Daily and seasonal patterns of lying and standing behaviour of dairy cows in a frestall barn

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Abstract
To examine the influence of environmental parameters on animal behaviour, an experimental programme was set up at a farm where anomalous behaviour of cows had been previously noted. The research was carried out in a free-stall barn (75 cows) where cow behaviour has been recorded by a time lapsed video system from June 2004 untill June 2005.
This paper aims to investigate daily behaviour pattern in a herd and to examine cows' response to different environmental conditions through the analysis of the data related to four weeks in different climatic conditions (August, October, December and January). The behaviour of cows has been expressed through indices based on number of cows involved in different activities (standing, lying, eating and drinking). Simultaneously temperature and humidity within the cowshed have been recorded using dataloggers and Temperature Humidity Index (THI) has been calculated.
The comparison of behaviour in different hours of the day shows a strong diurnal pattern, while the behaviour at the same hours of different seasons highlight a significant difference only in daylight hours, despite the difference in temperature. The behavioural indexes in summer and autumn differ significantly only one hour in the day (3 pm) while THI values are widely different (mean values of 73.26 and 62.17; standard deviation of 3.85 and 2.41, respectively for the two periods).
The results obtained suggest that THI values are not sufficient to explain the influence of the barn on cows' behaviour.

Keywords: THI, animal behaviour, dairy cow housing.

Introduction
Several authors have emphasised how environmental conditions of livestock buildings can significantly affect animal welfare and productivity (Armstrong, 1994; Bouraoui et al., 2002; D'Archivio and Zappavigna, 2007; Kadzere et al., 2002; West, 2003). Temperature, humidity and ventilation contribute to changes in environmental conditions and may have a significant effect on the physiological response of animals. Dairy cows are, in fact, able to adapt to a wide variety of environmental conditions, but the best performances can be obtained only in the area of thermal neutrality, to maximise the energy available for the production of milk. According to Kadzere and colleagues (2002), genetic selection for increase in milk production is related to increased heat produced by cows, which makes animals more susceptible to heat stress.

Most of the studies use the Temperature Humidity Index (THI) to measure thermal comfort and a THI ≥ 72 is usually considered the upper limit for dairy cows. Above this level cows generally reduce the milk yield because of heat stress (Igono et al., 1992; Ravagnolo and Misztal, 2002).

Cow behaviour is considered a good indicator of animal welfare (Overton et al. 2002). Therefore, the analysis of daily behaviour patterns has been used by several authors to study the benefits of different bedding and housing solution (Haley et al., 2000, Fregonesi et al., 2007).

Animal behaviour is considered one of the indicators of animal comfort and indices based on the time cows spend in different activities (lying, standing, eating, drinking) have been used by several authors (Cook et al., 2005; Overton et al., 2003). Some studies have raised the possibility that cow stress can be related to THI values below the heat stress and occurs also in temperate climates (Bluett et al., 2000; Kendall et al., 2006).

To evaluate the performance of the housing and management system of a herd, the observation of cows' behaviour in a limited number of days might give a partial information. In fact, the differences among seasons and the effect of external environmental conditions (temperature, humidity, etc.) affect the daily behavioral pattern of the herd (St-Pierre et al. 2003). As a preliminary step to long term observation of cows' behaviour, some information on the consistency of daily pattern and the variability due to the seasonality has be collected and analysed.

This paper aims to 1) investigate the consistency of daily behaviour pattern in a herd and the more representative time of the day to examine cows' response to environmental conditions 2) study cows' behaviour to examine its seasonality and 3) give indications on the methodology to evaluate the effect of the housing system on cows behaviour.

Materials and methods

This study has been carried out in dairy cattle farm in the province of Lodi, Italy, in a free stall cowshed, from June 2004 untill June 2005. The reinforced concrete precast structure has a rectangular layout of the dimensions 52 x 17.6 m with a north-south longitudinal axis and asymmetric gable roof, parallel to the longitudinal axes of the cowshed, and open ridge. The west pitch slope is 7%, while the east one is 5%. The building is without outside main wall and borders on the east side with an other building partially closed.

Figure 1 shows the microclimatic sensors and video cameras installation scheme in the barn, provided with 74 stalls placed on two lines head to head. The data loggers for the measurement of the temperature have been installed between the stall rows at a height of about 1.2 m from the animals floor to measure the air temperature as close as possible to the animals, but without been affected by the closeness of the animal self. The temperature and humidity sensors (weather stations Heavy Weather WS) have been installed over the feed manger using plastic pipes fixed to the roof beam to bring them at a height of 2 m from the animals floor, so that they can not be reached by the cows. All parameters were continuously measured and recorded every 30 minutes. The black-and-white cameras are provided with a sheltered container and a 3.6 mm lens. The mini lens provides a shot angle of about 67° and uses a CCD sensor of 1/3 inch. The cameras were connected to a 4 channel video capture card DVR 4200 integrated in a personal computer to perform an analogue to digital conversion of the signal for the subsequent storage on a hard disk. The digital video recording parameters has been set, thanks to the suited control software with a capture frequency of a frame per second. This value has been chosen as compromise between the possibility of maintaining a good comprehension of the animals movement and the size of the information to save.

Local weather conditions were used to be compared with the internal microclimatic data obtained by the described instrumentation.

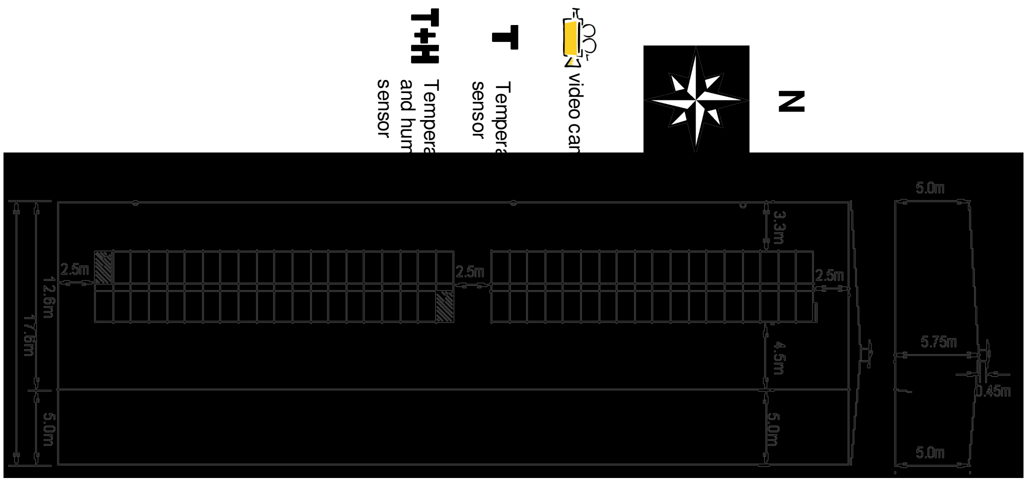

Figure 1. Plan and cross section of the cowshed with the position of the sensors and of the two video cameras with related shoot angles

Data from the two regional agency for environmental protection network weather stations of Sant'Angelo Lodigiano and Cavenago d'Adda were used for this purpose, which report hourly: temperature, relative humidity, global sun radiation, wind speed and direction, rainy condition. The analysis of the video recording data consisted in the evaluation of the number of dairy cows engaged in the different activities (feeding or drinking, resting, inactive standing) for the two sides (north and south) of the structure.

The time base to be used for the video analysis to extract the animals behaviour has been analyzed by Mitlohner et al. (2001) who have pointed out that to measure short time events (e.g. the drinking) it is necessary to use limited scanning periods (10 minutes), but that other behaviours, such as resting, can be adequately explained with scanning to 30-60 minutes. On the base of these experiences, the videotape have been analyzed hourly.

During the analysis, the hours connected to the cowshed management (milking and feeding) that influence the animals behaviour have been excluded. For the further processing of the collected data, some microclimatic and animals behaviour indices have been defined. Concerning the climatic aspects the Temperature Humidity Index (THI), widely utilized in bibliography, has been used to consider jointly temperature and humidity. It was calculated with the relation suggested by ASABE (ASABE, 2006):

$$\mathrm{THI} = t_{ba} + 0.36 t_{pr} + 41.2$$

Where:
t_{ba} = dry bulb temperature (°C)
t_{pr} = dew point temperature (°C)

Some indices have been used for the analysis of the data related to the behaviour. The first of this index is related to animals resting in the stall:

$$\text{Cow Lying Index} = \frac{\text{cows lying in stalls}}{\text{total cows}}$$

It represents the index of animal comfort and it is connected to the number of animals in the stall in comparison with the total number of heads (Cook et al., 2005).

Likewise are defined the index for the standing animals and the one that measures the cow tendency to move to the northern part of the building:

$$\text{Cow Stress Index} = \frac{\text{cows standing}}{\text{total cows}}$$

To consider the stall use by animal that are not engaged in other activities (eating and drinking) a further index has been calculates (Overton *et al*., 2002):

$$\text{Eligible Cow Lying Index (ECLI)} = \frac{\text{cow lying in stalls}}{\text{total cows - cows eating or drinking}}$$

Finally, to consider the use of the different areas of the barn Crowding Index (CI) calculated as the absolute value of the complement to one of the number of cows in a sector of the barn divided by the expected number of cows in that sector.

To study the seasonality of cow behaviour, four periods has been selected, according to the daily mean THI values.

As can be noticed from table 1, reporting the start and date of the periods and the number of hours analysed, there are some missing values due to management operation affecting cows (milking, feeding, litter renewal, video recording malfunctioning).

In particular, the hours from 5 to 8 in the morning and 16 to 19 in the afternoon have not been considered. Missing data has been removed for all the parameter analysed.

Table 1. Periods, number of observations and average daily THI

Period	Starting date	Ending date	Number of hours analysed
August	01/08/2004	07/08/2004	112
October	20/10/2008	26/10/2008	108
December	09/12/2004	15/12/2004	111
January	09/01/2005	15/01/2005	111

A simple statistical descriptive analysis was carried out to find mean and standard deviation values of the hourly behavioural indices and THI for each period and for all observations. The different periods were studied by the application of a one-way Analysis of The Variance (ANOVA). Tukey's HSD test was used to test the multiple comparisons.

Hourly values have been compared graphically for the four periods reporting the mean values and the amplitude of variability expressed as twice the standard error of the mean.

Results and discussion

Table 2 reports the mean values, standard deviations and ANOVA significant differences obtained from the analysis of the four periods.

It can be noticed how all behavioural indices show significant differences ($P<0.01$) between periods. Only CLI remain the same in October and December. The THI vales do not differe significantly in December and January.

Table 2. Mean standard deviation and significant differences for the behavioural indices and the THI for the four period of observation

	August		October		December		January		All	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
CLI	.54c	0.27	.64b	0.25	.65b	0.16	.80a	0.08	0.66	0.22
ECLI	.61d	0.26	.73c	0.21	.78b	0.1	.89a	0.05	0.75	0.20
CSI	.31a	0.2	.21b	0.15	.18c	0.06	.10d	0.04	0.20	0.15
CI	.45a	0.46	.33b	0.37	.13c	0.15	.08d	0.08	0.25	0.34
THI	73.26a	3.85	62.17b	2.41	47.42c	4.38	46.46c	2.79	57.33	11.69

The overall mean of the four periods of observation for the CLI and ECLI show a relative good use of the stalls but this results is influenced by the very good results obtained in January. The August values (54% and 61%, respectively) are lower and considered below the expected in a comfortable situation although the average THI values have a mean below the threshold value for heat stress of 74 reported by several authors. CSI shows a clear decrease from August to January not always justified by THI. The mean value of 20% of cows in the 24 hours in considered higher than the advised good practice, especially taking into account that the hours just after milking have not been observed. CI an unexpected high average value (25%) highlighting a strong preference of cows for the north side of the building all the year although there is a strong variation in the different periods of the mean values and a very high variability is reported by the standard deviation values.

Considering the differences expressed as percentage of the mean values of the four periods, the relative change of the indices have different patterns (figure 2). CLI and ECLI have a maximum variation of 20% and are practically the same in October and December. CSI and CI have higher variations, over 50% and 85%, respectively and show a strong reduction from December to January that cannot be explained by the variation of THI that does not have significant variation in this two periods.

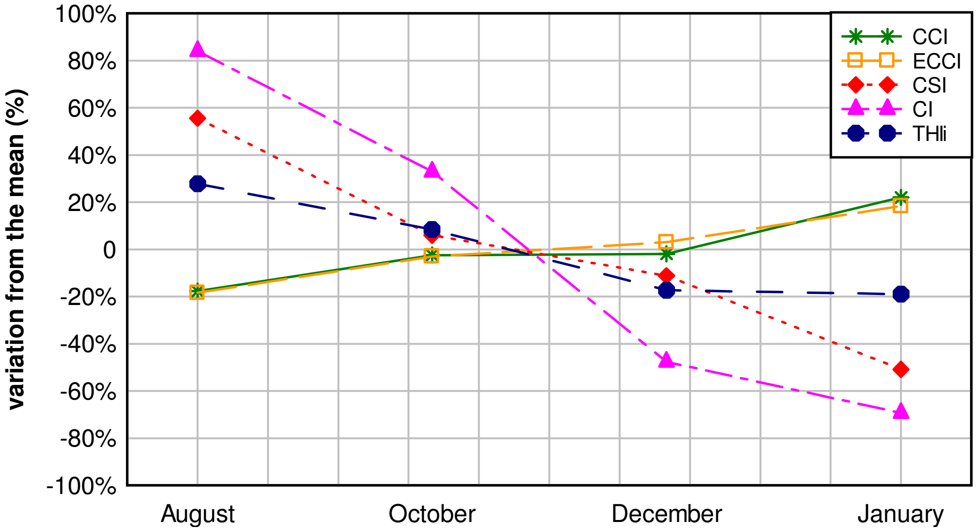

Figure 2. Relative variation of different behavioural indices and THI for the four periods of observation

The difference of the average values for the four period of observation can be better explained by the hourly analysis. Figure 3 reports the average values for each hour of the day for the behavioural indices. As can be noted, there is a clear diurnal patter and the differences among periods are minimised during nighttime. Slightly higher differences are shown in the evening, after the evening milking. This can be probably explained by the difference of THI and also by the daylight duration.

The night behaviour expressed by the four indices utilised show a good use of the stalls (ECLI is almost always over 80) and, as obvious consequence, a limited number of cow standing. The distribution of cows is regular in all the periods, and the CI index never reach the value of 10%.

During the day (from 9 to 15 hour), cows behaviour vary significantly in the different periods. CLI and ECLI show a similar pattern with a increasing values from August to

January. While The differences are always significant between January and the other periods, December differs from October just in some hours and August is for many hours similar to October.

CSI, as expected, result in an increase of values during the central hours of the day. It can be noticed that the maximum values are, for different periods at different hours: at 12 for August; 12 and 13 for October; 15 for December and January. It is also clear there are significant differences in the same period at different hours of the day.

The pattern of CI is following in some way the CSI although in August the values during the daytime are always very close to 100% as all cows are in the north part of the barn. The peak values in December and January are also for this index at 15 and significant differences between hours are reported.

The daily pattern of the behavioural index in the different periods is not always directly explained by the hourly values of THI (figure 4). The large variation of THI from August to October does not seems to be reflected in the behavioural index while he THI values in December and January are very similar with the exception of some hours. The hours with maximum values of THI in this two periods correspond to those of the CI and CSI. On the contrary in August and October, while the THI report a maximum value at the same hour (15), the behavioural index have their peak values around 12.

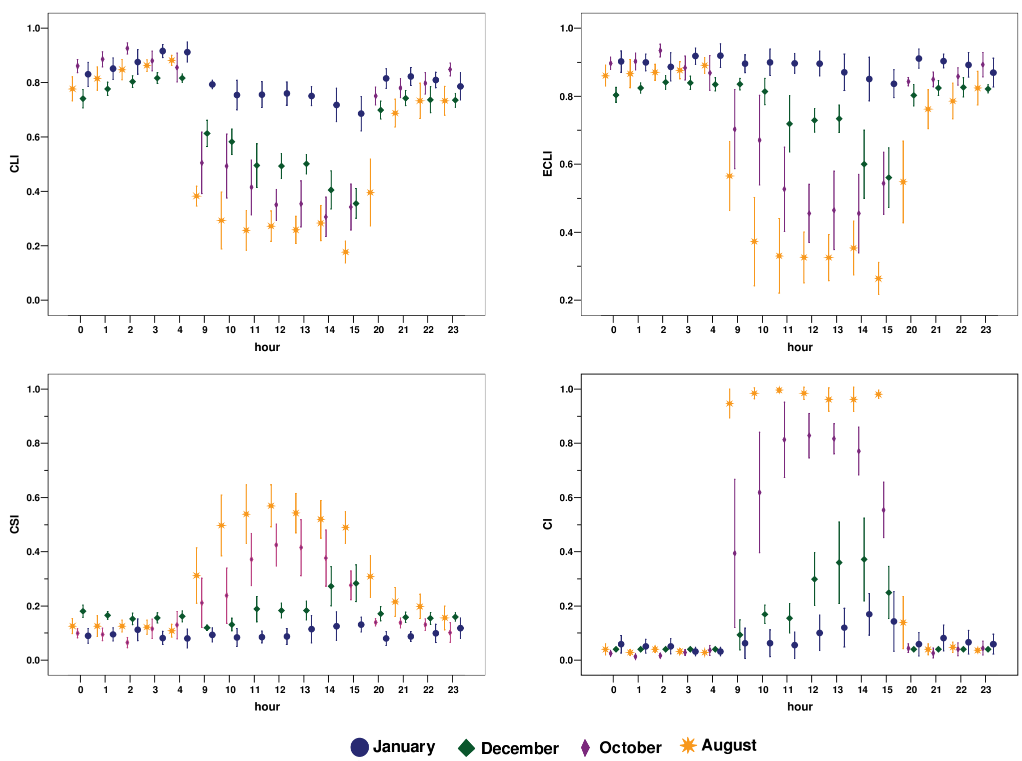

Figure 3. Average hourly values of the behavioural indices for the four periods of observation. The vertical bar represent twice the standard error of the mean

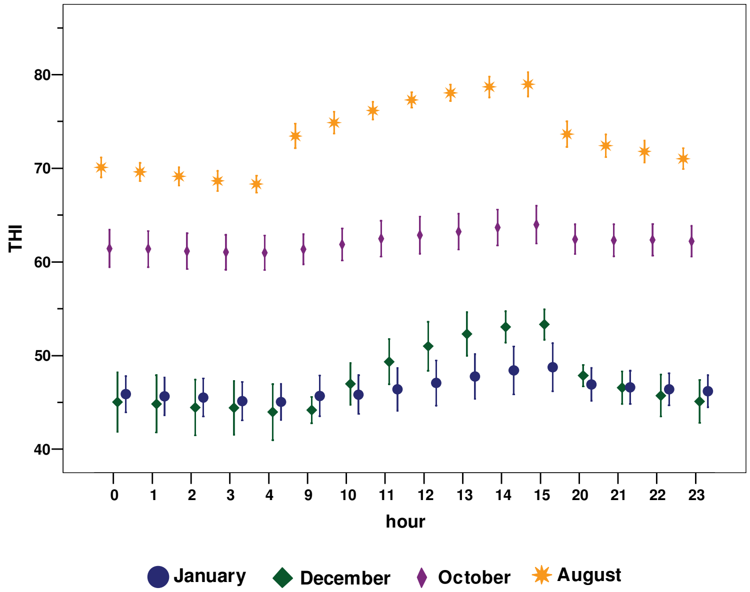

Figure 4. Average hourly values of the THI for the four periods of observation. The vertical bar represent twice the standard error of the mean

Conclusions

In the observed herd, the hourly pattern has shown a clear diurnal behaviour. Cows activity is limited during night and does not seem influenced by seasonality or THI. Thus, few information can be obtained observing the nigh time. During the day, cow behaviour varies significantly. The observation of the herd in only one hour of the day bring to results that might be not representative of the daily situation. The best period of observation seem to be from one hour after the morning milking to the start of the second one, but the observation of some hours after the second milking might improve the accuracy of the results.

Cows behaviour has resulted to be linked to the period of observation more than to THI. This aspect should be further investigated, but indicates that the evaluation of the influence of the barn and environmental conditions on cows behaviour must take into account also the seasonality.

CLI and ECLI indices are strongly correlated probably also because the observations have excluded the time soon after the milkings, and the use of one index or the other does not to improve the results.

The preference of cows to stay in one side of the barn should be considered to evaluate properly cow behaviour. Moreover, groups of animals in different side of a barn might show a different behaviour and therefore direct comparison might not give correct results.

Although more investigation is required to confirm the results obtained, it seems that experiments aiming to the evaluation of the influence of the barn on cow behaviour should not be short term observations (few days) and not referring of groups with few cows. Seasonal effect and crowding tendency should be taken into consideration to obtain results that can be transferred into practice.

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