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Cooling cows efficiently with sprinklers: Physiological responses to water spray

Jennifer M. Chen,* Karin E. Schütz,† and Cassandra B. Tucker*[1]
*Department of Animal Science, University of California, Davis 95616
†AgResearch Ltd., Hamilton 3240, New Zealand

ABSTRACT

Dairies in the United States commonly cool cattle with sprinklers mounted over the feed bunk that intermittently spray the cows' backs. These systems use potable water—an increasingly scarce resource—but there is little experimental evidence about how much is needed to cool cows or about droplet size, which is thought to affect hair coat penetration. Our objectives were to determine how sprinkler flow rate and droplet size affect physiological measures of heat load in a hot, dry climate, and to evaluate cooling effectiveness against water use. The treatments were an unsprayed control and 6 soaker nozzles that delivered four 3-min spray applications of 0.4, 1.3, or ≥4.5 L/min (with 2 droplet sizes within each flow rate) and resulting in 30 to 47% of spray directly wetting each cow. Data were collected from high-producing lactating Holsteins (n = 19) tested individually in ambient conditions (air temperature = 31.2 ± 3.8°C, mean ± standard deviation). Cows were restrained in headlocks for 1 h and received 1 treatment/d for 3 d each, with order of exposure balanced in a crossover design. When cows were not sprayed, physiological measures of heat load increased during the 1-h treatment. All measures responded rapidly to spray: skin temperature decreased during the first water application, and respiration rate and body temperature did so before the second. Droplet size had no effect on cooling, but flow rate affected several measures. At the end of 1 h, 0.4 L/min resulted in lower respiration rate and skin temperature on directly sprayed body parts relative to the control but not baseline values, and body temperature increased to 0.2°C above baseline. When 1.3 or ≥4.5 L/min was applied, respiration rate was lower than the control and decreased relative to baseline, and body temperature stayed below baseline for at least 30 min after treatment ended. The treatment that best balanced cooling effectiveness against water usage was 1.3 L/min: although ≥4.5 L/min reduced respiration rate relative to baseline by 4 more breaths/min than 1.3 L/min did (−13 vs. −9 breaths/min, respectively), each additional liter of water decreased this measure by only ≤0.1 breaths/min (≤1% of the total reduction achieved using 1.3 L/min). We found similar water efficiency patterns for skin temperature and the amount of time that body temperature remained below baseline after treatment ended. Thus, when using this intermittent spray schedule in a hot, dry climate, applying at least 1.3 L/min improved cooling, but above this, additional physiological benefits were relatively minor.
Key words: heat load, sprinkler, soaker, water conservation

INTRODUCTION

Weather conditions such as high air temperature and exposure to solar radiation cause cattle to gain heat. Cows dissipate heat through evaporation by increasing respiration rate, panting, and, to a limited extent, sweating (Gebremedhin et al., 2008). However, when this is insufficient, the accumulated heat load can increase body temperature and decrease milk yield (Wheelock et al., 2010) and fertility (De Rensis and Scaramuzzi, 2003) and, in extreme cases, can result in mortality (Stull et al., 2008; Vitali et al., 2009).

To manage heat load, dairy producers provide shade, fans, spray cooling (sprinklers/soakers with large droplets, or misters with fine droplets), or a combination of these resources: 94% of US dairies use at least one of these types of heat abatement (USDA, 2010). Spray cooling, typically provided either in the holding pen or at the feed bunk, is common (62% of milking herds ≥500 head; USDA, 2010) because it lowers body temperature and respiration rate (Valtorta and Gallardo, 2004; Kendall et al., 2007; Chen et al., 2013) and improves feed intake and milk yield in hot conditions (Keister et al., 2002). Although spray cooling is 1 of 3 main uses of potable water, along with drinking water (at least 57 to 110 L/d per cow; Kume et al., 2010) and water

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[1]Corresponding author: cbtucker@ucdavis.edu

used for milking (e.g., cleaning cows before milking, milking equipment, and the milking parlor, 170 to 734 L/d per cow; Meyer et al., 2006), the amount of water used for cooling varies widely among farms (e.g., 23 to 256 L/d per cow; G. Tresoldi, University of California–Davis; personal communication). Along with increasing global temperatures, decreasing precipitation or changes in precipitation patterns are predicted to limit water availability (Rosenstock et al., 2006). Therefore, the ability to reduce heat load in cattle while reducing water consumption is an important issue for US dairy production.

There is little evidence for how much water is needed to effectively cool cows. Spray reduces heat load through evaporation when the water is turned off, as well as by cooling the microclimate around the cow. Some heat may be dissipated through fluid convection when water drips from the body but this is associated with speculative concerns about mastitis (e.g., as suggested by Flamenbaum et al., 1986). To determine how much water is needed to cool via evaporation, Arkin et al. (1991) estimated the evaporative potential of a wet, excised hide ($\leq$0.23 L/m^2), and heat transfer models have been created for different ambient conditions (Kimmel et al., 1991; Gebremedhin and Wu, 2002). However, there has been little experimental validation on live cows, and comparing cooling effectiveness across studies is challenging, as some do not report how much water is used (Araki et al., 1985; Igono et al., 1987; Valtorta and Gallardo, 2004), or use variable units of measure: most commonly liters per minute (e.g., Chen et al., 2013) or liters per hour (e.g., Gallardo et al., 2005), but also cubic meters per hour (Flamenbaum et al., 1986), millimeters per centimeter squared per hour (Granzin, 2006), milliliters per meter squared per minute (Schütz et al., 2011), or millimeters per hour (Kendall et al., 2007). The only study to date that directly compared sprinkler flow rates (mounted over the freestalls and without unsprayed controls) found no differences in heat load when spraying 5.2, 8.2, or 11.7 L/min in 1.5-min applications in a hot, humid climate (Means et al., 1992). It seems likely that effective cooling can be achieved with less water than these relatively high flow rates; in a subsequent study that applied 5.2 L/min, Montoya et al. (1995) calculated from runoff that only 15% of the spray applied evaporated directly from the cows.

In addition to the amount of water, spray droplet size may play a role in cooling. Some smaller droplets may evaporate before reaching cattle; although this may cool the microclimate, the resulting increase in relative humidity may also reduce the potential for water to evaporate from the cows. Small droplets can also accumulate on the hair coat, which some have suggested may limit cooling effectiveness (Hahn, 1985; Flamenbaum et al., 1986) or even create an insulating barrier which traps heat (Armstrong, 1994; Mitlöhner et al., 2001). In contrast, larger droplets may be less likely to evaporate before reaching the cow and could better penetrate the hair coat to the skin, improving cooling effectiveness, but this has not been explicitly examined.

Our objective was to determine how sprinkler flow rate and droplet size influence physiological signs of heat load in a hot, dry climate and the efficiency of water usage. We predicted that measures of heat load would be lower for higher flow rates and larger droplet sizes (within a given flow rate).

MATERIALS AND METHODS

Animals and Housing

The study was conducted during the summer (June to August 2011) at the University of California-Davis dairy facility, with all procedures approved by the Institutional Animal Care and Use Committee. Twenty lactating, pregnant Holstein-Friesian dairy cows were used, with average parity 1.5 ± 0.5, DIM 181 ± 51, daily milk yield 39 ± 4 kg, and BW 643 ± 58 kg (mean ± SD).

Cows were tested in 2 consecutive cohorts (10 cows each) and acclimated to the home pen for at least 3 d before testing. This concrete-floored pen included a water trough (automatically refilled to 808 L), 16 shaded, sand-bedded freestalls with 3 fans (36-DMCH, 5 m^3/s; Future Products Corp., Mosinee, WI), and an ad libitum TMR formulated to NRC (1989) requirements using the PC Dairy system (Bath and Strasser, 1990). The shaded feed bunk was fitted with 6 sprinkler nozzles (TF-VP7.5 Turbo FloodJet wide-angle flat spray tip, 4.9 L/min; Spraying Systems Co., Wheaton, IL) that delivered 1.5 min of continuous spray, followed by 13 or 5 min off (at air temperature $\geq$22.2 or 29.4°C, respectively). These sprinklers were turned on only between 2200 and 0700 h, which was 6 h after to 6 h before the daily treatment period; this was done to ensure that body temperature results were due to the treatments imposed, because sprinklers can reduce body temperature for up to 6 h (i.e., after a 90-min treatment; Kendall et al., 2007).

Treatments

Treatments were administered in an area that was separated from the rest of the home pen with portable livestock fencing panels (Powder River, Provo, UT).