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Heat Stress in Dairy Cow Husbandry

Information on Technical Measuring Acquisition of Relevant House Climate Parameter

Heat stress is not only a topic in dairy cow husbandry in countries with hot climates. Even in Central Europe climate change associated with summer heat waves results in negative effects regarding animal welfare and milk yield for high performance cows. Measures to improve the heat transfer from the cow to its surroundings make sense in naturally ventilated cow sheds. Conceptual design of appropriate solutions for construction and ventilation systems requires knowledge about in-house climatic parameters and their effects on animals. For these purposes the ATB and the State Research Institute for Agriculture and Fishery Mecklenburg-Western Pomerania (LFA M-V) have conjointly been investigating them since 2004.

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Literature

References can be called up under LT 08312 via Internet www.landtechnik-net.de/literatur.htm

Heat stress in farm animals results from temperatures and high relative humidity outside and low air velocities in the animal zone. This kind of weather situations occur in the last years more frequently. Also in Germany it is not seldom, that for a several days period outside temperatures exceed the value 32 °C. Such climate conditions lead to a thermal stress for dairy cows, because they can not transfer enough surplus heat to the environment. This effect is intensified for high performance cows, as these cows have to transfer more heat to the environment because of increased feed consumption and because of a higher energy metabolism. The increased stress of animals affects the animal behaviour and the animal performance. E.g. the cows go to shady areas more often, the water intake increases, the feed intake decreases, the cows are standing more then lying and the breathing frequency, the salivation and the body temperature are increasing. On the other hand the pregnancy rate and milk yield is decreasing. This shows the negative effect of such extreme climate conditions have on animal welfare as well as on the profitability. Much more information is required to answer the following questions:

- When are the cows in heat stress?
- What is the influence on animal health and animal performance?
- Which solutions can be recommended for the buildings and for the ventilation systems in order to avoid and reduce heat stress?

Currently there are no satisfactory solutions available for the conditions in Germany.

However, many investigations regarding thermal comfort exist for human hygiene [1]. There, air temperature, air humidity, thermal radiation, air velocity and turbulence of air flow are considered. But all this knowledge cannot directly be transferred to animal welfare.

It is more difficult to define comfort for animals than for humans. In the literature different models to evaluate different influencing factors exist. All these factors provide a “Thermal comfort index”. In [2] an overview is given about such indices. Johnson [3] specifies under consideration of air temperature and air humidity a “Temperature and Humidity Index” (THI) for cattle:

$$THI = DBT + 0.36\ DPT + 41.2 \qquad (1)$$

with:

DBT: Dry Bulb Temperature (°C)

DPT: Dew Point Temperature (°C)

Due to calculations of (1), Johnson defined four characteristic zones: “no stress”, “low stress”, “middle stress” and “severe stress”.

Barnwell and Rossi [4] included the air velocity in their evaluation of thermal comfort. They found, that higher air velocities in the animal zone allow higher temperatures in the cow shed (see also [5] and [6]). Based on the presented knowledge and findings in literature, an experimental-set up was created to gather more knowledge regarding heat stress in animals.

Data collection

The investigations were carried out in a free ventilated non-insulated cow shed [7]. Also the metal roof has no insulation. The cow shed has the following size: length 96.15 m, width 34.2 m, height of the side wall 4.2 m, height of the gable 10.73 m, which leads to a room volume of 25,499 m^3. The lying box loose housing is designed for 364 dairy cows and is equipped with a winch-drawn dung channel cleaner. The ventilation is controlled by adjustable openings in the side walls, open doors and space boards in the gable walls and a permanently open ridge slot. In summer, three manually controlled ceiling fans (~ 7 m diameter) can additionally be switched on.

Since 2004 measurements of climatic conditions inside the building have been carried out by ATB in collaboration with the LFA M-V and data are collected from the animals.

Microclimate inside the building

- Air temperature und air humidity
- Globe thermometer temperature
- Surface temperature (structure)
- Air movement in the animal zone
- Gases (for example CO_2, NH_3, odour)
- Air volume flow

Climatic parameters outside

- Air temperature und air humidity
- Globe thermometer temperature
- Ammonia and odour
- Wind speed and wind direction

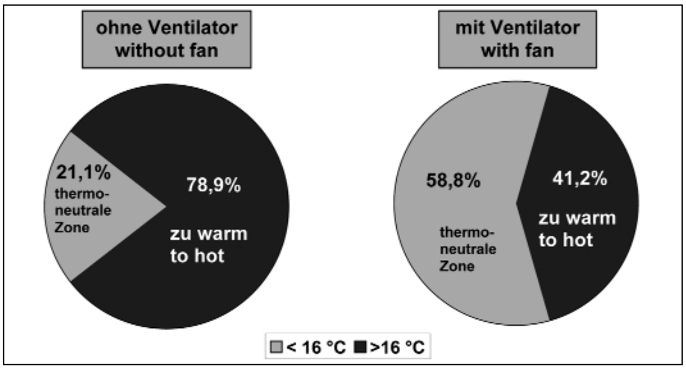

Fig. 1: Felt indoor air temperature when using ceiling fans in summer 2006 (July-August)

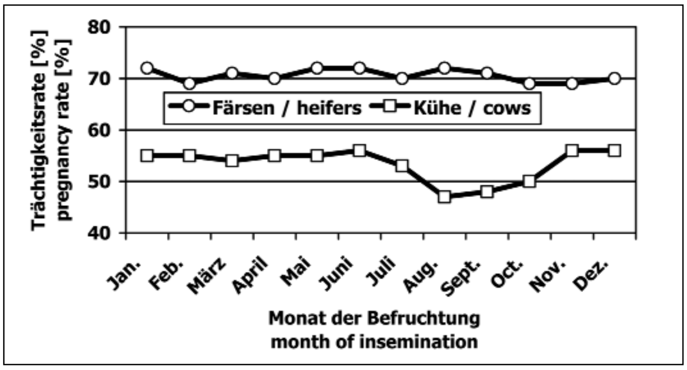

Fig. 2: Influence of month of insemination on pregnancy rates of heifers and cows

Parameters of the animals

- Milk yield
- Pregnancy rate
- Feed and water intake

With help of the obtained parameters the microclimate inside caused by natural ventilation can be evaluated. Results regarding the volume flow and the ammonia emissions are published in [7] and [8]. About the dispersion of emissions will be reported later.

Measuring results

Because the doors in the investigated cow shed are nearly permanently opened and the curtains of the side walls are often only half closed, also during the in-between season and in winter, the air exchange rate is high, even with low outside wind speed. During summer, if the air inlets and outlets are completely opened, the air exchange rate is still higher. At air exchange measurement with closed curtains and outside wind speed of 3 m/s, an average air exchange rate of 25 h^{-1} is measured. This corresponds to an air volume flow of ~ 1,700 m^3/h per cow. If the curtains are completely opened, then this value increases to about 5,000 m^3/h per cow. This air flow rate is much higher than the required maximum air flow rate in the standard DIN 18910 [9]. This is the reason for the small differences between inside and outside temperature – only the maximum values inside the cow shed are a little bit lower than the outside temperature. But during the night, due to the heat storage capacity of the structure, the inside temperature is a little bit higher than the outside temperature. A corresponding behaviour is shown for relative humidity. Temperatures measured in three different heights (3 m, 6 m and 9 m) in the middle of the cow shed show in summer at the maximum temperatures during the day a continuous rise from the floor to the roof. The temperature in 3 m height is about 2 K lower than the temperature measured in 9 m height. Parallel to the measured temperatures in three different levels, the globe thermometer temperature is measured to acquire information about the effect of radiation. The globe thermometers are struck by direct solar radiation only for a short time. Therefore and because of the high air exchange rate, the difference between air temperature and globe thermometer temperature is very low. Only during the periods of direct solar radiation, the globe thermometer temperature exceeds the air temperature up to5 K. At the outside measurement point, the difference between both temperatures is much bigger. Already in the morning, if the globe thermometer is struck by the solar radiation, the globe thermometer temperature exceeds the air temperature and between 12:00 noon and 18:00 the globe thermometer temperature is up to 10 K higher than the air temperature. In addition to the measurements with globe thermometers the infrared camera is used to measure the surface temperature of the structure during different weather conditions inside the cow shed. The results show understandably, that in case of direct solar radiation on the roof the temperature at the inner surface of the roof is higher than the air temperature inside the building. So e.g.on June 29, 2007 at 9:00 o'clock the roofing temperature inside was 27.6 °C but the air temperature inside is only 15 to 16 °C – thus a difference of about 12 K. Other examples show differences up to 20 K. Obviously due to the high air exchange rate and the large distance between roof and animal zone such high surface temperatures do not have a big negative influence on the animals. In connection with the heat input by radiation, Pache [10] suggest especially in view of light weight cow sheds to provide the roofs with insulation, to install sprinkler systems for evaporative cooling of the animals and to apply components with heat-storage capacity. Evaporative cooling and heat-storage mass are certainly reasonable measures, but in this connection the economic questions must be considered. Regarding the insulation of the roof, more basic research work is necessary. The effect of this measure must be seen always in combination with whole cover of the building (floor design, size of the building relative to the number of animals, wall design, roof pitch and orientation of the building), with the management techniques (for example (for example housing and grazing) and with the ventilation system. Finally the question of emissions is not to be disregarded. Another possibility of heat stress reduction is that increasing of air movement in the animal zone. Barnwell [11] reports, that evaporative cooling systems (increasing of air movement in the animal zone) guarantee good environmental conditions for the animals, if these systems are correctly installed and operated. With the ceiling fans mounted in the investigated cow shed, air velocities between 0.4 and 2.0 m/s were achieved. This corresponds to a decrease of the temperature by 4 K. By attaining this criteria it results, that corresponding to the measuring values of the interval from June to August 2007 without ceiling fans only 21.1 % of temperature values in the cow shed are acceptable, while with ceiling fans this part will go up to 58.8 % (*Fig. 1*). Investigations of the pregnancy rates show (*Fig. 2*) that regarding to this parameter, heifers do not have apparently a problem with high temperature values in summer, but in cows the pregnancy rate in summer will be influenced negatively. The investigation of other animal parameters has shown that the water consumption during summer increases and the feed intake as well as the milk yield decrease at hot days. .

Conclusion

- Natural ventilation is suitable for cow sheds
- Accompanying measures to reduce heat stress are reasonable (air movement; evaporative and mechanical cooling; heat storage; insulation)
- Basic research for evaluation of heat stress in case of production animals and regarding radiation are necessary
- Economic evaluations are not available

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