Variation in and relationship among environmental condition and total locomotor activity in dairy cows

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INTRODUCTION

Behavior is one of the most important indicators for assessing cattle health and welfare. The cow comfort improves economically important responses in dairy cattle such as feed intake, milk production, reproduction and health. The environmental variation in air temperature, relative humidity and rainfall were recognized as the potential hazards which affect the animal’s biological system.

Aim - The aim of this study was to investigate the influence of environmental conditions (ambient temperature, relative humidity and temperature-humidity index) on the total locomotor activity (TLA) behavior in dairy cows.

Materials and methods - 18 Modicana cows (5-8 years, mean body weight 512±78 kg), selected from two different farms (A and B), were enrolled in the study. During experimental period, ambient temperature and relative humidity were recorded by means of a data logger and the temperature-humidity index (THI) was calculated as indicator of thermal comfort for cattle. Each animals were equipped with an activity monitoring data loggers (Actiwatch-Mini®) in order to record the daily TLA. The ambient temperature and THI recorded during the experimental periods were within the upper critical zone. Two-way repeated measure analysis of variance (ANOVA) a significant effect of season (P < 0.0001), whereas no effect of farm on the amount of TLA was found. A trigonometric statistical model was used to describe the main rhythmic parameters: mean level, amplitude, acrophase and robustness of rhythm. Our results showed a circadian rhythm of daily TLA in all periods, with different percentages of robustness, and acrophase in the photophase.

Conclusions - These results provide insight into the TLA responses of dairy cow to different environmental conditions, allowing to better evaluate its ability to adapt and cope with environmental stress. Major changes in TLA were found at the hottest environmental condition therefore suitable measures should be adopted in order to minimize environmental stress and to improve animal welfare.

KEY WORDS

Cows, environmental conditions, temperature-humidity index, total locomotor activity.
MATERIALS AND METHODS

Animals and farms
Eighteen Modicana cows (5-8 years, mean body weight 512±78 kg), selected from two farms located in Sicily, Italy, were used for this study. All the animals were clinically healthy and free from internal and external parasites. They were treated for endoparasites twice a year. Their health status was evaluated based on rectal temperature, heart rate, respiratory profile, appetite, fecal consistency and hematologic profile. No subject showed sign of diseases during the study. All the animals were kept under natural photoperiod and ambient temperature. In both farms the cows were kept in an improved natural pasture area of about 20 ha. The cows were divided into two equal groups on the basis of the farm of origin.

The cows of group A were obtained from a farm located in Sicily, Italy (36°42'38"N 14°47'15"E, 51 m above sea level). The pasture vegetation consists of an 67/33% grass-clover mixture (mainly Lolium perenne, Festuca rubra, Trifolium pratense and Trifolium repens). Hay (tricosecale 40%, barley 40%, oats 20%) and water were available ad libitum. The area is characterized by: minimum and maximum mean annual temperature between 15.2°C and 21.9°C, mean annual relative humidity of 67.64% and mean annual rainfall of 35.6 mm.

The cows of group B were obtained from a farm located in Sicily, Italy (37°34'09"N 14°15'50"E, 930 m above sea level). The pasture vegetation consists of an 72/28% grass-clover mixture (mainly Arrhenatherum elatius, Phleum pratense, Lolium perenne, Festuca rubra, Bellis perennis, Hypochoeris lutea, Trifolium pratense and Trifolium resupinatum). Water was available ad libitum. This area is characterized by: minimum and maximum mean annual temperature between 9.5°C and 16.1°C, mean annual relative humidity of 76.39% and mean annual rainfall of 29.64 mm.

All treatments, housing and animal care were carried out in accordance with the standards recommended by the EU Directive 2010/63/EU for animal experiments.

Environmental conditions
Environ mental conditions recorded during the experimental period are showed in Table 1. Thermal and hygrometric records were carried out throughout the study by means of a data logger with a high reading accuracy and resolution (Model Tinytag Ultra 2, Gemini Data Logger, West Sussex, United Kingdom) placed inside the stanchion barn. Temperature-humidity index (THI), used as indicator of thermal comfort for cattle, was calculated using the U.S. Weather Bureau’s Temperature Humidity Index Formula for bovine specie10:

\[ \text{THI} = T°_{\text{ambient}} + (0.36 \times \text{point of steam condensation}) + 41.5 \]

Locomotor activity recording
In the present study, TLA of dairy cattle, which includes different behaviors, such as feeding, drinking, walking, grooming, ruminating as well as all conscious and unconscious movements was recorded. TLA was recorded at 4 period points of three consecutive days under differing environmental conditions: T1 (summer solstice), T2 (autumnal equinox), T3 (winter solstice) and T4 (vernal equinox). In order to record locomotor activity, all animals were equipped with Actiwatch-Mini® (Cambridge Neurotechnology Ltd., UK), actigraphy-based data loggers that record a digitally integrated measure of motor activity. This activity acquisition system is based on miniaturized accelerometer technologies and has been validated for automatic 24 h recording of activity in dairy cows11. The data loggers were mounted on headstalls that were accepted without any apparent disturbance. Actiwatch-Mini® utilizes a piezo-electric accelerometer that is set up to record the integration of intensity, amount and duration of movement in all directions. This type of sensor integrates the degree and speed of motion and produces an electrical current that varies in magnitude. An increased degree of speed and motion produces an increase in voltage. The corresponding voltage produced is converted and stored as an activity count in the memory unit of the Actiwatch-Mini®. Activity count is a generic term used to denote the amplitude of the signal produced by the accelerometer in the Actiwatch. The number of counts is proportional to the intensity of the movement. The electronics in the watch checks or samples the amplitude 32 times per second and it captures the highest amplitude in that second. This represents the peak intensity of the movement in that second. In the Actiwatch, the amplitude of each step can have a value between -128 and +128. These values are referred to as “counts”. The greater the number of counts, the higher the acceleration in the period represented by a particular step. It is important to stress that due to this improved way of recording activity data there is no need for sensitivity setting as the Actiwatch unit records all movement over 0.05 g.

Table 1 - Values of environmental temperature and relative humidity recorded during experimental periods (T1-T4) in both groups (A and B).

<table>
<thead>
<tr>
<th>Experimental Periods</th>
<th>Groups</th>
<th>Sunrise Time</th>
<th>Sunset Time</th>
<th>Environmental Temperature (°C)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>T1</td>
<td>A</td>
<td>05:10</td>
<td>20:54</td>
<td>16.0</td>
<td>28.9</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>05:10</td>
<td>20:58</td>
<td>15.4</td>
<td>25.2</td>
</tr>
<tr>
<td>T2</td>
<td>A</td>
<td>06:22</td>
<td>19:24</td>
<td>14.4</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>06:24</td>
<td>19:26</td>
<td>14.9</td>
<td>26.0</td>
</tr>
<tr>
<td>T3</td>
<td>A</td>
<td>06:41</td>
<td>17:16</td>
<td>4.5</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>06:44</td>
<td>17:17</td>
<td>6.5</td>
<td>11.0</td>
</tr>
<tr>
<td>T4</td>
<td>A</td>
<td>05:41</td>
<td>18:37</td>
<td>6.8</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>05:42</td>
<td>18:39</td>
<td>5.8</td>
<td>11.9</td>
</tr>
</tbody>
</table>

Statistical analysis
Two-way repeated measure ANOVA was used to assess the effect of season and of farm on TLA. P values < 0.05 were considered statistically significant. The data were analysed using the software STATISTICA 7 (StatSoft Inc.). In addition, a trigonometric statistical
model was applied to the mean values of each time series (the data points in a data set refer to successive observations made over time), so as to describe the periodic phenomenon analytically, by characterising the main rhythmic parameters according to the single cosinor procedure. Four rhythmic parameters were determined: mean level, amplitude (the difference between the peak, or trough, and the mean value of a wave), acrophase (the time at which the peak of a rhythm occurs), and robustness (stationarity of rhythmicity). The mean level of each rhythm was computed as the arithmetic mean of all values in the data set, the amplitude of a rhythm was calculated as half the range of oscillation, which in its turn was computed as the difference between peak and trough. Rhythm robustness was computed as a percentage of the maximal score attained by the chi-square periodogram statistic for ideal data sets of comparable size and 24 h periodicity. Robustness greater than 14% is above noise level and indicates statistically significant rhythmicity.

RESULTS

All the results were expressed as mean ± standard deviation (SD). The ambient temperature, relative humidity and THI observed during the four experimental periods (T1-T4) are shown in Figure 1. Data were normally distributed (P > 0.05, Kolmogorov-Smirnov test). The visual inspection of the actograms shows that the main TLA is concentrated almost exclusively during the photophase, with several activity episodes during the scotophase characterized by lower intensity and shorter duration than during the photophase. ANOVA revealed a significant effect of season (P < 0.0001) whereas no effect of farm on the amount of TLA was found. The application of the periodic model and statistical analysis of the cosinor enabled us to define the periodic parameters. Daily rhythmicity of TLA was observed in all studied periods in both groups. The acrophase occurred in the middle of the photophase in all periods in both groups (Figures 2 and 3). In particular, acrophase was observed between 13.43 and 16.66 during T1, between 13.01 and 16.27 during T2, between 10.53 and 11.30 during T3 and between 13.89 and 17.21 during T4. The amplitude of the rhythm statistically changed among the experimental period and was statistically lower at T2 and T3 respect to T1 (Figures 2 and 3). The robustness of the rhythm was not influenced by experimental periods (Figures 2 and 3).

DISCUSSION

The results of the present study confirmed that the TLA is influenced by environmental conditions. The ambient temperature and THI recorded during the experimental periods were within the upper critical zone (Figure 1). The thermo-neutral zone for a cow is between 5°C and 25°C. As ambient temperature increases, it becomes more difficult for a cow to cool herself adequately and enters heat stress. THI values of 70 or less are considered comfortable, 75–78 stressful, and values greater than 78 cause extreme distress with lactating cows being unable to maintain thermoregulatory mechani-
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The higher levels of TLA registered at T1 and T4 respect to T2 and T3, may be related to thermoregulatory behavior to cool the body in hot seasons. These data agree with the results of previous studies carried out on cattle during different seasons. These fluctuations during experimental periods can be attributed to a decrease in lying time following an increase of temperature and humidity values. Cows may stand in response to heat to maximize the surface area exposed to the environment, thus increasing the airflow around the body, whereas, in winter, spent more time lying down. Our results showed a diurnal daily rhythm of locomotor activity in all periods investigated. As previously observed, this study confirms that TLA exhibits a robust daily rhythmicity during the photophase in cows, therefore in this specie the daily rhythm can be poorly affected by external stimuli. Cattle have a marked diurnal behavior pattern, therefore grazing in cattle is adjusted to sunlight. Food has been considered a principal Zeitgeber for peripheral clocks in various mammalian species. Changes in the circadian pattern of eating and time spent eating are the behavioral response of the animal to the amount of food availability. Our results showed that acrophase statistically significant changed among the studied periods in both groups. Under free range conditions the periodicity of feeding is influenced by day-length and climatic conditions, and so resting is fixed by the same factors.

In conclusion, environmental conditions are related to cow behavior in terms of total locomotor activity. Our results indicate that in dairy cows subjected to different environmental conditions, most activity is concentrated in the photophase. These results provide insight into the TLA responses of dairy cow to different environmental conditions, allowing to better evaluate its ability to adapt and cope with environmental stress. Major changes in TLA were found at the hottest environmental condition therefore suitable measures should be adopted in order to minimize environmental stress and to improve animal welfare.

References


Figure 3 - Mean values (±SD) of four rhythmic parameters (robustness, amplitude, mesor and acrophase) observed during the experimental period (T1 - summer solstice, T2 - autumnal equinox, T3 - winter solstice and T4 - vernal equinox) in Group B.