Environmental Stress in Dairy Cattle

Part 2: Ways to Quantify Environmental Stress

There are four factors that affect the environmental stress due to heat load that cows experience: air temperature, relative humidity (RH), air speed, and radiation. As environmental temperature and RH increase, cows labor to dispose of excess body heat and if not successful, their core body temperature rises. The resulting environmental stress causes numerous negative effects on cows' production and health and is here referred to as heat stress. Heat stress was estimated in 2003 to cost the NY state dairy industry over $24 million annually[1].

The risk of heat stress is increased by high air temperature, high air humidity, and both direct and indirect exposure to solar radiation. The risk is reduced by air movement, shade, and evaporative or other cooling. Heat stress can be estimated from air temperature alone, but using a heat stress index is better because it accounts for multiple environmental parameters. The most common index used for heat stress is the temperature-humidity index (THI), which uses dry bulb temperature (T_{DB}) in °F as a baseline then adjusts to higher values for more humidity or lower values for less humidity. A more thorough index is the black globe humidity index (BGHI), which accounts for temperature and humidity as well as the effects of radiation and air movement (Figure 1). Even when cows are housed indoors, they are exposed to indirect solar radiation, which is only accounted for by BGHI not THI. Both index values are discussed below.

Calculating THI

There are different formulas for estimating THI from temperature and humidity. THI was first used by the US Weather Service in 1959 for humans but then used a few years later to estimate heat stress for dairy cows[2]. The original formula has been modified several times to make it more appropriate for dairy cows.

Care should be taken to verify that the formula used is consistent with the temperature scale in the data. A common formula for calculating THI for dairy cattle is as follows:

$$THI = T_{DB} - [(0.55 - 0.0055 \times \%RH) \times (T_{DB} - 58.8)]$$

where T_{DB} is temperature in °F and RH is relative humidity in percent[3].

Calculating BGHI

The BGHI was developed from the THI but with the dry bulb temperature (T_{DB}) replaced with the black globe temperature (T_{BG}). T_{BG} is essentially the equilibrium temperature measured inside a hollow black sphere. Thus,

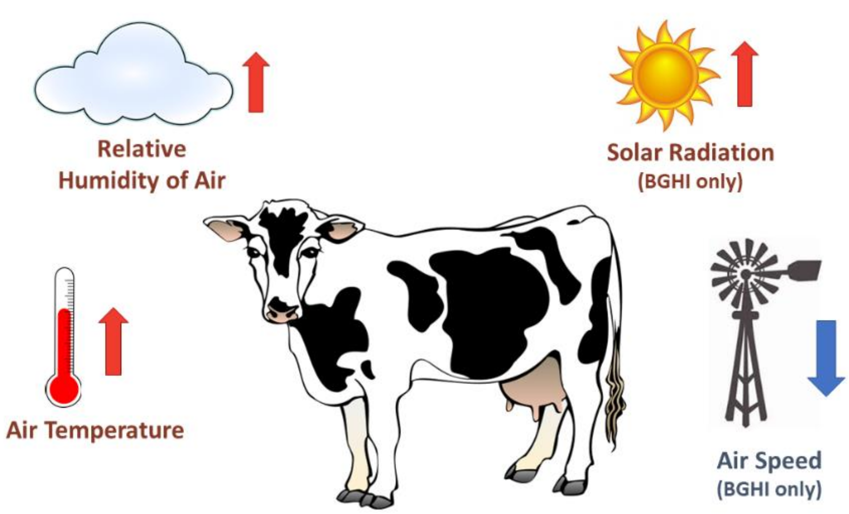

Figure 1. Environmental conditions used in THI and BGHI indexes

the more radiation is present (direct or indirect), the hotter the black globe will get. The black globe will, however, be cooled off by natural or mechanically-induced air currents. Thus, T_{BG} measures a combination of air temperature, solar radiation, and air currents, and BGHI includes the additional effects of relative humidity. The formula typically used for BGHI (adapted for input in ºF) is

$$BGHI = 0.556 \times T_{BG} + 0.2 \times T_{dew} + 17.32$$

where T_{BG} is black globe temperature (in ºF) and T_{dew} is dewpoint temperature (in ºF)[2].

T_{dew} is the temperature at which moisture starts to condense out of the air, but T_{dew} cannot easily be directly measured and instead is based on a complex formula combining T_{DB} and RH. Calculators are available online for calculating T_{dew} if T_{DB} and RH are known[4]. Although THI formulas have been updated to use RH directly instead of first calculating T_{dew}, all of the studies on BGHI used the older THI formulas to calculate BGHI and thus required first calculating T_{dew}.

Temperature only

Since both ambient temperature and humidity affect the level of heat stress of dairy cows, combining both into an index is a better way to estimate heat stress than temperature alone. However, if air humidity data is not available, heat stress can be fairly well estimated from temperature only in dry climates[3]. T_{BG} is preferable to T_{DB}, especially if cows are outdoors and thus exposed to direct sunlight. This is because T_{BG} accounts for radiation and air movement as well as ambient temperature. Therefore, T_{BG} is a more complete assessment of the heat stress the cow is experiencing[2]. For example, under direct sunlight, T_{BG} can be more than 10ºF hotter than T_{DB}.

Other considerations

The important parameter for the cows is the environment that they actually experience in the barn, which could have higher temperature or humidity than the outdoor air. A well-ventilated barn will maintain THI within the barn to one or two points of the outside air THI, but a poorly ventilated barn could have even more difference between the outdoor and indoor environment. Another consideration is whether heat stress mitigation is measured by the index being used. Sprinklers that apply water directly to cows' backs help alleviate heat stress but won't be directly quantified by THI or BGHI. Barn air movement and radiation exchange between cows and their surroundings also affect the cows' ability to lose heat and are quantified by BGHI but not by THI. Although BGHI includes more factors than THI to estimate the environment the cows are experiencing, both indices are helpful indicators of the level of heat stress of the cows and thus are useful tools for farmers to decide when and how to mitigate heat stress.

FACT SHEET SERIES

Environmental Stress in Dairy Cattle

AUTHORS

Kristy Perano, M.S.	kmp263@cornell.edu	(209) 418-5927
Curt Gooch, P.E.	cag26@cornell.edu	(607) 255-2088

REFERENCES

[1] St. Pierre et al. 2003. J. Dairy Sci 86:(E. Suppl.):E52-E77; [2] Buffington et al. 1981. ASAE 24(4):711-714; [3] Dikmen and Hansen 2009. J. Dairy Sci. 92:109-112; [4] Calculator for T_{dew} http://andrew.rsmas.miami.edu/bmcnoldy/Humidity.html.

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

This material is based upon work that is supported by the New York Energy Research & Development Authority (NYSERDA) under agreement #28264. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of NYSERDA.