It is warm outside today: How temperature affects dairy cows’ willingness to be on pasture

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**ABSTRACT**

The effect of Temperature Humidity Index (THI) on dairy cows’ willingness to be on pasture was examined. Information for 2 years regarding weather, milk production, and time for voluntarily passing a gate between the barn and pasture of cows milked with an automatic milking system was studied. When the THI exceeded 72 during the day, more cows spent time on pasture compared to when the THI was less than 72 (27.0% vs. 19.2% of cows on pasture, respectively). However, the time of day influenced the proportion of cows on pasture, and when the THI exceeded 72, more cows were on pasture at night and less during the afternoon compared to days when the THI was less than 72. In conclusion, even under Swedish conditions, THI might have an effect on cows’ behaviour. However, when the cows have free access to roughage and pasture, an increased THI does not affect milk production.

**INTRODUCTION**

When cattle are kept outside during the winter in Sweden, the management is regulated through the Swedish animal protection law regarding provision of shelter (Jordbruksdepartementet, 1988). This is, however, not the case during the summer season with mandatory grazing period of 4 months in the south, 3 months in the central region, and 2 months in the north. Even though previous research has shown that cows will use shade if provided and they will go inside during hot periods if allowed (Ketelaar-de Lauwere et al., 1999; Legrand et al., 2009), a clear recommendation regarding the provision of shade during the grazing season is constrained by the lack of knowledge concerning the level of heat stress dairy cattle are exposed to in a climate similar to the Swedish temperate climate. Research in the Netherlands has shown that cows milked with an automatic milking system (AMS) spent more time in the barn during warm weather conditions (Ketelaar-de Lauwere et al., 1999). These results indicate that even though dairy cows in northern Europe might not experience severe heat stress, they do experience some distress during the warm period, and if they do not have the opportunity to seek shelter from the heat, their welfare might be jeopardized.

Ambient temperature plays an important role in determining heat stress in dairy cattle, but it is the cows’ ability to reduce the body temperature that determines the level of heat stress. Cows can reduce their body temperature by sweat evaporation or an increased respiration rate, but on days with high air humidity, this ability is reduced. This means that on days with a low temperature but high air humidity, the heat stress experienced by the cow can be higher than on warmer days with low air humidity. In order to determine at which stage cows experience heat stress, the Temperature Humidity Index (THI) has historically been used. The THI calculates an index dependent on air temperature and humidity and the upper critical level for THI has historically been set as ≥72 (equated to 25°C and 50% humidity) at which point the milk production starts to decline due to heat stress (Igono et al., 1992; Armstrong, 1994; Ravagnolo et al., 2000; Kendall et al., 2006). However, there are indications that decline in milk production in high-yielding cows might occur already when the average THI is even lower (Bryant et al., 2007). The upper critical temperature for dairy cows in peak lactation have been found to be around 25°C (Berman et al., 1985); at this stage, the temperature starts to affect the cows’ ability to cope with the environment and it has also been shown that cows in peak lactation (days in milk (DIM) < 51) have a higher loss in production compared to cows in later lactation during
a warm period (Novak et al., 2009). Providing cows with shade reduces the body temperature compared to those without access to shade (Kendall et al., 2006; Tucker et al., 2008).

Dairy cows have been found to graze more during the night if provided with shade during warm days, as a response to a decreased grazing time during the day compared to those with no shade (Kendall et al., 2006). However, in total cows with or without shade graze an equal amount of time per day (Kendall et al., 2006; Tucker et al., 2008). Even though a high ambient temperature has been reported to reduce milk production and alter the composition (Hemsworth et al., 1995), the provision of shade in a temperate climate only affects the milk production and not the milk composition (Kendall et al., 2006).

The aim of this study was to examine if the weather conditions in a Scandinavian climate affect cows’, milked with an AMS, motivation to leave the barn and how the weather condition affects their diurnal rhythm, such as time spent on pasture and milk production.

**Methods**

The effect of THI (mean 60.2, min 32.5, and max 77.4) on dairy cows’ willingness to be on pasture was examined. Two years (2005 and 2007) of historical data from Kungsängens Research farm regarding milk production and time for passing a gate between the barn and pasture of dairy cows milked with an AMS were studied. In total, the production (average 25.9 kg milk/day) and behaviour data (passing a gate to exit or enter the barn) from lactation data of Swedish Red cows (year 1 = 76 cows, year 2 = 83 cows; 28 cows participated in both year 1 and 2; lactation 1–6) were analysed for time spent on pasture and daily milk production in relation to THI.

The barn was equipped with the DeLaval Voluntary Milking System (VMS™). The barn had a resting area with 56 cubicles (no of cows never more than no of cubicles), two identical feeding areas, and a collection area before one milking unit. Each feeding area had 10 separate feed troughs for roughage feeding and 1 concentrate feeder. Water troughs were placed both inside the barn and on the pasture. The cows had free access to pasture for 3 months (from June through August) and were not involved in any other studies that would inhibit their access to pasture during this period. Cows due to be milked had to pass the milking unit before they could reach the feeding area. From each feeding area, there was an exit gate out to a cow track going to the pasture area. The entrance to the barn was placed before, and the exit out to the pasture was placed after, the milking unit and selection gates. Thus, cows with milking permission that entered the barn could not leave the barn and return to the pasture without passing the milking unit to be milked. Each cow was identified with a transponder at milking, at selection gates, and at feed troughs and concentrate feeders. The time each cow passed the gate on her way out or in again from pasture was recorded by selection gates connected to a computer system. The cows could move freely between the barn and pasture, which were situated around the barn (between 50 and 260 m from the barn to the entrance of the pasture). The pastures were of mixed grass swards dominated mainly by Kentucky bluegrass (Poa pratensis) and meadow fescue (Festuca pratensis). The pastures did not have any shade (e.g. trees) for the cows. The cows had free access to roughage and were fed concentrate according to milk production in the barn. Weather data (shade temperature and humidity) were collected from a weather station 3 km from the barn. Based on these data, THI was calculated as follows:

\[
\text{THI} = (1.8 \times T + 32) - ((0.55 - 0.0055 \times \text{RH}) \times (1.8 \times T - 26))
\]

where \(T\) is the air temperature (°C) and \(\text{RH}\) the relative humidity (Tucker et al., 2008). Mean and maximum THI were calculated per calendar day. Mean and maximum THI and shade temperature data collected 2 days before were also used.

The cows had access to the AMS 24 hours a day and as a consequence of this, the number of milking events and milk production varies from day to day. In order to estimate the daily milk production, it was calculated as the sum of milk harvested from midnight to first milking, from first to last milking during a day, and from last milking to midnight; the first and last terms were estimated by linear interpolation using the last milking the day before and the first milking the day after, respectively, since this calculation model has been proven to give the best estimate of daily milk production from an AMS (Nielsen et al., 2010).

**Statistical method**

**Behaviour**

The proportion of cows on pasture at any given time obtained from the gates registering when a cow exited and entered the barn was analysed using a variance component analysis procedure in SAS® 9.1 (PROC MIXED) using the COVTEST option which produces asymptotic standard errors (computes the smallest possible standard error and assumes that misfit/noise is random) and Wald Z-tests for the covariance parameter estimates (Littell et al., 1996).
The solution option was used to compute parameter estimates for the fixed effects (Der & Everitt, 2002). Least-squares means of significant fixed effects were computed, and the PDIFF procedure was used to display the differences of the least square means by requesting the P-values (Littell et al., 1996).

The model for time spent on pasture included ‘maxTHI’ (1 = THI did not exceed 72 during the day; 2 = THI did exceed 72 during the day), ‘maxTHI’ × ‘time’ (time of day in hours), and ‘year’ (year 1 and year 2).

**Milk production**
The data from the milk production were analysed using the PROC MIXED procedure as described above. The model for milk production included ‘lactation number’ (1–6), ‘year’, and the ‘weather data’ (THI and max THI on the same day, one day before and two days before). The model included the interaction between cows and lactation number as both random and repeated effect. The repeated effect was regarded as a spatial power correlated structure.

**Results**

**Weather conditions**
Temperature and THI during the experimental periods are displayed in Table 1. Rainfall was not measured in this study.

**Behaviour**

**Time on pasture**
From the registration time for every cow exiting and entering the barn, it was calculated that on average the cows spent 453.8 ± 282.8 minutes (7 hours and 33 minutes) on pasture each day during the 2 years of data collection regardless of the weather condition. Figure 1 shows the average duration of each visit to pasture depending on when the cows left the barn regardless of the weather condition. The figure indicates that when the cows left the barn during the morning to late afternoon, they would spend longer time on pasture before returning to the barn compared to when they left the barn during the evening and night when they spent less time on pasture before returning to the barn.

**Proportion of cows on pasture**
On days when the THI was equal to or exceeded 72, at some stage more cows on average spent time on pasture than on days when the THI did not exceed 72 (Ismeans 27.0% ± 0.5% vs. 19.2% ± 2.8% of cows on pasture, respectively; $F_{1, 4398} = 8.04, P < .01$). Time of the day influenced the proportion of cows on pasture. Between 22:00 and 04:00 hours, more cows spent time on pasture on days when the THI was equal to or exceeded 72 at some stage during the day compared to days when the THI did not exceed 72. Furthermore, between 12:00 and 16:00 hours, less cows spent time on pasture when the THI was equal to or exceeded 72 at some stage during the day compared to days when the THI did not exceed 72 ($F_{1, 4398} = 39.8, P < .001$) (Figure 2). Year affected the proportion of cows on pasture, and in total the proportion of cows on pasture was higher in year 1 than in year 2 (Ismeans 23.8 ± 1.5% vs. 22.3 ± 1.5%, respectively; $F_{1, 4398} = 4.10, P < .05$).

Additionally to the results presented above, Figures 3 and 4 represent the proportion of cows being out on pasture at any given time during a cold day (THI did not exceed 60 at any time) and during a warm day (THI was above 70 between 08:00 and 21:00 hours), respectively. These figures clearly show that during days with cold weather conditions, the cows leave the barn in the morning and stay inside during the night, compared to days with warm weather conditions where the cows chose to stay inside until late in the afternoon and spent more time out on pasture during the night (Figures 3 and 4, respectively).

**Milk production**
Average milk yield for both years was 25.6 (SD 7.58) kg/day and no significant effect by THI or year at any time during the study was observed.

**Discussion**
Results from this experiment clearly show that cows have a preference to stay inside during days with high THI.

**Table 1. Temperature and THI during 3 months of the 2 years investigated.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Temperature (°C)</th>
<th>THI</th>
<th>THI &gt; 72</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>June</td>
<td>14.1</td>
<td>0.5–25.2</td>
<td>56.9</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>18.1</td>
<td>6.2–31.2</td>
<td>62.8</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>15.9</td>
<td>5.5–24.6</td>
<td>59.9</td>
</tr>
<tr>
<td>2</td>
<td>June</td>
<td>15.9</td>
<td>2.7–29.5</td>
<td>59.3</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>16.6</td>
<td>6.5–28.0</td>
<td>60.8</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>18.8</td>
<td>–0.4 to 28.2</td>
<td>61.2</td>
</tr>
</tbody>
</table>
Figure 1. The duration the cows spent outside on pasture depending on the time of the day when they left the barn. Mean value for all cows during the sampling period.

Weather conditions during the summer in northern Europe and even more so in Scandinavia do not reach the same high level of temperature as in southern Europe or tropical areas but still it seems that cows prefer (if having a choice) to stay indoors when the THI is high, findings also described by Legrand et al. (2009).

From the present study, it is not possible to make a clear conclusion regarding if dairy cows in Sweden are exposed to heat stress during the summer, based on a decrease in milk production, since the study does not include data on the body temperature or respiration rates of the cows. However, based on results from other studies examining heat stress in dairy cattle in more temperate climates (Kendall et al., 2006; Tucker et al., 2008) and the low increase in body temperature measured there, it can be assumed that due to the low THI at night, between 60 and 70 on the warmest day in the present study, cows will be able to lower their body temperature during the night and thereby potentially compensate for an increase in body temperature during the day. Legrand et al. (2009) noted in a study that cows producing 19.5–31.5 l milk/day choose to be indoors when THI was high and preferred to be outdoors at pasture during night time when it was cooler. This is similar to the results we observed in the present study, the cows spent more time inside during the day and more time outside during the night when the THI during the day was high (Figure 4). It is important to

Figure 2. Proportion of cows being out on pasture during the day on days when the THI did not exceed 72 (in total 165 days between 2005 and 2007) or on days when the THI was more than or equal to 72 at some stage during the day (in total 18 days between 2005 and 2007). The lsmeans and SE values are shown.
note that in most of the milk production systems with manual milking with grazing systems, cows cannot choose to go indoor during warm periods to seek shade. Cows are only indoor during the milking time and between milking they are out on pasture.

In the present study, the milk production during warm weather was maintained even though the THI exceeded 72 on several occasions, with the potential to have influenced the milk production negatively. Typically, milk yield decreases when cows are exposed to warm weather conditions (Kadzere et al., 2002), but since the cows in the present study had the possibility to stay or go inside during the warm period of the day and were offered silage and concentrate indoors, they could maintain a high energy intake and thus maintain the milk production, an effect that can also be accomplished with access to shade on pasture (Kendall et al., 2006). In a choice study, cows have been shown to choose to stay inside twice as often as to pasture right after milking, independent of the weather, if they are fed roughage ad libitum in the barn (Charlton et al., 2011). This is in contradiction to our study where the proportion of cows on pasture was as high as 60–80% after morning and afternoon milking on a day when the THI did not exceed 60 and 50–70% after afternoon milking on a day when the THI exceeded 72.

Our results for the present study with 2 years data were processed are similar to a previous behavioural study done at the same research station, where the majority of cows stayed out on pasture during the night, but during the dark part of the night (23:00–03:00 hours), no grazing was observed (Sporndly &
in contrast to these findings, in a study by Charlton et al. (2011) cows preferred to stay indoors during the night. as mentioned earlier, most dairy cows are kept in systems where they cannot choose between being indoors or outdoors. and if they are kept outdoors during daytime with no access to shade and the temperature is high, they will most likely reduce the grazing time due to a higher proportion of standing as mentioned above, consequently resulting in a reduced Dim from pasture (sporndly & wredle, 2004).

**Conclusion**

from this study, it can be concluded that under swedish weather conditions, the milk production from cows milked with AMS and with unlimited access to the barn/shade is not affected by THI within the range measured in this study. however, THI does affect their willingness to be on pasture during days with a high THI and it might be advisable to keep cows inside during the day on days with warm weather conditions if no shade is available out on pasture.

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**Disclosure statement**

No potential conflict of interest was reported by the authors.

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