**Müller, Hans-Joachim; Schultz, Merike and Loebsin, Christiane**

# Effect of insulated roofs on heat stress at dairy cows

High ambient temperatures can have effect on animal welfare. The response on heat stress of different animals depends on species, race, age and performance level. E.g. cows tolerate rather lower air temperatures during winter than hot weather periods in summer. For the latter situation measures are discussed, how to reduce the heat stress of high performance cows in order to save animal health as well as the high performance level. An improvement and development of livestock buildings and ventilation systems to reduce heat stress requires more knowledge about their impact and efficiency. This article describes data acquisition in three different, naturally ventilated cow sheds and gives an assessment of these investigations.

**Keywords**

Dairy cows, comfort, heat stress, climate parameters in animal houses, radiation

**Abstract**

Landtechnik 64 (2009), no. 2, pp. 112 - 115, 2 figures, 1 table, 7 references

Temperature peaks and longer-lasting hot weather periods in summer as a consequence of the climate change will have negative effects on husbandry of dairy cows. The thermal exposure of dairy cows, which is referred as heat stress, has a negative effect on animal welfare as well as on feed consumption and can lead to reduced milk yield and to decreasing pregnancy rates. These negative effects depends on how much the inside temperature demanded in the German Standard “DIN 18 910” [1] and other guidelines is exceeded.

According to Pache [2] the breathing rate rises, the rectal temperature increases and the cow must dissipate the metabolic heat by evaporation. Such conditions are a stress situation for high-performance cows. The heat loss of the cows depend on the ambient air temperature, the relative humidity, the surface temperature of the structure and the air velocity in the animal zone. Therefore these parameters has to be considered for the assessment of heat stress situations. To get more information about heat stress, the knowledge about thermal comfort from humans is often transferred to animals. This approach might present problems.

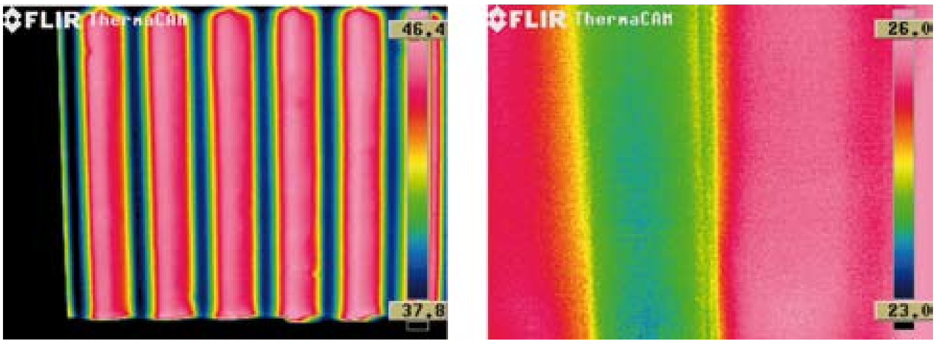
In the present article different assessment criterions are used regarding heat stress of dairy cows. In three different cow sheds climatic parameters in the animal zone are investigated.

## Assessment criterions

Extensive investigations exists to investigate human comfort at the work place. The European Standard “ISO 7730” for determination and interpretation of thermal comfort [3] is based on results of such investigations.

This standard contains evaluation parameters like energy transformation, insulation by clothing (in case of animals it can be the plumage, coat and others), average radiation temperature, air velocity and air humidity (see ISO 7726 [4]). Pache attempt in a study [2] to use the standard ISO 7726 for a comparative evaluation of two cow sheds (light construction and solid construction). Even if the transferability on animal husbandry is not given directly, some of the parameters for human well-being can be used. For example in [2] a measuring station to determine the thermal comfort for humans is used in the cow shed to determine the average radiation temperature **(equation 1)**.

Fig. 1




*Surface temperature in °C at the roof inside. Left: without insulation (stable B 1) / right: with insulation (stable B 2)*

$$t_r = [(t_g + 273)^4 + 2.5*10^8*v_a^{0.6}*(t_g - t_a)]^{1/4} - 273 \qquad (1)$$

**Equation 1** with:
$t_r$: average radiation temperature in °C according to ISO 7726
$t_g$: globe- or black-globe-temperature in °C
$t_a$: ambient dry temperature in °C
$v_a$: air velocity in m/s.
An overview about assessment criterions for farm animals is given in [5]. These criterions consider normally only the air temperature and the air humidity. Some of authors include additionally the influence of radiation and the air velocity. Panagakis [6] for example applies a Temperature-Humidity-Index (THI; equation 2) and include the influence of radiation by applying the globe-thermometer-temperature instead of the air temperature (BGTHI; **equation 3**).

$$THI = 0.8*T_a + [(RH/100)*(T_a - 14.3)]*46.4 \qquad (2)$$

$$BGTHI = 0.8*T_{bga} + [(RH/100)*(T_{bga} - 14.3)]*46.4 \qquad (3)$$

**Equation (2) and (3)** with:
$T_a$: ambient air temperature in °C
$T_{bga}$: globe-thermometer-temperature in °C
RH: relative humidity in %.
The criterions from the **equations 1 to 3** are used in the present article to evaluate measurements from summer 2008 in the three different cow sheds (A, B 1, B 2).

## Investigated cow sheds

### Description of cow shed A

Cow shed A is naturally ventilated (the room volume is 25 499 m³). The roof is made of metal and has no insulation.
The number of animals in the lying box loose housing is 364. The ventilation results from adjustable openings in the side walls, open doors in the gable walls and space boards by a permanently open ridge slot. In summer this ventilation system is supported by 3 ceiling fans (diameter 7.32 m) in the middle axis of the building.

### Description of cow shed B 1 and B 2

These both cow sheds are located at the same place and have the same shape. Both buildings are parallel arranged with a distance of 8 m. The main difference of the two cow sheds (B 1 and B 2) exist therein, that the roof of cow shed B 1 has no thermal insulation and the roof of cow shed B 2 is equipped with an insulation. The room volume is 10 685 m³ for B 1 and 8 648 m³ for B 2.

The number of animals is 215 for each cow shed. The ventilation takes place by adjustable openings in the side walls, open doors in the gable walls and by permanently open ridge slots. Cow shed B 1 is equipped by a ceiling fan (diameter 4.30 m) near the gable door above the feeding pass for test purposes.

## Concept of measurements

Since 2004 measurements of the indoor climate were carried out in cow shed A. The measurement periods ranged from 10 days to 6 weeks. In summer 2008 additional measurements were carried out in cow shed B1 and B1 for comparison purposes.

**Indoor climate measurements**
- Air temperature and humidity
- Globe thermometer temperature
- Surface temperature of the building surfaces (inside)
- Wind speed within the animal zone
- Air volume stream

**Outdoor climatic measurements**
- Air temperature and humidity
- Globe thermometer temperature
- Wind speed and direction

Animal data were not obtained within this study, but will be discussed in context of former investigations [7].

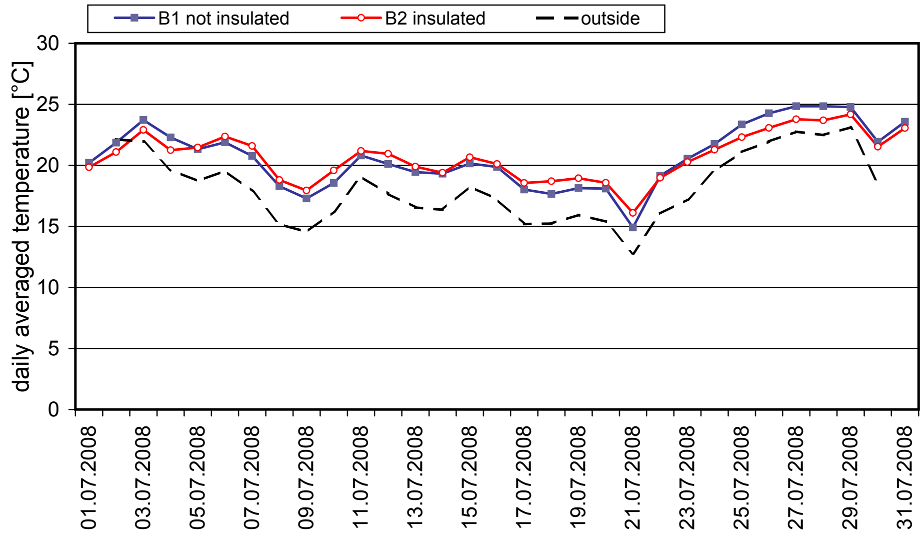
## Results and discussion

Measurements of indoor and outdoor air temperatures show only minor differences (ca. 2 K). A similar founding hold for the comparison of temperature measurements obtained in different cow sheds. It is assumed that a high ventilation rate is the major reason for these small differences. **Table 1** gives an overview of the ventilation rates measured by tracer gas technique for the three investigated cow sheds. All measured ventilation rates of **table 1** are much higher than the required upper limits of the DIN 18 910 [1] for ventilation rates in summer. Even though the difference of the inside roof surface temperature can reach 20 K for the insulated roof of cow shed B1 and the non-insulted roof of cow shed B2 **(figure 1)** the high ventilation rates lead only to minor differences for the measured indoor air temperatures of the two cow sheds. Comparing the ambient indoor air temperature with the measured globe thermometer temperature for cow shed B1 and B2 only differences less than 1.5 K can be observed. Only if sunshine through the opening hits directly a globe thermometer the temperature is increasing above the measured ambient indoor air temperature. In contrast, the outside measurements show higher temperatures (up to 17 K) for the measured globe thermometer temperatures due to radiation than the ambient outside air temperature. **Figure 2** compares the daily averaged air temperatures during July 2008 of cow shed B1 (non insulated roof) with cow shed B2 (insulated roof). On warm days where the daily average temperatures are < 20°C (with daily maximum temperatures up to 25°C) higher daily average temperatures are measured in cow shed B2 with insulation. This observation based on the fact that during night lower cooling rates occur in cow shed B2 which is insulated. On hot days (e.g. 27.07.2008 to 29.07.2008) where the daily average temperature is > 20°C (with daily maximum temperatures > 30°C) higher daily averaged temperatures of cow shed B1 without roof insulation are obtained than in cow shed B2 with the insulated roof **(figure 2)**. In this case the high daily maximum temperature influences the daily average significantly. On the other hand the comparison of the daily maximum temperatures measured in the two cow sheds show only differences around 0.5 K.

In many cow sheds ceiling fans are used to increase the air velocity within the animal zone to reduce possible heat stress for the animals. Velocity measurements within the animal zone in cow shed A and B1 with running ceiling fans show only small velocities < 0.5 m/s at the outer zones of the livestock buildings. The measured velocities within the animal zone are dependent on the outer boundary conditions as e.g. the wind direction. Altogether a heterogeneous velocity distribution with local velocities > 2 m/s can be observed within the animal zone. Given that, the calculation of the radiation temperature from **equation 1** is ambiguous because it is directly dependent on the velocity.

Based on the temperature measurements the THI is calculated with **equation 2**. On a hot day, e.g. 29.07.2008, where maximum outside temperatures are > 30°C the THI is estimated to 80 - 85. Referring to Panagakis [6] this value corresponds to the category „danger". Again no significant differences are obtained for the estimated THI-values of cow sheds with and without insulation. On warm days (20°C outside maximum temperature) the THI index stays below the critical value.

Fig. 2




*Run of the averaged daytime temperatures in cow shed B1 (roof not insulated), cow shed B2 (roof insulated) and outside temperature (July 2008)*

Table 1

*Air exchange rate measured by tracer gas technique*

| Day of measurement | Stable / Test | Wind speed outside in m/s | Air exchange rate in $h^{-1}$ | Air volume stream in $m^3$/h | Specific air volume stream in $m^3$/h per animal |
|---|---|---|---|---|---|
| 16.07.2008 | A / 1 | 2 | 24.8 | 637 475 | 1 751 |
| 16.07.2008 | A / 2 | 2 | 26.6 | 688 473 | 1 891 |
| 13.08.2008 | B 2 / 2 | 10 | 67.7 | 588 064 | 2 735 |
| 13.08.1008 | B 2 / 3 | 10 | 65.9 | 570 768 | 2 655 |

In context of the climate change discussion longer and stronger heat periods are expected for Germany. In that case the heat stress problem for dairy cows becomes an issue for Germany as well.

## Summary


- Large openings at the livestock buildings lead to high ventilation rates through naturally ventilation.
- The room-volume needed per cow should exceed 40 m³, but in any case not decrease below 30 m³.
- The measurements of this campaign showed no significant advantages regarding the indoor climate for a cow shed with an insulated roof.
- Further investigations regarding heat stress are planned, which shall include additional animal specific parameters.


## Literature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## Authors


**Dr.-Ing. Hans-Joachim Müller** and **Dr. rer. nat. Merike Schultz** are scientific workers at the Leibniz-Institute for Agricultural Engineering Potsdam–Bornim e.V. (ATB) (Head: **Prof. Dr. habil. R. Brunsch**), Max-Eyth-Allee 100, 14469 Potsdam, E-mail: hmueller@atb-potsdam.de

**Dipl. Ing. Christiane Loebsin** belongs to the technical staff of the State Institute for Agriculture and Fishery M-V, Institute for Animal Production, (Head: **Dr. P. Sanftleben)**, Wilhelm-Stahl-Allee 2, 18196 Dummerstorf, E-mail: c.loebsin@lfa.mvnet.de