Effects of Climate and Photoperiod on Feed Intake of Beef Bulls During Feedlot Performance Tests


Introduction

Weather has a strong impact on feed intake of beef cattle. Feed intake in turn alters animal performance. Therefore, understanding effects of environmental variables is of economic importance since weight gain is dependent on feed intake. Cattle adapt to changing weather conditions and maintain performance in a broad range of environments. However, coping with environmental stressors involves behavioral, physiological, and immunological functions, which are mobilized at different stressor levels to minimize adverse consequences (Hahn, 1999). Genetic diversity within a population can also influence level of response and degree of adaptability, so that what is stressful for some may not be stressful for others. Thermal stress can alter energetic efficiency of ruminants as evidenced by effects of cold stress on energy utilization by beef cattle (Delfino and Mathison, 1991). Mader and Davis (2004) reported alternative feeding regimens and sprinkling would be useful for decreasing susceptibility of cattle to hyperthermia. Other adverse environmental conditions (wind, precipitation, mud, humidity, etc.) can accentuate effects of thermal stress. Performance and mortality of feedlot cattle are heavily influenced by weather. Therefore, our objective was to identify and quantify impacts of selected climatic variables and photoperiod on feed intake of beef bulls during feedlot performance tests.

Experimental Procedures

Animal Testing Procedures. Detailed descriptions of the testing procedures, space allotments, and feeding and weighing procedures are found in a companion report (Tabler, Jr. et al., 2005). Feed intake data originated from bulls in University of Arkansas Cooperative Bull Tests at Fayetteville (one test per year; average start date: Nov 19), Hope (two tests per year; average start dates: Aug 18 and Feb 3), and Monticello (one test per year; average start date: Nov 5). A total mixed ration prepared commercially from the same formula (Tabler, et al., 2005) which analyzed weather data during 4-h windows immediately prior to morning and afternoon feeding periods. Three product terms were created and considered; Temp x RelH, DewP x RelH, and Temp x DewP. Feed intake data were over a 24-h period as opposed to a companion study (Tabler, et al., 2005) which analyzed weather data during 4-h windows immediately prior to morning and afternoon feeding periods. Three product terms were created and considered; Temp x RelH, DewP x RelH, and Temp x DewP.
Temp x Spd; and Temp x Rainfall. All variables were standardized to a mean zero and a variance of one and product terms were calculated from the standardized variables before the principal components were determined.

The number of principal components to include in the feed intake regression model was determined using the principal components regression (PCR) method within the partial least squares (PLS) procedure of SAS and the split-sample cross-validation procedure with every twentieth animal removed (van der Voet, 1994). Keep in mind principal components deal with variation among only the independent variables (in this case weather-related variables). Principal components are not a measure of effect on the dependent variable (feed intake). Each principal component was interpreted by considering only those variables whose coefficients were sufficiently large in magnitude relative to the largest absolute value of all coefficients in that principal component. All interpreted coefficients had a magnitude of at least 0.35.

The PRINCOMP procedure of SAS was used to generate eigenvalues and the percent variability among the independent variables explained by each principal component and the coefficients for each independent variable within each principal component. Finally, standard regression techniques using PROC REG procedures indicated which principal components within each period were significant with regards to the dependent variable (feed intake).

Regression. Since the weather variables tended to be highly collinear, regression of feed intake on them would be problematic. To avoid these issues, principal components were calculated from the standardized original variables and selected product terms. Feed intake was then regressed on a subset of the principal component values for each animal using standard regression techniques. For each 28-day period, the regression model is given by

$$Y_{ij} = \beta_0 + \beta_1 PC_{1ij} + \ldots + \beta_k PC_{kij} + e_{ij},$$

where j = number of trials, ij = number of animals in trial j, k is the number of principal components for the period, $Y_{ij}$ = feed intake for animal i from trial j, $PC_{kij}$ = the value of the kth principal component for the (i,j)th animal/trial combination, and $e_{ij}$ = random error associated with the (i,j)th animal.

Results and Discussion

Regressions of feed intake on principal components during periods 1 through 5 are presented in the right half of Tables 2 through 6, respectively. The left half of Tables 2 through 6 is not a measure of the effect on the dependent variable (feed intake), but instead, deals strictly with principal components, independent variables associated with those principal components, and the variation among those independent variables explained by each principal component. Considering the individual variables associated with each PC, initial weight and age were the most important variables in four of the five periods and had a strong effect ($P < 0.001$) on feed intake throughout the feeding trial. Temperature ranked above initial weight and initial age in importance during period 3 (Table 4).

Following closely behind weight and age in importance was a group of temperature-related variables that affected ($P < 0.001$) feed intake in four of five periods. Of this group, Temp was most important during the first four periods on trial while BP was most important during period 5. Principal component 1, which explained the greatest percentage of the variation in explanatory variables and was a temperature-related PC during each period, did not affect ($P = 0.359$) intake during period 1. Instead, a Temp x RelH interaction ranked second to weight and age during period 1 (Table 2). Even though temperature comes to mind first when environment is considered and temperature is the most thoroughly investigated environmental variable, environmental effects on beef cattle encompass more than temperature effects.

Wind speed, either alone or as a Temp x Spd interaction, followed temperature in importance affecting ($P < 0.001$) intake during periods 1, 2, 3, and 5 (Tables 2, 3, 4, and 6, respectively). A Temp x Spd interaction also appeared in PC12 during period 4 (Table 5) that affected ($P < 0.001$) intake along with Dlength although Dlength likely had the stronger influence based on coefficient magnitude. The effect of wind speed, temperature, and initial weight and age were fairly consistent across the entire feeding trial. Several remaining variables demonstrated a more random influence on intake at various times during the trial. For example, Rainfall and a Temp x Rainfall interaction followed wind speed in importance in periods 2 and 3; however, PC2 during period 2 did not affect ($P = 0.776$) intake while PC9 during period 3 did affect ($P < 0.001$) intake (Tables 3 and 4).

Several PCs representing a host of additional climate factors that explained only a small portion of variability had a strong influence on intake in each period. For example, PCs with barometric pressure (BP) as the dominant variable never explained more than 5.15% of variability (PC6 in Table 3); yet, BP-associated PCs had a strong effect on intake in period 1 ($P = 0.046$) and periods 2, 4, and 5 ($P < 0.001$). The BP PC did not affect ($P = 0.164$) feed intake in period 3. Additionally, Dlength was the major variable in PC12 in periods 2, 3, and 4 (Tables 3, 4, and 5, respectively). Even though PC12 explained only a small portion of the variability in each of those periods, it had a strong effect ($P < 0.001$) on feed intake. Similar patterns for other variables and interactions are evident throughout Tables 2 through 6.

Two to four PCs did not affect ($P > 0.10$) feed intake during the first four periods (Tables 2 through 5). All nine PCs during period 5 affected intake, PC8 ($P = 0.031$) and the remaining PCs ($P < 0.001$; Table 6). The R-squares for periods 1 through 5 were 0.43, 0.54, 0.51, 0.45 and 0.34, respectively.

Cattle are fed in a dynamic, outside environment, thereby increasing managerial challenges. It takes weeks for an animal to elevate its resting-heat production with the onset of winter, and weeks, whether cold or not, for it to subside at the end of winter. This means that energy that could go for performance is used to acclimate resting heat to the changing environment. The swine and poultry industries have, in large part, avoided the problem of outside environment by moving most commercial production inside. However, this solution is unlikely to occur in the cattle feeding industry anytime in the foreseeable future. Therefore, increased attention should be devoted to a better understanding of the complexities of the outside environment and weather-related components that make up that environment. This, in turn, would allow for increasingly accurate recommendations and improved modifications to feeding and management programs.

Implications

Results suggest feed intake of performance-tested beef cattle is influenced by a variety of climate variables throughout a feeding period. Climate and cattle constantly change making for challenging research. Yet, additional research is needed on individual climatic and photoperiodic variables to better understand overall weather-related effects on feed intake patterns.
Table 2. Regression of feed intake on principal components during first period on trial using 24-h weather variables.

<table>
<thead>
<tr>
<th>Principal components</th>
<th>Regression analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation among independent variables explained by each PC (%)</td>
<td>Parameter estimate</td>
</tr>
<tr>
<td>PC1 46.63</td>
<td>+Temp; +DewP; +Min; +Daylength; +Max</td>
</tr>
<tr>
<td>PC2 11.95</td>
<td>-RelH; -Rainfall</td>
</tr>
<tr>
<td>PC3 10.00</td>
<td>+Age; +Weight</td>
</tr>
<tr>
<td>PC4 9.21</td>
<td>+Temp x RelH</td>
</tr>
<tr>
<td>PC5 6.04</td>
<td>+Temp x Spd; +Rainfall; RelH</td>
</tr>
<tr>
<td>PC6 5.15</td>
<td>+BP</td>
</tr>
<tr>
<td>PC7 4.19</td>
<td>-Age; +Weight</td>
</tr>
<tr>
<td>PC8 3.86</td>
<td>+Temp x Spd; -Spd; -Temp x RelH</td>
</tr>
<tr>
<td>PC9 2.77</td>
<td>+Spd; +Temp x Rainfall; RelH</td>
</tr>
<tr>
<td>PC10 1.26</td>
<td>-Temp x Rainfall; +Temp x Spd; +Temp x RelH</td>
</tr>
</tbody>
</table>

Variables ranked based on coefficient magnitude.
### Table 4. Regression of feed intake on principal components during third period on trial using 24-h weather variables.

<table>
<thead>
<tr>
<th>PC</th>
<th>Variation among independent variables explained by each PC (%)</th>
<th>Variables</th>
<th>Parameter estimate</th>
<th>t-value</th>
<th>t-value rank</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
<td>39.12 +Temp; +DewP; +Max; +Dlength; +Min</td>
<td></td>
<td>20.54</td>
<td>27.48</td>
<td>2</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC2</td>
<td>12.64 +Temp x Rainfall; +Rainfall; +Temp x RelH</td>
<td></td>
<td>0.37</td>
<td>0.28</td>
<td>14</td>
<td>0.776</td>
</tr>
<tr>
<td>PC3</td>
<td>10.39 +Temp x Spd; +Spd</td>
<td></td>
<td>26.52</td>
<td>18.19</td>
<td>3</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC4</td>
<td>8.63 +Weight; +Age</td>
<td></td>
<td>44.30</td>
<td>27.72</td>
<td>1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC5</td>
<td>7.89 +Spd; +Temp x RelH</td>
<td></td>
<td>4.23</td>
<td>2.51</td>
<td>11</td>
<td>0.012</td>
</tr>
<tr>
<td>PC6</td>
<td>5.39 +Temp x Spd; +Rainfall; +Temp x Rainfall</td>
<td></td>
<td>-11.29</td>
<td>-5.56</td>
<td>8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC7</td>
<td>4.44 +BP</td>
<td></td>
<td>14.70</td>
<td>6.59</td>
<td>6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC8</td>
<td>3.88 +Age; +Weight</td>
<td></td>
<td>-16.58</td>
<td>-6.98</td>
<td>5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC9</td>
<td>3.01 +Rainfall; -Temp x RelH</td>
<td></td>
<td>3.09</td>
<td>1.14</td>
<td>13</td>
<td>0.296</td>
</tr>
<tr>
<td>PC10</td>
<td>2.40 +BP; +ReH; -Spd; -Rainfall</td>
<td></td>
<td>4.20</td>
<td>1.39</td>
<td>12</td>
<td>0.165</td>
</tr>
<tr>
<td>PC11</td>
<td>1.23 -Min; +Dlength</td>
<td></td>
<td>15.86</td>
<td>3.76</td>
<td>9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC12</td>
<td>0.76 +Dlength; -Max</td>
<td></td>
<td>50.69</td>
<td>9.53</td>
<td>4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC13</td>
<td>0.39 +Temp; -DewP; +Max; +Dlength</td>
<td></td>
<td>19.51</td>
<td>2.61</td>
<td>10</td>
<td>0.009</td>
</tr>
<tr>
<td>PC14</td>
<td>0.00 +Temp; -DewP</td>
<td></td>
<td>1096.44</td>
<td>6.41</td>
<td>7</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Variables ranked based on coefficient magnitude.

### Table 5. Regression of feed intake on principal components during fourth period on trial using 24-h weather variables.

<table>
<thead>
<tr>
<th>PC</th>
<th>Variation among independent variables explained by each PC (%)</th>
<th>Variables</th>
<th>Parameter estimate</th>
<th>t-value</th>
<th>t-value rank</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
<td>38.97 +Temp; +DewP; +Max; +Dlength</td>
<td></td>
<td>27.06</td>
<td>31.77</td>
<td>1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC2</td>
<td>12.14 +Temp x Rainfall; +Rainfall; +Temp x Spd</td>
<td></td>
<td>0.88</td>
<td>0.57</td>
<td>12</td>
<td>0.567</td>
</tr>
<tr>
<td>PC3</td>
<td>10.23 +Temp x RelH; +Rainfall; +ReH</td>
<td></td>
<td>-5.17</td>
<td>-3.15</td>
<td>8</td>
<td>0.002</td>
</tr>
<tr>
<td>PC4</td>
<td>9.50 +Weight; +Age; -Spd</td>
<td></td>
<td>37.92</td>
<td>21.66</td>
<td>2</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC5</td>
<td>6.32 +Spd; -Temp x Spd; +Weight</td>
<td></td>
<td>28.38</td>
<td>15.48</td>
<td>3</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC6</td>
<td>5.89 +Spd; +Temp x Spd; +Temp x RelH</td>
<td></td>
<td>1.91</td>
<td>0.96</td>
<td>11</td>
<td>0.339</td>
</tr>
<tr>
<td>PC7</td>
<td>5.20 +ReH; +Age</td>
<td></td>
<td>-5.47</td>
<td>-2.39</td>
<td>9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC8</td>
<td>3.67 +Age; -Temp x Rainfall; +Temp x Spd</td>
<td></td>
<td>-11.83</td>
<td>-4.34</td>
<td>7</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC9</td>
<td>2.88 -Rainfall; +Temp x Rainfall; -Temp x RelH</td>
<td></td>
<td>24.40</td>
<td>7.82</td>
<td>4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC10</td>
<td>1.99 +BP; -Temp x ReH; +Min</td>
<td></td>
<td>5.17</td>
<td>1.39</td>
<td>10</td>
<td>0.164</td>
</tr>
<tr>
<td>PC11</td>
<td>1.47 +Max; -Min</td>
<td></td>
<td>0.81</td>
<td>0.19</td>
<td>13</td>
<td>0.851</td>
</tr>
<tr>
<td>PC12</td>
<td>1.10 +Dlength; -Min</td>
<td></td>
<td>28.42</td>
<td>7.51</td>
<td>6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC13</td>
<td>0.64 +Max; +Dlength; -Temp; -DewP</td>
<td></td>
<td>-49.97</td>
<td>-7.83</td>
<td>5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC14</td>
<td>0.00 +Temp; -DewP</td>
<td></td>
<td>1151.56</td>
<td>7.54</td>
<td>7</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Variables ranked based on coefficient magnitude.

### Table 6. Regression of feed intake on principal components during fifth period on trial using 24-h weather variables.

<table>
<thead>
<tr>
<th>PC</th>
<th>Variation among independent variables explained by each PC (%)</th>
<th>Variables</th>
<th>Parameter estimate</th>
<th>t-value</th>
<th>t-value rank</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
<td>38.97 +BP; +Temp; +Min; +Dlength</td>
<td></td>
<td>19.47</td>
<td>22.38</td>
<td>2</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC2</td>
<td>12.84 +Temp x Rainfall; +Rainfall; +Temp x Spd</td>
<td></td>
<td>-4.95</td>
<td>-3.18</td>
<td>11</td>
<td>0.002</td>
</tr>
<tr>
<td>PC3</td>
<td>12.06 +Age; +Weight; +BP; +Spd</td>
<td></td>
<td>21.46</td>
<td>12.16</td>
<td>3</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC4</td>
<td>10.09 +Rainfall; +ReH</td>
<td></td>
<td>41.01</td>
<td>23.05</td>
<td>1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC5</td>
<td>10.09 +Weight; -BP; +Spd</td>
<td></td>
<td>7.73</td>
<td>3.58</td>
<td>9</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC6</td>
<td>6.85 +Spd; +Temp x Spd; +Temp x RelH</td>
<td></td>
<td>-9.31</td>
<td>-4.16</td>
<td>8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC7</td>
<td>5.31 +Rainfall; -Temp x Rainfall; -ReH</td>
<td></td>
<td>3.37</td>
<td>1.43</td>
<td>13</td>
<td>0.153</td>
</tr>
<tr>
<td>PC8</td>
<td>4.02 -Age; -Weight</td>
<td></td>
<td>21.46</td>
<td>7.28</td>
<td>6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC9</td>
<td>3.02 +Max; +Temp x Rainfall; +Temp x Spd</td>
<td></td>
<td>-3.28</td>
<td>-1.05</td>
<td>14</td>
<td>0.295</td>
</tr>
<tr>
<td>PC10</td>
<td>2.21 +BP</td>
<td></td>
<td>32.94</td>
<td>8.77</td>
<td>5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC11</td>
<td>1.65 +Min; -Dlength</td>
<td></td>
<td>6.83</td>
<td>1.62</td>
<td>12</td>
<td>0.106</td>
</tr>
<tr>
<td>PC12</td>
<td>1.11 +Dlength; -Temp x Spd; -Max</td>
<td></td>
<td>-50.90</td>
<td>-9.88</td>
<td>4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC13</td>
<td>0.51 -Temp; -DewP; +Max; +Dlength</td>
<td></td>
<td>-24.66</td>
<td>-3.23</td>
<td>10</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PC14</td>
<td>0.00 +Temp; -DewP</td>
<td></td>
<td>1151.56</td>
<td>7.54</td>
<td>7</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Variables ranked based on coefficient magnitude.