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THE EFFECT OF HEAT STRESS ON TIME SPENT LYING BY COWS IN A HOUSING SYSTEM*

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Abstract

Dairy cows are exposed to heat stress, the risk of which is increasing due to climate change. This could result in significant changes in the cows' lying time behaviour. The presented study shows the relationship between heat stress determined with the use of the Temperature Humidity Index (THI) and the daily lying time of 40 Holstein-Friesian dairy cows. Based on the calculated value of THI, two periods were specified, a neutral period (with a maximum daily THI value below 68) and warm period (with minimal daily THI value above 73). The obtained results were processed using analysis of the Spearman's correlation coefficient with significance at P<0.05. The results showed a decrease in daily total lying time between the neutral and warm periods from 11.3 to 9.4 h/d. During the warm period, the correlation between cows' lying time and increased THI shows that the relationship is significant inversely proportional, but in the neutral period that correlation was not significant. A decrease in the percentage of the lying cows and average lying time per hour was also noticeable between the daytime and night-time in warm periods, which was 2 times less than in the neutral period.

Key words: dairy cow, behaviour, THI, lying time, free stall barn

The problem of heat stress is associated with high air temperatures in conjunction with high relative humidity in the barn microclimate (Hill and Wall, 2015; Herbut et al., 2015). The high productivity of dairy cows contributes to the production of large amounts of metabolic heat that must be discharged from the cows' bodies. Above the thermally neutral zone, the animal can radiate body heat mainly through increased respiration rate, panting, drinking, sweating as well as reduced feed intake, milk yield and reproductive performance (Kadzere et al., 2002). Behavioural coping strategies include increased standing time, shade seeking, and decreased activity and

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movement (De Rensis and Scaramuzzi, 2003; Schutz et al., 2009). At higher air temperatures, however, the adaptive mechanisms of the cows fail to remove the excess heat generated (Gantner et al., 2011). Any deterioration of microclimate conditions in the barn creates significant changes in the above-mentioned characteristics (De Palo et al., 2006).

Dairy cattle kept in a free-stall system spend their entire lives in a barn, so a breeder should provide everything (i.e. the system of their maintenance, feeding, milking and the microclimate conditions in the barn) that is optimal for their welfare (Gaworski and Rocha, 2016; Hempel et al., 2016; Adamczyk et al., 2017). Suitable temperature and humidity conditions are particularly important because they affect the cows' rest conditions, their behaviour, hormonal and metabolic changes, and milk production (Horky, 2014; Herbut and Angrecka, 2018). One of the behavioural characteristics which is an indicator of the cows' physiological and health state is the length of their lying time (Tolkamp et al., 2010). As the cows spend from 8 to 16 h per day in a lying position (Tucker et al., 2003; Endres and Barberg, 2007; Radoń et al., 2014), the optimisation of their undisturbed lying time is very important for their health. It helps to avoid hoof diseases, lameness, and also helps to increase their feed consumption and rumination activity (De Palo et al., 2006; Grant, 2006). On commercial farms, lying time can be used as a measure of a cow's welfare (Vasseur et al., 2012). This is particularly important in the case of heat stress, which causes a reduction in lying time (Anderson et al., 2013).

The presented study aimed to determine the relationship between heat stress and dairy cows' lying time during the summer with special regard to daytime and nighttime. Summer time was divided into a neutral (N) and warm (W) period.

Material and methods

Barn structures

The study was conducted during the three summer months of June–August in 2013 in a free-stall barn in southern Poland in a typical mild climate. The barn ventilation was provided by a ridge vent as air exhaust, and air supply was in the form of longitudinal curtain walls.

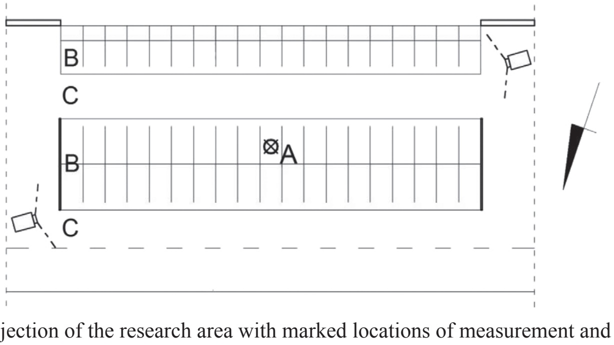

Figure 1. Projection of the research area with marked locations of measurement and observation cameras; A – measurement station, B – cubicles, C – manure alley

The separated area of 13.75×30.0 m housed 55 cubicles (120×250 cm), two manure alleys and a feeding alley, in which the cows were kept during feeding (Figure 1). All the cubicles were bedded with 15 cm-long cut straw (4 kg of straw per cow daily). The average straw thickness in the box area was 12 cm. The manure and feeding alley floors were made of grooved concrete. The manure was removed mechanically from the manure alleys once a day during morning milking.

Cows and feeding management

Forty Holstein-Friesian cows, with a mean daily milk production of 21.6 kg (SE1.7), were kept in a selected part of the barn (stocking density 10.31 m^2/cow). All the cows during the research period were between the 50th and 150th d of lactation and had similar body dimensions. The experiment was designed in such a way that the cows, in order to ensure a free choice, had more cubicles than the size of the group. During the research the cows were covered by zootechnical and veterinary care.

The feeds were administered as TMR at 9:00 a.m. and consisted of a mixture of corn silage, alfalfa and grass hay, dehydrated alfalfa, concentrate and mineral and energy components. Feeding was allowed throughout the 24-h period, except during milking. The cows were milked twice a day: at 7:00 a.m and 5:00 p.m.

Measurements of environmental conditions

The temperature and relative humidity were measured by an LB-710 sensor (Label, Reguły, Poland) with a measuring range for temperatures from –40 to +85°C and relative humidity from 0 to 99.9%. The air flow velocity was measured by an HD 103T sensor (Delta Ohm, Padua, Italy) with a measuring range of 0–5 m/s. The sensors were placed in the zone occupied by the cows 1 m above the floor in selected cubicles. The solar radiation values were measured by an LP Pyra 03 pyrometer (Delta Ohm, Padua, Italy). All the measurement results were recorded automatically every 6 minutes.

Based on the obtained results of the microclimate parameters measurements, the calculations of the THI value were made according to the formula (Mader et al., 2006):

$$THI = 4.51 + THI_{NRC} - (1.992 \cdot V) + (0.0068 \cdot RAD)$$

where:

THI_{NRC} – Temperature Humidity Index calculated based on the National Research Council formula (1971): $THI_{NRC} = (1.8 \times T_{db} + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T_{db} - 26)$, T_{db} – dry bulb air temperature, °C, RH – relative air humidity, %, V – air velocity, m/s, RAD – intensity of solar radiation, W/m^2.

Based on the calculated value of THI, periods that met the criterion neutral (with maximum daily THI value below 68) or warm (with minimal daily THI value above 73) were selected. Neutral periods were required to be preceded by at least 3 days with similar conditions, and warm periods of at least 3 days with a mean daily THI of less than 72. The selected periods were used to calculate reliable N – neutral and

W – warm test periods. Analysis of the research period was divided also into daytime (between morning and afternoon milking on the same day – 8:00 a.m to 4:00 p.m) and night-time (between afternoon and morning milking on the next day – 6:00 p.m to 6:00 a.m.).

Every behavioural event was associated with an average: THIavh (average hourly THI), and THIavd (average daily THI) value in the period in which the event occurred.

Measurements of lying time

In order to determine the lying time of the tested group of cows, a system of cameras equipped with infrared motion detection that allowed filming and taking of pictures was installed. The following data were collected over 90 consecutive days of video data:

– total lying time per day (LTD),
– average lying time per hour (LTH),
– percentage of cows lying down (LC).

The percentage of cows lying down was determined as the number of cows lying in relation to the total number of cows. Cows lying down means that at least the hind part of the animal's body was lowered down. It was assumed that when cows did not spend time lying that they spent time standing.

Statistical analysis

The LTD and LC with corresponding THI, with special regard to daytime and night-time, was processed using analysis of the Spearman's correlation coefficient (r) in the Statistica program (Version 12.0, 2013). The Student's t-test was used to estimate the statistical significance of the obtained values. Data were considered significant at $P<0.05$.

Results

Barn environmental conditions

Out of all the 81,600 obtained measurements, repeatable and representative periods N and W were chosen for the presentation of the results (Figure 2). The average THI values for each of the periods in the time of the three research months are presented in Table 1.

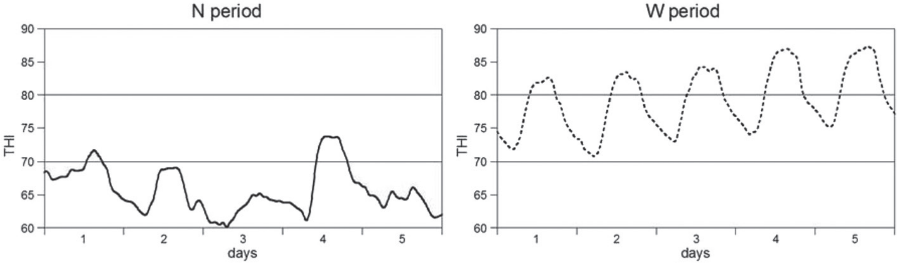

Figure 2. Charts of THI values in N and W periods

Table 1. Average THI values for N and W periods

Average THI	Period	
	N (SE)	W (SE)
Whole period	66 (3.4)	79 (4.7)
Night-time hours	65 (1.2)	77 (3.5)
Daytime hours	67 (1.7)	83 (2.5)

Lying down behaviour

It was found that LTD in the N was 11.3 h (SE 0.8). In the W period, a significant drop in LTD was noted and amounted to ca. 9.4 h (SE 0.6) (Figure 3). As calculated for the W period, the correlation shows that the relationship is inversely proportional with r = –0.94 (P<0.05), and in the N period the correlation was not significant (P<0.09).

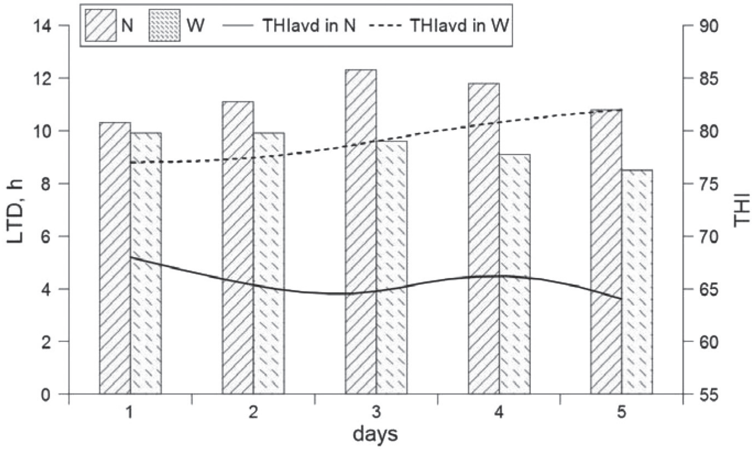

Figure 3. LTD (daily lying time) of the cow with respect to the THIavd (average daily THI) in N and W period

During the N period in the night-time hours, more of the cows were lying down than in the daytime hours (Table 2). Most cows (52.7%) were lying at 8:00 a.m. and the fewest at ca. 10:00 a.m. The increase in LC was usually visible at 3:00 p.m. when 52.3% of the group was lying (Figure 4). In the N period, no significant correlation was revealed between THI and LC (P<0.11).

Table 2. Average values of LC and LTH in each day's periods

Parameter	Time period			
	N		W	
	night (SE)	day (SE)	night (SE)	day (SE)
LC (%)	44.3 (3.1)	42.1 (2.5)	38.0 (3.7)	33.2 (2.1)
LTH (min)	27.0 (1.6)	25.0 (1.9)	22.0 (1.8)	20.0 (2.1)

The W period, in comparison to the aforementioned period, had smaller LC both at night-time and in the daytime. Between the periods of N and W, the difference in LC is noticeable – on average, the W period was lower by 6.3% during the night-time and 8.9% during the daytime. The difference in daily LC was lower in the N period by 14.4%. The difference between the mean LC during night-time and daytime in the N period was only 3.5%, and in the W period 11.6% (Table 2). During the afternoon hours, no increase in LC was observed and the average was 28.2% (Figure 4). The analysis of LC divided into night-time and daytime showed a strong correlation with the change in THI value, both at night (r = –0.63; P<0.01) and during the day (r = –0.70; P<0.03).

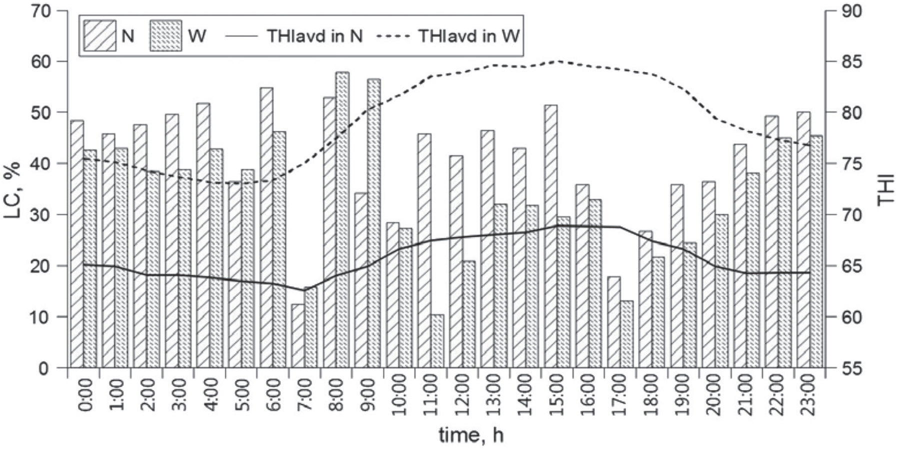

Figure 4. LC (lying cows) with respect to THIavh (average hourly THI) in N and W period

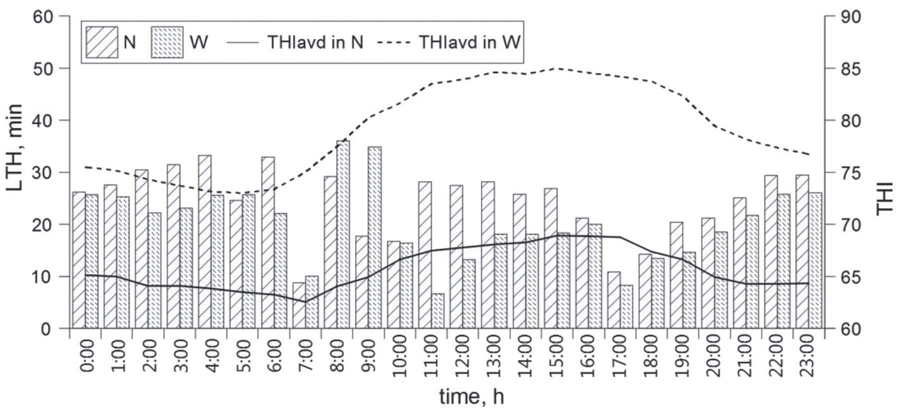

Figure 5. LTH (hourly lying time) of the cow in periods N and W

The pictures taken were used to calculate the LTH of the cows from the experimental group. In both periods, the cows spent the longest time lying at night between 8:00 p.m. and 6:00 a.m., but in the W the time was shorter (Figure 5).

LTH during the N period was independent of the range of THI values. It was observed that along with the deterioration of microclimatic conditions during W, relative to the N period there were significant differences in the length of lying time. During the N period, LTH was 26 min/h. During the W period, LTH amounted to 20 min/h (Figure 5).

During the W period, the cows were lying down on average 5 min/h shorter in the night-time and daytime than in the N period. The difference in LTH between the night-time and daytime hours in the N and in the W period was 2 min/h (Table 2).

Discussion

The total lying time of cows per day is an important indicator of their comfort (Norring et al., 2008). Cows show a strong behavioural need for lying, which is why interfering with this time is very detrimental for them (Steensels et al., 2012). A decline in LTD in relation to an increasing THI was characteristic for the specified research periods. The results obtained by the authors show a decrease in LTD between the N and W periods from 11.3 to 9.4 h/d. Studies by Cook et al. (2007) showed that an increase in THI from the neutral to hot period resulted in a decrease in lying time from 10.9 to 7.9 h/d. As a result of the authors' observations, in the months of June–August an LTD value of 602 min/d was obtained (nearly 10 h/d). A similar result of total length of lying time, but for the June–September period, given by Brzozowska et al. (2014) amounted to 605 min/d. With respect to the overall lying time from 8 to 16 h given by Tucker et al. (2003), in the summer period the total lying time was closer to the lower limit. According to Metz (1985), depriving cows of the possibility to have a rest in a lying position for 3 h, and according to Kanjanapruthipong et al. (2015) for 2 h, causes deterioration in animals' welfare by disturbing their daily routine. Our research confirms the observations above.

Both the LC and LTH values decreased with the increase in THI, which was especially visible during the W period. LTH in the W period was reduced by an average of 6 min/h. However, it should be noted that the calculated THI does not show high levels of heat stress in cows. Taking into account that the experiment was carried out on a group of cows with an average milk yield of 21.6 kg, it can be concluded that in high-yielding cows the shortening of lying time due to the increase in THI will be significant (Herbut and Angrecka, 2018).

The LC and LTH decrease was also noticeable between the daytime and night-time periods of W. Especially for the LC, which was more than 2 times less than in the N period. This disproportion was partially offset by morning rest, but it was observed that the cows at that time often chose to lie in the manure alleys, not in the cubicles. This can be a particularly negative behaviour because lying on a hard, concrete floor can be especially painful for cows since it causes, among others, pressure on the milk-filled udders (Osterman and Redbo, 2001).

Conclusions

Heat stress results in significant changes in the cows' lying time behaviour. During heat stress, cows will reduce their daily lying time. This dependency is inversely proportional to the THI level. Also, significant changes occurred in the longer lying time during the night-time when the THI value usually decreases.

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