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Air speed and heat load in a dairy cow barn – effects on animal welfare

The investigation of barn climate and heat stress is important with regard to both welfare of dairy cows and performance. For this reason climate measurements in- and outside of a natural cross ventilated dairy barn have been conducted. Special emphasis was devoted to measurements on air speed within the animal occupied zone of the stable. The air speed was heterogeneously distributed and the results showed areas which were permanently less ventilated than others. However, climate measurements should be correlated to physiological animal parameters in order to interpret the barn conditions in respect of thermal comfort of the animals. On hot days, the parameters analyzed showed clear differences from the other days.

Keywords

Barn climate, air speed, physiological animal parameters

Abstract

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Nowadays most dairy cows spend their entire lifetime indoors. The welfare of the animals thereby depends crucially on the climate conditions within their housing. Dairy cows are most comfortable in an environment with temperatures between 0 and 15 °C [1]. Milk production nowadays demands from the cow's metabolism performances comparable to those of a top athlete. Hereby significant amounts of metabolic heat are released. If this heat cannot be freely emitted, e. g. through surrounding temperatures being too high, the animals can then be subject to high heat loads or heat stress. When such heat loads are not compensated for, the observed results can be diverse, including a rise in body temperature with reduction in feed intake leading in turn to reduced milk production and poorer quality of milk [2].

To avoid heat stress adequate barn ventilation is required so that temperature and relative humidity are kept within an optimal range. With seasonal heat waves, or where animals are packed close together in the parlour collection area, for example, heat stress can occur. In such situations additional measures should be taken that support the natural thermoregulation of the animals. Increased air current velocity improves heat transfer from the animals' skin surface, creating a cooling effect [3]. Effective and accurate application of such additional ventilation is, however, only possible when the natural flow fields and their specific areas within the barn are known. For accurate timing of additional ventilation, the cattle manager has to be able to evaluate the heat stress loads on his animals.

For objective measurement of heat stress loads the most used parameter is the Temperature Humidity Index (THI) calculated from ambient air temperature and its relative humidity. However, this doesn't take account of the additional cooling effect of air speeds and also ignores other effects such as radiation which can, however, be taken account of through less well known parameters such as THIV [4] or Heat Load Index (HLI) [5].

One disadvantage of these evaluation parameters is the singular consideration of climate conditions; as in the past criteria which take account of the stress on the animal, are missing. For this reason investigations aimed at finding ways of supporting thermoregulation of high performance dairy cows were conducted. These took account of not only barn climate parameters but also their effects on the animals involved.

Materials and methods

Recordings of barn climate were carried out in cooperation with the Animal Production Institute, Mecklenburg-Vorpommern Research Institute for Agriculture and Fisheries. A herd of 380 dairy cows was housed in a non-insulated and naturally ventilated barn with cubicles. Wind shelter netting shielded the sides of the barn. Both gables incorporated four large door openings which were kept open during the recordings. One gable was clad with spaceboard, the other with trapezoid profile steel sheeting. Site orientation of the barn featured a southwest positioning to allow the prevailing wind from that direction access through one side. The barn was additionally equipped with three centrally positioned ceiling fans.

Measurements

In the summers of 2010 and 2011 a total of three recording campaigns took place and the climate factors air temperature and relative humidity recorded over a longer period at four evenly-spaced points within the barn. In the campaigns these factors were supplemented by black globe temperature measurements for determining radiation temperature. Additionally air velocity measurements were carried out in the animal housing areas of the barn (**Figure 1**). In the lying area such measurements always took place during milking time when this area was empty. The cows were arranged in four milking groups. Air movement was simultaneously measured by six ultrasonic anemometers sited at six positions where all three components of the air current velocity vector (u, v and w) were recorded. The data was recorded with the program reader of Ultrasonic Anemometer (RUSA, ATB Potsdam). (Details in [6]). The temporal resolution equalled 1 Hz and recording took place in time series of 180 s in each case. During milking time for two of the four groups twelve measurements were taken with two consecutive measurements carried out at each of the six recording sites. In total, time series recordings were carried out at 36 measurement sites distributed over the entire barn area. Anemometers were positioned at around 1.5 m above ground level approximately representing the shoulder height of the cows.

All air velocity measurements were carried out in the absence of the cows in order to avoid damage to the sensitive instruments by the animals. A construction to protect the instruments, e.g. a cage, would have substantially falsified the results (as indicated by van Wagenberg et al). In this case it was calculated that a 20% increase in air turbulence intensity would be caused by a protective cage around an anemometer [7].

This was why the measurements were carried out in areas of the barns which are used by the cows, but without the presence of the cows. Simultaneously recorded were the wind conditions outside the barn using a further ultrasonic anemometer. The data recording outdoors took place in the same temporal resolution as the recording within the barn.

The exterior climate conditions were recorded by a weather station in the vicinity of the barn. Additionally, temperature and relative humidity in the immediate surroundings were measured on two sides of the barn building.

Details of physiological animal parameters and information from animal observations complemented the recordings, the former comprising analyses of heartbeat and breathing frequencies, skin surface and rectal temperatures and cow behaviour, also on days when temperatures were moderate. Heartbeat frequency was measured continually using the Polar Equine RS800CX system (Polar Electro, Kempele, Finland) secured on the animal with a body belt. Skin surface temperature was determined via sensor integrated in the belt and additionally monitored by wireless pyrometer (RAYMX4PTDG, Raytek, Berlin). Measurement of rectal temperature took place hourly (digital thermometer ApoNorm Sensitive, ApoNorm, Hillscheid). Breathing frequency (visual) measurement was also hourly, as was observation of behavioural parameters. Hereby, the actions of the animals (walking, standing, lying, feeding and drinking), their respective locations, as well as any conspicuities (e.g. restiveness, apathy) were also recorded.

Fig. 1

Wind measurements within the barn (Photo: Stollberg)

Results

Wind data was evaluated for assessment of the any air currents present. The recorded time series of the wind components were statistically evaluated with the program SAS 9.2 (SAS Institute Inc., Cary, NC, USA) and for individual time series, in each case 180 s, mean value and standard deviation were calculated. Subsequently the result and the direction of the three dimensional air velocity vector were calculated from the air velocity components. Additionally, the degree of turbulence T_i was calculated for an overview of turbulent air flows. Finally the data was classified according to the exterior wind conditions or direction. The results from all 36 recording points covering two wind directions are summarised in **Table 1**.

The results indicate substantial fluctuations in air velocities within the barn. The velocity vector vertical component w was almost zero and in most cases negative thus associated with a downward movement. However, the standard deviation for very small mean values nearing zero was markedly higher than the recorded mean, so that an upward or downward movement could not be clearly identified. The vertical component was insignificantly small where the animals were not present. Where they were present, however, vertical temperature gradients (warm body surface s of the animals and temperature of the surrounding air) could take place that could lead to enhancement of upward air currents. In this case higher values for the vertical components of air velocity could be expected. The air speed of insignificantly small vertical components led to a dominance of horizontal air speeds which could barely be differentiated from the three dimensional air velocity V_{3D}. The relationship of the recorded interior air velocity (V_{3D}) to air current velocity outdoors (V_{out}) was approx. ¼ to ⅓, reflecting the braking effect of the wind shelter netting. The air flows within the building were very turbulent, as confirmed by the > 0.3 degree of

Table 1

Overview of the measured air velocity data for two wind directions (WD) at all locations. Values represent a mean value of a 180 s time series.

WD		u [m/s]	v [m/s]	w [m/s]	σ_u [m/s]	σ_v [m/s]	σ_w [m/s]	V_{3D} [m/s]	V_{3D}/V_{out} [-]	T_i [-]
N	95 % Quantile	0,10	-0,17	0,05	0,44	0,63	0,32	0,92	0,35	1,15
	Median	-0,15	-0,31	-0,01	0,26	0,27	0,12	0,48	0,23	0,57
	5 % Quantile	-0,47	-0,63	-0,08	0,13	0,13	0,08	0,29	0,14	0,30
SW	95 % Quantile	0,93	0,44	0,04	0,87	0,92	0,39	1,32	0,53	1,55
	Median	0,33	0,08	-0,02	0,30	0,30	0,15	0,57	0,28	0,58
	5 % Quantile	0,17	-0,23	-0,14	0,14	0,14	0,06	0,31	0,18	0,38

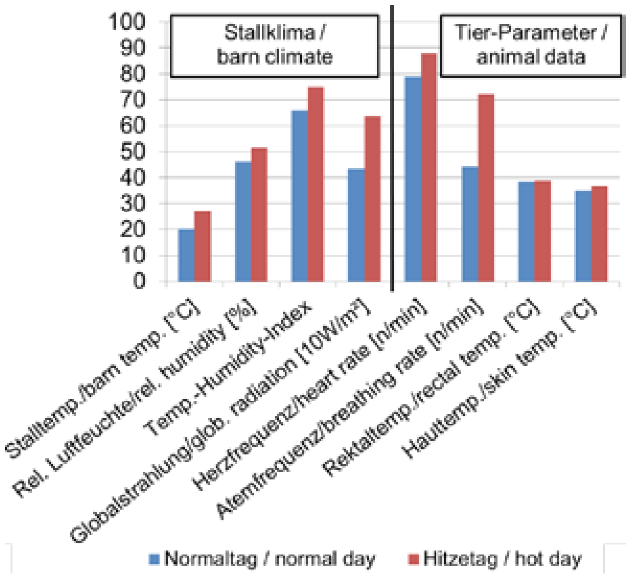
turbulence calculated from conditions in the barn. The rapidity of air fluctuations was over 30% higher than with average air current flow. Thus the air flows in the barn were not uniform, but instead tended to have the character of gusts.

Observing the recorded air velocities from a spatial point of view (V_{3D}) showed that despite the open form of the barn there were areas in the interior where, independently of outdoor wind velocities and directions, air flows and their velocities were small. Animals in such areas could be subject to increasing heat stress under unsuitable climatic conditions. In these areas of the barn targeted measures for additional ventilation, e. g. fans, could be effectively applied.

Through observation of temperature and humidity data alone, on the other hand, there is no way of differentiating between the comfort zones. Neither does recording of barn climate parameters alone allow a clear statement regarding stress load on the animals and effects of barn climate are also probably influenced by animal individual factors (milk production, pregnancy, body condition score) and thus different from animal to animal. Because of this, physiological and ethological animal parameters were recorded on a hot day (high outdoor temperatures) and a normal day (moderate outdoor temperatures). Observation of the animals alone allowed the effects of areas with different air flow velocities to be determined. When the temperatures were moderate, the cows utilised the entire interior of the barn, conversely on warm days the cows congregated increasingly at the drinking points and in areas with higher air flow velocities and less in the cubicle area. Cow movement activities reduced in warm days and water intake increased.

Complementary to the recorded animal-related parameters the THI (from temperature and humidity data) is used as evaluation parameter for determining heat stress situations. Thereby the calculation formula according to CIGR [8; 9] is applied. The THI values are presented and compared with the physiological parameters in **Figure 2**. On a warm day a THI value of > 74 was achieved which according to CIGR [9] is aligned to the position "alert" (light heat stress situation). Despite this, the recordings of the animal physiological parameters demonstrated marked differences on both days (**Figure 2**). Especially the breathing and heartbeat frequencies, as well as the analysis of heart frequency variability, showed themselves good indicators for early identification of stress loads, being themselves natural short-term reactions to stress. On the other hand, skin and rectal temperatures are less suitable in this respect because the body always attempts to retain the required body temperature as effectively as possible and to steer against any deviations.

Fig. 2



Measurements of barn climate and animal data in a dairy stable at a normal and a hot day

Conclusions

The air velocity in the animal occupied areas of barn interiors is an important parameter in evaluation of interior climate for dairy cow comfort. Air flow velocities in naturally ventilated barns are very heterogeneously distributed and turbulence occurs. Therefore there can be areas within naturally ventilated barns with different climatic comfort and these should be taken account of when evaluating barn climate to avoid heat stress for the animals through possible additional effective measures.

In future further recording over longer periods should take place and the correlation of barn climate data with animal physiological data intensified so that the comfort and/or stress situations of animals can be recognised and effective measures developed.

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