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Heat stress risk factors of feedlot heifers[☆]

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Abstract

Heat stress in cattle results in millions of dollars in lost revenue each year due to production losses, and in extreme cases, death. Death losses are more likely to result from animals vulnerable to heat stress. A study was conducted to determine risk factors for heat stress in feedlot heifers. Over two consecutive summers, a total of 256 feedlot heifers (32/ breed/ year) of four breeds were observed. As a measure of stress, respiration rates and panting scores were taken twice daily (morning and afternoon) on a random sample of 10 heifers/ breed. Weights, condition scores, and temperament scores were taken on 28-day intervals during the experiment. Health history from birth to slaughter was available for every animal used in this study. It was found that at temperatures above 25 °C, dark-hided animals were 25% more stressed than light-colored; a history of respiratory pneumonia increased stress level by 10.5%; each level of fatness increased stress level by approximately 10%; and excitable animals had a 3.2% higher stress level than calm animals. Not only did the stress level increase with these risk factors, but average daily gain was reduced. The Charolais cattle gained significantly more than all other breeds of cattle tested. Calm cattle gained 5% more than excitable cattle. Finally, cattle treated for pneumonia gained approximately 8% slower than non-treated cattle. The results of this study have not only revealed heat stress risk factors of breed (color), condition score (fatness), temperament, and health history (treated or not treated for pneumonia), but have also shown the effectiveness of using respiration rate as an indicator of heat stress. © 2006 Elsevier B.V. All rights reserved.

Keywords: Feedlot cattle; Heat stress; Respiration rate; Pneumonia; Color

1. 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 factors 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), compromised immune systems, more fat cover, and possibly highly excitable animals.

[☆] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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(T.M. Brown-Brandl).

Hungerford et al. (2000) conducted an investigation of a heat wave that killed more than 5000 head of cattle in northeastern Nebraska during the summer of 1999 to determine risk factors for heat related deaths. It was determined that cattle of greater weight and cattle on a program with no antibiotics, hormones, or feed additives were at greater risk of death. The most striking outcome of this study found that black cattle were 5.7 times more likely to die from heat stress than other colors of cattle. Little research has been conducted to determine the effect of health or temperament on the response to elevated temperatures, although studies have shown that compromised immune systems (Donovan et al., 1998; Wittum et al., 1996) and excitable cattle (Voisinet et al., 1997) can cause reduced gains in feedlot cattle.

Respiration rate has been shown to be a good indicator of thermal stress (Brown-Brandl et al., 2005b; Gaughan et al., 2000; Hahn et al., 1997). Respiration rate increases in a non-linear fashion in response to increasing ambient temperature, with a breakpoint or a threshold of between 20–25 °C (Eigenberg et al., 2002; Hahn et al., 1997). The advantages of using respiration rate 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 the ambient dry-bulb temperature associated with it (Brown-Brandl et al., 2005a).

Along with respiration rate, the behavior of the animal changes as ambient temperature increases. Young and Hall (1993) listed behaviors exhibited by cattle experiencing excessive heat loads including the onset of open-mouthed, labored panting, and excessive salivation/drooling. They suggested that these behaviors are 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. The panting score uses behavior of the animal to assess its “heat stress” level; a panting score 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 objectives of this study were to determine if health status, breed (with differing coat colors), condition score, and temperament are risk factors for susceptibility to heat stress in feedlot heifers, and to determine if these potential risk factors (except

condition score) lead to reduced performance during the summer time period.

2. Materials and methods

Two-hundred fifty-six feedlot heifers of four breeds (Angus, Charolais, Gelbvieh, and MARC III crossbred [Pinzgauer, Red Poll, Hereford, Angus]) from the USDA–ARS U.S. Meat Animal Research Center’s (USMARC) population were selected for this study (32 heifers/ breed/ year). The study was conducted over two consecutive summers (2002 and 2003) in the US-MARC feedlot (located 9.6 km west and 3.2 km north of Clay Center, Nebraska). Angus cattle were black; MARC III were mostly dark-red (three of 64 were black, some were solid, others had white tailheads and/or white faces); Gelbvieh were tan in color; Charolais were white. The breeds of cattle used in this experiment had hide colors that corresponded to the reported hair color (Angus – Black hair and black hide, MARC III – dark-red hair and dark-red hide, Gelbvieh – tan hair and tan hide, Charolais – white hair and pink hide). Each year heifers initially weighing 393.5 ± 45.4 kg were assigned to one of four adjacent pens (64.6×18.3 m) by breed (32 heifers/pen). Heifers were implanted with Synovex-H (200 mg testosterone propionate and 20 mg estradiol benzoate) approximately 40 days before the study began. Synovex-H is a growth promotant and was implanted in these animals to replicate U.S. cattle industry procedures. Heifers were then fed twice daily, before 0800 h and after 1300 h, and had free access to water. Live weights, body condition scores, and temperament scores were recorded every 28 days.

Condition scores were taken on an expanded 27-point scale due to the close similarity of cattle using the traditional 9-point scale (for comparison of these two systems see Table 1). For analyses purposes, condition scores were predicted on a daily basis by linearly interpolating between 28-day readings, and then categorizing into one of four condition score (CS) categories ([6] $CS < 18.5$; [7] $18.5 \leq CS < 21.5$; [8] $21.5 \leq CS < 24.5$; [9] $CS \geq 24.5$).

Two observers, working independently, assigned a temperament score to each animal (Table 2), based on the heifers behavior in the enclosed scale. The two observers’ temperament scores were averaged to yield a single temperament score per weigh date. To

Table 1

Comparison of standard 9-point visual body condition scores scale and an expanded 27-point visual body condition scores scale

9-point Scale	27-point Scale	Description ^a
1	1–3	Extremely thin, all skeletal structures are visible
2	4–6	Very thin. Skeletal structures are visible
3	7–9	Thin. Muscle tissue is evident, but not abundant
4	10–12	Marginal, ribcage backbone junction becoming less visible
5	13–15	Muscle tissue is nearing maximum, fat deposit behind shoulder is noticeable, ribs are covered slightly
6	16–18	Muscle tissue volume is at a maximum, fat deposit behind shoulder is obvious, ribs are covered completely with fat beginning to cover rump
7	19–21	Fat deposits behind shoulder and at tailhead are obvious, flat appearance is beginning to dominate topline
8	22–24	Fat deposits are flattening rump, fat is filling brisket and over shoulder
9	25–27	Obese, flat appearance dominates, brisket is heavy

^a Descriptions from Hardin, 1990.

determine a single temperament score (TS) per animal, temperament scores from throughout the experiment were averaged together, and then categorized in two classes (calm animals – TS < 1.5; excitable animals – TS ≥ 1.5).

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.

Ten days prior to initiating the experiments, cattle were preconditioned to observers. During the preconditioning period, two observers spent 1 h twice daily walking outside pens. Measurements of respiration rate and panting score (Table 3) (Mader and Davis, 2002) were made twice daily (0800 h and 1430 h) during six 5-day periods between June 24 and August 9 in 2002, and twelve 3- to 5-day periods between May 20 and August 6 in 2003. On scheduled experimental days, two observers, working independently, each randomly selected five animals in each

pen to observe. A total of 40 animals were observed each period. For each selected animal, an identification number, standing or lying behavior, panting score, and respiration rate 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 animal observations, an average ambient temperature was calculated for the analyses.

All animals used in the study were born and raised at the USMARC; therefore a complete health history was available for each individual animal. The disease evaluated in this manuscript was pneumonia. The number of times an animal was diagnosed and treated for pneumonia was aggregated into a single number without regard to date of incident.

Data collected over two summers were compiled into one data set, and then assigned to one of ten temperature categories (TC) based on dry-bulb tem-

Table 2

Temperament scoring system

Score	Description of animal's behavior while confined to a chute ^a
1	Calm, no movement
2	Restless shifting
3	Squirming, occasional shaking of restraint device
4	Continuous vigorous movement and shaking of restraint device
5	Rearing, twisting or violently struggling

^a Voisinet et al., 1997.

Table 3

Description of panting scores

Score	Description ^a
0	Normal respiration, ~60 or less breaths/min
1	Slightly elevated respiration, 60–90 breaths/min
2	Moderate panting and/or the presence of drool or small amount of saliva, 90–120 breaths/min
3	Heavy open-mouthed panting; saliva usually present, 120–150 breaths/min
4	Severe open-mouthed panting accompanied by protruding tongue and excessive salivation

^a Panting scores were assigned based on visual observation of behavior, not on the estimation of respiration rates.

perature (t_{db}) (TC 1: $t_{db} \leq 12$; TC 2: $12 < t_{db} \leq 15$; TC 3: $15 < t_{db} \leq 18$; TC 4: $18 < t_{db} \leq 21$; TC 5: $21 < t_{db} \leq 24$; TC 6: $24 < t_{db} \leq 27$; TC 7: $27 < t_{db} \leq 30$; TC 8: $30 < t_{db} \leq 33$; TC 9: $33 < t_{db} \leq 36$; TC 10: $t_{db} > 36$).

Analyses were completed to determine if breed, temperature, condition score, health, temperament and/or the interactions of these factors impact the respiration rate or panting score. The data were compiled and analyzed using the following model.

$$\begin{aligned}
 y_{ijklm} = & \mu + \alpha_i + \beta_j + \delta_k + \gamma_l + \kappa_m + \alpha\beta_{ij} + \alpha\delta_{ik} \\
 & + \alpha\gamma_{il} + \alpha\kappa_{im} + \beta\delta_{jk} + \beta\gamma_{jl} + \beta\kappa_{jm} + \delta\gamma_{kl} \\
 & + \delta\kappa_{km} + \gamma\kappa_{lm} + \alpha\beta\delta_{ijk} + \alpha\beta\gamma_{ijl} + \alpha\beta\kappa_{ijm} \\
 & + \alpha\delta\gamma_{ikl} + \alpha\delta\kappa_{ikm} + \alpha\gamma\kappa_{ilm} + \beta\delta\gamma_{jkl} + \beta\delta\kappa_{jkm} \\
 & + \beta\gamma\kappa_{jlm} + \delta\gamma\kappa_{klm} + \alpha\beta\delta\gamma_{ijkl} + \alpha\beta\delta\kappa_{ijkm} \\
 & + \alpha\delta\gamma\kappa_{iklm} + \beta\delta\gamma\kappa_{jklm} + \alpha\beta\delta\gamma\kappa_{ijklm} + \varepsilon_{ijklm}
 \end{aligned}$$

Where: μ is the overall mean, α_i is the effect of the i th breed, β_j is the effect of the j th temperature category, δ_k is the effect of the k th finish category, γ_l is the effect of the l th temperament category, κ_m is the effect of the m th number of cases of pneumonia, and ε_{ijklm} is the error term. All the interaction terms were included in the initial analysis. A step-down analysis was performed to determine significant effects; all interaction terms that did not significantly contribute to the model ($P > 0.10$) were eliminated until the model contained main effects and only significant interaction terms. The final model for respiration rate is presented below, followed by the final model for panting score.

$$\begin{aligned}
 y_{ijklm} = & \mu + \alpha_i + \beta_j + \delta_k + \gamma_l + \kappa_m + \alpha\beta_{ij} + \beta\delta_{jk} \\
 & + \beta\gamma_{jl} + \beta\kappa_{jm} + \delta\gamma_{kl} + \alpha\gamma_{il} + \alpha\beta\delta_{ijk} \\
 & + \alpha\beta\delta\gamma_{ijkl} + \alpha\beta\delta\gamma\kappa_{ijkm} + \varepsilon_{ijklm}
 \end{aligned}$$

$$\begin{aligned}
 y_{ijklm} = & \mu + \alpha_i + \beta_j + \delta_k + \gamma_l + \kappa_m + \beta\gamma_{jl} + \delta\gamma_{kl} \\
 & + \delta\kappa_{km} + \alpha\beta\delta_{ijk} + \beta\delta\gamma_{jkl} + \alpha\beta\delta\gamma_{ijkl} \\
 & + \alpha\beta\delta\kappa_{ijkm} + \alpha\beta\delta\kappa_{ijkm} + \varepsilon_{ijklm}
 \end{aligned}$$

To investigate certain effects in more detail, analyses were conducted on one or two effects at a time as described below. For simplicity of further

analysis, animals treated at least one time for pneumonia were categorized as the treated group, while remaining animals were placed in the untreated group. Animals previously treated for pneumonia were removed from all analyses, except where health history was included.

Differences in respiration rate and panting score at each of the temperature categories were determined by using the following model:

$$y_i = \mu + \alpha_i + \varepsilon_i$$

where: μ is the overall mean, α_i is the effect of the i th temperature category, and the error term of ε_{ij} . Least square means procedure was used to determine differences in respiration rate or panting score at each temperature category at the $P < 0.05$ level.

Differences in respiration rate and panting score responses among different breeds (Angus, MARC III, Gelbvieh, and Charolais), condition score (6, 7, 8, 9), health (treated and untreated), and temperament (calm and excitable) were tested, using the general linear model procedure in SAS (SAS, 2000) using the following model:

$$y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ij}$$

where: μ is the overall mean, α_i is the effect of the i th factor of interest (breed, condition score, etc.), β_j is the effect of the j th temperature category, $\alpha\beta_{ij}$ is the interaction term of the factor of interest and the temperature category, and the error term of ε_{ij} . Least square means procedure was used to determine differences in the main effects, and interaction of the main effect and the temperature category at the $P < 0.05$ level.

Three additional analyses were conducted using two factors on the Charolais and Angus breeds only. The first analysis investigated breed and health (treated and untreated); the second analysis investigated breed and condition score ($CS < 8$ and $CS \geq 8$, only); the third analysis investigated breed and temperament (calm < 1.5 and excitable ≥ 1.5). These three analyses combined two factors of interest into one risk factor; for example, Angus heifers and had been previously treated for pneumonia were categorized as Risk 1; Charolais heifers and had been previously treated for pneumonia were categorized as Risk 2; Angus heifers and had not been treated for

pneumonia were categorized as Risk 3; Risk 4 category was assigned to Charolais heifers which had not been treated for pneumonia. The following model was used to analyze the effect of risk category:

$$y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ij}$$

where: μ is the overall mean, α_i is the effect of the *i*th risk, β_j is the effect of the *j*th temperature category, $\alpha\beta_{ij}$ is the interaction term of the risk and the temperature category, and the error term of ε_{ij} . Least square means procedure was used to determine differences in the main effects, and differences in the main effects at each temperature category at the $P < 0.05$ level.

The impact of breed, health history, and temperament on the average daily gain was tested, using the

general linear model procedure in SAS (SAS, 2000), using the following model:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \delta_k + \alpha\beta_{ij} + \alpha\delta_{ik} + \beta\delta_{jk} + \alpha\beta\delta_{ijk} + \varepsilon_{ij}$$

where: μ is the overall mean, α_i is the effect of the *i*th breed, β_j is the effect of the *j*th temperament category (calm or excitable), δ_k is the effect of the *k*th health category (treated or untreated), and the error term of ε_{ijk} . All the interaction terms were included in the initial analysis. A step-down analysis was performed to determine significant effects; all interaction terms that did not significantly contribute to the model ($P > 0.10$) were eliminated until the model contained main effects and only significant interaction terms. The final model is presented below. Least square

Table 4
Significant effects on cattle respiration rates and panting scores

Effects	Respiration rate ^a	Panting score
Breed of cattle (breed)	$P < 0.0001$	$P < 0.0001$
Temperature category (temperature)	$P < 0.0001$	$P < 0.0001$
Finish	$P = 0.0014$	$P = 0.2793$
Temperament score (temperament)	$P = 0.2226$	$P = 0.6197$
# of cases of pneumonia (pneumonia)	$P = 0.0151$	$P = 0.8454$
Breed × temperature	$P = 0.0006$	N/A
Breed × finish	N/A	$P = 0.0583$
Breed × pneumonia	$P < 0.0001$	$P = 0.0099$
Breed × temperament	N/A	N/A
Temperature × finish	$P < 0.0001$	N/A
Temperature × pneumonia	$P < 0.0001$	$P = 0.0124$
Temperature × temperament	$P = 0.0725$	N/A
Finish × pneumonia	$P < 0.0001$	$P = 0.0037$
Finish × temperament	N/A	N/A
Pneumonia × temperament	N/A	N/A
Breed × temperature × finish	N/A	$P = 0.0003$
Breed × temperature × pneumonia	N/A	N/A
Breed × temperature × temperament	N/A	N/A
Breed × finish × pneumonia	N/A	N/A
Breed × finish × temperament	N/A	N/A
Breed × pneumonia × temperament	N/A	N/A
Temperature × finish × pneumonia	$P < 0.0001$	$P = 0.0003$
Temperature × finish × temperament	N/A	$P = 0.0595$
Temperature × pneumonia × temperament	N/A	N/A
Finish × pneumonia × temperament	N/A	N/A
Breed × temperature × finish × pneumonia	N/A	N/A
Breed × finish × pneumonia × temperament	N/A	N/A
Breed × temperature × pneumonia × temperament	N/A	$P = 0.0446$
Breed × temperature × finish × temperament	N/A	N/A
Temperature × finish × pneumonia × temperament	N/A	N/A
Breed × temperature × finish × pneumonia × temperament	$P < 0.0001$	$P = 0.0023$

^a N/A= Effect was not included in the final model due to the lack of significance.

Table 5

Average condition score, temperament, and number of treated animals per breed

	Angus	MARC III	Gelbvieh	Charolais
Beginning condition score	19.3 ± 0.02 ^a	17.9 ± 0.02 ^b	16.0 ± 0.02 ^c	16.1 ± 0.02 ^c
Ending condition score	24.9 ± 0.02 ^a	24.0 ± 0.02 ^b	22.5 ± 0.02 ^c	22.4 ± 0.02 ^c
Average temperament score	1.28 ± 0.09 ^a	1.29 ± 0.08 ^a	1.55 ± 0.08 ^c	1.60 ± 0.08 ^c
Number of treated animals (total of 64)	19 ± 3.2 ^{a,b,c}	22 ± 3.2 ^b	11 ± 3.2 ^{cd}	10 ± 3.2 ^d

^{a,b,c} Numbers in a single row with differing superscripts were significantly different ($P > 0.05$).

means were used to determine significant differences in the main effects at the $P < 0.05$ level.

$$y_{ij} = \mu + \alpha_i + \beta_j + \delta_k + \varepsilon_{ij}$$

3. Results and discussion

The initial analyses (Table 4) have shown that an animal stress level due to heat stress is impacted by a combination of factors, including the interaction of temperature category and all remaining factors of interest (breed, finish, number of cases of pneumonia, and temperament). To further investigate these impacts of different risk factors, individual effects were tested separately, thus overlooking the unbalanced nature of the data (see Table 5).

Environmental conditions and number of points at each temperature category are shown in Table 6. Respiration rate and panting score increased with temperature category. The increase of respiration rate with temperature is well documented (Brown-Brandl et al., 2003; Eigenberg et al., 2000; Hahn et al., 1997; Mader et al., 1999). Since respiration rate is affected by all weather factors (Eigenberg et al., 2004), others

including wind speed, dew-point temperature, and solar radiation should be examined. In the third and ninth temperature category, respiration rate 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; panting scores were not significantly different from 0 until the fourth temperature category (19.4 °C), and showed a significant increase at temperature category 5 (22.5 °C) (Fig. 1). Eigenberg et al. (2004) found a similar threshold temperature of approximately 25 °C for respiration rate.

The impact of breed was striking – breed, temperature category, and breed by temperature category all affected respiration rate and panting score ($P < 0.0001$). Angus and MARC III had the highest respiration rate (94.0 ± 1.2 breaths/min and 93.4 ± 1.2 breaths/min, respectively) and panting score (0.64 ± 0.2 and 0.58 ± 0.3 , respectively), followed by Gelbvieh (respiration rate – 84.6 ± 1.0 breaths/min; panting score – 0.42 ± 0.2), then Charolais (respiration rate – 78.1 ± 1.0 breaths/min; panting score – 0.35 ± 0.2). Upon closer evaluation of breed by

Table 6

Average environmental conditions and number of points in each temperature category

Temperature category	Temperature range (°C)	N	Dry-bulb temperature (°C)	Dew-point temperature (°C)	Solar radiation (W/m ²)	Wind speed (m/s)
1	$t_{db} \leq 12$	80	9.5 ± 1.5	5.5 ± 3.1	414 ± 85	5.0 ± 0.0
2	$12 > t_{db} \leq 15$	360	13.9 ± 0.9	10.7 ± 3.1	292 ± 151	4.8 ± 3.8
3	$15 > t_{db} \leq 18$	240	16.7 ± 0.9	13.1 ± 1.8	331 ± 128	9.5 ± 3.5
4	$18 > t_{db} \leq 21$	1040	19.4 ± 0.9	14.0 ± 2.6	422 ± 223	7.7 ± 4.4
5	$21 > t_{db} \leq 24$	1040	22.5 ± 0.8	17.2 ± 2.0	360 ± 137	8.3 ± 4.7
6	$24 > t_{db} \leq 27$	1380	25.5 ± 0.8	16.9 ± 3.2	471 ± 205	10.8 ± 5.7
7	$27 > t_{db} \leq 30$	900	28.6 ± 0.8	16.5 ± 3.3	635 ± 227	11.0 ± 5.6
8	$30 > t_{db} \leq 33$	800	31.7 ± 0.7	16.5 ± 4.5	748 ± 176	9.7 ± 4.8
9	$33 > t_{db} \leq 36$	641	34.0 ± 0.8	18.5 ± 2.1	823 ± 64	14.6 ± 4.2
10	$t_{db} > 36$	140	37.6 ± 0.8	14.3 ± 1.7	681 ± 108	11.6 ± 6.5

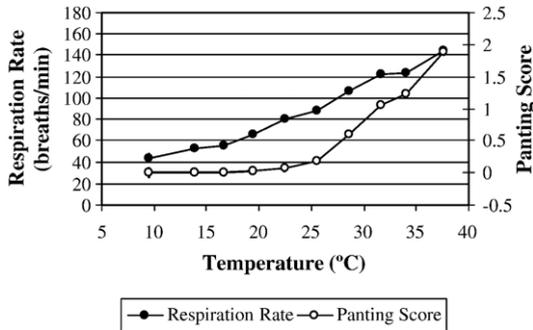


Fig. 1. The effects of increasing temperature on respiration rate and panting score of feedlot heifers. Error bars represent the standard error associated with each point.

temperature category interaction, it appeared that Charolais responses separated from the group at a fairly low temperature. Charolais’ respiration rate was significantly lower than Angus and MARC III respiration rate at temperature category 4 (19.4 °C), and significantly lower than Gelbvieh at temperature category 5 (22.5 °C) (Fig. 2a and b). Charolais panting score followed a similar trend, being significantly lower than Angus at temperature category 5 (22.5 °C), MARC III at temperature category 6 (25.5 °C), and Gelbvieh at temperature category 7 (28.6 °C). Gelbvieh separated from the group at temperature category 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 the adsorption of light-hided animal was only 27% (da Silva et al., 2003). The companion paper, Brown-Brandl et al., (2006), found that the dark-hided breeds of cattle (Angus, MARC III) had not only higher respiration rate, panting score, and hide surface temperatures, but also adjusted their behavior more under hot conditions compared to cool conditions than the light-hided breeds of cattle (Gelbvieh, Charolais).

Condition score, health status, and temperament contain 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 respiration rate and panting score ($P>0.05$). Animals with condition score of six had the lowest respiration rate (78.2 ± 1.0 breaths/min) and panting score (0.30 ± 0.02). Animals with condition score of seven had the

next lowest respiration rate (85.3 ± 0.7 breaths/min) and panting score (0.44 ± 0.01), followed by condition score of eight and nine (respiration rate – 92.3 ± 0.8 breaths/min, 96.3 ± 1.6 breaths/min and panting score – 0.58 ± 0.02 , 0.66 ± 0.04 , respectively). Fig. 3a and b show responses of animals with differing condition score as temperature increases. Animals with condition score of six started separating from the other groups at temperature category 5 (22.5 °C). At temperature category 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.

Animals treated for respiratory pneumonia any time from birth to slaughter (treated) had higher

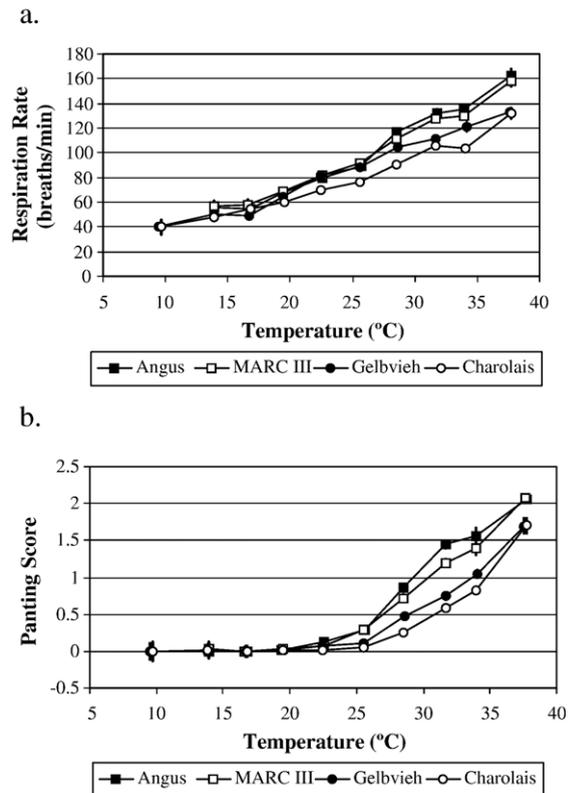


Fig. 2. Respiration rate (a) and panting score (b) response differences between feedlot heifers of four differing breeds (Angus – black; MARC III – dark-red; Gelbvieh – tan; and Charolais – white). Error bars represent the standard error associated with each point.

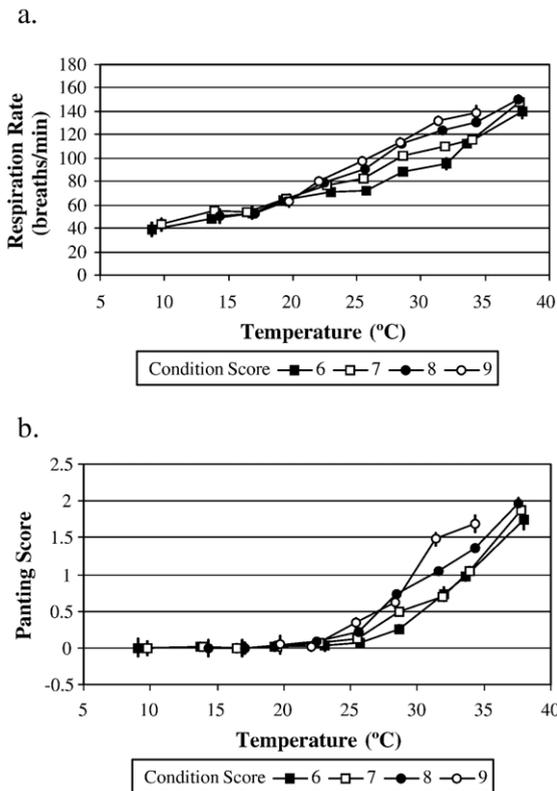


Fig. 3. Respiration rate (a) and panting score (b) response differences between feedlot heifers of four different condition scores. Error bars represent the standard error associated with each point.

respiration rate (92.1 ± 0.9) and panting score (0.57 ± 0.02) than those never diagnosed with respiratory pneumonia (untreated) (respiration rate – 86.7 ± 0.6 breaths/min; panting score – 0.48 ± 0.01). Treated animals were affected more by increasing temperature than untreated animals ($P < 0.0001$) (Fig. 4). Treated animals had a significantly higher respiration rate from temperature category 5 (22.5°C) through temperature category 9 (34.0°C). The panting score followed a similar trend, but differences did not appear until higher temperatures (temperature category 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 the animals that were treated for pneumonia had lasting effects such as lung lesions (a result of scar tissue forming in the lungs due to a respiratory disease). Buhman et al. (2000) found

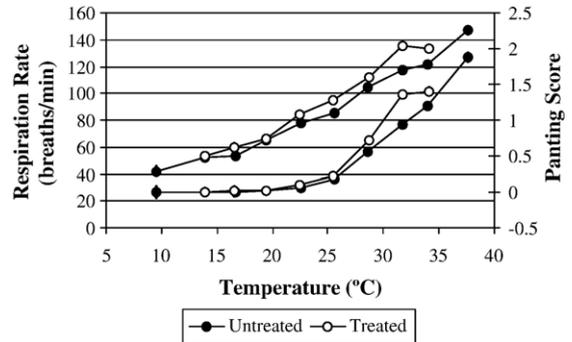


Fig. 4. Respiration rate and panting score response differences between feedlot heifers diagnosed and treated for respiratory pneumonia any time from birth to slaughter (treated), and those never diagnosed with respiratory pneumonia (untreated). Error bars represent the standard error associated with each point.

only fair agreement between treated animals and those with lung lesions, which does not seem to be the case with these animals, but is likely the case in a typical feedlot herd.

Calm heifers ($\text{TS} < 1.5$) had lower respiration rates (85.4 ± 0.6 breaths/min) but similar panting scores (0.49 ± 0.02) compared to excitable heifers (respiration rate – 88.4 ± 0.8 breaths/min; panting score – 0.48 ± 0.01). Although temperament appeared to have a smaller impact than other factors investigated, there were significant differences (Fig. 5). Calm heifers had significantly lower respiration rate in all temperature categories above 5 (22.5°C), except for temperature category 8 where the two categories were similar.

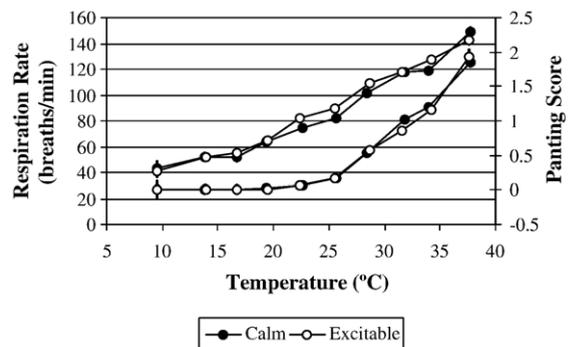


Fig. 5. Respiration rate and panting score response differences between feedlot heifers with temperament scores less than or equal to 1.5 (calm), or greater than 1.5 (excitable). Error bars represent the standard error associated with each point.

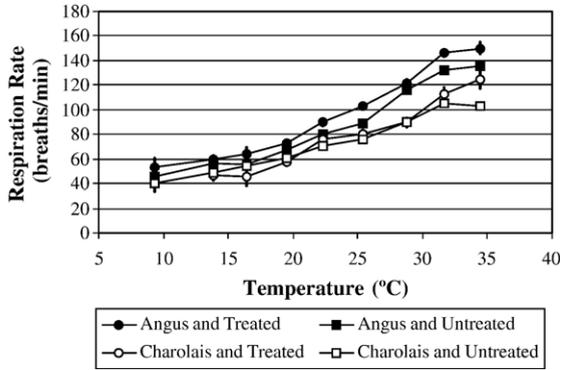


Fig. 6. Respiration rate responses of Angus and Charolais heifers that were either diagnosed and treated for respiratory pneumonia any time from birth to slaughter (treated), or those never diagnosed with respiratory pneumonia (untreated). Error bars represent the standard error associated with each point.

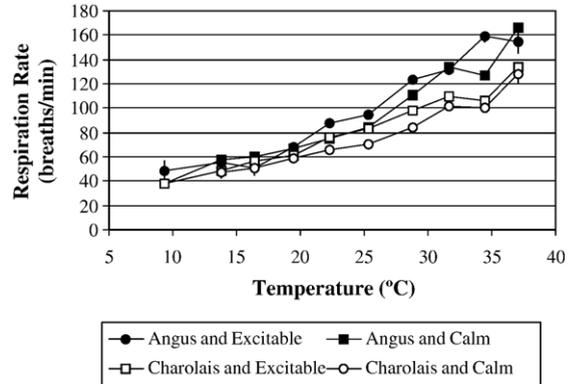


Fig. 8. Respiration rate responses of Angus and Charolais heifers that either had a temperament score of less than or equal to 1.5 (calm) or greater than 1.5 (excitable). Error bars represent the standard error associated with each point.

When multiple factors were compared, effects of each factor remained consistent (Figs. 6–8), and the effects appeared to be additive. All comparisons between categories in this section were made at temperatures greater than 25.5 °C (temperature category 6). Fig. 6 illustrates the combined effects of health (as measured by cases of pneumonia) and breed (only Charolais and Angus). This combined analysis revealed the impact of breed as follows: Angus heifers had 25.4% higher respiration rates than Charolais. Heifers treated for pneumonia had 10.5% higher respiration rates than untreated. When these two categories were combined, treated Angus heifers

had 38.7% higher respiration rates 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% analyzed above. A similar agreement occurred with breed effect; the difference between treated Angus and Charolais heifers was 27.7%, and in untreated Angus and Charolais heifers it was 26.0%.

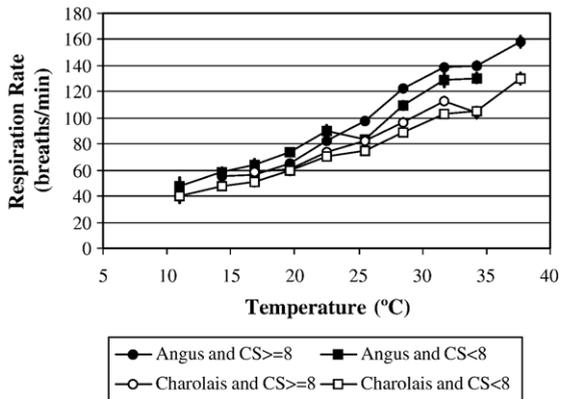


Fig. 7. Respiration rate responses of Angus and Charolais heifers that either had a condition score (CS) greater than or equal to 8, or less than 8. Error bars represent the standard error associated with each point.

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

The final comparison of this type was completed using temperament score and breed (Charolais and Angus only). Temperament scores were divided into two categories as done in previous analyses (calm – temperament score < 1.5; excitable – temperament score \geq 1.5) (Fig. 8). Excitable Angus heifers had a 36.6% higher respiration rate than the calm Charolais heifers. Excitable heifers had about an 8.0% increase in respiration rate compared to the calm heifers. This is a substantially larger difference than was found in the temperament analysis. The Angus heifers had a 20.8% higher respiration rate than the Charolais heifers.

These risk factors not only impact apparent stress levels, but also average daily gain. Breed ($P=0.0075$), health history ($P=0.0454$), and temperament ($P=0.0017$) had effects on average daily gain over the summer time grow-out period. None of the interaction effects were significant ($P>0.2$). The Charolais heifers had significantly higher gain (1.60 ± 0.04 kg/day) than the other three breeds ($P<0.01$) (Angus – 1.45 ± 0.04 kg/day; MARC III – 1.46 ± 0.04 kg/day; Gelbvieh – 1.49 ± 0.04 kg/day; $N=64$ for all breeds). While breed is confounded in these differences in gain, there is some evidence that stress level had an impact as well. There were no significant differences between the other three breeds ($P>0.3$). This seems to be logical because the Charolais heifers were significantly less stressed than the other three breeds at temperatures above 19.5 °C. The Gelbvieh heifers were only significantly less stressed at temperatures above 28.6 °C, and there was no significant difference in stress level between the Angus and MARC III heifers. The MARC III and Angus heifers were able to compensate for approximately 20 additional days (22 days – 2002; 18 days – 2003) of stress (above 28.6 °C) to maintain a gain similar to the Gelbvieh heifers. However, the animals could not compensate for approximately 49 days of additional stress above 19.5 °C (44 days – 2002; 54 days – 2003) to maintain a gain similar to the Charolais.

The health history significantly impacted average daily gain ($P=0.0454$); heifers that had never been treated for pneumonia had a gain of 1.54 ± 0.02 kg/day ($N=194$), compared to a gain of 1.46 ± 0.04 kg/day ($N=62$) for heifers that had been treated. Similar results have been reported by Wittum et al. (1996), and Donovan et al. (1998). Donovan et

al. (1998) found that early pneumonia (before 6 months of age) significantly reduced total weight gain through 14 months. Wittum et al. (1996) found that cattle with lung lesions (found at slaughter) were associated with a reduction in daily gain.

Temperament also had a significant impact ($P=0.0017$) despite a relatively minor increase in stress level. Calm heifers had a higher gain (1.56 ± 0.03 kg/day; $N=140$), compared to excitable heifers (1.44 ± 0.03 kg/day; $N=116$). This suggests that temperament alone could have an impact on gain, and not just the secondary effect of stress level. Voisinet et al. (1997) found similar results; they concluded cattle that were quieter and calmer during handling had higher average daily gains than cattle that became agitated during handling.

4. Conclusions

This study determined that temperature, breed, condition score, health history (history of pneumonia), and temperament had effects on both respiration rate and panting score, the two parameters used in this study to measure heat stress. Black and dark-red animals (Angus and MARC III) were similar in their respiration rate responses to increasing temperature. However, dark animals (both Angus and MARC III) had an average respiration rate that was 10.6% higher than Gelbvieh heifers, and 25.4% higher than the Charolais heifers. Gelbvieh heifers had a 10.3% higher average respiration rate than the Charolais heifers. This increase in respiration rate indicates a larger imbalance in the ratio of heat loss to heat production/gain in the animals, thus indicating an increase in stress. Heifers with higher condition scores had significantly higher respiration rates than heifers with lower condition scores. Animals which were treated for pneumonia between birth and slaughter averaged 10.5% higher respiration rates under stressful conditions than untreated animals; the difference between the two groups was evident at temperatures above 22.5 °C. Temperament had a small effect; excitable heifers had a 3.2% increase in respiration rate under stressful conditions, compared to calm heifers. Panting scores showed a similar trend in all factors except temperament, where no difference was found.

In addition to the physiological indicators of increased stress, there were impacts on average daily gain. Breed, temperament, and previous cases of pneumonia all significantly affected average daily gain. Charolais heifers gained significantly more than any of the other breeds, possibly due to the lower stress level during approximately 49 days in the summer. Calm cattle (1.56 kg/day) gained significantly more than excitable cattle (1.44 kg/day). Cattle previously treated for pneumonia grew significantly slower (1.46 kg/day), compared to 1.54 kg/day for untreated animals.

Several researchers have reported that respiration rate is a good indicator of stress (Brown-Brandl et al., 2005b; Gaughan et al., 2000; Hahn et al., 1997). Results of this study illustrate sensitivity of respiration rate. While a single measurement of respiration rate would not indicate if an animal is sick, knowing condition score, breed (color), health history, and temperament, a producer could determine which animals are at higher risk of suffering production losses under heat stress conditions, and could manage those animals accordingly.

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