Assessing Heat Stress Effects on Production Traits of Holsteins in a Temperate Region

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Temperature humidity index

- Climate change: extreme hot waves will be seen as a real threat
- Heat stress is influenced by the combination of ambient temperature ($T_{db}$), relative humidity ($RH$), solar radiation ($RAD$), wind speed ($WS$)
- Temperature humidity index (THI)  
  $TI_1 = (1.8 \times T_{db} + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T_{db} - 26)$
  NRC, 1971

  Å Developed in empirical model
  Å Ignore effects of environmental parameters (RAD & WS)
  Å Biological (rectal temperature, sweating) and cow specific differences (breed, production...) are also ignored
### New thermal indices

<table>
<thead>
<tr>
<th>Thermal Indices</th>
<th>$T_{db}$</th>
<th>RH</th>
<th>RAD</th>
<th>WS</th>
<th>Biological effects &amp; cow specific differences</th>
<th>Developed under range of $T_{db}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent Temperature Index (Baeta et al., 1987)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☺</td>
<td>16 to 41 °C</td>
</tr>
<tr>
<td>Environmental Stress Index (Moran et al., 2001)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☺</td>
<td>22 to 45 °C</td>
</tr>
<tr>
<td>Adjusted THI (Mader et al., 2006)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☻ ☻</td>
<td>17 to 36 °C</td>
</tr>
<tr>
<td>Heat Load Index (Gaughan et al., 2008)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☻ ☻</td>
<td>8 to 45 °C</td>
</tr>
<tr>
<td>Comprehensive Climate Index (Mader et al., 2010)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>☻ ☻ ☻</td>
<td>-30 to 45 °C</td>
</tr>
</tbody>
</table>
# New thermal indices

<table>
<thead>
<tr>
<th>Thermal Indices (TI)</th>
<th>T&lt;sub&gt;db&lt;/sub&gt;</th>
<th>RH</th>
<th>RAD</th>
<th>WS</th>
<th>Biological effects &amp; cow specificity differences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TI1: THI</strong> (NRC, 1971)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TI2: Adjusted THI</strong> (Mader et al., 2006)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>😊😊</td>
</tr>
<tr>
<td><strong>TI3: Heat Load Index</strong> (Gaughan et al., 2008)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>😊😊</td>
</tr>
<tr>
<td><strong>TI4: Equivalent temperature index</strong> (Baeta et al., 1987)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>😊</td>
</tr>
<tr>
<td><strong>TI5: Environmental Stress Index</strong> (Moran et al., 2001)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>😊😊</td>
</tr>
<tr>
<td><strong>TI6: Comprehensive Climate Index</strong> (Mader et al., 2010)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>😊😊😊</td>
</tr>
</tbody>
</table>

- **Temperature humidity indices**
- **Apparent temperature indices**
Objective

Evaluation of HS effects on production traits of Holsteins under a temperate environment using large field data and comprehensive TI indices as indicators of production traits losses
Data

- **Historical performance data (2000-2011)**
  - 230,192 TD milk, fat, and protein yields records
  - 23,963 cows
  - 604 herds

- **Historical hourly meteorological data (2000-2011)**
  - 14 Meteo stations
  - Tdb, RH, RAD, WS
Thermal indices

• THI indices

Å TI₁: THI  
(NRC, 1971)  
THI = (1.8 × T\text{db} + 32) − (0.55 − 0.0055 × RH) × (1.8 × T\text{db} − 26)

Å TI₂: Adjusted THI  
(Mader et al., 2006)  
THI\text{adj} = 4.51 + THI − (1.992 × WS) + (0.0068 × RAD)

Å TI₃: Heat Load Index  
(Gaughan et al., 2008)  
HLI = 8.62 + (0.38 × RH) + (1.55 × BG) − (0.5 × WS) + e^{(2.4−WS)} if BG> 25  
HLI = 10.66 + (0.28 × RH) + (1.3 × BG) − WS if BG<=25

• Apparent temperature indices

Å TI₄: Equivalent Temperature Index  
(Baeta et al., 1987)  
ETI = 27.88 − (0.45 × T\text{db}) + (0.010754 × T\text{db}^2) − (0.4905 × RH) + (0.00088 × RH^2)

Å TI₅: Environmental Stress Index  
(Moran et al., 2001)  
ESI = (0.63 × T\text{db}) − (0.03 × RH) + (0.02 × RAD) + 0.0045 × (T\text{db} × RH)− 0.073 × (0.1 + RAD)^{-1}

Å TI₆: Comprehensive Climate Index  
(Mader et al., 2010)  
CCI = RH\text{adj} + WS\text{adj} + RAD\text{adj}
Data

- Daily TI: average of hourly values over 24h
- The reference station was matched to each herd based on minimum distances (7.6 km)
- The mean of TI over the previous 3 days before each TD was designed as TI reference for the current TD
Thresholds identification:

- Random regression TD model (no effect of HS)
  \[ y = HTD + AGS + LS + \sum \phi a + \sum \phi p + \sum \phi h + e \]  
  Model 1

- Broken line regression model
  \[ y^* = y - (HTD + AGS + LS) \]
  \[ y^* = c + \varepsilon ; \quad \text{when } x \leq \text{THR} \]
  \[ y^* = a + \beta x + \varepsilon ; \quad \text{when } x > \text{THR} \]  
  Model 2
Production losses due to HS

1- Ability of TI to detect production losses
   RRTD model (with effect of HS)

\[ y = HTD + AGS + LS + \sum \phi \beta + \sum \phi_s a + \sum \phi_s p + \sum \phi_s h + e \]

2- Yearly production losses \( (y_{\text{loss}}) \)

\[ y_{\text{loss}} = \beta * \sum_{\text{day}=1}^{365} (TI_{\text{day}} - THR) \]

\( \beta \): rate of decline and THR: the specific threshold for each TI
A- Milk

Least square means (LSM) for daily milk yield using different THI indices

Thresholds

Milk yield (Kg/d)

Thermal index

THI1

THI2

THI3

0.164

0.152

0.123
Thresholds

1- Milk

2- Protein

LSM for daily 1) milk and 2) protein yields using different THI and Apparent temperature indices
Thresholds

3- Fat

- High temperature and heat load in the grazing period
- Reduction of forage intake
- Inadequate fiber levels in rations
## Thresholds

<table>
<thead>
<tr>
<th>Thermal Indices</th>
<th>THR</th>
<th>Other Studies</th>
<th>Rate of decline / unit of TI (β)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Milk (kg)</td>
</tr>
<tr>
<td><strong>TI₁</strong></td>
<td>62</td>
<td>69¹, 72², 78³, 80⁴ 60⁵</td>
<td>-0.164</td>
</tr>
<tr>
<td><strong>TI₂</strong></td>
<td>64</td>
<td></td>
<td>-0.152</td>
</tr>
<tr>
<td><strong>TI₃</strong></td>
<td>80</td>
<td></td>
<td>-0.123</td>
</tr>
<tr>
<td><strong>TI₄</strong></td>
<td>18</td>
<td></td>
<td>-0.146</td>
</tr>
<tr>
<td><strong>TI₅</strong></td>
<td>16</td>
<td></td>
<td>-0.109</td>
</tr>
<tr>
<td><strong>TI₆</strong></td>
<td>20</td>
<td></td>
<td>-0.154</td>
</tr>
</tbody>
</table>

¹ Bouraoui et al. (2002); ² Bohmanova et al. (2007); ³ Dikmen and Hansen (2009); ⁴ Bookum et al. (2011); ⁵ Brügemann et al. (2011)
Production losses

Yearly loss of milk during 2000-2011 (12-yr Average) and the year of 2003
Production losses

Yearly loss of milk, fat and protein during 2000-2011 and the year 2003
Conclusions

- Losses for production traits were confirmed
- The six TI identified lower heat stress thresholds compared to tropical, subtropical and Mediterranean regions
- $\text{TI}_2$ and $\text{TI}_6$ showed highest production losses
- Genetic variation of heat stress tolerance should be evaluated for the six TI
Aknowledgments

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Production data

Meteorological data
Thank you for your attention

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