Using water to cool cattle: Behavioral and physiological changes associated with voluntary use of cow showers

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ABSTRACT

Water is commonly used to cool cattle in summer either at milking or over the feed bunk, but little research has examined how dairy cows voluntarily use water separate from these locations. The objectives were to describe how and when dairy cattle voluntarily used an overhead water source separate from other resources, such as feed, and how use of this water affected behavioral and physiological indicators of heat stress. Half of the 24 nonlactating cattle tested had access to a “cow shower” composed of 2 shower heads activated by a pressure-sensitive floor. All animals were individually housed to prevent competition for access to the shower. Over 5 d in summer (air temperature = $25.3 \pm 3.3^\circ\text{C}$, mean $\pm$ standard deviation), cattle spent 3.0 ± 2.1 h/24 h in the shower, but considerable variability existed between animals (individual daily values ranged from 0.0 to 8.2 h/24 h). A portion of this variation can be explained by weather; shower use increased by 0.3 h for every 1°C increase in ambient temperature. Cows preferentially used the shower during the daytime, with $89 \pm 12\%$ of the time spent in the shower between 1000 and 1900 h. Respiration rate and skin temperature did not differ between treatments [53 vs. 61 breaths/min and 35.0 vs. 35.4°C in shower and control cows, respectively; standard error of the difference (SED) = 5.6 breaths/min and 0.49°C]. In contrast, body temperature of cows provided with a shower was 0.2°C lower than control cows in the evening (i.e., 1800 to 2100 h; SED = 0.11°C). Cows with access to a shower spent half as much time near the water trough than control animals, and this pattern became more pronounced as the temperature-humidity index increased. In addition, cattle showed other behavioral changes to increasing heat load; they spent less time lying when heat load index increased, but the time spent lying, feeding, and standing without feeding did not

differ between treatments. Cows had higher respiration rate, skin temperature, and body temperature as heat load index increased, regardless of treatment. These data suggest that cattle, when given the opportunity, will make considerable use of a shower to reduce heat load, but that individuals are highly variable in their use of this resource. The variability between cows indicates that the behavioral response to water is likely an important, but poorly understood, consideration in the design of sprinkler systems used for summer cooling.

Key words: behavior, body temperature, heat stress, shower

INTRODUCTION

Exposure to summer weather affects both the physiology and behavior of dairy cattle. Increased heat load elicits behavioral and physiological responses, including increased core body temperature and respiration rate, and reduced activity, feed intake, and milk yield (Hahn, 1999; Ominski et al., 2002; West, 2003). Heat stress negatively affects reproductive performance in dairy cattle (Roman-Ponce et al., 1977; De Rensis and Scaramuzzi, 2003) and can result in death (Stull et al., 2008; Vitali et al., 2009).

Water is used to cool cattle to reduce the effects of heat load. For example, 40% of large herd operators in New Zealand use sprinklers while cows are waiting to be milked (Tucker et al., 2005), and 62% of dairies with more than 500 cows in the United States use sprinklers or misters for heat abatement (USDA, 2010). Indeed, in more intensive dairy systems, water is used to cool cows before or during milking or while at the feed bunk or both. In the latter, sprinklers or misters are installed over the feed bunk, wetting the cow's back. Considerable evidence suggests that water effectively reduces indicators of heat stress such as respiration rate and body temperature (Gaughan et al., 2004; Kendall et al., 2007). Cooling with water results in an increase in feed intake and milk production (Keister et al., 2002).

Despite the effectiveness of cooling with water, some evidence indicates that overhead spray may be aversive

Received October 5, 2010.

Accepted March 21, 2011.

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for cows. For example, cows seek shelter, particularly when it is raining in winter (Vandenheede et al., 1995); when exposed to wind and rain, cows were 5 times more likely to stand with their heads lowered compared with their sheltered counterparts (Tucker et al., 2007), perhaps to protect sensitive areas such as the ears from water. In summer, cows sprinkled before milking spend more time standing with their heads down, possibly because this is the only part of the body they can readily move away from the water (Schütz et al., 2011). Cattle prefer shade to sprinklers for cooling after walking to the milking parlor in summer, despite the fact that water reduced skin temperature and respiration rate more than shade (Schütz et al., 2011). In addition to the behavioral responses to sprinklers and rain, body temperature will rise when sprinklers are used on cooler days ($<23^{\circ}\text{C}$, 90 min of sprinkler exposure) and we speculate that this is due to vasoconstriction to maintain core temperature (Kendall et al., 2007). Some researchers have found that body temperature will rise shortly after sprinkling (Araki et al., 1985), but this has not been replicated by others (Gaughan et al., 2004). It is likely that these differences between experiments can be explained by weather conditions. Igono et al. (1987) reported, in an unreplicated study, that when given the choice in very warm conditions ($>27^{\circ}\text{C}$), cattle preferred to use freestalls sprayed with water and cooled with fans. Indeed, in many dairy systems, water cooling is offered in proximity to resources, such as feed or the lying area, making it difficult to assess the voluntary use of water alone.

Understanding voluntary use of water for cooling can provide insight into when and how cows will choose to use this resource. Previous research focused on production traits (milk yield or weight gain) and provide only anecdotal evidence about voluntary use of water offered in the form of a cow shower. For example, Kelly et al. (1955) report that one animal spent 3 h/d in a shower. Seath and Miller (1948) report that cattle used a shower for 1.3 to 4.9 h, and that shower use increased with ambient temperature (within the range of 27 to 36°C), but these authors did not provide details about how they recorded sprinkler use or which part of the body cows chose to expose to water.

The primary objective was to describe the voluntary use of water located away from other resources and how this use related to environmental conditions in summer. A second objective was to understand how voluntary use of water affected behavioral and physiological indicators of heat stress. We predicted that voluntary use of water would increase with warmer weather, would be directed away from the head region, and that use of water would mitigate the behavioral and physiological responses to heat load.

MATERIALS AND METHODS

Animals, Housing, Management, and Treatments

This study was conducted at the University of California, Davis, from June to August 2008. All procedures involving animals were approved by the Institutional Animal Care and Use Committee. Twelve pairs of pregnant nonlactating Holstein-Friesian dairy cattle, between 16 and 42 mo of age, were selected from the University dairy herd (28 ± 12 mo, mean $\pm$ SD). The animals were between 24 and 160 d before parturition at the start of the experiment and were in their first to fourth lactation. The animals had a BW of 601 ± 125 kg and a BCS between 2.5 and 3.75 on a 10-point scale (Ferguson et al., 1994). The percentage of black hair was measured from digital photographs of both sides of each cow using image analysis software (1.38x ImageJ, Wayne Rasband, National Institutes of Health, Bethesda, MD) and the animals used in the experiment were $60 \pm 27\%$ black.

In each replicate, 4 animals were tested at 1 time. The animals were individually housed in 4 adjacent pens that allowed for visual, auditory, and limited social contact through the fence. All pens measured 18×7 m divided into a 6×7 -m roofed (and therefore shaded) area with a feed bunk and a 12×7 -m outdoor area. Half of the pens had their own water trough, whereas the other 2 shared a trough positioned between them. The floor throughout the pens was concrete. Within the shaded area, cows were provided with a lying area (3.6×2.4 m), consisting of Animat rubber mats (Animat, Saint-Elie d'Orford, Quebec City, QC, Canada) covered with 15 cm of rice hulls. All pens were cleaned each morning between 0800 and 1000 h. Water and feed (16% almond hulls, 5% dry cow pellets, 26% alfalfa, 53% oats, 91% DM) were available ad libitum. Animals were fed twice daily, between 0800 and 0900 h and between 1600 and 1700 h. A fly repellent (Flying Insect Kit, Waterbury Company, Waterbury, CT) device was installed in each pen, and this device sprayed a small amount of insecticide over the lying area every 15 min.

To evaluate voluntary use of water, half of the animals were housed with access to a "cow shower" (Figure 1) kept in the outdoor area of 2 of the pens. The use of an individual cow shower allowed exploration of voluntary use of water, away from other resources, such as feed and the lying area, for experimental purposes. This is not a common or necessarily practical cooling method on commercial farms. Two of the pens were equipped with a shower, a $2.4 \times 2.4 \times 2.4$ -m wooden structure located 6 m from the feed bunk, in the outdoor area. The cows could access the shower from all 4 sides, with a minimum distance of 2.2 m around the perimeter.

Two shower heads were attached to a wooden frame and were located 2.4 m above the floor and 0.7 m from the edge of the shower. The shower heads were 5.3 cm in diameter and were placed on the same side of the shower, 1.2 m apart. The flow rate through the shower head was 7.25 ± 0.07 L/min. The floor of the shower was covered with a waterproof membrane (Bituthene 4000, Grace & Co.-Conn., Columbia, MD), a soft pad (K&S International, Wheeling, IL), and a waterproof canvas. These materials covered sensors (Trosen Robotics, Westchester, IL) that were activated when at least 27.2 kg was applied to the shower floor. When these sensors were activated, a signal was transmitted to a relay (NTE Electronics Inc., Bloomfield, NJ), which opened a water valve controlled by an electric solenoid, resulting in water flow from the shower heads. When weight was removed from the shower floor, the water flow stopped. All pens had corrugated fiberglass panels (2.45×2.45 m) attached to a portion of each fence adjacent to the shower to minimize any water movement between pens. The showers remained in the same location for the duration of the experiment and a control pen was adjacent to each shower pen.

Animals with access to a shower and those without (i.e., control animals) were paired by parity (either pairs of primiparous or multiparous animals) and coat color of a shaved 8×8 cm area on the shoulder to facilitate skin temperature measurement. Data were collected during 5 consecutive experimental days; each experimental day began at 1000 h and ended at 0959 h the following day. Directly before data collection,

4 cows (2 animals with access to a shower, 2 control animals) were moved into the facility at the same time. Cows with access to a shower were individually trained to use the shower for a variable period, depending on how quickly they achieved the predetermined criteria: ≥ 3 voluntarily uses of the shower for more than 1 min at a time, with at least 2 legs on the shower and interacting with the water (e.g., getting any part of the body wet, licking from the water). During the training period, cows had free access to the shower and a food reward was initially used to encourage animals to walk onto the shower, but these events were not counted toward completion of the training criteria. All animals had previous experience with water cooling, most commonly with a sprinkler system in their home pen. All cows were able to achieve the training criteria within 1 to 8 d (4 ± 2 d).

Climatic Measures

Air temperature (**T**, °C), relative humidity (**RH**, %), wind speed (**WS**, m/s) and direction, rainfall, black globe temperature (**BGT**, °C), and solar radiation were recorded at 5-min intervals using a portable weather station (110-WS-18, Novalynx Corp., Grass Valley, CA) at the experimental site. Heat load index (**HLI**) and temperature-humidity index (**THI**) were used as indicators of thermal comfort for dairy cows and were calculated according to the equation reported in Gaughan et al. (2008) and Igono et al. (1992), respectively:

$$\begin{aligned} \text{HLI} = & \text{IF}[\text{BGT} > 25, 8.62 + (0.38 \times \text{RH}) \\ & + (1.55 \times \text{BGT}) + \exp(-\text{WS} + 2.4) - 0.5 \times \text{WS}, \\ & 10.66 + (0.28 \times \text{RH}) + (1.3 \times \text{BGT}) - \text{WS}] \end{aligned}$$

$$\begin{aligned} \text{THI} = & (1.8 \times \text{T} + 32) - [(0.55 - 0.0055 \times \text{RH}) \\ & \times (1.8 \times \text{T} - 26)]. \end{aligned}$$

Water temperature of both showers and of all water troughs was measured on the day before and after each replicate began and ended, respectively. Measures were taken every 2 h from 0800 to 1800 h using a digital thermometer (Fisherbrand Traceable Digital Thermometer, Fisher Inc., Pittsburgh, PA).

Physiological Measures

Internal body temperature was recorded at 5-min intervals using a modified controlled internal drug release device (CIDR, InterAg, Hamilton, New Zealand) fitted with a microprocessor-controlled Minilog-TX data

Figure 1. A photograph of the cow shower used in the experiment. Photo credit: Sylvia Wright, University of California Davis.

logger (Vemco Ltd., Shad Bay, Nova Scotia, Canada). Temperature loggers were inserted into the vaginal cavity of all cows 1 d before the start of data collection and removed after 5 d.

During the 5 d of data collection, respiration rate, open-mouth panting, and skin temperature were measured every hour from 1000 to 1800 h by trained observers. Respiration rate was recorded for all cows by counting flank movements for 30 s and converted to a per minute basis to facilitate comparisons with other studies. Presence or absence of open-mouth panting (open mouth breathing, sometimes with the tongue extended) was recorded during this 30 s. Four observers were used to collect these data and inter-observer reliability, as measured by correlation, was $r = 0.92$ for respiration rate. Skin temperature was measured in the shaved area of the shoulder with a thermocouple (5SC-TT-T-30-36, Omega Engineering Inc., Stamford, CT). To minimize disturbance to the animals, skin temperature was not measured while cows were in the shower.

Behavioral Measures

Thirteen video cameras (WV-BP334 CCTV Camera, Panasonic Syst., Suzhou, China; 13VG2812ASII lenses, Tamron Co. Ltd., Saitama, Japan) connected to a digital video recording device equipped with a digital surveillance system (V8.1 GeoVision Surveillance System Inc., Taipei, Taiwan) were used to record behavior. Each pen was equipped with 2 cameras and 4 red lights to facilitate video recording at night. Time budget information (lying—flank in contact with the ground; standing—any state where the cow is not lying and does not have her head over the feed bunk; feeding—head over the feed bunk) and cow location (i.e., shaded vs. outdoor area, delimited by a white line on the ground) were recorded with instantaneous scan sampling every 10 min during all 5 d. In addition, time spent near the water trough (any part of her head or neck above the trough) was measured with a single camera per pen and estimated with instantaneous scan sampling every 30 s over 5 d.

To monitor shower use, an additional video camera and a red light were placed over each shower. The shower was divided in 2 areas when scoring the video recordings: an area measuring 2.4×0.8 m and including both shower heads (" ≤ 0.25 m of water"), and the remainder of the shower (2.4×1.6 m; ">0.25 m from water"). When cows were more than 0.25 m from the water, they were unlikely to get wet, in most situations. The duration of visits to the shower (i.e., the animal has at least 1 hoof on the shower floor) was continuously recorded. When an animal was present in the shower, the parts of the body ≤ 0.25 m of water were recorded at

30-s intervals with instantaneous scan sampling. Reflective tape (3M Products, St. Paul, MN) was attached to 4 points on the cow: the poll, on the withers, along the sacral ligaments, and along the tail-head ligaments with Kamar adhesive glue (Kamar Products Inc., Zionsville, IN). The tape divided the body in 4 segments: the head, neck, flank, and hindquarters. To estimate drinking from the shower, licking events were recorded as occurring or not (1/0 sampling) in every 30-s interval. Licking was defined as the tongue extended toward the water.

Behavioral information was collected from video recordings by multiple trained observers. Inter-observer reliability, as measured by percentage of agreement, averaged $99 \pm 1\%$ for time budget information, $99.5 \pm 0.3\%$ for time spent near the water trough, and $97 \pm 1\%$ for overall shower use.

Statistical Analyses

Statistical analyses were performed with SAS (version 9.1; SAS Institute, 2003), using individuals as the experimental unit ($n = 24$). Individual daily shower use, time budget information (expressed as time spent in each behavior), time spent near the water trough, body temperature, and weather data were averaged over a 24-h period. In addition, minimum, maximum, and the amplitude (maximum – minimum) of body temperature were calculated for each day and averaged over the 5-d period. Respiration rate and skin temperature data were averaged from hourly data collected each day over an 8-h period (i.e., 1000 to 1800 h). Corresponding values for daytime weather were calculated (1000 to 1900 h); a 9-h period was used to account for the duration of data collection.

Descriptive information is provided for shower use, including total time, number of visits, and body parts exposed to the 2 areas of the shower. Differences between treatments in time budgets (feeding, lying, standing, cow location, near water trough) and physiological responses (respiration rate, body, and skin temperature) were tested with a 2-sample *t*-test (error df = 22) in SAS (SAS Institute, 2003). In addition to the analysis of the daily patterns over 24 or 8-h periods, differences at each hour were explored for skin and body temperature and respiration rate. Hourly averages were calculated over the 30 d of recording for these 3 variables in each treatment. Differences between treatments were then tested by hour with a 2-sample *t*-test (error df = 22) in SAS (SAS Institute, 2003).

To assess the influence of weather on behavioral and physiological variables, daily averages from each cow were used to calculate the slope of the relationship between the response variable (time spent in the

shower, time spent lying, standing, feeding, near the water trough, body temperature, respiration rate, and skin temperature) and daily means for HLI, THI, and ambient temperature (PROC REG procedure; 5 values per animal were used to generate slopes). This information was used in 2 ways. A 1-sample *t*-test (error df = 23 for all variables, except shower use: df = 11) was used to compare these slopes to 0 to assess if the effect of weather was different from chance. Second, when appropriate, the effect of treatment on the response to weather was compared with a 2-sample *t*-test (error df = 22) in SAS (SAS Institute, 2003).

Mean differences in response to treatment are provided with the standard error of the difference (**SED**). Descriptive measures that were not intended for inferential comparisons are reported as mean $\pm$ SD. Ranges are reported as the highest and lowest individual daily values.

RESULTS

Environmental Conditions

Weather variables recorded during the experiment are summarized in Table 1. Several measures of heat load are reported, including ambient temperature, HLI, and THI, to facilitate comparisons with other work. The mean water temperature in the showers was $26.8 \pm 2.8^\circ\text{C}$, and the temperature of the water in the troughs was $24.9 \pm 5.0^\circ\text{C}$.

Shower Use

Cows spent 3.0 ± 2.1 h/24 h in the shower (range from 0.0 h to 8.2 h/24 h), which corresponded to 23 $\pm$ 15 visits/24 h (range from 0 to 78 visits/24 h). Thus, water use per cow was $2,610 \pm 1,828$ L/24 h (range from 0.0 to 7,154 L/24 h). Forty one percent of the visits lasted less than 1 min, and the duration of the visits longer than 1 min averaged 14 ± 9.5 min; the longest visit was 2.7 h.

When in the shower, cows were predominantly observed with at least one part of their body within 0.25 m of the water: $82 \pm 28\%$ of the time spent in the shower was in this area, but considerable variability existed between animals (range from 9 to 100%; Figure 2). All parts of the body were observed within 0.25 m of the shower heads. The head, neck, flank, and hindquarters were observed within 0.25 m of the shower heads for $49 \pm 34\%$, $70 \pm 28\%$, $74 \pm 38\%$, and $30 \pm 21\%$ of the time cows spent in this area, respectively. Only $13 \pm 13\%$ of shower use involved the entire body, in which all 4 regions were within 0.25 m of the water simultaneously. When cows were observed within 0.25 m of the shower heads, $6 \pm 11\%$ of the 30-s intervals contained a licking event, and again, considerable variation existed with a range from 0 to 45%. Shower use occurred primarily during the daytime: $85 \pm 12\%$ of the total time spent in the shower was between 1000 and 1900 h (range from 21 to 100%; Figure 3). A positive relationship was observed between daily shower use and daily weather conditions (HLI, THI, ambient temperature; $P \leq 0.001$; Figure 4). For example, shower use increased by 0.3 h for every 1°C increase in ambient temperature.

Time Budgets

Treatments did not differ in time spent lying or feeding [11.5 vs. 11.1 (standard error of difference, **SED**, = 0.515) h/24 h for lying time and 4.9 vs. 4.7 (SED = 0.389) h/24 h for feeding time, control vs. shower, respectively; $P \geq 0.500$]. Time spent standing without feeding did not differ between treatments, but access to a shower influenced where cows stood in the pen. Cows provided with a shower spent an additional 1.9 h/24 h standing in the outdoor area compared with control cows (SED = 0.57 h; $P = 0.004$). This behavior occurred predominantly during the day (Figure 5). Cows provided with a shower spent less time near the water trough than control cows [27.6 vs. 60.1 (SED = 11.3)/min/24 h respectively; $P = 0.008$].

Table 1. Summary of daily environmental conditions during 30 experimental days from June to August 2008¹

Weather variable	Daily (24 h)			Daytime (1000 to 1900 h)		
	Mean	SD	Range	Mean	SD	Range
Temperature ($^\circ\text{C}$)	25.3	3.3	18.2–31.4	32.6	3.8	25.7–40.2
Relative humidity (%)	42	13	19–64	24	9	12–41
Wind speed (km/h)	0.8	0.5	0.4–2.8	1.2	0.5	0.8–3.4
Solar radiation (W/m^2)	242	42	169–308	590	86	390–733
Black globe temperature ($^\circ\text{C}$)	30.2	3.3	23.2–36.1	45.7	4.1	37.7–52.5
Temperature-humidity index	70	3.5	62–77	77	3.5	70–84
Heat load index	69	5.5	54–81	92	6.8	70–101

¹Means, SD, and range (minimum to maximum of daily mean values) are given for 24 h and for 9 h during daytime (1000 to 1900 h).

Figure 2. Mean time ($\pm$ SD; h/24 h) spent in 2 areas of the shower for each of 12 cows during 5 d of recording, either less or more than 0.25 m from the shower heads.

Weather (HLI, THI, and ambient temperature) affected time budgets. Lying time decreased in warmer conditions (e.g., increasing HLI, THI, and ambient temperature; $P \leq 0.001$), whereas time spent standing without feeding increased ($P \leq 0.001$). Feeding time was not affected by weather ($P \geq 0.393$). The

effect of the weather on time budgets differed between treatments for only 2 behaviors: time spent standing and time spent near the water trough. For standing time, a positive relationship with THI ($P = 0.043$) and ambient temperature ($P = 0.028$) was more marked in cows provided with a shower (Table 2). Cows tended

Figure 3. Mean time ($\pm$ SD min/h) spent in 2 locations in the shower either more or less than 0.25 m from the shower heads ($n = 12$ cows; 5 d of recording/cow, 24 h/d). The heat load index (HLI) was averaged hourly over the 30-d experiment.

Figure 4. Mean time (h/24 h) spent in the shower per cow ($n = 12$, 5 d of recording/animal, 24 h/d) in relation to the mean daily heat load index (HLI). Individual animals are represented by a unique symbol.

to spend more time near the water trough as THI increased when they did not have access to a shower ($P = 0.095$; Table 2).

Physiological Responses

In the evening (i.e., 1800 to 2059 h), body temperature was at least 0.2°C lower in cows with access to a shower ($P \leq 0.05$; Figure 6), and respiration rate

followed a similar trend in the late afternoon (i.e., 1700 to 1800 h: 62 vs. 50 breaths/min in control and shower, respectively, $\text{SED} = 5.4$, $P = 0.074$; and 1800 to 1900 h: 63 vs. 51 breaths/min in control and shower, respectively, $\text{SED} = 5.6$, $P = 0.052$). Panting occurred rarely (0.5% of the observations) and was associated with high respiration rates (105 ± 9 breaths/min, mean $\pm$ SD). Only control cows were observed open-mouth panting. Average respiration rate, skin temperature, and body

Figure 5. Mean time (min/h) spent standing outdoors for cows with or without access to a shower ($n = 12$ animals per treatment, 5 d of recording/animal, 24 h/d). Error bars represent SE.

Table 2. Mean and standard error of the difference of means (SED) of slopes for the linear relationship between behavioral and weather variables¹

Response variable (h/24 h)	Shower	Control	SED	<i>t</i> -value _{1,22}	<i>P</i> -value
Temperature-humidity index					
Lying	−0.23	−0.16	0.046	1.51	0.146
Standing without feeding	0.32	0.17	0.069	−2.14	0.043
Feeding	−0.07	0.01	0.064	1.20	0.243
Standing outdoors	0.22	0.02	0.092	−2.07	0.050
Near water trough	3.65	9.68	2.326	1.75	0.095
Heat load index					
Lying	−0.16	−0.11	0.043	1.12	0.277
Standing without feeding	0.21	0.12	0.048	−1.91	0.070
Feeding	−0.04	0.004	0.04	0.98	0.338
Standing outdoors	0.14	0.02	0.065	−1.74	0.096
Near water trough	−0.26	−0.55	0.513	−0.56	0.580
Ambient temperature (°C)					
Lying	−0.24	−0.17	0.048	1.56	0.133
Standing without feeding	0.33	0.17	0.068	−2.36	0.028
Feeding	−0.07	0.02	0.069	1.24	0.228
Standing outdoors	0.23	0.01	0.097	−2.24	0.036
Near water trough	−0.43	−0.46	1.066	−0.03	0.976

¹All variables were measured for 5 d, 24 h/d. Half the animals (*n* = 24 in total) had access to a shower, activated with a pressure-sensitive floor.

temperature (minimum, maximum, average, and amplitude) did not differ significantly between treatments ($P \geq 0.160$; Table 3).

Physiological variables were affected by weather: respiration rate, skin temperature, and body temperature increased with THI, HLI, and ambient temperature ($P < 0.001$). These patterns were apparent for all animals; no treatment differences were observed in response to weather ($P \geq 0.197$).

DISCUSSION

Dairy cattle, when offered the choice, spent 3 h/24 h in a “cow shower,” indicating that cattle will voluntarily use water that is separate from other resources. Considerable variation was observed between individuals in their use of the shower. For example, 1 cow almost never used the shower, whereas another spent up to 8 h/24 h in it. Several factors may explain this variation. First,

Figure 6. Body temperature (°C) of dairy cattle with or without access to a shower (*n* = 12 animals per treatment, 5 d of recording/animal, 24 h/d), in relation to time of the day. Error bars represent SE; * $0.05 < P \leq 0.1$; ** $P \leq 0.05$.

Table 3. Respiration rate, skin temperature, and body temperature of dairy cattle provided with a shower compared with animals without (control)¹

Response variable	Shower	Control	SED	<i>t</i> -value _{1,22}	<i>P</i> -value
Respiration rate (breaths/min)	53	61	5.6	1.46	0.160
Skin temperature (°C)	35.0	35.4	0.49	0.92	0.369
Body temperature (°C)					
Mean	38.9	38.9	0.03	0.58	0.568
Minimum	38.2	38.1	0.05	−0.76	0.453
Maximum	39.6	39.8	0.11	0.88	0.386
Amplitude (maximum – minimum)	1.5	1.6	0.14	1.03	0.312

¹Respiration rate (recorded hourly from 1100 to 1800 h); skin temperature (recorded hourly from 1100 to 1800 h); and mean, minimum, maximum, and amplitude body temperature (recorded every 10 min, 24 h/d) were averaged from data collected from 12 animals in each treatment, over 5 d of recording/animal.

shower use increased with warmer weather, by 0.3 h/24 h for every 1°C increase in ambient temperature, supporting results of others (Seath and Miller, 1948). Two individuals were tested in cooler temperatures, <20°C (Figure 4), and their reduced use of the shower may be explained by these test conditions. Second, individual animals may differ in preference for water. Cattle show no preference for 10-min of sprinklers over ambient conditions, even after a 2-km walk to the milking parlor in summer (Schütz et al., 2011). There, even the individuals that chose to use sprinklers still tried to protect their head from the water by positioning their head outside of the sprinkled area 4 times more than animals that chose shade. Others found that cattle lower the head in response to overhead water (Kendall et al., 2007; Tucker et al., 2007) or describe complete avoidance of water when possible (Marcillac-Embertson et al., 2009). In the current study, cattle spent more than half of their time in the shower with their heads near the shower heads. We speculate that the discrepancy between the willingness to wet the head in the current study and previous work may be influenced by several factors not yet explored, including previous experience, degree of control over the water source, and the design features, including droplet size and force and flow rate. For example, all cows reached the training criteria and had previous experience with water cooling in their home pens, yet some animals may not have learned the benefits of standing under the water. The variability between cows indicates that the behavioral response to water is likely one important consideration in the design of sprinkler systems used for summer cooling.

Patterns of shower use provide insight into when water cooling is preferred by dairy cattle. Cows predominantly used the shower during daytime and shower use increased with warmer weather. These results suggest that the animals used the shower as a cooling device. Indeed, cows provided with a shower had lower body temperature in the late afternoon and evening, when internal and external heat load is highest. Shower use

was highest in the hours before this peak in body temperature, and it seems that cows used the shower to dissipate heat before this point; water cooling reduces body temperature for hours after exposure to water (Gaughan et al., 2004; Kendall et al., 2007).

Access to a shower influenced where animals spent time in the pen. Control cows were twice as likely to spend time near the water trough, especially as THI increased. Unshaded cattle are more likely to spend time near the water trough (Mader et al., 1997; Widowski, 2001; Schütz et al., 2010) for several reasons. The previous studies that have found an increase in time around the water trough were conducted in dirt pens or pasture, and the moist area around the water trough may be a cooler microclimate. Indeed, cattle will spend more time in moist areas, created by sprinklers, that are 20% cooler than other areas of the pen (Marcillac-Embertson et al., 2009). A favorable microclimate is one explanation for the results in the current experiment; however, because the pens were concrete it is unclear how long the cooler microclimate might last. Alternatively, perhaps control cows spent more time near the water trough because they were drinking more water overall or drinking more frequently to reduce heat load. Indeed, cows with access to a shower spent 6% of the time in the shower licking from the shower heads. Although this is considerably less time than they spent near the water trough, it does indicate that ingestion of small amounts of water may be part of the behavioral response to heat load and it would be useful to measure this trait in future experiments.

Cows with access to a shower spent 1.9 h/24 h more time standing outdoors. This may be a function of the shower location; time spent standing outdoors, as with shower use, was most marked during the daytime. These results indicate that cows subjected to high heat load may have preferred being in the shower, even when exposed to direct sunlight, rather than staying in the shade. The increase in the time cows with a shower spent standing outdoors could explain, in part, why providing

access to water did not result in significantly lower skin temperature. Wetting the skin and coat usually lowers the temperature (Schütz et al., 2011), especially when measured immediately after exposure to water. Surface temperature increased with solar radiation; thus, water cooling may only consistently decrease skin temperature if measured immediately after or during water use or when provided in combination with shade.

In contrast to location within the pen, access to a shower did not affect time spent feeding, standing without feeding, or lying down. In some cases, time spent feeding corresponds with feed intake (Nielsen, 1999); however, the latter was not measured in the current study. Changes in time budgets associated with heat load were observed in both treatments. Cows spent more time standing without feeding and less time lying as ambient temperature and heat load increased, which supports results of others (Overton et al., 2002; Zähler et al., 2004; Schütz et al., 2010). Cattle may stand in response to heat to maximize the surface area exposed to the environment, thus increasing the airflow around the body. Alternatively, standing may affect lung capacity during respiration and improve the efficiency of this cooling method, but neither idea has been evaluated experimentally. The increase in standing in response to heat load was more marked in cows with access to a shower; however, this result is best explained by more shower use in warmer conditions.

Weather affected all physiological variables. Skin temperature, respiration rate, and body temperature increased with warmer weather, supporting results of previous studies (Schütz et al., 2010, 2011). These changes were similar between treatments. Although access to a shower reduced body temperature in the evening, treatment did not affect average daily temperature. Similarly, access to a shower provided only a moderate reduction in respiration rate, in part because all animals had access to shade. Indeed, the average respiration rates seen in this study were relatively low. The role of shade in mitigating the cooling effect of water spraying in cattle was previously reported by Mitlöhner et al. (2001) and Kendall et al. (2007), who found that the reduction in respiration rate and body temperature associated with water cooling was less marked when the animals had access to shade (10 breaths/min and 0.8°C with no shade vs. 3 breaths/min and 0.2°C with shade, respectively, in Mitlöhner et al., 2001; 48 breaths/min and 0.5°C with no shade vs. 30 breaths/min and 0.3°C with shade, respectively, in Kendall et al., 2007). Finally, the benefits of access to a shower, and the magnitude of the treatment differences, may have been more marked in lactating or older and larger animals with a higher heat load.

CONCLUSIONS

These data suggest that cattle, when given the opportunity, will make considerable use of a shower to reduce heat load, as measured by both physiological and behavioral changes, but that individuals are highly variable in use of this resource. The variability between cows indicates that the behavioral response to water is likely one important, but largely unexplored, consideration in the design of sprinkler systems used for summer cooling.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the contributions of Amanda Grout and David Ledgerwood from UC Davis in making this project possible. We also thank the staff from the Animal Science Department of UC Davis for their technical assistance, and all the students involved in the project, with particular thanks to Geoffrey DeJaynes, Erin Mintline, Catherine Lopez-Aguado, Amanda Hall, Priya Motupalli, and Kelly Ware for their help with data collection. This research was funded by the Animal Compassion Foundation (Austin, TX).

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