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Case Study: Mitigation of heat stress in feedlot cattle by applying reflective pigments to the dorsal body surface

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ABSTRACT

Heat stress in feedlot cattle has serious animal welfare and economic implications. The objective of this experiment was to determine whether a titanium dioxide coating applied to the dorsal midline of cattle would reflect solar radiation and mitigate heat stress. Feedlot heifers (n = 30; 269 ± 27.6 kg) were randomly assigned to a noncoated (control) or titanium dioxide–coated treatment. Coating was applied to the dorsal midline except for a control area over the dorsal anterior midline. Reflectance was measured with a suspended modified digital camera in a blue band, a green band, and a near-infrared band. Skin surface temperature was measured with a suspended infrared thermal imaging sensor. Vaginal thermometers recorded the internal body temperature of heifers. Reflectance in the blue, green, and red edge to near infrared bands were found to be 5.7, 8.8, and 10.3 times greater ($P < 0.001$), respectively, for the coated areas compared with the noncoated areas. Dorsal surface temperature averaged 39.1 and 42.4°C for coated and noncoated areas, respectively ($P < 0.001$). Reflectance values and skin surface temperatures suggest that the coating decreased solar energy absorption. Over a 2- to 3-h period of exposure to natural solar radiation on a day with temperature–humidity index of 86.9, titanium dioxide–coated cattle had stable body temperatures, whereas the body temperatures of control heifers increased 0.8°C. A reflective coating applied to the dorsal midline could be an opportunity to decrease solar radiation energy absorbed by feedlot cattle.

Key words: cattle, feedlot, heat stress, mitigation, reflective coating

INTRODUCTION

In the cattle feeding areas of the United States, most years have periods when heat causes animal discomfort and profit losses. Heat waves during 1995, 1999, 2006, 2009, 2010, and 2013 caused documented death losses of more than 5,000 cattle, and almost 15,000 cattle died in 2011 (Mader, 2014). Economic losses from decreased performance likely exceed those associated with livestock death by 5- to 10-fold (Mader, 2014). In beef cattle, the response to heat stress begins with sweating and can end with death (Brown-Brandl et al., 2006; Mader et al., 2006). In addition to economic losses, animal welfare concerns by the public are high profile, legitimate, and growing. The feedlot industry, and animal agriculture in general, needs better tools to mitigate heat stress.

Absorption of heat from exposure to direct solar radiation is a major contributor to the body heat load. Cattle present the dorsal surface toward the sun during the time of day when the solar irradiation is highest, and therefore, this surface receives the most solar irradiance. An intervention that increases light energy reflectance from the dorsal surfaces, particularly in the energy-dense visible to near-infrared light spectrums, should result in reduced surface heating and heat load accumulation when the animal is exposed to sunlight similar to that observed with light colored animals (Maia et al., 2015). Titanium dioxide is a highly reflective pigment that is approved for use as a feed ingredient (AAFCO, 2009) and is also used in sunscreens and food colorings. Titanium dioxide has been shown to reflect light energy and reduce transdermal heat transfer through bovine skins in laboratory experiments (Bartle et al., 2017). Titanium dioxide coatings represent a potential means to mitigate heat stress in feedlot cattle. Therefore, the objectives of this pilot study were to determine (1) whether reflective pigments would reflect solar radiation from the skins of cattle and (2) whether coating the dorsal surface of feedlot cattle with a reflective pigment would reduce surface heating and body temperature increases caused by solar radiation energy.

MATERIALS AND METHODS

The protocol and procedures for this study were reviewed and approved by the Institutional Animal Care and Use Committee of Kansas State University (#3457). Weather data were collected at the Kansas State University Mesonet station. The temperature–humidity index

Authors Bartle, Thomson, and Reinhardt are inventors in the pending patent, which is owned by Kansas State University. University policies and procedures were followed in the development and application of the patent.

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(THI) was calculated using the following equation: THI = 0.8 × ambient temperature + [(% relative humidity ÷ 100) × (ambient temperature − 14.4)] + 46.4 (Mader et al., 2006).

Heifers (n = 30; initial BW = 269 ± 27.6 kg) were purchased from a sale barn in Northeast Kansas and allowed to acclimate to the facilities for about 3 wk before the start of the experiment. Heifers received typical feedlot processing at arrival. They were vaccinated against viral disease [bovine viral diarrhea virus types 1 and 2, infectious bovine rhinotracheitis, parainfluenza-3, and bovine respiratory syncytial virus (Pyramid, Boehringer Ingelheim, Ridgebury, CT)] and against *Clostridia* diseases caused by *Clostridium chauvoei*, *Clostridium septicum*, *Clostridium novyi*, *Clostridium sordellii*, *Clostridium perfringens* types c and d bacterin toxoid (Vision 7, Merck Animal Health, Madison, NJ); treated with an injectable dewormer (doramectin, Dectomax, Zoetis Animal Health, Parsippany, NJ) and an antibiotic (ceftiofur, Excede, Zoetis Animal Health); and implanted (200 mg of trenbolone acetate and 40 mg of estradiol, Revalor- XS, Merck Animal Health). Cattle consisted of 29 black heifers and 1 red heifer. Heifers were fed 2.3 kg/d of a mixed diet containing 85% concentrate and had ad libitum access to grass hay and water. Heifers were housed in a soil-surfaced pen with about 49 m^2/animal; no shade was available in the pen. Observations took place during July of 2015. The red heifer was randomly assigned to the treatment, did not receive a vaginal thermometer, and is included only in the reflectance data.

The titanium dioxide coating was an experimental formulation provided by LA-CO Industries Inc., Elk Grove Village, Illinois. The formulation used was selected from 6 formulations evaluated for durability and persistence (S. J. Bartle and D. U. Thomson, unpublished data). The week before the first experimental day, heifers were visually observed and scored for panting using the scale described by Gaughan and Mader (2014; 1 = normal respiration and 4 = severe open-mouth panting). Heifers were ranked and then blocked by panting score and randomly assigned to noncoated (**CON**) or titanium dioxide–coated (**COAT**) treatments to equalize panting scores across treatments. Coating was applied to the dorsal midline except for a control area over the dorsal anterior midline.

The morning of the first experimental day, the heifers were weighed and vaginal temperature thermometers were applied to random heifers (10 of 15 per treatment). Heifers were sorted into treatment groups as they exited the chute. Heifers in the COAT treatment (n = 15) were then put through the chute a second time, and a titanium dioxide coating was applied. Coatings were applied along the dorsal midline from the shoulder to the tail head using an electronic airless sprayer (Tradeworks 150 Electric Airless Sprayer, Graco, Minneapolis, MN) and a tip that covered a path 25.4 cm wide when held 30.5 cm from the surface. Coating was applied until there was 80% or more coverage over the skin. To provide an uncoated control skin area on each COAT heifer, an area of dorsal skin with a 20-cm diameter over the anterior midline (shoulders) was masked during coating application and the mask removed after the coating was applied (Figure 1). After vaginal thermometers and coatings were applied, all cattle were returned to a single home pen.

Images (reflectance and skin surface temperature) were collected between 1200 and 1400 h CST. Reflectance spectrum from black to no color was expressed on a 0- to 255-unit scale. Vaginal temperature collection started on experimental d 1 at 0830 h CST. Vaginal temperatures were recorded every 30 min using recording thermometers (Hobo U12 Stainless Temp Logger, Onset, Cape Cod, MA) attached to a blank controlled internal drug-release (CIDR) insert. Hourly weather data were collected from the Kansas State University weather station located approximately 3.5 km from the feedlot.

The procedures were repeated a week later on experimental d 2. Heifer assignment to treatment was the same as on d 1, in part because about 20% of the cattle coated on d 1 had an estimated 10% of their dorsal surface coating remaining. Vaginal temperature collection started at about 1130 h CST. Images (reflectance and skin surface temperature) were collected starting at approximately 1330 h CST.

Skin surface temperature data were collected with an infrared thermal imaging sensor (Tau 2 320, FLIR, Wilsonville, OR) pointed vertically down, with 8-bit radiometric resolution, and 7- to 14-μm wavelength sensitivity, giving it a −66 to 150°C temperature sensing range (Figure 1). Skin surface temperature treatment differences were determined comparing uncoated and coated areas of the same animal. Although the thermal sensor produced excellent temperature resolution and precision within a given set of environmental conditions, absolute temperature estimations required standardization relative to known reference temperatures. Reference temperatures were derived from a painted panel with black, white, and 50% gray color bands, placed in the vicinity of the target areas, so that thermal images included data points within the reference panel as well as the heifers. To reduce edge-effect artifacts in temperature estimates, the thermal sensor was suspended 15 m above ground level to ensure a minimum of 4 data points enclosed within the boundaries of each area of interest. Pixels overlapping area of interest boundaries were excluded. The reference panel temperatures were determined with a hand-held infrared thermometer, with emissivity set to 0.95 (Fluke 62 Mini, Evert, WA). A linear regression model was used to calibrate the thermal image according to the reference panel temperatures.

The ability of a surface to reject solar radiation is estimated based on the intensity of the reflected light, measured using a modified digital camera (Canon S100, Canon USA Inc., Long Island NY; modified by LDP LLC, Carlstadt, NJ) to generate an 8-bit image, reporting 3 broad bands: a near-infrared band (700 to 780 nm; peak sensitivity at 710 nm) and 2 visible light bands: green (500