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Short communication: Comparison of ambient temperature, relative humidity, and temperature-humidity index between on-farm measurements and official meteorological data

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ABSTRACT

The objectives of the study were to compare the climate conditions of 7 dairy farms with the climate recorded at the closest official meteorological station. Specifically, we set out to compare the ambient temperature, relative humidity, and the resulting temperature-humidity index (THI) from 7 different barns with those data obtained from the closest official meteorological stations and to compare the climate conditions between 4 different locations within 1 barn. Measures of correlation and agreement demonstrated that climate conditions differ significantly between the barn and the corresponding official meteorological stations as well as between 4 different locations inside 1 barn. The ambient temperature was higher (6.4 ± 3.6°C) in the barn than at the official meteorological station. The relative humidity was higher at the official meteorological station (0.2 ± 7.2%) than in the barn. The THI was higher (11.1 ± 6.5) in the barn than at the official meteorological station. Days with an average THI ≥ 72 were 64 and 4 out of 756 experimental d in the barn and at the official meteorological station, respectively. Also, in a comparison of 7 different barns, ambient temperature and THI were significantly higher than at the closest corresponding official meteorological station. These results indicate that climate conditions should be obtained from on-farm measurements to evaluate potential heat stress and to develop effective measures to abate heat stress of dairy cows.
Key words: dairy cow, heat stress, climate, temperature-humidity index

Short Communication

In the last 50 yr, annual milk yield per cow has increased more than 3-fold (Hansen, 2000). It is closely related to increased DMI and increased metabolic heat production (Kadzere et al., 2002). Heat production and congestion, in combination with compromised cooling capability because of environmental conditions, causes the heat load in cows to increase to the point that body temperature rises (Burfeind et al., 2012) and DMI and milk production decline (Wilson et al., 1998; Ravagnolo et al., 2000; West et al., 2003). Particularly in hot seasons, cows are metabolically challenged to emit excess body heat (Purwanto et al., 1990; West, 2003). Maintenance expenditures at 35°C increase by 20% over thermoneutral conditions of 16°C or lower (NRC, 1981). These processes can cause suboptimal reproductive performance of dairy cows, such as a decrease in conception rate during the hot season by 20 to 30% compared with the winter season (De Rensis et al., 2002) and important economic losses (Collier et al., 2006). Climate conditions may be a major contributing factor to the low fertility of dairy cows during summer months, especially in high-yielding cows (Kadzere et al., 2002).

Heat stress is becoming increasingly important because an increase in milk yield is related to a decrease in heat tolerance (Berman et al., 1985; West, 2003) and milk yield is expected to further increase (Hansen, 2000; van Arendonk and Liinamo, 2003). Accordingly, associations between heat stress, milk yield, and the effect of heat stress on the reproductive performance of dairy cows has become an important issue (Kadzere et al., 2002). The majority of studies about heat stress in livestock have been conducted in tropical or subtropical areas or during hot climate conditions (e.g., Florida, Mexico, southwest United States) because the negative effects are obvious in these climates. However, a dearth of information exists from moderate climates in the temperate latitudes (e.g., central Europe, northern United States, Canada), although extreme temperatures can occur in summer months (Alcamo et al., 2007). Furthermore, changes in the moderate climates in the temperate latitudes have been anticipated (Menzel et al., 2006; Alcamo et al., 2007).

Most of the studies investigating heat stress obtained meteorological data from a meteorological sta-

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tions located in the vicinity of the study sites, but the value of information from weather stations to augment dairy records is not known (Ravagnolo et al., 2000). As reviewed by Silanikove (2000), cows release heat and humidity via convection, conduction, and radiation through expired air and through excrement to the environment. Evaporative water loss can be up to 1.5 kg/h per cow (Berman et al., 1985), and heat production of cows exposed to 35°C (141.8 kcal/kg) is 13.9% higher than that of cows kept at 20°C (124.5 kcal/kg; Robinson et al., 1986). Recently, it has been demonstrated that a trend exists in the dairy industry toward fewer and larger dairy farms housing more cows under one roof (Winsten et al., 2010), which might increase the risk of suboptimal climate conditions. Additionally, heat is often released by radiation from machinery located in the barns and humidity is released through cleaning processes. Obviously, all these factors can lead to considerably different climate conditions in confinement systems compared with those of a meteorological station recording outdoor data.

Therefore, the objectives of the study were to compare the climate conditions of dairy freestall facilities with the climate recorded from the closest official meteorological station. Specifically, we set out (1) to compare ambient temperature (**AT**), relative humidity (**RH**), and temperature-humidity index (**THI**) measured over a period of 24 mo from 1 barn with the climate obtained from the closest official meteorological station, (2) to compare AT, RH, and THI from different locations within 1 barn, and (3) to compare the climate conditions measured onsite at 7 different barns with data obtained from the closest official meteorological station.

Data Collection

The first and the second experiment were conducted simultaneously on a commercial dairy farm in Sachsen-Anhalt, Germany (barn 1), from May 2010 to May 2012. The herd consisted of 1,150 Holstein dairy cows with an average milk production of 10,124 kg (4.1% fat, 3.4% protein). The barn was positioned in a northeast-southwest orientation with open ventilation and a mechanical fan system. Sixty fans were installed above the stalls and controlled manually by the farm manager. All cows were housed in a freestall facility with slatted floors and freestalls equipped with rubber mats. Three weeks before the expected date of calving, cows were housed in a close-up pen until first milking. This outdoor pen was covered by a roof attached to the outdoor wall of the main building with 2 open sides and a deep-bedded straw pack. Fresh cows were kept in a fresh cow pen until 5 DIM. From 5 DIM onward, cows were grouped in the high-yielding pen depending on lactation and reproductive status. Lactating cows were milked 3 times/d and kept in the holding area for approximately 0.5 h each before milking. The fresh cow and high-yielding pens, as well as the holding area, were located in the main barn, whereas the fresh cow pen was located nearby an exterior wall with an additional fresh air supply. The high-yielding pen and the holding area were located side by side with free air circulation.

Ambient temperature and RH within barn 1 were recorded using 4 Tinytag Plus II loggers (Germini Loggers Ltd., Chichester, UK) secured in the middle alley of the different pens at beams 3 m from the ground at 4 different locations (i.e., close-up pen, fresh cow pen, high-yielding pen, holding area) within the barn. These loggers measured AT from −25 to 85°C with an accuracy of ±0.3°C and a resolution of 0.01°C and RH from 0 to 100% with an accuracy of ±3% and a resolution of 0.3%. These data were recorded hourly and loggers were calibrated by the manufacturer at the beginning and the end of the study and accuracy was checked. Additionally, AT and RH recorded at the same times were obtained from a meteorological station located 18 km east of the barn. Ambient temperature and RH data were used to calculate the THI according to the equation reported by Kendall and Webster (2009):

$$\mathrm{THI} = (1.8 \times \mathrm{AT} + 32) - [(0.55 - 0.0055 \times \mathrm{RH}) \times (1.8 \times \mathrm{AT} - 26)].$$

In experiment 1, climate data were collected from barn 1, positioned in the high-yielding pen, and compared with the climate data collected from the official meteorological station from May 2010 to May 2012. In experiment 2, climate data were collected from the 4 different locations within barn 1 and compared with each other from May 2010 to February 2011. In experiment 3, climate data were collected from 7 different barns of 6 different commercial dairy farms in Brandenburg and Sachsen-Anhalt, Germany. These data were compared with the climate data collected from the closest corresponding official meteorological stations for the period from June 2012 to October 2012. Loggers and position of the loggers were identical to experiment 1. Detailed information for barns 2 to 7 are summarized in Table 1.

Statistical Analyses

Data from the onsite climate loggers and from the official meteorological station were downloaded into Excel spreadsheets (Office 2010, Microsoft Deutschland GmbH, Munich, Germany) and analyzed using SPSS for Windows (Version 19.0, SPSS Inc., IBM, Ehningen,