HEAT STRESS RISK FACTORS FOR FEEDLOT HEIFERS

T.M. Brown-Brandl1, R.A. Eigenberg, J.A. Nienaber

ABSTRACT

Extreme summertime conditions result in millions of dollars in lost revenue every year due to production and death losses. Anecdotal evidence suggests that these losses stem from animals particularly vulnerable to heat stress. A study was conducted to determine risk factors for heat stress in feedlot heifers. Two-hundred fifty-six feedlot heifers of four genotypes (32/genotype/year) were observed for 6 – 8 weeks in two consecutive summertime periods. As a measure of stress, respiration rates and panting scores were taken twice daily (morning and afternoon) on a random sample of 10 heifers/genotype. Weights, condition scores, and temperament scores were taken on a 28-day interval during the experiment. Health history from birth to slaughter was available for every animal used in this study. It was determined that stress level (respiration rate/ panting score) was impacted by genotype (or color), a history of respiration illness, temperament, and degree of fatness. Daily weight gains were also impacted by genotype (or color), a history of respiration illness, and temperament. These results illustrate the sensitivity of respiration rate as an indicator of stress, and indicate that animals at risk for heat stress can be identified for possible applications of precision animal management.

KEYWORDS. Stress, respiration rate, pneumonia, hide color, precision animal management

INTRODUCTION

Hot weather has negative effects on animal performance and well-being. Reductions in feed intake, growth, and efficiency are commonly reported in heat-stressed cattle (Hahn, 1999). Impacts of heat load on these production parameters are quite varied, ranging from little to no effect in a brief exposure, to death of vulnerable animals during an extreme heat event (Hahn and Mader, 1997). Vulnerable animals have been described as ones with dark or black hides (Busby and Loy, 1996; Hungerford et al., 2000; Mader et al., 2001), animals with compromised immune systems, animals with more fat cover, and possibly highly excitable animals.

Respiration rate has been shown to be a good indicator of thermal stress (Brown-Brandl et al., 2002; Gaughan et al., 2000; Hahn et al., 1997). Respiration rate increases in a non-linear fashion in response to increasing ambient temperature with breakpoint or a threshold of between 20 - 25ºC (Eigenberg et al., 2002; Hahn et al., 1997). The advantages of using respiration rate (RR) are that it is readily observable in a production setting (Hahn et al., 1997), and little time lag occurs (in an outdoor setting) relative to ambient dry-bulb temperature associated with it (Brown-Brandl et al., 2004).

Along with RR, the behavior of the animal changes as ambient temperature increases. Young and Hall (1993) listed behaviors exhibited by cattle experiencing excessive heat loads, with the onset of open-mouthed, labored panting, and excessive salivation/drooling suggested as indicators of an animal failing to cope with stress. Mader and Davis (2002) used this information to develop a management tool called a panting score (PS). The PS uses behavior of

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the animal to assess its “heat stress” level; a PS range from 0, indicating a non-stressed animal, to 4, describing an animal suffering from heat stress (severe open-mouthed panting, accompanied by protruding tongue and excessive salivation).

The objective of this study was to determine effects of health status, genotype, condition score, and temperament on RR, and PS under various environmental conditions.

**MATERIALS AND METHODS**

Two-hundred fifty-six feedlot heifers (393.5±45.4 kg) of four genotypes (Angus, Charolais, Gelbvieh, and MARC III crossbred [Pinzgauer, Red Poll, Hereford, Angus]) from the MARC population (32 heifers/genotype/year) were assigned to one of four adjacent pens (64.6 x 18.3 m) by genotype (32 heifers/pen/year). The study was conducted over two consecutive summers (2002 - 2003) in the USDA-ARS-MARC feedlot (lat 40° 33’ N Long 98° 10’ 30” W). Angus cattle were all solid black; MARC III were mostly dark red (three of 64 were black—some were solid, while others had white tailheads and/or white faces); Gelbvieh were solid tan in color; Charolais were solid white. Each year heifers initially weighing 393.5±45.4 kg were assigned to one of four adjacent pens (64.6 x 18.3 m) by genotype (32 heifers/pen). Heifers were then fed twice daily and had free access to water. Live weights, body condition scores (Hardin, 1990), and temperament scores (Voisnet et al., 1997) were recorded every 28 days. Throughout the study, weather data (dry bulb temperature, dew point temperature, solar radiation, wind speed, and wind direction) were collected, using an automated weather station (Vantage Pro, Davis Industries) located in the middle of the four pens.

Measurements of RR and PS (Mader and Davis, 2002) were made twice daily (0800 and 1430) during six 5-day periods between June 24 and August 9 in 2002, and twelve 5-day periods between May 20 and August 6 in 2003. On scheduled experimental days, two observers, working independently, each randomly selected five animals per pen to observe. For each selected animal, id number, standing or lying behavior, and RR were recorded. Respiration rates were determined by visual observation of flank movement, timing 10 breathes with a stopwatch. Based on weather data recorded prior to and immediately after set of animal observations, an average ambient temperature was calculated for the analyses.

Condition scores were predicted on a daily basis by linear interpolation between 28-day readings, and then categorized into one of four condition scores ([6] CS<18.5; [7] 18.5≤CS<21.5; [8] 21.5≤CS<24.5; [9] CS≥24.5). Temperament scores were averaged over the experiment and then categorized in two classes (calm animals – TS<1.5; highly excitable animals – TS≥1.5). Health history included animals previously diagnosed and treated for pneumonia. These were placed in the treated group, while remaining animals were placed in untreated group.

Data collected over two summers were compiled into one data set and then assigned to one of ten temperature categories (TC 1: 1_{db}≥12; TC 2: 12< 1_{db}≤15; TC 3: 15< 1_{db}≤18; TC 4: 18< 1_{db}≤21; TC 5: 21< 1_{db}≤24; TC 6: 24< 1_{db}≤27; TC 7: 27< 1_{db}≤30; TC 8: 30< 1_{db}≤33; TC 9: 33< 1_{db}≤36; TC 10: 36< 1_{db}). Differences in RR and PS responses between different genotypes (Angus, MARC III, Gelbvieh, and Charolais), condition score (6, 7, 8, 9), health (treated and untreated), and temperament (calm and highly excitable) were tested, using the general linear model procedure in SAS (SAS, 2000). The model included parameter of interest (genotype, condition score, etc.), temperature category, and interaction term. Two analyses were conducted using two parameters. The first analysis investigated genotype (Charolais and Angus, only) and health (treated and untreated), and the second analysis investigated genotype (Charolais and Angus, only) and condition score (CS<8 and CS≥8, only). These two analyses combined two parameters of interest into one risk factor; for example, Risk 1 Angus and treated, Risk 2 Charolais and treated, Risk 3 Angus and untreated, and Risk 4 Charolais and untreated. The model included risk factor, TC, and interaction term. Animals previously treated for pneumonia were removed from all analyses except where health history was included.
The impacts of risk factors, including genotype, health, temperament, and average gain over the entire experimental period were examined using the general linear model procedure in SAS. The impact of combined risk factors of temperature and genotype and health and genotype on gain were also analyzed using the general linear model procedure in SAS, as completed for the RR analysis.

RESULTS AND DISCUSSION

Environmental conditions and number of points at each temperature category are shown in Table 1. Respiration rate and PS increased with temperature category (Figure 1). The increase of RR with temperature is well documented (Brown-Brandl et al., 2003; Eigenberg et al., 2000; Hahn et al., 1997; Mader et al., 1999). Since RR is affected by all weather parameters (Eigenberg et al., 2004), others should be examined. In the third and ninth TC, RR did not seem to increase as expected; upon closer examination, it was found that wind speed increased during those time periods, which could explain this anomaly. Panting score illustrated the threshold temperature of approximately 22°C. PS were not significantly different from 0 until the fourth TC (19.4°C), and showed a significant increase at TC 5 (22.5°C). Eigenberg et al. (2004) found a similar threshold temperature of approximately 25°C.

Table 1. Average environmental conditions and number of points in each temperature category.

<table>
<thead>
<tr>
<th>Temperature Category</th>
<th>Temperature Range (ºC)</th>
<th>Number of Observations</th>
<th>tdb (ºC)</th>
<th>tdp (ºC)</th>
<th>Solar Radiation (W/m²)</th>
<th>Wind Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12&gt; tdb ≥ 15</td>
<td>80</td>
<td>9.5±1.5</td>
<td>5.5±3.1</td>
<td>414±85</td>
<td>5.0±0.0</td>
</tr>
<tr>
<td>2</td>
<td>15&gt; tdb ≥ 18</td>
<td>240</td>
<td>13.9±0.9</td>
<td>10.7±3.1</td>
<td>292±151</td>
<td>4.8±3.8</td>
</tr>
<tr>
<td>3</td>
<td>18&gt; tdb ≥ 21</td>
<td>1040</td>
<td>19.4±0.9</td>
<td>14.0±2.6</td>
<td>422±223</td>
<td>7.7±4.4</td>
</tr>
<tr>
<td>4</td>
<td>21&gt; tdb ≥ 24</td>
<td>1040</td>
<td>22.5±0.8</td>
<td>17.2±2.0</td>
<td>360±137</td>
<td>8.3±4.7</td>
</tr>
<tr>
<td>5</td>
<td>24&gt; tdb ≥ 27</td>
<td>1380</td>
<td>25.5±0.8</td>
<td>16.9±3.2</td>
<td>471±205</td>
<td>10.8±5.7</td>
</tr>
<tr>
<td>6</td>
<td>27&gt; tdb ≥ 30</td>
<td>900</td>
<td>28.6±0.8</td>
<td>16.5±3.3</td>
<td>635±227</td>
<td>11.0±5.6</td>
</tr>
<tr>
<td>7</td>
<td>30&gt; tdb ≥ 33</td>
<td>800</td>
<td>31.7±0.7</td>
<td>16.5±4.5</td>
<td>748±176</td>
<td>9.7±4.8</td>
</tr>
<tr>
<td>8</td>
<td>33&gt; tdb ≥ 36</td>
<td>641</td>
<td>34.0±0.8</td>
<td>18.5±2.1</td>
<td>823±64</td>
<td>14.6±4.2</td>
</tr>
<tr>
<td>9</td>
<td>36&lt; tdb</td>
<td>140</td>
<td>37.6±0.8</td>
<td>14.3±1.7</td>
<td>681±108</td>
<td>11.6±6.5</td>
</tr>
</tbody>
</table>

Figure 1. The effects of increasing temperature on respiration rate and panting score of feedlot heifers. Error bars represent the standard error associated with each point.

The impact of genotype was striking—genotype, TC, and genotype by TC all affected RR and PS (P<0.0001). Angus and MARC III had the highest RR (94.0±1.2 bpm and 93.4±1.2 bpm, respectively) and PS (0.64±0.2 and 0.58±0.3, respectively), followed by Gelbvieh (RR – 84.6±1.0 bpm; PS – 0.42±0.2), then Charolais (RR – 78.1±1.0 bpm; PS – 0.35±0.2). Upon closer evaluation of genotype by TC interaction, it appeared that Charolais responses separated from the group at a fairly low temperature. Charolais’ RR was significantly lower than Angus and MARC III RR at TC 4 (19.4°C), and significantly lower than Gelbvieh at TC 5 (22.5°C) (Figure 2a and 2b). Charolais PS followed a similar trend being significantly lower than Angus at TC 5.
(22.5°C), MARC III at TC 6 (25.5°C), and Gelbvieh at TC 7 (28.6°C). Gelbvieh separated from the group at TC 7 (28.6°C). Results seemed logical due to hide color differences, which affect the adsorption of solar radiation. Adsorption of solar radiation from a black-hided animal was 93%, while a light-hided animal was only 27% (da Silva et al., 2003).

Figure 2. Responses of feedlot heifers of four differing genotypes (Angus – Black; MARC III – Dark Red; Gelbvieh – Tan; and Charolais – White) to increase temperature (a. Respiration rate; b. panting score). Error bars represent the standard error associated with each point.

Condition score, health status, and temperament have anecdotal evidence to suggest these factors influence responses to stress; however, there are few refereed papers documenting their effect. Animals with higher condition scores had higher RR and PS (P<0.05). Animals with CS of six had the lowest RR (78.2±1.0 bpm) and PS (0.30±0.02). Animals with CS of seven had the next lowest RR (85.3±0.7 bpm) and PS (0.44±0.01), followed by CS of eight and nine (RR – 92.3±0.8 bpm, 96.3±1.6 bpm and PS – 0.58±0.02, 0.66±0.04, respectively). Figures 3a and 3b show responses of animals with differing CS as temperature increases. Animals with CS of six started separating from the other groups at TC 5 (22.5°C). At TC 6 (25.5°C), effects of higher condition scores began to separate out. This also supports a threshold temperature of approximately 25°C as found by Eigenberg et al. (2004). At higher temperatures, points appear to come together; this may be due to limited number of observations at higher temperature categories.

Figure 3. Responses of feedlot heifers of four different condition scores to increase temperature (a. Respiration rate; b. panting score). Error bars represent the standard error associated with each point.

Animals treated for respiratory pneumonia any time from birth to slaughter (treated) had higher RR (92.1±0.9) and PS (0.57±0.02) than those never diagnosed with respiratory pneumonia (untreated) (RR – 86.7±0.6 bpm; PS– 0.48±0.01). Treated animals were affected more by increasing temperature than untreated animals (Figure 4a and 4b, P<0.0001). Treated animals had a significantly higher RR from TC 5 (22.5°C) through TC 9 (34.0°C). The PS followed a similar trend, but differences did not appear until higher temperatures (TC 7 – 28.6°C). This was a very significant finding—it suggested that early respiratory illness has a lasting impact. An analysis to help describe that lasting impact could not be performed, due to low numbers of treated animals. These results also suggest that treated animals were infected with a respiratory disease, unlike results reported by Buhman et al. (2000), who found only fair agreement between treated animals and those with lung lesions.
Calm heifers (TS<1.5) had lower RR (85.4±0.6 bpm) but similar PS (0.49±0.02) compared to highly excitable heifers (RR – 88.4±0.8 bpm; PS – 0.48±0.01). Although temperament appeared to have smaller impact than other parameters investigated, there were significant differences. Calm heifers had significantly lower RR in all TC above TC 5 (22.5°C), except for TC 8 where two categories were the same (Figure 4a and 4b).

A similar comparison was completed using condition score and genotype. For this comparison, CS greater than or equal to eight were grouped together (finished), and CS less than eight were in another group (lean). All comparisons between categories in this section were made at temperatures greater than 25.5°C (TC 6). As with the other comparison, effects of CS and genotype appeared to be additive. A finished Angus had 31.6% higher RR than a lean Charolais. Finished animals had 6.8% higher RR than lean animals. This is slightly less than was found in the CS analysis (11.4% between CS 6 and CS 7; 11.4% between CS 7 and CS 8; 5.3% between CS 8 and CS 9). Finished Angus had 23.6% higher RR than finished Charolais, which is similar to the difference found in lean heifers (22.8%).

These risk factors not only impact apparent stress levels, but also impact an important production parameter, average daily gain. Genotype (P=0.0019), health history (0.0743), and temperament (P=0.0251) had effects on average daily gain over the summer time grow-out period. The Charolais heifers had significantly higher gain (3.59±0.07 kg/day) than the other three genotypes (P<0.01) (Angus – 3.24±0.07 kg/day; MARC III – 3.24±0.07 kg/day; Gelbvieh – 3.29±0.07 kg/day).

When multiple parameters were compared, effects of each parameter remained consistent (Figures 6, 7), and effects appeared to be additive. All comparisons between categories in this section were made at temperatures greater than 25.5°C (TC 6). In the genotype comparison, Angus heifers had 25.4% higher RR than Charolais. Heifers treated for pneumonia had 10.5% higher RR than untreated. When these two categories were combined, treated Angus heifers had 38.7% higher RR than untreated Charolais. The difference between treated and untreated heifers averaged 9.3% (Angus – 10.0%, Charolais – 8.6%), which matches overall health effect of 10.5%. A similar agreement occurred with genotype effect; the difference between treated Angus and Charolais heifers was 27.7%, and in untreated Angus and Charolais heifers was 26.0%.

A similar analysis was conducted using condition score and genotype. Results from this analysis were similar to the CS analysis (11.4% between CS 6 and CS 7; 11.4% between CS 7 and CS 8; 5.3% between CS 8 and CS 9). Angus had 51.9% higher RR than Charolais. Angus had 16.4% higher RR than Charolais at TC 6. These results are similar to those found in the genotype analysis (10.5% between Angus and Charolais at TC 6). When these two categories were combined, Angus and Charolais had 51.9% higher RR than the other two genotypes (MARC III – 3.24±0.07 kg/day; Gelbvieh – 3.29±0.07 kg/day).

The Charolais heifers had significantly higher gain (3.59±0.07 kg/day) than the other three genotypes (P<0.01) (Angus – 3.24±0.07 kg/day; MARC III – 3.24±0.07 kg/day; Gelbvieh – 3.29±0.07 kg/day).
kg/day; N= 64 for all genotypes). There were no significant differences between the other three genotypes (P=0.6). This seems to be logical because the Charolais heifers were significantly less stressed than the other three genotypes at temperatures about 19.5 °C. The Gelbvieh heifers were only significantly different above 28.6 °C, and there was no significant difference between the Angus and MARC III heifers. While the MARC III and Angus heifers were able to compensate for about 20 days above 28.6°C (22 – 2002; 18 – 2003) of the additional stress to maintain the gain of the Gelbvieh, the animals could not compensate for approximately 40 days above 19.5°C (22 – 2002; 18 – 2003) to maintain a gain relative to the Charolais.

The health history tended to impact average daily gain (P=0.0743); heifers that had never been treated for pneumonia had a gain of 3.4±0.04 kg/day (N=194), compared to a gain of 3.2±0.08 kg/day (N=62) that had been treated. Remarkably, temperament had significant impact (P=0.0251) despite a relatively minor increase in stress level. Calm heifers had a higher gain (3.4 ±0.05 kg/day; N=140), compared to excitable heifers (3.2±0.06 kg/day; N=116). This suggests that temperament alone could have an impact on gain and not just the secondary effect of stress level.

When the effects of genotype and health status were combined some of the gain differences remained. Charolais heifers that had never been treated for pneumonia had significantly higher gain (3.6±0.08 kg/day; N=54) than the other categories: Angus previously treated (3.3±0.13 kg/day; N=19), Angus not previously treated (3.2±0.08 kg/day; N=45) and Charolais not previously treated (3.4±0.18 kg/day; N=18). There were no other significant differences.

The combined effects of temperament and genotype had similar differences as the combined effects of genotype and health status. Calm Charolais heifers had significantly higher gain (3.8±0.10 kg/day; N=28) than any of the other categories: Calm Angus Heifers (3.2±0.12 kg/day; N=42), Excitable Angus heifers (3.2±0.08 kg/day; N=22), Excitable Charolais heifers (3.4±0.09 kg/day; N=36). There were no significant differences between the other categories.

**CONCLUSION**

This study found that relative stress level, as measured by RR and PS, was impacted by temperature, genotype, CS, health history, and temperament. These factors (genotype, health history, and temperament) not only impacted the relative stress, but also reduced the daily gain of these animals. This information provides the first step in identifying animals vulnerable to heat stress, so producers can treat those animals differently than the main herd (i.e. precision animal management).

In addition to identifying animals, this research also illustrates sensitivity of RR and PS as a tool for detecting heat stress in a herd of animals. While a single measurement of RR would not indicate if an animal is sick, knowing CS, genotype (color), health history, and temperament a producer could determine which animals are at higher risk under heat-stress conditions, and manage those animals accordingly.

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