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Cooling cows with sprinklers: Spray duration affects physiological responses to heat load

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ABSTRACT

Sprayed water reduces heat load in cattle. Determining appropriate spraying strategies (i.e., time on and off) may improve cooling efficiency and reduce water use. Our objective was to evaluate the effects of a single spray on the surrounding air temperature (AT), time it takes the coat to dry, and physiological responses to heat load in dairy cows. In a crossover design, spray duration (0, 0.5, 1.5, 3, and 13 min; flow rate: 4.9 L/min) was tested in 15 Holstein cows (milk yield: 37.7 ± 2.6 kg/d) restrained in shaded head gates at the feed bunk for up to 1.75 h. Each treatment was replicated on 3 d (15 d total/cow) when AT, humidity, and temperature-humidity index averaged 31 ± 3°C, 27 ± 10%, and 76 ± 2, respectively (mean ± SD). Water temperature at the nozzle outlet and dripping from the cow was measured every 1 s and averaged (mean ± SD) 29.7 ± 1.4 and 30.3 ± 0.8°C, respectively. Respiration rate, skin temperature of the shoulder and upper leg, and the surrounding AT were measured before and after the spray application and every 3 min for 30 min. At the same intervals, using water-sensitive paper we measured the time the coat took to dry. In contrast to the control, immediately after the spray was turned off, all water treatments reduced skin temperature on the shoulder (range of mean ± SE: −1.1 to −4.4 ± 0.2°C). Within the same period, treatments ≥1.5 min reduced respiration rate (range: −7 to −24 ± 2 breaths/min) and the surrounding AT (range: −0.3 to −1.7 ± 0.0°C). Only spraying cows for ≥3 min reduced leg surface temperature during spray duration (range of reduction: −0.1 to −0.6 ± 0.0°C). Spray duration had little effect on the time it took the coat to dry. Cows sprayed for 13 min took 2 min longer to dry compared with the other treatments (15.9 vs. 13.8, 14.9, and 14.2 ± 0.6 min, respectively, for 0.5, 1.5, and 3 min). No additional cooling was observed in this phase except on windier days, when leg temperature and respiration rate reductions tended to be more marked (slope estimates: −0.06 and −3.6, respectively). Cooling benefits, as well as changes in AT surrounding the leg, were more pronounced when water was sprayed for longer. In this study, cooling was observed primarily when water was turned on, not during the time it took the coat to dry.

Key words: heat loss, evaporation, soaker, water temperature

INTRODUCTION

Compared with shade alone, sprayed water is an effective strategy to reduce heat load in cattle (Kendall et al., 2007; Chen et al., 2013, 2016a). However, changes in weather patterns, including drought periods, have raised concerns about using potable water in agriculture, requiring more efficient use of this resource (World Resources Institute, 2011). In California, for example, it was estimated that a 1,000-cow dairy farm uses between 2,300 and 25,600 L of water hourly to cool lactating cows in their home pen during the summer (Tresoldi et al., 2017). Although the upper range of water use may relieve heat load and enhance welfare and production, other studies have found that using more water does not necessarily result in more cooling (Means et al., 1992; Chen et al., 2016a).

Dairy cows are usually sprayed at the milking parlor (waiting or holding area) and in their home pen by nozzles located over the feed line or directed toward resting areas (Valtorta and Gallardo, 2004; Anderson et al., 2013; Tresoldi et al., 2017). The quantity of water used can be manipulated in several ways, including via flow rate, spray type (e.g., misters vs. soakers), the temperature threshold at which the spray is activated, and the timing of when the water cycles (i.e., time on and off or, respectively, spray duration and time to dry; Tresoldi et al., 2017). The effects of these manipulations on cow cooling are variable. For example, the rate at which water is applied has been shown to affect cooling but only to a certain extent; no differences in

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heat load were found when comparing flow rates ≥1.3 L/min (Means et al., 1992; Chen et al., 2015, 2016a). In contrast, manipulating the time when the spray is activated (usually controlled by air temperature; **AT**) can affect water use and responses to heat load in cattle. For example, Morrison et al. (1981) found that using higher AT thresholds (i.e., less water; 32 vs. 22°C) resulted in lower feed intake in beef cattle.

The effects of spray timing on cow cooling are poorly understood. The time the water is on and off varies across studies, ranging from 10 s to 6 min and from 3.5 to 14 min, respectively (Flamenbaum et al., 1986; Brouk et al., 2003; Tresoldi et al., 2017). Others have found that cows exhibited lower respiration rates and body temperature when wetting frequency was shorter (every 5 vs. 10 or 15 min for every 1 min of spray/cycle; Brouk et al., 2003) and coat wetting was longer (20 or 30 vs. 10 s of spray every 4.5 min; Flamenbaum et al., 1986) than when more time elapsed between spray or when water was sprayed for less time. However, more research is needed to understand how timing affects cow cooling to optimize water use.

Sprinklers are thought to reduce heat load in cattle mainly via evaporation when water is turned off and via fluid and air convection on skin and coat surfaces (Kimmel et al., 1991; Hillmann et al., 2001; Gebremedhin and Wu, 2002). Some researchers have also speculated that the small droplets of water could reduce the temperature of the air cows inhale, enhancing cooling (Bucklin et al., 1991). To our knowledge, no studies have systematically examined how sprayed water affects the time it takes the coat to dry or the effects of the latter on physiological responses to heat load in cattle. In addition, little is known about how the duration of spray affects cooling in cattle. Thus, the objective of this study was to estimate how the duration of spray affects the time it takes for the coat to dry and physiological responses to heat load in dairy cattle up to 30 min after the end of the spray application. We hypothesized that cooling would occur during both spray application and the drying time that follows. We also hypothesized that the duration of spray would have little effect on the time it takes the coat to dry but would be positively related to reduction of heat load in cattle in a linear fashion.

MATERIALS AND METHODS

Animals and Housing

This study was carried out in August 2015 at the University of California, Davis Dairy Teaching and Research Facility, and all procedures were approved by the University of California, Davis Institutional Animal Care and Use Committee. Fifteen lactating Holstein cows with average milk yield 37.7 ± 2.6 kg/d, DIM 243 ± 85, and parity 1.5 ± 0.8 lactations were used. All cows were housed in the same area as a single herd between the evening (1900 h) and morning (0700 h) milkings. During the daytime, however, cows were split into 3 groups of 5 cows each, balanced for milk production. The daytime group pens were made using removable fencing panels (Power River, Provo, UT) and plywood (at the feed bunk area; 2.4 m high × 3.7 m long). Cows had access to a water trough, shaded feed bunk with a solid roof, and sand-bedded freestalls. Cows were fed a TMR ad libitum twice daily. Cooling was provided through 2 fans positioned above the stalls and sprayed water at the feed bunk line (TF-VP7.5 Turbo FloodJet wide-angle flat-spray tip, 4.9 L/min; Spraying Systems Co., Wheaton, IL).

Experimental Design

Cows were tested 35 m away from the home pen in 5 individual testing pens measuring 3.7 by 2.4 m (length × width). These pens were built using fencing panels as described above and were enclosed with plywood on the sides to minimize water drift. Two white canopy tents (north–south orientation; total length × width: 18 × 6 m, polyethylene 180 g/m^2; Delta Canopy, McKinney, TX) were used side by side to shade the testing area. Cows were restrained using head gates, and fresh water and feed (TMR topped with grain and alfalfa hay) were provided. In each testing pen, spray water was mounted at the center of the pen, 2 m above the floor. To generate a flow rate of 4.9 L of water/min, the spray apparatus consisted of a nozzle (same model as described above) and a 207-kPa water pressure regulator (PR55-30; Hendrickson Bros., Corona, CA). The water pipe connecting the main water source and the spray nozzles was partially exposed to direct sunlight throughout the day.

The 5 treatments varied in terms of spray duration: (1) 0 s, where no spray was applied (shade only); (2) 0.5 min, which we found to be sufficient to soak the coat from shoulder to hip as determined in a pilot study using 6 cows; (3) 1.5 min; (4) 3 min; and (5) 13 min, which we estimated as the minimum duration necessary for the skin to reach a temperature similar to the water sprayed. This was based on our group's previous results showing that when sprayed water temperature averaged 30.4°C, shoulder temperature was reduced from about 38.5 to 36.5°C after 3 min of water application (Chen