J. Dairy Sci. 96:1844–1855
http://dx.doi.org/10.3168/jds.2012-5947

Evaluation of heat stress effects on production traits and somatic cell score of Holsteins in a temperate environment

H. Hammami,*†[1] J. Bormann,‡ N. M'hamdi,§ H. H. Montaldo,# and N. Gengler*
*Animal Science Unit, Gembloux Agro-Bio Tech, University of Liège, B-5030 Gembloux, Belgium
†National Fund for Scientific Research, B-1000 Brussels, Belgium
‡Administration of Agricultural Technical Services, L-1019 Luxembourg, Luxembourg
§Animal Science Department, High Institute of Agronomy of Chott-Mariem, TN-4042 Sousse, Tunisia
#Departamento de Genética y Bioestadística, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, Ciudad Universitaria, D.F. 04510, Mexico

ABSTRACT

This study was aimed to evaluate the degree of thermal stress exhibited by Holsteins under a continental temperate climate. Milk, fat, protein, and somatic cell count test-day records collected between 2000 and 2011 from 23,963 cows in 604 herds were combined with meteorological data from 14 public weather stations in Luxembourg. Daily values of 6 different thermal indices (TI) weighted in term of temperature, relative humidity, solar radiation, and wind speed were calculated by averaging hourly TI over 24 h. Heat stress thresholds were first identified by a broken-line regression model. Regression models were thereafter applied to quantify milk production losses due to heat stress. The tipping points at which milk and protein yields declined were effectively identified. For fat yield, no valid threshold was identified for any of the studied TI. Daily fat yields tended to decrease steadily with increasing values of TI. Daily somatic cell score patterns were marked by increased values at both lowest and highest TI ranges, with a more pronounced reaction to cold stress for apparent temperature indices. Thresholds differed between TI and traits. For production traits, they ranged from 62 (TI_1) to 80 (TI_3) for temperature-humidity indices (THI) and from 16 (TI_5) to 20 (TI_6) for apparent temperature indices. Corresponding somatic cell score thresholds were higher and ranged from 66 (TI_1) to 82 (TI_3) and from 20 (TI_5) to 23 (TI_6), respectively. The largest milk decline per unit of mild, moderate, and extreme heat stress levels of 0.164, 0.356, and 0.955 kg, respectively, was observed when using the conventional THI (TI_1). The highest yearly milk, fat, and protein losses of 54, 5.7, and 4.2 kg, respectively, were detected by TI_2, the THI index that is adjusted for wind speed and solar radiation. The latter index could be considered as the best indicator of heat stress to be used for forecast and herd management in a first step in temperate regions under anticipated climate changes.
Key words: thermal index, heat stress, temperate climate, dairy cattle

INTRODUCTION

Climate change is expected to have an impact on animal production throughout the world (IPCC, 2007). Climate extremes are more likely, exposing previously temperate regions to sustained hot periods. Under temperature, relative humidity (**RH**), solar radiation (**RAD**), and wind speed (**WS**) that exceed their thermal comfort zone, dairy cows suffer from heat stress. Heat stress reduces milk production, reproductive performance, and profit (St-Pierre et al., 2003; Bohmanova et al., 2007; Boonkum et al., 2011).

Temperature-humidity index (**THI**), which uses dry bulb temperature (**T_{db}**) and wet bulb temperature, was initially developed by Thom (1959) as a heat index for human comfort but it remained the most common heat stress indicator used until now for different animal species. Various THI more adapted to cattle comfort were later developed (Bianca, 1962; Berry et al., 1964; NRC, 1971). Most of those indices were evaluated as potential predictors of heat stress and milk yield losses of dairy cattle using large data sets in humid and hot tropical environments (Bohmanova et al., 2007; Dikmen and Hansen, 2009). The THI is still the most widespread indicator of heat stress; however, it has its limitations because it is (1) an empirical representation, (2) assumes that all animals react similarly to environmental stressors, and (3) does not account for other environmental effects (e.g., WS and RAD) and cow-specific effects (e.g., age and breed). Recently, technological advances have facilitated the collection of large and precise additional environmental parameters (e.g., RAD, WS, and duration of exposure) and physiological parameters (e.g., respiration rate, rectal and core body

Received July 16, 2012.
Accepted November 11, 2012.
[1]Corresponding author: hedi.hammami@ulg.ac.be

temperature, and sweating rate). New thermal indices (**TI**) that incorporated those environmental and physiological data in addition to cow specificities (e.g., breed and age) have been developed to overcome the various THI limitations (Mader et al., 2006; Gaughan et al., 2008; Mader et al., 2010).

Comprehensive scientific studies related to heat stress in dairy cattle were exclusively conducted in the United States using large local performance and weather data (Bohmanova et al., 2007; Aguilar et al., 2009; Sánchez et al., 2009) and also similar data from tropical regions (Boonkum et al., 2011). Even if differences in thresholds of heat stress for different combination of regions and THI indices (Bohmanova et al., 2007) were found, the THI (NRC, 1971) was extensively used to estimate the thresholds of heat stress. A THI value of 72, which corresponds to 22°C at 100% humidity, has been continuously applied as a reference for genetic evaluation of heat tolerance in US Holsteins for daily milk (Bohmanova et al., 2005; Aguilar et al., 2010). Adjusted THI and new TI incorporating RAD and WS were not evaluated, probably due to unavailable data for the later parameters, but mainly because cows in the United States are generally housed under shade structures during periods of heat stress or may even benefit from cooling systems.

Studies on heat stress effects in temperate regions and especially in Europe are scarce. The few studies focused on evaluating heat stress in dairy cattle (Broucek et al., 2007; Reiczigel et al., 2009; Gantner et al., 2011) pointed out an increase in heat stress days for the past 30 yr, with an extreme hot summer in 2003. In 2003 alone, more than 80 d exceeded the THI of 72 in Eastern Europe. Nevertheless, these studies were based on limited data sets and arbitrarily used the THI value of 72 as the threshold of heat stress onset. Recently, a study using data from Germany observed a decline in protein yield in Holstein dairy cattle from a THI of 60 (Brügemann et al., 2011). The authors reported that this low threshold was associated with a decline in protein yield at phenotypic level and a decrease in genetic variances and heritabilities.

Under expected climate change, evaluation of heat stress relief and knowledge of possible genotype by environment interactions is of increasing interest. Selection for heat tolerance in Holsteins based on THI in genetic evaluation is, therefore, possible also in temperate regions (Brügemann et al., 2011) and could be a sustainable strategy to supplement feed or housing modifications. Nevertheless, knowledge of heat stress thresholds is first needed. Thermal indices and their appropriate thresholds are not fixed features for any population and they may change with the ability of animals to adapt to environmental conditions. To our knowledge, no study has focused on evaluating heat stress effects based on large field data and using either old or new TI that included WS and RAD in addition to T_{db} and RH. The main objective of this study was to assess the effect of heat stress on production traits and SCS of Holsteins bred under temperate climate conditions using the most comprehensive thermal comfort indices.

MATERIALS AND METHODS

Data

A total of 230,192 first-lactation test-day records for milk, fat, and protein yields and SCC from 23,963 Holstein cows collected between 2000 and 2011 in 604 herds by CONVIS Herdbuch, Service Elevage et Génétique (Ettelbruck, Luxembourg) and provided by United Datasystems for Animal Production [Vereinigte Informationssyteme Tierhaltung (VIT), Verden, Germany] were used in this study. Only records from cows with DIM between 5 and 330 were retained. Cows were required to have at least 5 records. Somatic cell score was calculated according to the formula SCS = $\log_2$ (SCC/100) + 3.

Hourly meteorological data (T_{db}, RH, WS, RAD, and rain) collected between 2000 and 2011 in 14 public stations in Luxembourg, were provided by Administration des services techniques de l'agriculture (ASTA, Luxembourg). Six TI were calculated using T_{db} (°C), RH (%), WS (m/s), and RAD (W/m^2) as follows:

TI_1: temperature-humidity index (NRC, 1971):

$$\mathrm{THI} = (1.8 \times T_{db} + 32) - [(0.55 - 0.0055 \times \mathrm{RH}) \times (1.8 \times T_{db} - 26)]; \quad [1]$$

TI_2: adjusted THI (THI_{adj}; Mader et al., 2006):

$$\mathrm{THI}_{adj} = [4.51 + \mathrm{THI} - (1.992 \times \mathrm{WS}) + (0.0068 \times \mathrm{RAD})], \quad [2]$$

where

$$\mathrm{THI} = (0.8 \times T_{db}) + [\mathrm{RH} \times (T_{db} - 14.4)] + 46.4;$$

TI_3: heat load index (HLI; Gaughan et al., 2008):

$$\mathrm{HLI} = 8.62 + (0.38 \times \mathrm{RH}) + (1.55 \times \mathrm{BG}) - (0.5 \times \mathrm{WS}) + e^{(2.4 - \mathrm{WS})}, \text{ when BG} > 25; \quad [3]$$

$$\mathrm{HLI} = 10.66 + (0.28 \times \mathrm{RH}) + (1.3 \times \mathrm{BG}) - \mathrm{WS}, \text{ when BG} \leq 25,$$