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Adjustments for Wind Speed and Solar Radiation to the Temperature-Humidity Index

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Adjustments to the temperature-humidity index for wind and solar heat can provide a more accurate estimation of heat stress in cattle.

Summary

Data from three separate feedlot finishing trials were combined into one data set to determine wind speed and solar radiation adjustments to the temperature-humidity index equation based on degree of panting and ambient environmental conditions. Regression equations were used to determine the relationship between observed panting and current temperature-humidity index, wind speed and solar radiation for developing correction factors. Based on these calculations, for each 1 mile/hour increase in wind speed, THI should be decreased approximately 1 unit, and for each 3 Langley increase in solar radiation or 10% increase in cloud cover, THI should be decreased approximately 1 unit.

Temperature Humidity Index (THI)

Relative Humidity, %

Temperature, °F	30	35	40	45	50	55	60	65	70	75	80	85
100	84	85	86	87	88	90	91	92	93	94	95	97
98	83	84	85	86	87	88	89	90	91	93	94	95
96	81	82	83	85	86	87	88	89	90	91	92	93
94	80	81	82	83	84	85	86	87	88	89	90	91
92	79	80	81	82	83	84	85	85	86	87	88	89
90	78	79	79	80	81	82	83	84	85	86	86	87
88	76	77	78	79	80	81	81	82	83	84	85	86
86	75	76	77	78	78	79	80	81	81	82	83	84
84	74	75	75	76	77	78	78	79	80	80	81	82
82	73	73	74	75	75	76	77	77	78	79	79	80
80	82	72	73	73	74	75	75	76	76	77	78	78
78	70	71	71	72	73	73	74	74	75	75	76	76
76	69	70	70	71	71	72	72	73	73	74	74	75

THI = Temp – (.55 – (.55 x (RH/100))) x (Temp – 58)

Normal < 74 | Alert 75 - 78 | Danger 79 - 83 | Emergency > 84

Figure 1. Temperature Humidity Index (NOAA, 1976, Operations Manual Letter C-31-76. NOAA Kansas City, MO).

Introduction

The Livestock Weather Safety Index (LWSI) is commonly used as a benchmark to determine the susceptibility of cattle to heat stress, by assigning potentially heat stressed animals into normal, alert, danger and emergency categories. The LWSI is based on the temperature-humidity index (THI), which quantitates environmental conditions using a combination of temperature and relative humidity (Figure 1). Although THI has been effectively used as a heat stress indicator, correction for wind speed and solar radiation are needed.

Solar radiation can greatly influence heat load, while changes in wind speed result in altered convective cooling. Both solar radiation and wind speed alter the ability of the animal to maintain thermal balance. Accounting for these two environmental variables in the temperature-humidity index would greatly improve the applicability of the LWSI under varying environmental conditions.

Procedure

Three hundred sixty feedlot steers were used as the database for this trial. These steers originated from three trials previously reported (Nebraska Beef Reports 2000 and 2001) involving management strategies designed to reduce the effect of heat stress on summertime feedlot performance of cattle. Experiments 1 (84 head) and 2 (96 head) were conducted from June 23 to Sept. 13, 1999 (82 days), while Exp. 3 (192 head) was conducted from June 8 to Aug. 30, 2000 (83 days). Panting scores were assigned to individual animals at 1700 hour by visual observation using the scoring system presented in Table 1. These observations were made on days 9 to 15, 20 to 22, 29 to 31 of Exp. 1 and 2,

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and additionally on days 36 to 37 of Exp. 1 and days 54 to 55, and 68 to 69 of Exp. 2. During Exp. 3, observations were made on days 18 to 19, 29 to 33, 40 to 41, 54 to 55, 58, 61 to 62, and 78 to 79. The combination of these observation times resulted in a total of 5,520 individual panting score assessments.

Weather variables used during this trial are presented in Table 2. All variables (except solar radiation) were collected continuously and compiled hourly using a weather station located in the center of the feedlot facility. Solar radiation was obtained from the High Plains Climate Center automated weather station located .5 mile west and 1 mile north of the feedlot facilities. In order to determine temperature-humidity index (THI), ambient temperature (Ta) and relative humidity (RH) readings were combined using the equation:

$$THI = Ta - (.55 - (.55 \times (RH/100)))*(Ta - 58)$$

A regression equation was developed to determine the relationship between panting score and weather variables at the time of panting score assignment. To develop correction factors for THI based on wind speed (WSPD) and radiation (RAD) mean climatological data were used to predict a panting score. The ratio of WSPD and RAD parameter estimates to THI were used to determine correction factors. For graphical purposes, wind speed was altered by + one standard deviation from the mean and a new panting score was calculated. The resulting THIs were plotted against WSPD and RAD, with the slope of the lines being the adjustment factor for WPSD and RAD.

National Oceanic and Atmospheric Administration (NOAA) weather reports were used to develop a relationship between RAD and cloud cover (CCVR). These reports were compilations of CCVR data observed during mid-afternoon in Sioux City, IA during the months of July and August. Once this relationship was determined, an adjustment factor for CCVR could be determined using identical procedures to those for WSPD and RAD.

Table 1. Panting scores assigned to steers.

Score	Description
0	Normal respiration, ~60 or less breaths/min
1	Slightly elevated respiration, ~ 60 - 90 breaths/min
2	Moderate panting and/or drooling mouth, ~ 90 - 120 breaths/min
3	Heavy open-mouthed panting and drooling mouth, ~ 120 - 150 breaths/min
4	Severe open-mouthed panting accompanied by protruding tongue and excessive salivation

Table 2. Mean, maximum and minimum values for temperature (Ta), relative humidity (RH), temperature-humidity index (THI), wind speed and solar radiation at 1700 hours on the days panting scores were assigned.

Item	Mean + SE	Maximum	Minimum
Temperature, ºF	86.5 + 7.2	97.7	65.1
Relative humidity, %	58.3 + 12.4	92.0	37.5
THI	79.7 + 5.2	86.2	63.9
Wind speed, mi/h	8.3 + 3.4	16.1	2.5
Solar radiation, Langley's	29.9 + 9.5	42.4	1.3

Table 3. Parameter estimates for the regression equation describing the relationship between panting score at 1700 hours and temperature-humidity index (THI), wind speed, and solar radiation at 1700 hours (R^2 = .47).

Variable	Parameter estimate + SE	P - value
Intercept	- 6.3173 + .2876	< .0001
THI	.0972 + .0040	< .0001
Wind speed, mph	- .1042 + .0054	< .0001
Solar radiation, Langley's	.0302 + .0019	< .0001

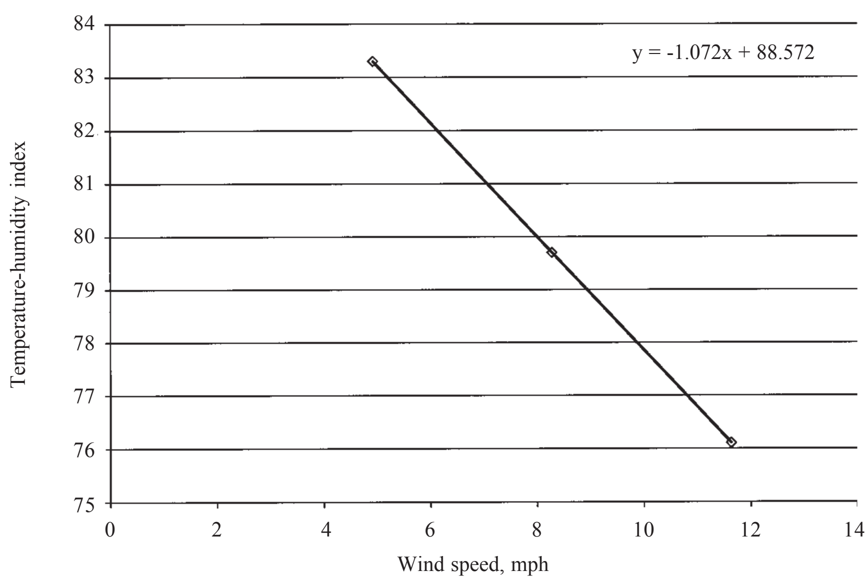

Figure 2. Effect of wind speed on temperature-humidity index. Based on the slope of the line, for every 1 mile/hour increase in wind speed, THI should be decreased 1.072 units.

Results

Mean, maximum and minimum values for THI, wind speed and solar radiation for the days that panting scores were assigned are presented in Table 2. Temperature during panting score assessment averaged 86.5 + 7.2 ºF, while relative humidity averaged 58.3 + 12.4 %. This resulted in average THI being 79.7 + 5.2 units. The LWSI classifications for heat stress are as follows: Normal (< 74),

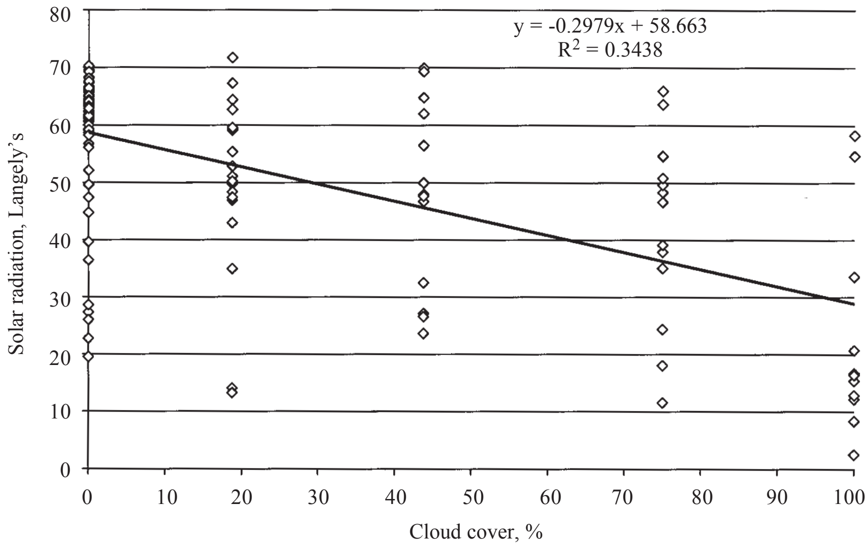

Figure 3. Effect of cloud cover on solar radiation. Based on the slope of the line, for every 25% increase in cloud cover, solar radiation should be decreased 7.45 Langely's. Average solar radiation at 0% cloud cover was 58.62 Laygley's.

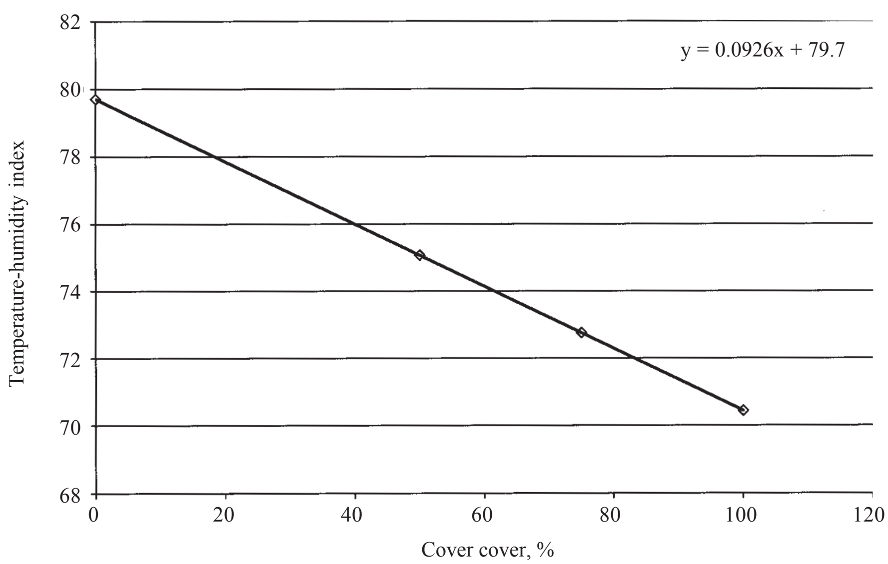

Figure 4. Effect of cloud cover on temperature-humidity index. Based on the slope of the line, for ever 25% increase in cloud cover, THI should be decreased 2.315 units.

Alert (74 < THI < 79), Danger (79< THI < 84), and Emergency (THI > 84). The range of THI for the days in which panting score was determined on the animals represented all categories of the LWSI.

Measurements of wind speed and solar radiation also were composed of a wide range of conditions (2.5 to 16.1 mph and 1.3 to 42.4 Langley's, respectively). Inferences made regarding application of this model must remain within the bounds of the ranges of environmental variables measured.

The parameter estimates for the effects of THI, WSPD and RAD on panting score of the steers are presented in Table 3. The ratio of the coefficients for WSPD and THI is -1.072. Figure 2 describes the relationship with each point representing the THI, based on the prediction equation, that would be needed to produce an equivalent panting score when WSPD was average and + 1 standard deviation. The slope of this line also represents the adjustment for THI based on WSPD. Thus, for every 1 mph increase in WSPD, THI should be adjusted down 1.072 units.

Identical procedures were used for RAD adjustment as were used to develop the WSPD adjustment. The ratio of the coefficients for RAD and THI and the slope of the line suggests for each Langley increase in RAD, THI should be increased 0.311 units. Information regarding the amount of RAD present is not always available. Certain on-site weather stations may have capabilities to supply this information to producers, since local weather reports do not routinely supply RAD levels. One measure that may be visually assessed is the amount of cloud cover (CCVR) present. A more precise relationship is not present between CCVR and RAD because factors other than CCVR affect the amount of RAD (Figure 3). Such factors include dust, pollution levels, incidence of the sun, type of cloud cover (thin, cirrus clouds vs. thick, cumulonimbus clouds) and altitude. While the amount of incoming RAD is not proportionally related to CCVR, a reasonable relationship does exist (Figure 4). Based on this relationship, every 25% increase in CCVR reduces RAD by 7.45 Langley's. By using this relationship it was determined that for every 25% increase in CCVR, THI should be decreased 2.315 units (Figure 4).

Close monitoring of weather variables is essential in determining the potential for heat stress related complications in livestock operations. The LWSI long has been used as an indicator for potential heat stress related losses, however its precision is questioned under conditions of varying wind speed and radiative heat load. Adjustments proposed in this report should allow producers to more accurately predict the potential for heat stress within the bounds of the environmental variables measured.

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