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Impact of heat stress on conception rate of dairy cows in the moderate climate considering different temperature–humidity index thresholds, periods relative to breeding, and heat load indices

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ABSTRACT

The objectives of this retrospective study were to investigate the relationship between temperature–humidity index (THI) and conception rate (CR) of lactating dairy cows, to estimate a threshold for this relationship, and to identify periods of exposure to heat stress relative to breeding in an area of moderate climate. In addition, we compared three different heat load indices related to CR: mean THI, maximum THI, and number of hours above the mean THI threshold. The THI threshold for the influence of heat stress on CR was 73. It was statistically chosen based on the observed relationship between the mean THI at the day of breeding and the resulting CR. Negative effects of heat stress, however, were already apparent at lower levels of THI, and 1 hour of mean THI of 73 or more decreased the CR significantly. The CR of lactating dairy cows was negatively affected by heat stress both before and after the day of breeding. The greatest negative impact of heat stress on CR was observed 21 to 1 day before breeding. When the mean THI was 73 or more in this period, CR decreased from 31% to 12%. Compared with the average maximum THI and the total number of hours above a threshold of more than or 9 hours, the mean THI was the most sensitive heat load index relating to CR. These results indicate that the CR of dairy cows raised in the moderate climates is highly affected by heat stress.

1. Introduction

In the last 60 years conception rate (CR) in high-yielding dairy cows decreased from 55% to 35% worldwide, and is suggested to further decrease in Germany [1–3]. One important factor for decreasing reproductive efficiency in dairy cows is heat stress, which may reduce CR up to 23% [4]. High-yielding cows are particularly affected by heat stress, because the heat tolerance decreases with increasing milk yield and dry matter intake [5,6]. As milk yield of dairy cows is expected to further increase [7,8], the negative impact of heat stress will become more important. There is a trend in the dairy industry toward fewer and larger dairy farms housing more cows under one roof [9], which might increase the risk of suboptimal climate conditions [10,11].

Heat stress can have major effects on fertility and embryonic survival in lactating dairy cows [12]. These include compromised endometrial function and secretory activity, smaller follicular size, and suppressed dominance of the large follicle [13]. Disturbances in hormonal balance include decreased serum estradiol concentration [14,15], decreased plasma concentration of LH, and

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decreased progesterone secretion [13]. Furthermore, oocyte quality [16,17], embryo development [18–20], and embryo survival [13] are impaired by heat stress. These processes lead to a decrease in CR in the subtropical areas during the hot season at 90 and 135 days postpartum (33% and 62%) ranging between 20% and 30% compared with the winter season (46% and 76%) [21]. Thus, heat stress is one impacting factor responsible for extensive economic losses to the dairy industry [22].

Morton, et al. [23] estimated that heat stress defined as a daily maximum temperature–humidity index (THI) of 72 or more from Day 35 before to Day 6 after the day of breeding decreases CR of lactating dairy cows by around 30% points relative to days of breeding in which there was no heat load from Day 35 before to Day 6 after the day of breeding. The majority of studies about heat stress in dairy cattle were conducted in tropical or subtropical areas (e.g., Florida, Mexico, and Southwest of USA), because the negative effects are obvious in these climates. However, the average THI in the moderate climates in the temperate latitudes (e.g., Central Europe, Northern US, and Canada) can also reach the threshold of 72 during summer months. Most recently, we demonstrated that the THI threshold of 72 was reached on 162 of 756 experimental days inside a commercial dairy barn in Germany. This observation highlighted the importance of heat stress even in the moderate climates [24].

Heat stress in the period around the day of breeding was consistently associated with reduced CR [4,23]. Furthermore, negative effects of heat stress have been identified from 42 days before to 40 days after insemination [25]. The mechanisms by which heat stress impairs conception considering for specific periods, however, remain unclear [23,26].

Therefore, the objective of the present study was to examine the effects of heat stress on reproductive performance of dairy cows in the moderate climates of the temperate latitudes. Specifically, we set out (1) to investigate the relationship between THI and CR of lactating dairy cows, (2) to determine a critical threshold of THI on the day of breeding for CR, and (3) to identify periods of exposure relative to the day of breeding during which heat stress is most closely associated with impaired CR. In addition, we assessed whether the mean THI is more closely associated with CR than the maximum THI or the total number of hours above the mean THI threshold in certain periods of exposure relative to day of breeding.

2. Materials and methods

2.1. Herd and barn

The retrospective study was conducted on a commercial dairy farm located in Sachsen-Anhalt, Germany from May 2010 to October 2012. The herd consisted of 1150 Holstein dairy cows with an average milk production of 10,345 kg (4.0% fat and 3.3% protein). The barn was positioned in a NE–SW orientation with open ventilation and a mechanical fan system. Sixty fans were installed above the stalls, and were controlled manually by the farm manager. All cows were housed in a free-stall facility with slatted floors and beds equipped with rubber mats. Group composition was dynamic with cows entering and leaving the experiment, depending on their calving dates. Cows were fed a TMR. The rations were formulated to meet or exceed the requirements of the National Research Council [27]. Lactating cows were milked three times a day at around 6 AM, 2 PM, and 10 PM.

2.2. Reproductive management

The voluntary waiting period was set at 49 days postpartum. Between 35 and 49 days, cows received an initial injection of 25 mg PGF2α (Dinoprost, Dinolytic; Zoetis Deutschland GmbH, Berlin, Germany) and a second injection of 25 mg PGF2α 2 weeks later to regress the CLs. Cows that showed estrus after the second injection of PGF2α were artificially inseminated. Pedometers (Milkline, Gariga di Podenzano, Italy) and visual observation were used to detect estrus. Cows that did not show estrus after the second injection of PGF2α were examined and treated with an Ovsynch program initiated 12 days later. On this day, treated cows received an initial injection of 100 μg of GnRH (Gonadorelin, Gonavet Veyx; Veyx-Pharma GmbH; Schwarzenborn, Germany). Seven days later at the same time, cows received 25 mg PGF2α to regress the CLs, and 48 hours later, a second injection of 100 μg of GnRH to induce ovulation of the dominant follicle. The artificial insemination (AI) was performed 16 to 17 hours after the second injection of GnRH. Cows that showed estrus after the injection of GnRH of the Ovsynch program were inseminated prematurely. Cows with a CL at the time of examination (i.e., after the second injection of PGF2α) were treated with a modified Ovsynch program. Cows received 25 mg PGF2α to regress the CLs, and 48 hours later, an injection of 100 μg of GnRH to induce ovulation of the dominant follicle. The AI was performed 16 to 17 hours after the injection of GnRH. Inseminations at detected estrus were performed within 12 hours after detection of estrus. Inseminations after Ovsynch and modified Ovsynch program and inseminations at detected estrus were performed with frozen-thawed or fresh semen. Cows after cesarean section, with adhesions of the uterus, and repeat breeder cows in third or higher lactation received natural service by the bull. Pregnancy diagnoses were performed 34 days after the day of breeding with transrectal ultrasonography by the herd veterinarian. Cows that were not pregnant and without a CL were reassigned to the Ovsynch protocol. Cows that were observed in estrus more than 10 days after AI were assumed nonpregnant and reinseminated.

2.3. Data collection

Ambient temperature (AT) and relative humidity (RH) within the experimental barn were recorded using a Tinytag Plus 2 logger (Gemini loggers Ltd, Chichester, UK) secured at a beam 3 m from the ground. These loggers measured AT from −25 °C 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. Ambient temperature