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Respiration Rate – Is It a Good Measure of Heat Stress in Cattle?

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ABSTRACT: Two studies, the first in the USA and the second in Australia were undertaken to investigate respiration rate (RR) responses of growing grain fed cattle exposed to hot climatic conditions. In the first study (Exp 1) eight Hereford x Angus x Simmental steers were exposed to 24 h cyclic hot conditions (24^o C to 39^o C). In the second study (Exp 2) six Murray Grey x Hereford steers were used. In this study ambient temperature (T_a) ranged from approximately 24^o C to 45^o C. Two cooling periods were used in Exp 2: day cooled (DC) or night cooled (NC). In each study RR was measured over three 24 h periods and generally increased as T_a increased. However, the rate of change was not constant either between studies or over time. In Exp 2, DC cattle typically showed an increase in RR at night when T_a was decreasing. In both studies RR lagged behind T_a by approximately 2 h. RR can be used as an indicator of heat stress in cattle, provided animal condition, prior exposure, ambient conditions (increasing or decreasing T_a) and previous cooling strategies are considered.

Key Words: Cattle, Respiration Rate, Heat Stress

INTRODUCTION

The performance, health, and comfort of feedlot cattle may be adversely affected by climatic conditions (Hahn *et al*., 1998; Mader *et al*., 1999). The ability of feedlot managers and consultants to assess likely climatic effects on cattle is of utmost importance, not only to ensure that the animals' welfare is not impaired, but also in order to maintain animal performance and profitability. Respiration rate (RR) has long been used as an indicator of heat stress in cattle. However, the effect of ambient temperature (T_a) on RR is influenced by age, sex, genotype, level of performance, nutrition, time of feeding, body condition of the animals, as well as previous exposure to hot conditions, feedlot design, any cooling strategies imposed, and other environmental factors.

The present studies were undertaken to clarify the relationship between changing environmental conditions on RR in *Bos taurus* cattle.

MATERIALS AND METHODS

Two experiments were undertaken to study the effect of T_a on RR in cattle.

The first experiment was conducted at the US Meat Animal Research Center (MARC), Clay Center, NE. Eight MARC III (Hereford x Angus x Simmental) steers (initial BW 375 kg, final BW 475 kg) were housed in two controlled-environment chambers. The 120 d study involved three repeated cycles of thermoneutral cyclic conditions (TNC) between 9^o to 26^o C for 12 d. This was followed by 9 d exposure to cyclic hot conditions (HOT) at approximately 24^o to 39^o C. Corresponding ranges of Temperature Humidity Index THI were from 52.5 to 70 for TNC and 72.5 to 85.0 for HOT. Constant dewpoint temperatures (t_{dp}) were used for the two cyclic conditions. For TNC, t_{dp} was 7^o C, and for HOT, t_{dp} was 17^o C. This resulted in two different levels of relative humidity (RH) in the vicinity of 25^o C. For TNC, RH was 32% at 25^o C, and for HOT, RH was 60% at 25^o C. Ambient temperature and RH were recorded at 30 minute intervals.

Respiration rates (RR) were recorded by manual observation (using a stopwatch and counting uninterrupted flank movements: time taken for 20 breaths) for three 24 h periods starting at 0800 h or 0900 h on day 7 or 8 of exposure to chronic HOT (Julian days 220, 242 and 262). For each steer, concurrent continuous tympanic temperatures (TT) were recorded at 30 s intervals by portable dataloggers connected to thermistor probes in the ear canal, using the methods of Hahn *et al*. (1990) and Nienaber *et al.* (1990).

The second experiment was undertaken at The University of Queensland, Gatton (UQG), Queensland. In this study six Murray Grey x Hereford steers (initial BW 239 kg, final BW 337 kg) were used in an 80 d Latin-square design study involving two cooling treatments. Steers were housed in 3m x 1m stalls in controlled-environment chambers. Treatments were day cooling (DC) (0800 h to 1500 h), and night cooling (NC) (1600 h to 0700 h). The T_a ranged from 24 to 45^o C over each 24 h period. Temperature increased from 0800 h and peaked at about 1300 h and was then allowed to fall. This was done to mimic typical natural summer conditions. Steers were cooled using sprinklers (150 micron droplet size) positioned 1.7 m above each steer and with fans (2 m/s air speed). The sprinkler system was controlled by an automated system (Rotem Model RCC-2, Rotem Agricultural Computers Ltd, Israel). For DC steers, the sprinklers were set to turn on for 5 min every 20 min when T_a exceeded 28^o C. At 1500 h the sprinklers and fans were turned off. Sprinklers and fans were then turned on for those steers that had not been wetted during the day. The steers were then cooled from 1500 h to 0800 the following day.

Ambient temperature and relative humidity were recorded on a data logger (YSI 400, Mini-Mitter, Sunriver, OR, USA) every 2 min. The THI was calculated as in Exp 1.

Rectal temperature (RT) was continuously recorded for each steer and averaged every 2 min. (Smart Reader 8, ARC Systems, Brisbane). The RR was measured using the method described in Exp.1. The data was collected over three 24 h periods.

In both studies the steers were fed high energy feedlot diets ad-libitum and had access to water at all times.

In both studies the functional relationships between RR, Ta, TT (Exp 1) and RT (Exp 2) were investigated using regression analysis and correlation analysis (SAS, 1993). Further analysis was undertaken to look at changes in animal responses over time, and between day and night (Exp 1), and cooling period (Exp 2) .

Data for both studies were pooled for three 24 h periods. Means, maximums and minimums represent the pooled data.

RESULTS

Experiment 1

The RR data were analyzed for steers on day 7 of exposure to HOT (T_a cycled from 24 – 39^o C).
The RR on day 220, 242 and 262 were similar, while TT was higher on day 242 and day 262 (Table 1).

Table 1. Mean RR, TT and THI under chronic hot condition.

Day	RR	TT	THI
220	102.2^a	39.65^a	78.9^a
242	109.0^a	39.91^b	79.2^a
262	109.5^a	39.87^{ab}	79.2^a
S.E.	3.87	0.09	1.05

[a,b]Means in a column differ ($P <$ 0.05).

The response of RR to T_a during the chronic hot period tended to change over time, with RR at a given T_a increasing as the animals grew. The functional relationships of RR to T_a from day 220 to day 262 are presented in Table 2.

Table 2. Relationship of RR and T_a

Day	Relationship	r^2
220	RR = 11.66 + 2.87T_a	0.43
242	RR = 6.67 + 3.20T_a	0.51
262	RR = 4.96 + 3.27T_a	0.42

The effect of time of day on RR and TT were examined by dividing each 24 h period into a day (0800 h – 1900 h) and night (2000 h – 0700 h) period. Generally for steers with similar TT, RR were higher during the night period (Figure 1).

RR response lagged increases in T_a by about 2 h (0 to 3 h lag). The correlation coefficients for RR (RR = f(T_a)) lags 2 h behind T_a, and for each animal ranged from 0.61 to 0.88.

The TT also lagged behind T_a. The lag ranged from 2 to 5 h behind T_a, with a mean of 4 h. The TT lagged behind RR by 2 h.

The RR responses to a particular T_a were not constant. The RR is influenced by T_a (above some threshold; Hahn *et al.*, 1997). However, the effect of a particular T_a on RR is dependant on whether T_a is increasing or decreasing.

Experiment 2

The mean maximum THI over the three 24 h periods was 94.6, while the mean minimum was 78. The NC steers had lower (P<0.05) RR and RT (54.9 bpm and 39.0^o C respectively) than those cooled during the day (77.8 bpm and 39.2^o C respectively). The RR and RT increased markedly in the DC cattle following cessation of cooling, even though THI and T_a were falling. Peak RR and RT were lower for individuals within the DC group,133 bpm and 40.1^o C, respectively, than for NC cattle with peaks of 200 bpm and 40.7^o C respectively.

The RR responses to T_a for DC and NC steers are presented in Table 3.

Table 3. RR responses to T_a for DC and NC steers

Treatment	Relationship	r^2
DC		
1600 – 0700 h	RR = 152.3 - 2.5T_a	0.23
0800 – 1500^c h	RR = 164.4 - 2.8T_a	0.35
NC		
0800 – 1500^{c}h	RR = -160.4 + 6.9T_a	0.83
1600 – 0700 h	RR = -66.23 + 3.1T_a	0.25

[c] cooling period

There were lags in the RR response to increasing T_a. The lags for the NC steers (during the day) were approximately 2 h. When T_a was decreasing and cooling was imposed the RR response was almost immediate, with RR decreasing by 100 bpm in 3 h. There was a tendency for RR to decrease about 1.5 h prior to decreasing T_a and cooling being imposed. RT lagged T_a by 3 h, and RR by 1 h. For the DC cattle no lags were evident.

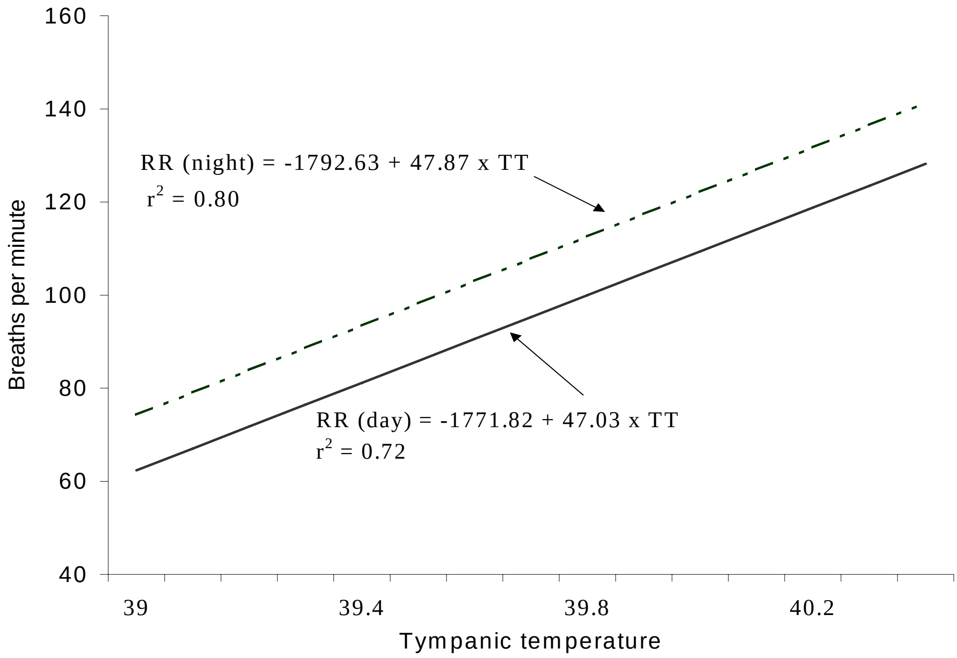

FIGURE 1. Differences in rr between night and day, for experiment 1.

DISCUSSION

These studies demonstrate that the effect of T_a on RR is not constant and is subject to a number of influencing factors. Under hot conditions, the increase in RR varied from 2.8 breaths/min (BPM) to 3.3 BPM for each 1^o C increase in T_a. The data from Exp 1. demonstrates that the animal response changes over time. As body condition (i.e. fatness) increased the cattle became more susceptible to heat stress, hence the greater RR response (approximately 1 bpm/ degree increase in T_a) to hot conditions, even for cattle with prior exposure to HOT. Thus fatter cattle, even those with some adaptation to hot conditions are more susceptible to heat stress.

The difference in RR response to a particular TT between night and day (Figure 1) suggests a difference in thermal sensitivity between day and night (Mundia and Yamamoto, 1997). Furthermore, Kabunga (1992) suggested that animals were able to cope with heat stress by storing heat during the day and dissipating it at night. Cattle may increase RR during cooler night time periods to enhance heat dissipation.

The decrease in RR while cattle were exposed to HOT in Exp 2 is consistent with previous observations (Gaughan *et al.*, 1999). It is likely that a RR ceiling exists (Spiers *et al.*, 1994). A decreasing RR is therefore not always indicative of an animal coping with hot conditions. This is likely due to a shift in RR dynamics from rapid open mouth panting to a deep phase open mouth panting which is slower.

In Exp 2 the day-cooled cattle had RRs at night that were considerably higher (80 to 120 bpm) than expected. Previous studies have shown that cattle (similar to those used in this study) exposed to temperatures of 24^o C to 28^o C would have a RR in the vicinity of 40 to 60 bpm (Hahn *et al.*, 1997). The higher rate seen here is a result of the day time cooling. The cooling of the cattle during the day (7 h cooled) does not allow them to adjust to the warm conditions at night (17 h not cooled), particularly if DMI is high during the day. Although night time conditions were not hot the cattle were “suddenly” exposed to an effective temperature greater than when they were being cooled. They likely do not have time to adjust, via sweating, panting or adjusting feed intake to the increase in effective T_a. Anecdotal evidence points to cooled cattle being set up for a fall after cooling ceases (T.L. Mader, personal communication).

The effect of previous cooling is an important consideration. Normal management practice is to cool cattle during the hottest part of the day, with little night-time cooling. Field evidence from both Australia and the USA has shown that many heat stressed cattle die late at night or early morning (Mader and Gaughan, unpublished data). The NC cattle were exposed to hot conditions for seven hours, and although peak RR and RT were higher than for the DC cattle, overall RR and RT were lower because they were cooled for 17 h. The opportunity for night time recovery is an important element in coping with excessive heat loads (Scott *et al.*, 1983; Hahn and Mader, 1997).

RR and body temperature indicates lags were seen in both studies. The length of the lag for RR were similar in both studies. Differences between TT (Exp 1) and RT (Exp 2) are probably due to differences in the rate of temperature change. The increase in T_a in Exp 2 was much faster (reached peak 4 h after T_a started to rise), where as in Exp 1, peak T_a was reached about 7 h after T_a started to rise.

The reasons for the lags are not clear. Increasing T_a will have an effect on RR, however increasing RR may also increase body temperature. The influence of thermal factors on RR and RT may be mediated through different mechanisms; RR is a mode of thermo-regulation while RT (and TT) are the result of thermal equilibrium (Kabunga 1992).

CONCLUSION

Respiration rate is a useful indicator of the animals thermal load. The RR will vary according to animal condition, prior exposures, whether ambient temperature is increasing or decreasing and previous cooling strategies. Because it takes time for animals to "warm up", RR observations should be made at least two to three hours prior to the hottest part of the day.

The observations suggest that for non-cooled, healthy growing grain fed cattle the following applies.

- The animal responses to high ambient temperature change over time due in part to changes in body condition and adaptation.
- Respiration rate responses to a given ambient temperature differ between night and day.
- Changes in RR and body temperature lag behind changes in T_a by 2 to 4 hours.
- A fall in RR while T_a is increasing may indicate an animal failing to cope.
- RR observations should be made in conjunction with panting observations e.g. rapid open mouth or deep phase open mouth.

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