crosses with heat tolerant breeds are similar to that of the Chinampo cattle in the present study.

Sprinkle et al. (24) reported a daytime increase in rectal temperature in Tuli × Angus and Brahman × Angus similar to that in the Chinampo cows we studied. In that work, the Angus cows had afternoon temperatures similar to those of Holstein and Jersey cows in the present study.

In conclusion, the responses of the physiological variables studied show that the 3 breeds of cow responded differently to climatic factors associated with heat stress, and that Chinampo cows were more tolerant than Holstein and Jersey cows.

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