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# Characterizing heat mitigation strategies utilized by beef processors in the United States

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## ABSTRACT

During lairage at slaughter plants, cattle can be exposed to extreme heat conditions from pen densities and holding pen microclimates. While research outlining heat mitigation strategies used in other sectors of the beef supply chain is available, there is no published data on the use of heat mitigation strategies at slaughter plants. The objective of this study was to characterize short-term heat mitigation strategies used by commercial beef slaughter plants in the United States. Twenty-one beef slaughter plants, representing an estimated 60% of beef slaughter in the United States, were included in the study. All plants indicated use of at least one heat mitigation strategy, and five of them used more than one type. Sprinklers/misters were the most commonly used heat mitigation type ($n$ = 17, 81%), and fans were the least common type ($n$ = 4, 19%). Shade usage was present in several plants ($n$ = 7, 33%), ranging from barn style roofs to shade cloths. Respondents indicated that they believed heat mitigation strategies provide benefits both to cattle well-being and meat quality outcomes. Future research should focus on the effectiveness of these techniques in improving animal well-being and quality outcomes in the slaughter plant environment and protocols for optimum implementation.

**Key words:** animal welfare, beef cattle, cattle processors, heat mitigation, shade, sprinklers

## INTRODUCTION

Although livestock are able to adapt to weather conditions and environmental stressors, prolonged or extreme exposure to these conditions can result in a multitude of animal welfare, performance, and meat quality concerns. Initial efforts by cattle to maintain homeostasis when environmental temperatures exceed the animal's thermoneutral zone, include using evaporative cooling via sweating and increasing respiration (Blackshaw and Blackshaw, 1994; Gaughan et al., 2000). Increasing respiration, or excessive panting, however, can alter blood acid-base balance which can result in reduced feed intake, decreased activity, deleterious effects on production and physiologic status, and can even lead to death (Blackshaw and Blackshaw, 1994; West, 2003). Cattle will also attempt to reduce metabolic heat production by reducing feed intake (Finch, 1986). Both chronic and acute heat-stressed cattle have demonstrated decreased growth rates, carcass weights, fat thickness, and poor meat quality characteristics such as potential hydrogen (pH), tenderness, and color (Nardone et al., 2010; Summer et al., 2019). Acute heat-stressed cattle specifically, have shown increases in circulating cortisol, norepinephrine, and epinephrine levels (Sylvester-Bradley and Wiseman, 2005), indicating heightened stress responses. Short term heat stress also alters both protein synthesis and ribosomal gene transcription, resulting in lower protein deposition (Jacob, 1995), ultimately affecting meat quality. Additionally, not being able to find or use shade can impact the animal's ability to express natural behaviors leading to a negative affective, or mental state, which also can impact overall welfare status (Polsky and von Keyserlingk, 2017).

Implementing a management strategy to decrease heat load can help alleviate some of the heat stress that cattle might endure. There are multiple heat mitigation strategies utilized in cattle production settings including providing shade structures, sprinklers, misters, or fans. The majority of research investigating heat mitigation strategies and their impacts on beef cattle performance, health, and behavior has focused primarily on feedlot cattle (Boren et al., 1961; Mader et al., 1999; Mitlöhner et al., 2001; Mitlöhner et al., 2002; Gaughan et al., 2010; Blaine and Nsahlai, 2011; Lees et al., 2020; Rusche et al., 2021). Cattle are highly motivated to seek shade on hot days, and have even been shown to compete for shade and choose shade over laying down (Schütz et al., 2008; Hagenmaier et al., 2016). Furthermore, some studies have reported that adding shade or sprinklers to housing environments can reduce both the ground surface temperature and the radiant heat load on the cattle themselves (Blackshaw and Blackshaw, 1994; Schütz et al., 2011; Hagenmaier et al., 2016; Giro et al., 2019). Other studies have found that providing shade can reduce respiration rate during periods of high heat loads, increase feed intake, and decrease number of deaths leading to improved animal well-being (Busby and Loy, 1997; Blaine and Nsahlai, 2011; Sullivan et al., 2011; Brown-Brandl et al., 2013). The impacts of other types of heat mitigation strategies, such as sprinklers and fans, throughout the beef cattle supply chain have been minimally researched.

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Despite the reported benefits of shade for cattle (reviewed by: Edwards-Callaway et al., 2021), industry data, albeit limited, indicates minimal usage of shade provisions in feedlots across the United States (NAHMS, 2013; Samuelson et al., 2016; Simroth et al., 2017; Rusche et al., 2021). To the authors' knowledge there is little to no published information quantifying shade usage in other parts of the beef cattle supply chain, particularly the slaughter sector. Although little is known about the reasons producers choose not to utilize shade as a heat mitigation strategy, concerns for the cost of adding and maintaining shade structures and the lack of information regarding the cost-benefit associated with shade implementation may influence these decisions (Edwards-Callaway et al., 2021).

A recent review of the impacts of shade on cattle well-being in the beef supply chain revealed the need for published data on the use of heat mitigation strategies in lairage pens at slaughter plants (Edwards-Callaway et al., 2021). Although cattle are not typically in lairage pens at plants for a long period of time (e.g., several hours), hot weather can still have a major impact on the heat load experienced by cattle while at the facility potentially causing acute heat stress. This is especially true due to extreme heat and/or increased stocking densities (as compared to feedlots) causing warmer microclimates, and ultimately leading to welfare issues such as open-mouth breathing (OMB) and challenges with mobility (Nielsen et al., 2020; Mijares et al., 2021). Benchmarking current shade provisions used at slaughter plants would be helpful in establishing a current state of heat mitigation usage in the slaughter sector of the cattle industry so that their benefits could be further explored. Thus, the objective of this study was to characterize short-term heat mitigation strategies utilized at slaughter plants in the United States.

## MATERIALS AND METHODS

All materials used in the study and the plan for research were approved by the Colorado State University Institutional Review Board (#20-10268H) prior to the start of the study.

### Sample Population and Recruitment

The population of interest for this study was corporate-level employees of large beef cattle processors in the United States. One individual from each slaughter company was recruited via email to explain the study and provide a link to the survey. Each individual then completed the survey for all slaughter plants that they represented within their company. Survey responses were gathered from September through November of 2020. All responses remained anonymous and no identifying information, other than the region of the United States that each plant was located in, was collected. All questions in the survey were optional, except consenting to participate in the survey, and a survey respondent could opt-out at any time.

### Survey Content

The survey was created using Qualtrics software (Qualtrics, Provo, UT, USA). Before the survey was distributed, two coauthors reviewed the questions to ensure questions were clear and concise and evaluated the entire survey for question flow and functionality.

The survey included a total of 28 questions with the intention for it to take less than 15 minutes to complete. For a selection of questions, if it was identified that a plant used a given heat mitigation strategy, a branching method of follow-up questions were asked. The survey questions were grouped into three categories including: demographics and plant information, heat mitigation strategies used, and perceptions of heat mitigation use. The heat mitigation strategies of interested included: shade, sprinklers/misters, and fans. Question types included open-ended, dichotomous, multiple choice, and multiple answer. The survey questions are provided as Supplementary Material.

### Statistical Analysis

After all respondents had taken the survey, all data were exported to Microsoft Excel (Microsoft Corporation, Redmond, WA). The data were summarized with descriptive statistics. Each plant provided the average number of cattle slaughtered per day at their facility, the number of holding pens that they had and their average pen density. These estimates were used to calculate an average of each parameter for each region of the United States. Each plant also provided information regarding type(s) of cattle slaughtered at their location (fed-native, fed-Holstein, cull-dairy, and/or cull-beef). This information was used to determine the number of plants in each region that slaughtered each type(s) of cattle. Additionally, each plant provided type(s) of heat mitigation used. This information was also summarized by region. An important note to consider is that 15 of the 21 plants slaughtered more than one type of cattle, and 5 plants used more than one type of heat mitigation strategy.

## RESULTS

A total of 21 surveys were submitted. All surveys were ≥ 80% complete and therefore included in the analysis. The average number of cattle slaughtered per day provided by each plant's survey response was summed (76,500 head) to calculate the estimated number of head slaughtered per day for this sample population. From this daily total, the approximate number of head slaughtered annually was calculated (19,890,000 head). Using the number of slaughtered commercial and on farm cattle calculated by the United States Department of Agriculture (USDA) Livestock Slaughter Summary, we were able to determine that the total estimate for the survey responses covered approximately 60% of all commercial and on farm cattle slaughter (USDA, 2021).

Table 1 shows average plant information by region of the contiguous United States. Approximately half (48%, $n$ = 10) of the plants were located in the Midwest region, 10% ($n$ = 2) of the plants were in the Northeast region, 19% ($n$ = 4) of the plants were in the Southwest region and 24% ($n$ = 5) were in the West region. Out of the 21 plants, 95% ($n$ = 20) slaughtered fed native cattle, 71% ($n$ = 15) slaughtered fed Holsteins, 33% ($n$ = 7) slaughtered culled dairy cattle and 33% ($n$ = 7) slaughtered culled beef cattle. Fifteen of these plants slaughtered more than one type of cattle.

Of the plants surveyed, 5 (24%) used more than one type of heat mitigation strategy, and every plant used at least one type of heat mitigation strategy. The most common heat mitigation type used was sprinklers and/or misters ($n$ = 17, 81%) and the least common type was the use of fans ($n$ = 4, 19%). Sprinklers and misters were most commonly used in the West, Southwest, and Midwest regions over other heat mitigation types, whereas shade structures were the most commonly used heat mitigation type in plants in the Northeast region. A majority ($n$ = 12, 71%) of the plants that used sprinklers/misters would turn them on when temperatures reached 26.7°C or warmer and would use them typically during the summer months. Two of the plants in the West would turn their sprinklers on when temperatures reached 35°C. For plants that used fans, 3 would turn them on when temperatures reached 26.7°C or warmer, and 1 plant in the West turned them on when temperatures were above 35°C. Shade structures were the second most commonly used ($n$ = 7, 33%). All shade structures used by the plants were permanent and ranged anywhere from barn roofs, gabled barn roofs ,or flat roofs, to shade cloths. Three of the plants had the ability to close the sides or windows of their barns during colder months, whereas 2 of the plants had barns with open sides.

A national temperature map (Figure 1) was created using the National Centers for Environmental Information data

**Table 1.** Summary of slaughter plant demographics and heat mitigation strategies used by region

| | Average plant information[b] | | | Type of cattle slaughtered[c] | | | | Heat mitigation strategies used[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Region[a] (# of plants represented) | # of Cattle slaughtered/day | # of Holding pens | Pen density | Fed-Native | Fed-Holstein | Cull-Dairy | Cull-Beef | Shade structures | Sprinklers/ misters | Fans |
| Midwest(10) | 4,030 | 39 | 73% | 10/10 | 6/10 | 3/10 | 3/10 | 3/10 | 8/10 | 1/10 |
| Northeast(2) | 1,800 | 43 | 75% | 2/2 | 2/2 | 2/2 | 2/2 | 2/2 | 0/2 | 1/2 |
| Southwest(4) | 4,525 | 26 | 71% | 4/4 | 3/4 | 1/4 | 1/4 | 1/4 | 4/4 | 1/4 |
| West(5) | 2,900 | 32 | 80% | 4/5 | 4/5 | 1/5 | 1/5 | 1/5 | 5/5 | 1/5 |

[a]Midwest (IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI), the West (CA, CO, ID, MT, NV, OR, UT, WA, WY), the Southwest (AZ, NM, OK, TX), the Southeast (AL, AR, FL, GA, LA, KY, MS, NC, SC, TN, VA, WV) and the Northeast (CT, DE, MA, ME, MD, NH, NJ, NY, PA, VT, RI).
[b]Each plant provided the average number of cattle slaughtered per day at their facility, the number of holding pens that they had and their average pen density. These estimates were used to calculate an average of each parameter for each region of the United States.
[c]Values in these cells show the number of plants in each region (numerator) that slaughter each named type of cattle out of the total number of plants represented of each region (denominator).
[d]Values in these cells show the number of plants in each region (numerator) that named each type of heat mitigation out of the total number of plants represented of each region (denominator).

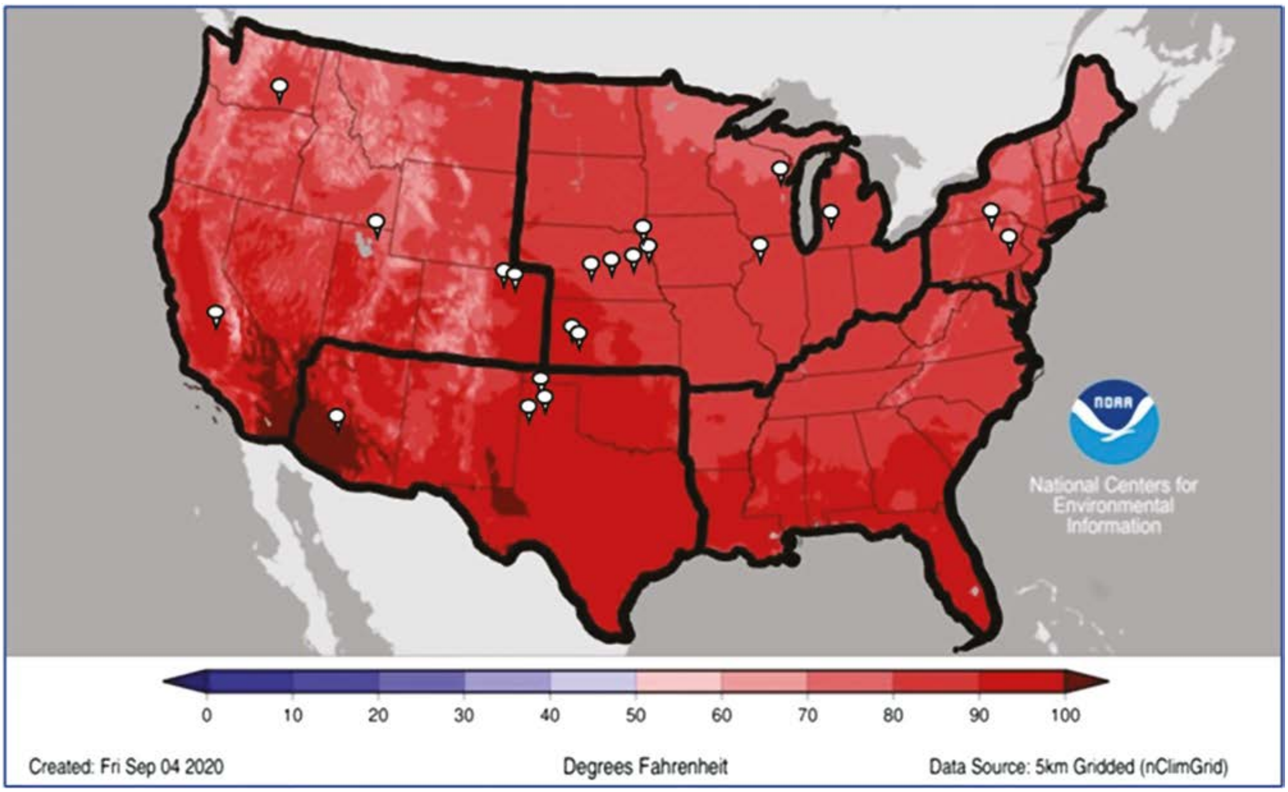


**Figure 1.** A map of the contiguous United States including the average maximum temperature during the months of June through August of 2020 (image adapted from NCEI, 2020). The dark black lines denote the regions represented in this study: Midwest (IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI), the West (CA, CO, ID, MT, NV, OR, UT, WA, WY), the Southwest (AZ, NM, OK, TX), the Southeast (AL, AR, FL, GA, LA, KY, MS, NC, SC, TN, VA, WV) and the Northeast (CT, DE, MA, ME, MD, NH, NJ, NY, PA, VT, RI). Approximate locations of plants that participated in the survey are denoted by the white location icons.

(NCEI, n.d.). The temperature map shows the average maximum temperature from June through August of 2020 providing a visual representation of weather during the hottest time of the year in the United States. Black borders added to the figure denote the different regions of the contiguous United States (Midwest, Southwest, Northeast, Southeast, or West) that were used to categorize plant location in this study, and white location pins have been added to the map showing approximate locations of plants that participated in the survey. Parts of the Southwest and West regions of the United States experienced the highest average temperatures compared to the other regions; all plants in these regions had sprinklers and/or misters they could use in warmer weather conditions.

Respondents were asked if they believed that heat mitigation strategies provide benefits, to which all respondents said yes, except for one who did not respond. Respondents were also asked to list and explain the benefits of heat mitigation from their own perspectives (respondents were not asked to support their answers with evidence). Many of the responses mentioned the cattle would be cooler when heat mitigation is used and therefore the cattle "*are more comfortable*" and are "*easier to move*". Additionally, respondents mentioned that added heat mitigation strategies "*provide air movement… which helps reduce humidity*," "*provides a cooler environment*" and ultimately would "*prevent*" or "*reduce stress*." "*Less downers*" and "*reduced euthanasia*" were also mentioned as possible benefits to utilizing heat mitigation strategies. The idea of seeing "*quality benefits such as reduced dark cutters*" was also mentioned. One respondent mentioned that providing heat mitigation strategies is beneficial "*where necessary*" as plants in certain regions may not have as much of an issue with heat stress. Another respondent also noted that the addition of heat mitigation strategies can benefit employees as well, leading to "*better engagement which improves animal handling and ability to handle more adverse situations*."

## DISCUSSION

Currently, there are no published reports that summarize the use of heat mitigation strategies in lairage pens at beef slaughter plants. In current industry conversations focused on cattle welfare at slaughter, the importance of managing extreme heat via the use of shade or another type of heat mitigation strategy such as sprinklers or fans is often discussed (L.N. Edwards-Callaway, personal communication). The objective of this study was to determine heat mitigation strategies utilized at slaughter plants in the United States to help characterize what techniques are currently being used to manage extreme heat. While this study does not represent all beef slaughter plants in the United States, the data collected is representative of an estimated 60% of all commercial and farm cattle slaughter in the United States including information from many of the larger sized plants. Additionally, the majority of data that report the impact of heat abatement on cattle production and welfare was collected in a feedlot setting. The slaughter plant is substantially different both in design (e.g., pen surface, pen material, stocking density) and in time spent in the facility (e.g., several hours at a slaughter plant compared with several months at a feedlot) and these differences are considered in the following discussion.

Heat stress management has been an area of focus across the beef cattle industry in the United States in recent years due to a variety of factors; one being increased number of extreme heat events and climate variability (Brown-Brandl et al., 2003). There have been several heat waves in the United States that have caused extensive death loss in feedlots, ultimately having significant negative impacts on animal welfare and producer profitability (Busby and Loy, 1997; Hahn and Mader, 1997; Brown-Brandl et al., 2006). Of feedlots in the Midwest that participated in a heat mitigation usage and perceptions survey, all respondents indicated that they had experienced loss in performance and mortality from heat stress events with 87% of feedlots describing their losses as "minor", and 13% describing their losses as "moderate" (Rusche et al., 2021). Busby and Loy (1997) identified that shade assisted in reducing death loss in feedlot cattle during an extreme heat event reporting a significant decrease in death loss of cattle that were provided shade (0.2%) compared to those that were not provided shade (4.8%). Additionally, Busby and Loy (1997) reported that 10 out of 100 head of cattle that were not provided with sprinklers during the extreme heat died, whereas all cattle that were provided with sprinklers survived. Although the feedlot environment is appreciably different from the slaughter plant, the positive impact on cattle welfare demonstrated by implementation of heat abatement in feedlots sets the precedent for exploring the potential benefits of heat mitigation on relevant welfare outcomes in cattle during lairage at the plant.

The majority of research on the effectiveness of heat mitigation strategies in the beef cattle industry has focused on performance indicators in feedlot cattle (Mader et al., 1999; Mitlöhner et al., 2001; Mitlöhner et al., 2002; Gaughan et al., 2010; Blaine and Nsahlai, 2011; Sullivan et al., 2011). For example, the use of shade has shown improvements in performance outcomes such as body weight, average daily gain, and hot carcass weights in feedlot cattle (Blaine and Nsahlai, 2011). A meta-analysis of fifteen published studies comparing the use of shade compared with no shade in feedlot settings indicated increases in final body weights, gain efficiency, hot carcass weights, and dressing percentages, and improved marbling scores for feedlot cattle that were provided with shade (Edwards-Callaway et al., 2021). Mitlöhner et al. (2002) reported a decrease in the prevalence of dark cutting carcasses when cattle had access to shade in a feedlot setting as compared with those that did not; it is important to note that this was a longer term study during the feeding period and thus the short-term impacts of shade at slaughter plants has yet to been investigated. Dark cutting was also mentioned by survey respondents; one respondent indicated that heat mitigation strategies provide "*quality benefits such as reduced dark cutters*". There are many variables that impact the prevalence of dark cutters related to both the environment preslaughter and management during the marketing process (Kreikemeier et al., 1998; Scanga et al., 1998) and thus the inclusion of heat abatement techniques implemented in both the feedlot and slaughter plant environments is warranted in future studies exploring meat quality outcomes.

As mentioned, the feedlot and slaughter plant environments are different, one difference being the amount of time that cattle spend at each location. Cattle remain in the feedlot for a significantly longer time allowing them to recover from a severe heat event, whereas cattle in holding pens at the slaughter plant may not be given a chance to recover before being processed. Additionally, the stocking densities are considerably different. The North American Meat Institute (NAMI) guidelines for best animal handling and management practices at the slaughter plant state that the recommended square footage that should be allotted per animal in lairage is 20 to 24 ft$^2$ (1.87 to 2.22 m$^2$) for cattle 1,200 to 1,600 lbs. (545 to 720 kg), respectively (NAMI, 2021). For feedlot cattle, the FASS (Federation of Animal Science Societies) Ag Guide provides detailed recommendations for space allocation in finished cattle housing, however, it is quite variable and is dependent upon type of facility (e.g. open lots vs. barns) and size of animal (e.g. calves vs. finished cattle; [FASS, 2020]). The National Cattlemen's Beef Association (NCBA) Beef Quality Assurance (BQA) National Manual does not provide specific guidance on stocking density, but the BQA Feed Yard Assessment does recommend that animals should be capable of lying down, standing up, and moving freely (National Cattlemen's Beef Association (NCBA) Beef Quality Assurance, 2017, 2019). Generally, space allocation is greater for cattle at feedlots than at the plant. Although slaughter facilities make efforts to provide cattle with the recommended space allowance, the authors have observed overstocked holding pens, and these increased stocking densities can create an extreme microclimate during certain environmental conditions, increasing the thermal stress experienced by the cattle. While cattle are not in lairage pens for very long at plants in the United States, we postulate that this extreme microclimate can have deleterious effects on both welfare and meat quality, such as increases in cortisol levels and other stress-related hormones as well as decreased performance outcomes, as similar microclimates in feedlots, trailers and on intensive farms have led to these outcomes (Sylvester-Bradley and Wiseman, 2005; Mazzenga et al., 2006; Mader et al., 2007; Bryan, 2013; Goldhawk et al., 2014; Summer et al., 2019).

Slaughter plants in this study used a variety of heat mitigation strategies such as sprinklers/misters, shade structures, and/or fans. All shade structures used by plants in this survey were permanent and were either barn structures or shade cloths. Shade structures can reduce heat accumulation from solar radiation and come in many different shapes and sizes such as steel roofs, shade cloths, polyethylene mesh, and gabled barn roof (Edwards-Callaway et al., 2021). The degree of protection from solar radiation is also an important design feature as shade structures offering more protection allow for lower minimum body temperatures in cattle (Tucker et al., 2008). The most common type of shade structure reported in this study was a barn roof, although in general, shade structures were not as common as other types of heat mitigation strategies.

While there are no specific guidelines for heat mitigation at plants, heat stress is considered in both the NAMI audit guide (NAMI, 2021) and the Federation of Animal Science Societies's (FASS) Guide for the Care and Use of Agricultural Animals (FASS, 2010). Although the FASS guide is intended for cattle used in, research and teaching, it can be used as guidelines for management practices and commercial use, including recommendations for shade requirements in feedlots. This guide indicates that 1.8 to 2.5 m$^2$ (19.4 to 27 ft$^2$) is the amount of shade required for larger cattle in feedlots, and shade is strongly recommended for cattle in hospital pens (McGlone and FASS, 2010). This information was interestingly not included in the latest version of the guide (FASS, 2020). However, Silva & Maia (Silva and Maia, 2013) presented a summary of "desired figures" for area of shade availability per animal from selected studies and found that the values ranged from 1.8 to 9.6 m$^2$ (19.4 to 103.3 ft$^2$) acknowledging, in their experience, that 1.8 m$^2$ is not enough room for animals that are lying down. The NAMI audit guide requires all plants to have extreme heat management tools in place if needed, and therefore if an animal is found to be heat stressed it is counted as a deficiency during the transportation audit (NAMI, 2021). It is speculated that shade structures are not commonly used in slaughter plants due to the cost of implementation, they can be difficult to work around, and the fact that cattle are not there for very long. However, shade structures can be advantageous over other heat mitigation strategies such as sprinklers or fans because shade does not require a series of daily decision making regarding whether to turn on the sprinklers or fans and for how long, therefore simplifying heat management (Rusche et al., 2021). It should be noted that some facilities may have automated systems that are activated at certain temperatures which would be advantageous from a management perspective.

Sprinklers and misters are typically the most common type of heat mitigation strategy used across facilities. They work by directly wetting the hide to reduce heat load and respiration rate in cattle (Tresoldi et al., 2018). Wetting the ground or floor of feedlot holding facilities can be effective in cooling cattle where shade is sparse or nonexistent (Mader, 2003; Mader and Davis, 2004). Although a study in dairy cattle reported preference for shade over sprinklers (Schütz et al., 2011), spraying water has shown to more effectively reduce heat load (e.g., lower body temperature) in cattle compared with shade alone (Kendall et al., 2007; Chen et al., 2013; Chen et al., 2016). Wetting cattle using sprinklers in the morning, before cattle experience high heat loads, also enhances the cooling method (Davis et al., 2003). The addition of sprinklers in feedlots has also proven to decrease panting, have a positive effect on the microclimate of cattle feeding areas and reduce the susceptibility of cattle to hyperthermia (Mader et al., 2007). Plants surveyed in this study typically turn sprinklers on when temperatures reach 26.7 °C and are sometimes used continuously or rotate on and off every thirty minutes until temperatures subside. As a routine protective practice the FASS guide recommends using a timer to provide 5 to 10 minutes of spray during each 20- to 30-min period for effective wetting (FASS, 2020). It is speculated that sprinklers and misters are more commonly used by plants because they are easier to implement at older facilities compared to shade structures, however, with an industry focus on sustainability and reduction of resource use, water conversation efforts may change strategies implemented in the future. Respondents were not asked about challenges with heat mitigation, therefore no disadvantages were given, however, one study surveying heat mitigation strategy perceptions of respondents from feedlots indicated that most struggled with issues of additional mud from water application that partially outweighed the perceived benefits (Rusche et al., 2021). It would be interesting to investigate challenges associated with the use of sprinklers at slaughter plants. Currently, there is also a need for studies quantifying effectiveness of sprinklers and misters in improving cattle welfare at the plant or the optimal protocol for use. Future research needs to address the importance of airflow and other impacting factors as inappropriate use of sprinklers can also negatively impact welfare.

Fans promote air movement that can be beneficial during hot weather and can help enhance other natural ventilation systems while reducing heat load and optimizing performance traits in beef cattle (FASS, 2010; Marchesini et al., 2018). Air movement as a heat mitigation strategy has been mentioned in other studies as well, specifically related to air movement under shade structures being critical in ensuring heat stress relief (Silva and Maia, 2013; Luttrell and Keane, 2016). Fans are typically the least used heat mitigation strategy potentially because they need to be mounted to structures such as barns for effective air movement and require electricity which may not be readily accessible in certain locations. It is also speculated that fans are difficult to maintain compared to sprinklers or shade structures. Any combination of these heat mitigation strategies, such as the use of shade and misters, only enhances the reduction in heat stress experienced by beef cattle (Mitlöhner et al., 2001). Using sprinkler systems and fans in conjunction with one another have also proven to significantly increase the rate of weight gain for feedlot heifers exposed to long term elevated ambient temperatures (Garner et al., 1989).

Although not identical environments, there may be some similarities between the microclimate in cattle lairage pens and compartments on cattle trailers that can help us understand potential welfare and quality outcomes. Ambient temperatures in the microclimate of cattle transport trailers has also been thoroughly researched (Bryan, 2013; Goldhawk et al., 2014; Goldhawk et al., 2015). Livestock trailer microclimates offer increased humidity and temperature from the presence of cattle supplying heat and moisture to the environment from metabolic and thermoregulatory processes (Randall and Patel, 1994). Also, because of the increased stocking densities, air movement is reduced, further reducing ventilation and heat dissipation that would naturally occur in an environment with more space or mechanical ventilation (Albright, 1990). High ambient temperatures during transport have shown increases in the amount of shrink in cattle (González et al., 2012a; Schwartzkopf-Genswein et al., 2016). Greater incidences of shrink during transport has also been associated with greater incidence of lame, nonambulatory and dead animals due to transportation (González et al., 2012b). Providing access to stress-reducing environments such as shade structures, and minimization of extreme heat microclimates, can minimize death losses industry-wide (Eigenberg et al., 2005). Lairage pens pose a similar challenge with increased stocking densities and thermal conditions that do not allow for proper heat dissipation or airflow without implementation of heat mitigation strategies.

The results of this survey indicate that all the slaughter plants within the study population provide some type of heat mitigation for cattle during lairage. Although this sample does not represent the entire United States cattle slaughter sector, it does suggest that heat mitigation is likely an integral part of preslaughter animal management at slaughter facilities. The most common heat mitigation type used were sprinklers/misters and the least common were fans. Respondents to the survey believed that heat mitigation strategies do provide benefits such as "*reducing stress*" and provide "*quality benefits such as reduced dark cutters.*" The effects of different heat mitigation strategies in cattle have been studied in both feedlots and cow-calf operations, showing increases in both well-being and performance outcomes in cattle. However, as mentioned previously, there is limited research exploring the effectiveness of heat abatement techniques for cattle during lairage at slaughter facilities. Future research should focus on quantifying the benefits of shade and other heat mitigation strategies on cattle welfare, and ultimately meat quality outcomes, in lairage pens at slaughter plants.

## Supplementary Data

Supplementary data are available at *Translational Animal Science* online.

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## Conflict of interest statement

None declared.

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