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Investigating the impact of pre-slaughter management factors on indicators of fed beef cattle welfare – a scoping review

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Introduction: The impact of pre-slaughter management practices on fed beef cattle welfare is a multifaceted and well researched subject matter. Factors such as transportation, handling, lairage time and several animal characteristics can directly impact the cattle's behavior, mobility, blood lactate and cortisol levels, likelihood of injury and ultimately overall cattle welfare. Animal welfare continues to grow as a critical component of slaughter in the fed beef industry, yet a formal review of related research does not exist.

Methods: A scoping review was performed in order to (1) catalog pre-slaughter management factors that impact fed beef cattle welfare at the time of slaughter, (2) identify indicators used to evaluate the impact of pre-slaughter management on fed beef cattle welfare at slaughter, and (3) gain further understanding of the relationship between pre-slaughter management factors and fed beef cattle welfare outcome indicators at slaughter. Three data bases were ultimately searched: PubMed, CAB Abstracts, and Web of Science. The concepts used in the database searches were the population of interest (i.e., fed beef cattle), the location in the supply chain, preslaughter management factors, and welfare outcomes.

Results: A total of 69 studies were included in final analysis for this review, including studies from six geographic regions around the globe. Studies involving alternative slaughter methods (e.g., religious stunning or mobile slaughter) were not included in the formal analysis of this review, but still merited an in-depth discussion within this paper. After reviewing the studies, a total of 37 pre-slaughter factors and 69 indicators of welfare were measured throughout. Pre-slaughter management factors were then categorized by: animal characteristics; environmental characteristics; handling; lairage; transportation; and water/feed. Outcomeindicators of welfare were categorized into: behaviors; health, injury and disease; physiological; and stunning and insensibility.

Discussion: Pre-slaughter factors relating to transportation and handling, and welfare outcomes measured by behaviors and physiology were of the most

researched throughout the studies.The results of this review offer a catalogue of commonly researched factors and indicators of welfare measured during the pre-slaughter phase, as well ast he relationships between them. This review also offers further substantial evidence that a multitude of events in the pre-slaughter phase affect fed beef cattle welfare and a collection of highly applicable welfare indicators to expedite further research on the effects of pre-slaughter factors and the application of improved practices.

KEYWORDS

abattoir, beef cattle, management, slaughter, welfare indicators, well-being

1 Introduction

Animal welfare is a highly researched (Broom, 2011; Gallo and Huertas, 2016; Edwards-Callaway and Calvo-Lorenzo, 2020; Nalon et al., 2021) and multifaceted topic which addresses an animal's individual state in regards to its ability to cope with its environment (Broom, 1986). Interestingly, there is no universally accepted definition of animal welfare or definitive guidance on what specifically constitutes 'good' or 'bad' welfare for each species (Wigham et al., 2018). For example, the American Veterinary Medical Association refers to animal welfare as the state of the animal, the treatment it receives, and that protecting an animal's welfare means providing for its physical and mental needs (AVMA, 2022). Whereas, the World Organization for Animal Health describes animal welfare as the physical and mental state of an animal in relation to the conditions in which it lives and dies (OIE, 2022). While these definitions share a similar foundation, they vary slightly in their notions of what is causing the impacts on animal welfare itself. Animals that experience negative or poor animal welfare will attempt to cope and counteract any adverse effects from their environment (Broom, 1986; Broom, 1988). Lack of success in their attempt to counteract poor conditions may lead to detrimental effects both mentally and physically (e.g., stress or sickness), and these effects can be observed and measured. Along with the ethical and moral aspects of ensuring acceptable welfare standards for animals, improving an animal's welfare has the potential to positively influence economic outcomes (Gibson and Jackson, 2017).

Globally, efforts have been made across every stage of cattle production to develop standards, protocols, and regulations, both voluntary and involuntary, to help ensure rearing conditions promote positive animal welfare states (NFACC, 2013; AHA, 2016; Executive Council, 2018; NAMI, 2021; NCBA, 2022). Even when these protocols are followed, there will undoubtedly be scenarios in the animal's life where a multitude of stressors may lead to compromised welfare conditions and induce distress, fear, injury or pain. One of these scenarios is the pre-slaughter phase of cattle production. Loading of meat animals for transportation to slaughter initiates the beginning of a potentially stressful process as animals are moved from a familiar environment to the slaughterhouse, where the animals are exposed to potential stressors, such as handling and mixing with other animals (Terlouw et al., 2008). Although the cattle industry has made great efforts to reduce stress during pre-slaughter processes (da Costa et al., 2012; Grandin, 2012; Edwards-Callaway and Calvo-Lorenzo, 2020), there are some unavoidable events that can impact welfare even if relatively brief. Several studies have previously explored the impacts of various stressors in the pre-slaughter phase on animal welfare outcomes (Hogan et al., 2007; Terlouw et al., 2008; Weeks, 2008; Mendonça et al., 2016; Njisane and Muchenje, 2017a; Castro de Jest et al., 2021), and attention has been given to reducing the negative impacts associated with pre-slaughter management (Grandin, 2014; Frisk et al., 2018; Grandin and Cockram, 2020).

The pre-slaughter phase of the cattle production is comprised of several components including loading, transportation to the slaughter plant, unloading, lairage, handling and slaughter. Several other factors are also important components of this phase such as individual animal characteristics, transportation conditions, stocking densities, adverse weather conditions and other novel environmental factors. Collectively, this wide array of factors makes it difficult to determine which ones specifically are contributing to an animal's welfare state (Bourguet et al., 2010). Different approaches to measuring animal welfare at slaughter plants have been employed including the use of: animal-based scoring systems, qualitative behavior assessments, weighted scoring systems, morphometric indicators, and biological and hematological measures (Grandin, 2010; Velarde and Dalmau, 2012; Losada-Espinosa et al., 2018; Wigham et al., 2018). Often studies focusing on cattle welfare during the pre-slaughter phase include the evaluation of a key predictor on welfare outcomes; for example, research exists studying the effects of: transportation stress

on physiological responses (Chacon et al., 2005), animal handling on injuries (Jarvis et al., 1996b; Valadez-Noriega et al., 2018), physiological responses and behavior (Ahsan et al., 2014; Hagenmaier et al., 2017; Hultgren et al., 2020) and lairage duration on behavior and blood constituents (Liotta et al., 2007; Özdemir et al., 2022). Common physiological responses to stress include elevated levels of blood cortisol and catecholamines (e.g., epinephrine) as well as changes in heart rate and body temperature (Burdick et al., 2010; Abubakar et al., 2021). Changes in behaviors vary widely that can be either positive (e.g., lying or ruminating) or negative (e.g., aggressive interactions with other cattle or vocalizing) (Tarrant et al., 1988; Cockram, 1990; Grandin, 1998b).

As animal welfare continues to grow as a critical component of slaughter in the beef industry, a significant number of studies have emerged covering the impacts of pre-slaughter management factors and their effects on indicators of fed beef cattle welfare (Losada-Espinosa et al., 2018; Edwards-Callaway and Calvo-Lorenzo, 2020; Losada-Espinosa et al., 2021; de Marchi et al., 2022). However, a formal review and compilation of these studies does not exist. A comprehensive evaluation of the existing literature is necessary to provide an overview of animal welfare indicators measured during the pre-slaughter phase and pre-slaughter management factors that may impact these indicators.

The research question for this scoping review was "What are measurable management factors and subsequent indicators of welfare in fed beef cattle at slaughter, and what are the relationships between them?" The research question for this scoping review was addressed through three main objectives. The first objective was to catalog pre-slaughter management factors that impact fed beef cattle welfare at the time of slaughter. The second, was to identify indicators used to evaluate the impact of pre-slaughter management on fed beef cattle welfare at slaughter. Lastly, the third objective was to gain further understanding of the relationship between pre-slaughter management factors and fed beef cattle welfare indicators at slaughter.

2 Materials and methods

This scoping review was conducted using the methodological framework outlined by Arksey and O'Malley (2005) and advanced by Levac et al. (2010), and utilized the reporting guidelines from the PRISMA checklist and flow diagram (Page et al., 2021).

2.1 Eligibility criteria

2.1.1 Population, factors & outcomes

The population of interest for this scoping review was beef cattle (i.e., fed beef cattle), and the studies of interest were included if they investigated pre-slaughter management factors and indicators of animal welfare. While bulls and cows are not considered as fed beef cattle in the United States, several of the studies from other geographic regions reported mainly processing bulls and cows and therefore these animal types were included in the population when they were considered primarily beef animals. Pre-slaughter management factors were defined as any procedures adopted by workers, slaughter facilities or companies during loading, transportation, unloading, lairage and the actual slaughter process. Other factors present during the pre-slaughter period that were considered relevant included animal characteristics (e.g., breed), environmental characteristics (e.g., temperature and humidity), handling, water and/or feed access, and additives fed one month prior to slaughter were also included in analysis. All types of slaughter facilities, stunning methods, and pre-slaughter management strategies were included to ensure there was a comprehensive list to catalog pre-slaughter management factors that may impact fed beef cattle welfare at the time of slaughter. Including all slaughter facility types, pre-slaughter management strategies and slaughter methods in the discussion also provides a comprehensive catalog of strategies and methods to identify potential areas of the pre-slaughter process that may warrant further research attention. Welfare outcomes were broadly defined as any measure related to one of the three conceptions of animal welfare as outlined by Fraser et al. (1997): biological functioning, affective states, and natural living. For example, biological functioning included cattle health and condition and physiological parameters; affective states included reactivity, head posture, emotional states, and vocalizations; natural living included social and sexual behaviors, eating, drinking and lying down. The outcomes of pre-slaughter management investigated were categorized as: behavior; health, injury and disease; physiological; and stunning and sensibility.

2.1.2 Limitations

Only papers written in English were included. Research articles covering alternative slaughter types (e.g., religious slaughter, on-farm slaughter, mobile slaughter, and slaughter without captive bolt stunning first) were included in the discussion, but not included in the final analysis. Due to the differences of slaughter methods and systems' possible impact on welfare outcomes, the decision was made to discuss these papers separately.

2.2 Search

2.2.1 Information sources

A librarian knowledgeable in systematic reviews was consulted when identifying databases for the literature search.

Three data bases were ultimately selected for this scoping review: PubMed, CAB Abstracts (EBSCO; including a filter for peer-reviewed articles), and Web of Science. The concepts used in the database searches were the population of interest (i.e., fed beef cattle), the location in the supply chain (i.e., pre-slaughter), pre-slaughter management factors, and welfare outcomes. Other livestock species (e.g., dairy) not of interest were excluded in the searches. The final searches were performed on August 2nd, 2022.

2.2.2 Search strategy

Initial search strategies were tested on PubMed against a few core references to verify that the core studies were present in the search results. After consultation with the librarian and other research members, a final search string was developed. The same search string was used for all three databases, and peer-reviewed was selected as a filter when available, which was only for CAB abstracts. The final search string and information on the databases searched is available in Table 1.

2.2.3 Selection of sources

All sources from the three databases were collated, uploaded to Zotero, an open-source citation management software (Zotero, Fairfax, VA), and software tools were used to remove duplicates. One reviewer performed the first level of screening of titles to remove any sources that were not relevant to the concepts. For the second level of screening, abstracts and full-text articles were reviewed by two independent reviewers to further exclude sources according to the inclusion criteria. If there was disagreement between the reviewers, each paper was then reviewed together and discussed until an agreement was made. Only primary studies, written in English that covered the inclusion criteria were included in this study. One additional article was discovered post-database searches after reviewing the bibliographies from the original database search results and was included in the final analysis.

2.3 Data charting and synthesis of results

Two reviewers discussed and determined the variables of interest to extract from the articles. All articles were reviewed by one researcher and variables of interest were extracted and collated into Microsoft Excel (Microsoft Corporation, Redmond, WA) for each article. The variables were then summarized and organized into categories of predictor variables and outcome variables, and the number of articles investigating each individual variable was reported. Geographic region(s) of each study was also extracted and reported using the regions defined by the United States Department of Homeland Security's office of Immigration Statistics (DHS, 2022).

3 Results

3.1 Study selection

From the three databases searched, 5,197 records were found and downloaded, and 862 of them were removed as duplicates. A total of 4,335 records were then screened for this scoping review. As a result of title screening, 4,041 records were removed for irrelevant topics, leaving 294 records for abstract and full-text screening. When inclusion and exclusion were criteria were applied, 216 records were excluded based on the wrong population, wrong outcomes, wrong location in the beef supply chain, non-English studies, or non-primary studies (i.e., studies that reviewed existing literature). One additional article was found post-database search leading to a total of 78 articles

TABLE 1 Databases and search string for a scoping review covering pre-slaughter management factors and their impacts on indicators of fed beef cattle welfare.

Database	Interface	Dates Included[1]
PubMed	NCBI	1950 – 2022
Cab Abstracts[2]	CABI	1973 – 2022
Web of Science Core Collection	Web of Science	1945 – 2022

Search String (All Databases)[3]

(Fed OR Native OR Cattle OR Heifer OR Steer OR Beef OR "Beef Cattle" OR "Fed Cattle" OR "Fed Beef") AND ("Preslaughter management" OR Preslaughter OR Slaughter OR Antemortem OR Harvest OR Pre-Harvest OR Pre Harvest OR Preharvest OR Abattoir) AND (Lairage OR Transport* OR Handling OR Mitigation OR Management OR Weather OR Pens OR "Holding Pens") AND (Stress OR Welfare OR Behavior OR Mobility OR Physiologic OR Biomarker OR Blood OR Well Being OR Pain OR Injury OR Lactate OR Cortisol OR Epinephrine OR Metabolite OR Distress) NOT (Dairy OR Broiler* OR Poultry OR Swine)

[1]Dates shown above were provided by each database's respective preset year range. Date exclusions were not applied during database searches.
[2]'Peer Reviewed' was applied as a filter on this database during the search.
[3]An asterisk was used to include suffixes for the identified word.

and 1 conference abstract (Mach et al., 2007) included based on the criteria. The authors removed studies from formal analysis where alternative slaughter methods were used (10), because of the possibility of the differing slaughter methods having an impact on welfare outcomes but included them in their own section of the discussion. Therefore, a total of 69 studies were included in the formal analysis. A flow diagram outlines the study selection process in Figure 1.

3.2 Study characteristics

Studies were distributed across six different geographical regions with the majority of studies conducted in Europe (n = 30), followed by North America (n = 15), South America (n = 11), Africa (n = 8), Oceania (n = 4) and Asia (n = 3). Two studies took place in two regions (Grandin, 2001; Teke, 2013). Proportions of each geographic region's representation is displayed in Figure 2. Studies that reported when their data was collected (n = 24) took place between the years of 1981 and 2020, and all studies included in the final analysis were published between 1984 and 2022. The number of animals used or observed in the studies ranged from 5 to 290,866, with the average number of animals being approximately 5,718. Eight studies did not report the number of animals included. Over 39 breeds and crosses of cattle were represented, with the most common breed being of Charolais influence, followed closely by Limousin, Angus, Friesian and Hereford. Eighteen studies did not report the breeds of cattle used or observed. Cattle ages studied ranged from 9 months to 9 years, however the majority

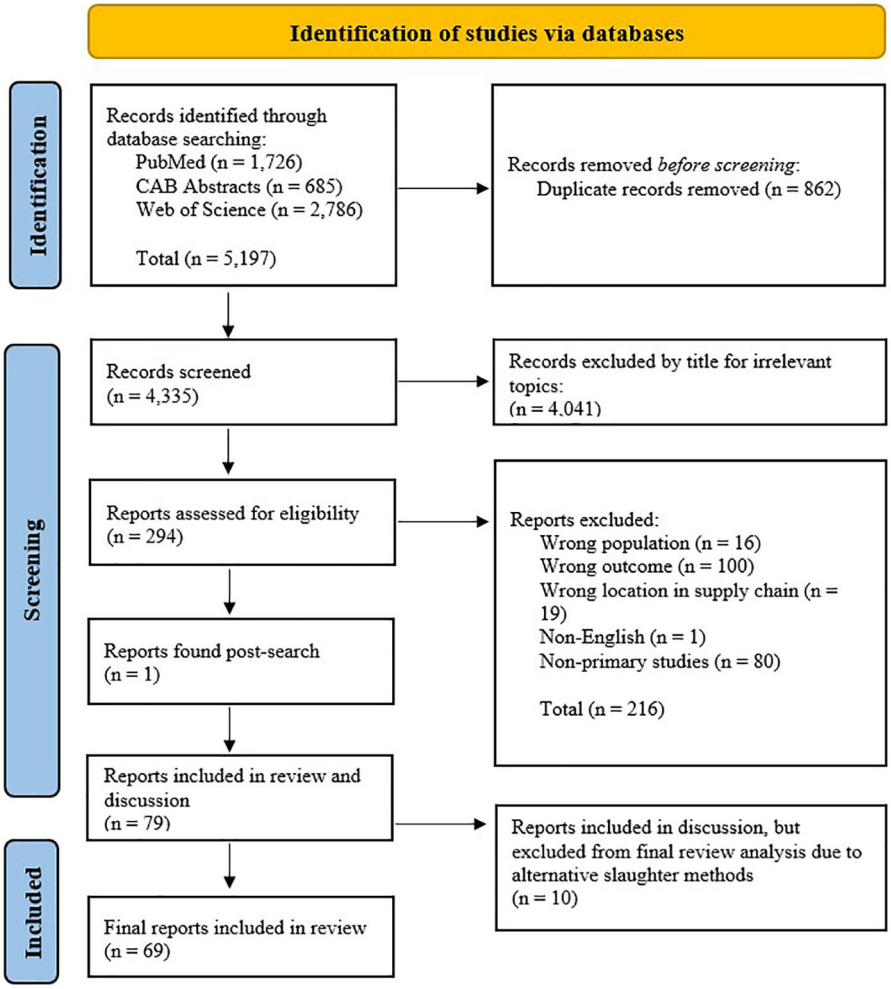

FIGURE 1
PRISMA flow diagram outlining the identification and inclusion of articles depicting pre-slaughter management factors and fed beef cattle welfare outcomes. Flow chart adapted from the PRISMA 2020 Statement (Page et al., 2021).

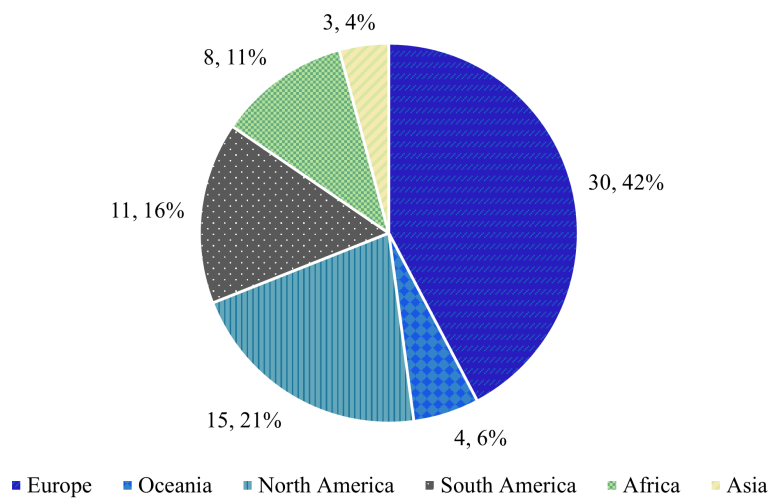

FIGURE 2
Number and percentage of studies included in the final scoping review analysis reported by demographic region[1] (n = 69[2]). Results are reported as (n, %). [1]Study locations were categorized into geographic regions as defined by the United States Department of Homeland Security's Office of Immigration Statistics (DHS, 2022). [2]Two studies took place in more than one region.

of studies included cattle ranging from 12 to 24 months, and 39 studies did not report the ages of cattle. Studies with mixed sex (heifers, steers, bulls and/or cows) were the most common (n = 25), followed by steers (n = 14), bulls (n = 13), heifers (n = 1) and cows (n = 1). Fifteen studies did not report the sex of cattle used or observed. Cattle originated from several sources; however, farms were the most common (n = 21), followed by unspecified animal handling facilities (n = 7), feedlots (n = 6), pastures (n = 5), markets (n = 1), multiple origins (n = 8) and 21 studies did not specify the origin of their cattle.

3.3 Measures

Predictor and outcome variables of interest were identified by the author of the scoping review as relevant to pre-slaughter management factors (predictors) and their effects on indicators (outcomes) of welfare and were then collated into categories. A breakdown of predictor and outcome variables measured for each category is summarized in Table 2. In the behaviors category of Table 2, all behaviors were collated and summarized into larger behavioral categories; the authors recognize that some of the specific behaviors could have been classified into multiple categories but based on the context of the paper and the reason the measurement was taken as part of the specific study, behaviors were classified as presented.

3.3.1 Predictors

After reviewing the 69 studies, a total of 37 unique predictor variables were categorized into the following categories: animal characteristics, environmental characteristics, handling, lairage, transportation or water/feed. The number of studies including a predictor within each category were recorded and are displayed in Figure 3. Some studies explored more than one predictor, therefore, the total number of transportation predictors (n = 71) reported in Figure 3 exceeds the total number of studies included in the final analysis (n = 69). Out of these five categories, transportation was studied the most (n = 71) in papers reviewed for this scoping review. Within transportation, distance and duration of transportation was measured the most, followed by the mention of general transportation. General transportation in this case meaning the study transported animals and looked at downstream effects of this factor, but no other specific characteristics of the experience were evaluated. The second most studied factor was handling (n = 56). Within handling, general handling was measured the most frequently. General handling, similar to general transportation, meaning the study observed animal handling and downstream effects of this factor, but again, no other specific characteristics of the experience were evaluated. The handling category also included slaughter practices such as stun to stick time (i.e. the time from being stunned to exsanguinated) and stun quality (e.g., missed stuns or number of stuns to render the animal unconscious). The evaluation of animal characteristics was included in 43 studies and the most commonly measured animal characteristic was origin of cattle prior to being transported to the slaughter facility. Environmental characteristics (n = 33) included temperature and humidity, noise levels and facility design and condition. The most measured lairage predictors (n = 32) were lairage duration and

TABLE 2 Preslaughter management factors and fed beef cattle welfare indicator categories with subsequent measurable variables of interest from studies included in analysis (n = 69) for a scoping review.

	Category	Measurable Variables
Predictor	Animal Characteristics	Origin of Cattle, Temperament, Presence of Horns, Sex, Breed, Age and Health/Condition Upon Arrival to the Slaughter Plant
	Environmental Characteristics	Bedding/Substrate Availability, Time of Day, Temperature/Humidity, Shadows, Light, Noise, Facility Size and Facility Design/Condition
	Transportation	Group Size, Driver Experience, Cattle Location in Trailer, Trailer Type, Trailer Condition, Stocking Density, Travel Distance/Duration, Social Mixing, Wait Time to Unload and General Transportation
	Handling	Prior to Transport, Loading/Unloading Duration, General Animal Handling, Stun Quality and Stun to Stick Time
	Water/Feed	Alternative Feeding System/Feed Additives, Fasting Duration and Water Consumption
	Lairage	Group Size, Social Mixing, Lairage/Resting Duration and Lairage Density
Outcome	Cattle Health, Injury & Disease	Mortality, Mobility/Lameness, Injuries and General Health/Condition
	Behavior	• Movement (e.g., slip, fall, walking) • Social (e.g., aggression, mounting) • Fight, Flight or Freeze (e.g., reactivity, avoidance, evacuations, kick, vocalize) • Stress Response (e.g., muscle tremors, open mouth breathing, eliminating) • Standing (e.g., idling, immobile) • Emotional States and Temperament • Eating, Drinking and Ruminating • Lying and Sitting • Exploratory • Vigilance
	Stunning & Insensibility	Post-Stunning Behaviors/Insensibility Checking (e.g. rhythmic breathing or corneal reflex), and Bleed Out Time
	Physiological	Vital and Blood Parameters, Electroencephalogram Recording and Brain, Foot, Skin, Liver, Adrenal Gland, Saliva and Urine Samples

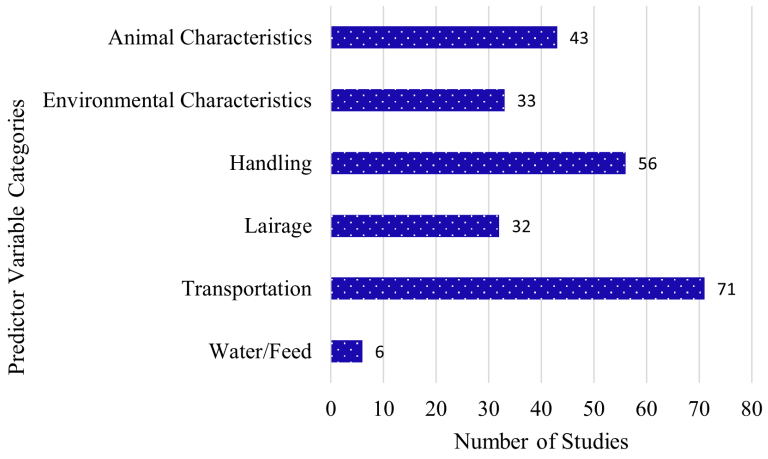

FIGURE 3
Number of studies per each predictor category included in the final scoping review analysis out of the total collection (n = 69[1]). [1]Several studies reported multiple factors within each category, therefore the total number of variables reported in each category represent more than total studies included in the analysis.

density. The least measured factor across the studies was water and feed (n = 6). This category included measures such as fasting duration, water consumption and alternative feeding systems or feed additives prior to transport for slaughter.

3.3.2 Outcomes

After reviewing the 69 studies, a total of 69 outcome variables were measured and categorized into the following categories: behavior; cattle health, injury and disease; physiological or

stunning and insensibility, and the number of studies measuring each category were recorded and are displayed in Figure 4. Out of these categories, physiological parameters were evaluated the most (n = 68) in studies reviewed for this scoping review. Within physiological parameters, blood parameters were measured substantially more than others such as vital measurements or urine parameters. Cattle behaviors were the next commonly measured indicators of welfare (n = 40), with the most frequently measured being the frequency of falls, vocalizations and slips. Cattle health, injury and disease (n = 12) was commonly assessed by recording injuries, mortality and mobility or lameness at the slaughter plant. The final category, stunning and insensibility indicators (n = 7), were measured as post-stunning behaviors or checking for signs of insensibility and bleed out time. Frequently measured behavioral signs to check for insensibility were the lack of corneal reflex (n = 5) and rhythmic breathing (n = 4).

4 Discussion

4.1 Summary of main findings

4.1.1 Factors and outcomes

Transportation and handling were the most highly researched pre-slaughter factor categories found in this collection of papers. The effects of transportation on beef cattle welfare are extensively researched and reviewed (Fike and Spire, 2006; Huertas et al., 2010; Schwartzkopf-Genswein et al., 2012; Schwartzkopf-Genswein et al., 2016) as transportation presents a period in the pre-slaughter phase that is considered one of the most stressful events that cattle must experience during their lifetime (Chambers and Grandin, 2001; Schuetze et al., 2017). For some cattle, depending on the production system they have been raised in, transport to the slaughter plant may be the first time they have been in a trailer. Livestock transportation regulations and policies vary greatly across areas of the world (e.g., Twenty-Eight Hour Law, 1994; CARC, 2001; European Council, 2005a) as do cattle production systems and associated infrastructure (i.e., pasture-based vs. feedlot; Gonzalez et al., 2022) which can all shape transportation logistics and thus impacts on welfare. There are many different components to transportation as well, including but not limited to, transportation duration and distance, the microclimate in the trailer, and driver experience, which have all been incorporated into the studies included in this review (e.g., Tarrant et al., 1992; González et al., 2012; Chulayo et al., 2016; Valadez-Noriega et al., 2018). Animal handling was also highly represented as a pre-slaughter management factor of interest. There have been considerable efforts in educating stakeholders about low-stress handling techniques as the benefits to reducing animal stress are clear (Grandin, 2012; Grandin, 2014). Additionally, animal handling is a component of pre-slaughter management that can be more easily controlled and manipulated as compared to other factors such as the environment or facility design and thus a target area to identify improvements. Lastly, many of the industry regulations and guidelines globally highlight the need to have trained employees that understand the basic principles of low-stress animal handling (Government of Canada, 2018; OIE, 2018; GRSB, 2021) and thus this area has perhaps received more attention in relation to cattle welfare at slaughter.

4.1.2 Factor and outcome relationships

To assess the relationships between pre-slaughter management factors and outcome indicators of welfare for fed beef cattle, the

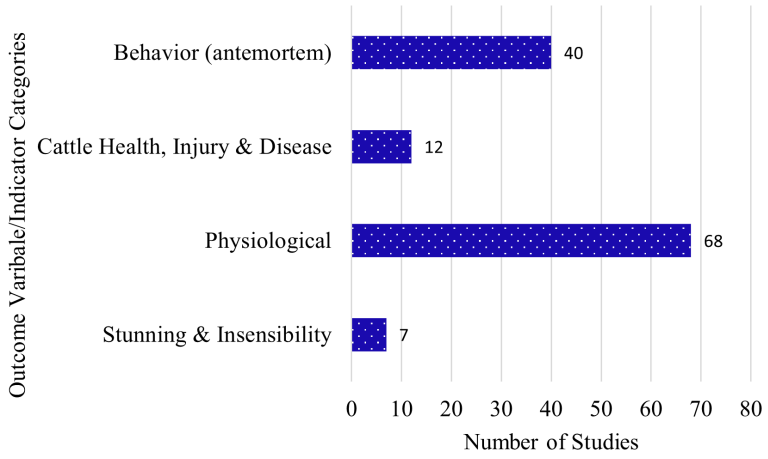

FIGURE 4
Number of studies per each outcome category included in the final scoping review analysis out of the total collection (n = 69[1]). [1]Several studies reported multiple outcomes within each category, therefore the total number of variables reported in each category represent more than total studies included in the analysis.

following discussion will be arranged by the categories of outcomes and a discussion on each one's relationship with pre-slaughter management factors. Main factors and outcomes will be highlighted throughout this discussion. Relationships between variables with less research or no significant impact will be limited in discussion.

4.1.3 Behavior

Allowing an animal to perform natural highly-motivated behaviors has been a foundational component of many animal welfare frameworks (e.g., the Five Freedoms, FAWC, 1993; Fraser's Three Circles, Fraser et al., 1997; the Five Domains Mellor et al., 2020). Additionally, current frameworks for welfare assessment encourage both the promotion of positive experiences and the reduction of negative experiences (Green and Mellor, 2011). Even though the pre-slaughter phase represents a relatively short period within the animal's lifetime, it is still important to provide cattle with the opportunity to express positive natural behaviors such as lying, exploring, and ruminating. Upon arrival at a slaughterhouse, the state of the animal will depend upon the nature and duration of their experience from their place of origin, and the new physical and social environment is likely to affect the ability of the cattle to rest and relax (Cockram, 1990). In several studies, the frequency of both positive (e.g., ruminating, eating or drinking) and negative (e.g., aggression or vocalizing) behavioral states were measured (Cockram, 1990; Jarvis et al., 1996b; Njisane and Muchenje, 2014; Njisane and Muchenje, 2017b; del Campo Gigena et al., 2021). Lying time can be an important welfare indicator in cattle (Haley et al., 2000; Tucker et al., 2021). In a slaughter plant, lying behavior would most commonly occur during lairage as cattle experience a period of inactivity (i.e., no handling) during holding. Studies have shown that lying behavior tended to increase with lairage duration, where 26% of focal animals were lying down by 3 hours in lairage (Jarvis et al., 1996b), however, this is highly influenced by time of day, activity within the pen and origin of cattle (Cockram, 1990; Cockram, 1991; Jarvis et al., 1996a). Cockram (1990) reported that the mean number of head alert reactions to external stimuli in cattle originating from a market decreased with time in lairage and occurred the least in steers over heifers with a space allowance of greater than $5m^2$ per animals, a sign that cattle were acclimating to the new environment. One study comparing cattle that did not experience transportation or lairage with ones that were transported and held for durations up to 24 hours, found reduced aggression frequency (0.00 compared to 0.57 at 24 hours) (e.g., butting) with conspecifics in the group that went straight to slaughter (Özdemir et al., 2022); this is a logical finding as there were reduced opportunities for animal-to-animal interactions in the direct slaughtered group.

Cattle are also motivated to spend time eating and drinking (Schütz et al., 2018); the availability of food and water for cattle during this pre-slaughter phase varies across production systems. The origin of the cattle (i.e., market vs. farm) has been shown to influence drinking time; cattle from markets drank for significantly longer and more often at the plant than cattle coming from farms (Jarvis et al., 1996b). This may be indicative of an extended period of water deprivation for cattle originating from markets. Related, cattle being transported from farms over 80 miles away from the abattoir drank significantly more than cattle transported for shorter distances (Jarvis et al., 1996a) from the extended water deprivation period. Cattle ruminate while resting, and time spent ruminating is a direct indicator of animal welfare status in ruminants (del Campo et al., 2021). del Campo et al. (2021) reported that as lairage time increased (from 3 to 15 hours), the frequency of rumination decreased from approximately 40% to 15% of time; one study reported that rumination decreased by as much as 34% when cattle were held for over 12 hours (Mach et al., 2007), a finding that was likely partially related to gut fill. In summary, many factors can influence the expression of behaviors during the pre-slaughter phase, however, past research does show that cattle still have the ability to express highly motivated behaviors at different points in the pre-slaughter period.

Movement behaviors, such as slipping, falling, jumping, and loss of balance were frequently measured throughout multiple studies. Studies have demonstrated that these types of behaviors are impacted by both animal handling techniques (Cockram and Corley, 1991; Hemsworth et al., 2011; Huertas et al., 2018; Cevallos-Almeida et al., 2021) and facility condition or type (Grandin, 1996; Disanto et al., 2014; Romero et al., 2017; Willson et al., 2021) and many of them can negatively impact animal welfare by increasing the risk of injury to the animal. Generally, these movement behaviors are observed during periods of animal handling which can occur at multiple times throughout the pre-slaughter period allowing for assessment at a variety of locations and stages. Additionally, these types of behaviors are relatively easy to observe and quantify and are thus practical methods of assessing welfare in a slaughter plant environment. Loading and unloading of cattle are activities during the pre-slaughter period in which handling intensity increases and thus several studies have evaluated the impacts on welfare outcomes from these events (Jarvis et al., 1996b; von Holleben et al., 2003; Hagenmaier et al., 2017). Loading has been shown to be more stressful for cattle than unloading, as the frequency of falls (approximately 33%) and balking (approximately 50%) was greater during loading than unloading (approximately 15% and 10%, respectively; María et al., 2004), possibly due to the cattle being moved into an unfamiliar environment. However, unloading can be more difficult when temperatures are lower,

when the duration of transportation is longer, and if cattle are mixed immediately before loading (Mounier et al., 2006), demonstrating the interactive effects of multiple pre-slaughter factors. Once cattle are loaded onto a trailer there are limited opportunities to assess behavior without the use of technology (i.e., cameras in the trailer, accelerometer on the cattle) but it has been reported that during transport, cattle frequently lose their balance with sudden stops or on roads with curves and gravel portions (Tarrant et al., 1988; Wikner et al., 2003). Additionally, increases in transportation duration (60 minutes versus 180 minutes) and greater Temperature-Humidity Index (THI) classes (<60, ≥60<70 and ≥70) have been associated with increased restlessness frequency (7.0% during 60 minutes of transportation and 11.8% during 180 minute transportation duration, and 8.1% in THI class <60, 9.8% in ≥60<70 and 10.8% in ≥70) in cattle on trailers during transport (Costa et al., 2003). Within the slaughter plant cattle have the potential to slip and fall in areas where active handling occurs such as the holding pens, the single-file alley, or moving into the stun box or restrainer system (Costa et al., 2006).

Vocalization is another behavior that is measured as a welfare indicator in research studies focusing on pre-slaughter management; similar to the movement behaviors, vocalization can be measured at a variety of time points throughout the pre-slaughter period and is relatively simple to quantify. Cattle have been observed to vocalize at the plant from aversive and novel events such as prodding with electric prods, slipping at or near the stunning box, missed or inadequate stuns, sharp edges from poor facility conditions, being moved through holding pens to the single-file, or excessive pressure from restraint devices (Grandin, 1998b; Grandin, 2001; Cevallos-Almeida et al., 2021). Due to these events, measuring vocalizations is a valuable indicator of animal welfare and it can be compared across animal handling facilities (Grandin, 2017). Increased vocalizing has been observed more in cattle being moved after overnight lairage (number of vocalizations ranged from 0-29 per group) compared to cattle being moved after a shorter lairage duration (ranged from 0-4 per group; Cockram and Corley, 1991), likely because cattle housed overnight had time to rest and recuperate. Again, there are many factors that impact cattle behavior during the pre-slaughter phase and vocalization is a welfare indicator that is responsive to changes in handling and the environment that cattle experience.

Many of the above descriptions of behavioral outcomes include some component of animal handling. The impact of human-animal interaction on animal welfare is well-documented (Mota-Rojas et al., 2020; Acharya et al., 2022). As noted above, animal handling during this pre-slaughter phase can have negative impacts on welfare outcomes; most of the research found focused on negative actions of the animal handlers during intense animal handling events (e.g., loading, movement at the plant) and the subsequent cattle behavioral responses (e.g., balking, falling, vocalizing; Cockram and Corley, 1991; Grandin, 2001; Hemsworth et al., 2011; Doyle et al., 2016). Probst et al. (2013) took a different approach and explored positive handling interactions prior to the commencement of the pre-slaughter period. In their study, Probst et al. (2013) discovered that gentle touching and increased interactions with handlers in the few weeks prior to slaughter decreased avoidance distances in cattle at the abattoir, suggesting that positive human handling prior to being transported for slaughter can reduce an animals' fear of humans. While gentle touching of each animal is not practical in most commercial settings, these results do raise the question of whether increased animal handler interactions of other manners (e.g., walking through the pens or moving cattle) may be a plausible solution to decreasing stress responses in cattle prior to slaughter.

4.1.4 Health and injury

There are several pre-slaughter management factors that impact the prevalence of cattle injury and health outcomes. Previous literature has identified relationships between pre-slaughter management factors specifically during transport and welfare outcomes, including weight loss, traumatic lesions and even death, for both cattle and other livestock species (Knowles et al., 1993; Knowles et al., 1994; Villarroel et al., 2001; Gallo et al., 2003). Overall health and well-being can be impaired and the onset of severe stress can be observed in animals being transported (Minka and Ayo, 2010). A survey of transporters commercially hauling cattle for long durations reported that cattle condition was good (98.66% of journeys), fair (1.28%) and poor (0.05%) at time of loading, but the prevalence of journeys with 'fair' or 'poor' conditioned cattle increased 2.7-fold and 4.2-fold upon unloading (96.3% good, 3.49% fair and 0.21% poor) as a result of transportation stress (González et al., 2012). Another survey of livestock haulers reported that almost half of its participants (48.6%) observed up to five animals with injuries inflicted during transportation to the plant, however, this could be a low estimate as drivers have been documented to have limited ability to recognize pain and injuries in animals (Valadez-Noriega et al., 2018).

An animal's ability to move through the pre-slaughter phase and navigate the different transport and handling systems is critical. Cattle mobility and lameness are important considerations and have been focused on significantly more in recent years within the fed cattle industry, particularly in the United States (Edwards-Callaway and Calvo-Lorenzo, 2020). Mobility is a multifactorial issue impacted by not only weight, THI, sex, and days on feed (DOF; (González et al., 2012; Edwards-Callaway et al., 2017; Martinez et al., 2021; Mijares et al., 2021), but also transportation (e.g., distance hauled) and lairage factors (e.g., lairage duration; Hagenmaier et al., 2017). One study within this review, however, reported a rather low prevalence of lameness (0.7%; Burgstaller et al., 2022) compared to other studies ranging from as low as 1.1% to 54.8% of cattle reported as clinically lame (Dudley, 2017), likely because the

sample size of this study consisted of mostly young bulls and calves rather than older cattle. Older cattle are typically more prone to mobility issues due to age-related variations in their physiological status (Gavrilova and Sementovskaya, 2021). Individual animal characteristics (e.g., horned or different weight categories), truck flooring conditions, falls during loading or unloading, and trailers with inadequate conditions such as loose or protruding boards, screws or nails have also been shown to be associated with increased injury and lesions in cattle at the abattoir (Lee et al., 2017; Brito et al., 2019).

4.1.5 Physiological

Studies in this review included several physiological measures ranging from vital parameters to metabolites measured in biological samples, however, blood metabolites were the most commonly measured within this category, comprising approximately 65% of studies. Hematological blood indicators are known to be the primary determinants of an animal's ability to adapt to its environment and thus are useful parameters to include in welfare assessment (Anderson et al., 1999). Specific hematological parameters such as neutrophil/lymphocyte ratios, cortisol, adrenaline and noradrenaline are commonly used to measure the stress response to pre-slaughter management in cattle (Warriss, 2010; Cucuzza et al., 2014; Mirzad et al., 2018). Adrenal hormones in particular, such as cortisol, represent one of the most important physiological parameters to measure the stress response as various stressors can result in its release, and is used in several studies assessing the impact of pre-slaughter management on cattle welfare (Mitchell et al., 1988; Ndlovu et al., 2008; Burdick et al., 2010; Tarantola et al., 2020). Common blood parameters measured in studies included in this review included cortisol, creatine kinase (CK) and catecholamines such as epinephrine and norepinephrine but the selection of physiological parameters measured varies substantially between studies. As cattle attempt to maintain homeostasis, adaptive responses such as these physiological changes attempt to restore that balance (Carrasco-García et al., 2020).

Generally, regardless of the pre-slaughter predictors assessed, most studies have found that physiological parameters change in response to management manipulations (Rulofson et al., 1988; Tarrant et al., 1988; Chacon et al., 2005; Tadich et al., 2005; Romero et al., 2014). For example, transportation effects on blood parameters were highly researched in studies included in this review. Transportation has been shown to induce changes in the composition of blood along with other parameters such as heart rate, hormones, metabolites, enzymes and even skin dehydration (Fazio and Ferlazzo, 2003; Gregory, 2008), however, these effects will vary based on transportation duration, road conditions, and age, breed, and previous experiences of the cattle. Several studies discovered that transportation stress was substantial enough to elevate blood concentrations of antidiuretic hormone (Ballarin et al., 2006), epinephrine and norepinephrine concentrations (Mitchell et al., 1988; Rulofson et al., 1988), glucose (Jarvis et al., 1996a), lactate (Chacon et al., 2005; Gruber et al., 2010), cortisol (Villarroel et al., 2003; Romero et al., 2014; Bertoloni et al., 2016; Capra et al., 2019), LDH (Birhanu et al., 2019), and creatine phosphokinase (CPK, i.e., creatine kinase or CK; Tarrant et al., 1992; Tadich et al., 2005). Cattle can be transported in various ways across the globe and thus transport conditions vary greatly; in the US, cattle are transported using livestock trailers, whereas other geographic regions such as Oceania may export cattle for slaughter overseas *via* ship. Cattle transported by sea are usually subjected to longer transport times and extended periods of feed withdrawal (Phillips, 2008). Route of transportation has also shown differences in plasma CK levels as cattle transported by sea and road experienced mean plasma CK levels of 1,137.86 (IU/L) compared to cattle subjected to only road transportation and a saleyard pathway (596.79 IU/L; Loudon et al., 2019), however, both transportation pathways resulted in cattle with elevated plasma CK levels as published normal basal concentrations range from 35 to 280 IU/L (Radostits et al., 2000).

Lairage at the slaughter plant presents a particularly challenging period prior to slaughter as several factors such as lairage duration, mixing with unfamiliar cattle, stocking density and temperature microclimates differ in severity at each plant and offer their own varying degrees of stress for cattle (Edwards-Callaway and Calvo-Lorenzo, 2020). Several studies explored the impact of varying lengths of time spent in lairage on physiological outcomes (Tadich et al., 2005; Liotta et al., 2007; Giannetto et al., 2011; de Marchi et al., 2022). Allowing animals to rest in lairage for longer durations has shown a reduction in: CK and LDH activity (Chulayo and Muchenje, 2017), glucose, lactate and protein blood levels (Pighin et al., 2015) and cortisol concentrations (Liotta et al., 2007; Chulayo et al., 2016). Grosskopf et al. (1988) reported that blood parameters such as total plasma cortisol decrease in value as time in lairage increased (203 nmol/L immediate slaughter, 128 nmol/L after 3 hours of lairage and 85 nmol/L after overnight lairage), however, plasma CK was greater in cattle with a lairage period of 3 hours (513 U/L) compared to cattle slaughtered immediately upon arrival to the abattoir (372 U/L), with a decrease in values in cattle held overnight (112 U/L). Differing results between studies likely are partially due to differences in other pre-slaughter management practices, such as transportation time. The stress impacts of mixing non-familiar groups of cattle is a highly researched area (Šímová et al., 2016; Hubbard et al., 2021), particularly during the pre-slaughter phase. Warriss et al. (1984) found that when mixing unfamiliar cattle during lairage, those that exhibited the most animal-to-animal interactions compared to other animals had greater levels of CPK and free fatty acids (FFA) concentrations and decreases in plasma lactate,

indicating that liver and muscle glycogen was depleted from the stress of social mixing.

The pre-slaughter process involves several instances where cattle will be moved to different locations (e.g., loading or unloading, moving from holding pens to the drive alley and through the single file) all of which present a challenge if facilities and handling techniques are suboptimal (Disanto et al., 2014). High levels of cortisol can be attributed to inadequate handling of cattle during the pre-slaughter and slaughter phase (Mitchell et al., 1988; Carrasco-García et al., 2020; Guarnido-Lopez et al., 2022). Cattle exposed to low-stress slaughter conditions (i.e., less time being transported and moved through the slaughter process at the abattoir) resulted in lower heart rates and stress hormone concentrations (Reiche et al., 2019). Cattle that fell from slippery flooring or improper handling, were lame, or were injured during transportation showed mean levels of CK and cortisol increasing by 43U/I and 8 ng/ml, respectively, compared to those without injury (von Holleben et al., 2003). When stunning animals, it has been discovered that animals needing to be stunned more than once had increased blood cortisol concentrations compared to those that only required one stun to be rendered unconscious (Chulayo et al., 2016; Njisane and Muchenje, 2017b). Studies such as the ones presented here offer further evidence on the importance of animal handling and stunning training, and how they are essential in improving efficiency and animal welfare (Ceballos et al., 2018; Večerek et al., 2021).

Potential relationships between behavior and blood parameters have also been explored (Burdick et al., 2010; Stockman et al., 2012). Temperamental cattle have been reported to have greater cortisol and epinephrine concentrations compared to calmer cattle post-transportation (Burdick et al., 2010). Stockman et al. (2012) found that cattle scored as 'nervous' or 'anxious' prior to being slaughtered had greater plasma lactate concentrations than those that were calmer; this effect was also associated with the amount of time waiting to be slaughtered (i.e., end of the queue vs. the beginning of the queue). Other animal characteristics such as breed, which also could influence temperament, have also been explored (Doornenbal et al., 1988; Prisacaru, 2014). In one study examining the relationships between Bonsmara, Nguni and Angus breeds and physiologic parameters, Bonsmara cattle were reported to have the greatest concentrations of adrenaline, noradrenaline and dopamine and Nguni had the greatest serum cortisol concentrations suggesting that both breeds had increased responses to the stress associated with the pre-slaughter period (Ndlovu et al., 2008). In a similar study, Angus cattle had lower levels of urinary creatinine compared to other breeds such as Limousin and Blond d'Aquitain, suggestive of a lesser stress response to slaughter events such as transportation and stunning (Bourguet et al., 2015). Results from these studies suggest the possible need for breed specific pre-slaughter management strategies, however, further research is warranted in this area, specifically investigating differences between breeds underrepresented in current research.

Vital parameters such as heart rate were also commonly measured as indicators of welfare after particularly stressful events during the pre-slaughter phase. Heart rate variability in cattle can be used to quantify stress from physical, emotional and pathological origins (von Borell et al., 2007), all of which can be caused by events in the pre-slaughter phase. For example, cattle recovered resting heart rates during longer journeys compared to those only transported for thirty minutes where all cattle maintained elevated heart rates (Chacon et al., 2005), suggesting that time to recuperate during transportation may be beneficial. Also, cattle that showed more resistance to handling during human exposure prior to transport for slaughter have also shown to have faster heart rates during loading (Terlouw et al., 2012).

4.1.6 Stunning and insensibility

The actual act of slaughter can have a significant impact on animal welfare and thus is an important consideration when evaluating the pre-slaughter period. In non-religious slaughter systems, an animal will be stunned prior to further processing, required by law (e.g., The Humane Methods of Slaughter Act, USDA-FSIS, 1978), in order to render the animal insensible to pain. Despite the significance of ensuring effective stunning to overall welfare, few studies in this review measured post-mortem behaviors of cattle following stunning (Grandin, 1998a; Miranda-de la Lama et al., 2012; Mpamhanga and Wotton, 2015; Romero et al., 2017; Cevallos-Almeida et al., 2021). These studies were primarily assessing behaviors indicative of return to sensibility which included eye reflexes, blinking, rhythmic breathing and righting reflexes (Grandin, 1994). Agitation just prior to stunning, such as using a pre-slaughter crush restraint for the purpose of cattle identification, have resulted in a less effective stun as rhythmic breathing, rotation of the eyeball and limb movement at sticking in stunned cattle was significantly reduced when crush restraint was not used (Mpamhanga and Wotton, 2015). A notable point to consider is employee behavior related to the stunning and exsanguination process; stunning operators can become fatigued, resulting in cattle that are not efficiently stunned and the need for multiple stunning attempts to render the animal unconscious (Grandin, 1998a). The single study measuring pre-slaughter effects on bleed-out times did not find any significant effects of genotype, transportation groups or durations of lairage on bleed out times (Njisane and Muchenje, 2017b).

4.1.7 Gaps in research

Several pre-slaughter factors and indicators of fed beef cattle welfare have been identified in this review; however, some underrepresented welfare-friendly practices and useful indicators of welfare should be investigated further. While factors such as transportation, handling, animal and environmental characteristics, and lairage factors have been

extensively measured in studies assessing pre-slaughter management on welfare outcomes, factors related to water and feed provision have not been thoroughly researched in this space. Fasting duration for both feed and water have been studied (Jarvis et al., 1996a; Jarvis et al., 1996b; Clariget et al., 2021), but little information is known about the implications of these factors on the welfare of cattle. Analyzing the interactions between fasting durations and water deprivation on both cattle condition and cattle responses to stressful experiences would be beneficial to understand.

Behavioral and physiological parameters were included in the majority of studies in this review, however indicators of welfare related to cattle health, injury and disease and stunning and insensibility were underrepresented. Although in the United States there has been considerable attention paid to cattle mobility at the slaughter plant (Eastwood et al., 2017; Lee, 2017), mobility and lameness were measured in less than 5% of papers in this review. Heat stress is another area of concern particularly for cattle in the finishing and pre-slaughter phases of the industry as climate change continues to impact both cattle welfare and production efficiency (Berman, 2019; Lees et al., 2019). Several recent studies have been conducted exploring the implementation of heat mitigation strategies and their benefits for cattle in the beef supply chain (Mitlöhner et al., 2002; Rusche et al., 2021; Davis et al., 2022). Heat stress behaviors such as open-mouth breathing was only measured in one study in this review (Hagenmaier et al., 2017). Surprisingly, the impacts of heat mitigation on cattle welfare during the pre-slaughter phase was not measured in any of the studies included in this review.

4.2 Global differences

Although animal welfare is relevant to beef cattle production systems globally, there is a clear difference in how welfare is studied across global geographic regions, as was identified in this scoping review. It is important to consider the vast differences in both supply chain structures and management systems (Aghwan and Regenstein, 2019; Gonzalez et al., 2022), but also perceptions about animal welfare across different areas of the world (Toma et al., 2012; Alonso et al., 2020; Abdulhaleem, 2022), specifically between developed and developing nations. Perceptions about animal welfare are impacted by cultural, socioeconomic, and religious factors and thus differences in animal care practices are likely to be observed between different countries (Karesh, 1995; Agoramoorthy and Hsu, 2012; Abdulhaleem, 2022). Developed nations often have the capacity to invest resources in more progressive animal welfare efforts while developing countries may be faced with challenges that supersede animal care concerns, such as political instability, food insecurity, and human health and well-being (Karesh, 1995). However, public concern for higher standards of animal welfare is increasing throughout the world, even in developing countries (Harper and Henson, 2001). Additionally, as this scoping review focused on pre-slaughter management specifically, trends in meat consumption and dietary rules differ globally and therefore could impact the research focus in certain geographic regions (Eliasi and Dwyer, 2002). Thus, it is important to note that the exclusion of non-English papers likely limits the cultural and geographic diversity of research studies found in this scoping review.

The World Organization for Animal Health (WOAH), a globally recognized entity, has developed a framework with specific recommendations for how member countries should construct their animal care standards (OIE, 2018) for a selection of livestock species. Other globally recognized organizations such as the Global Roundtable for Sustainable Beef (GRSB) work to encourage learning and adoption of best animal health and welfare practices across sections of the globe (GRSB, 2022). The GRSB encompasses twelve national roundtables (e.g., Mexican, Brazilian, European, Southern Africa and Australian roundtables), serving their members, regions and countries with projects and initiatives for a more sustainable, efficient, and profitable beef industry that would include promoting and progressing cattle welfare. While the efforts of organizations like these are profound, there is a large gap in animal welfare conditions between developed and developing countries (e.g., countries in Europe versus countries in Africa and Asia) often posing a challenge when trying to establish universal benchmarks for animal welfare progress. In the area of slaughter welfare, the OIE Terrestrial Code includes a chapter outlining animal welfare considerations for food animals during pre-slaughter and slaughter processes (OIE, 2016) slaughter processes are defined as "any procedure that causes the death of an animal by bleeding" thus encompassing both religious and non-religious methods.

As outlined in the results, articles studying pre-slaughter management factors and their impacts on indicators of welfare in fed beef cattle are spread widely across the global geographic regions. The greatest percentage of studies were conducted in Europe; Europe is the third largest beef producing region globally (Canadian Beef, 2021; OECD, 2022). The European Union (EU) has numerous and advanced laws protecting the welfare of farmed animals (Simonin and Gavinelli, 2019) with provisions for both welfare on-farm, during transport, and at slaughter (European Council, 2005b; European Union, 2008; European Council, 2009). Governmental institutions in the EU use a polling instrument, the Eurobarometer, to regularly assess consumer insights on a variety of political and social subjects, including animal welfare (European Union, 2022). In the 2016 report, 94% of EU respondents indicated it was important to protect animal welfare and more than half (59%) indicated they would pay more for products that came from "animal welfare-friendly" production systems (European Commission, Directorate-General for Health and Food Safety, 2016). European countries are often regarded as having progressive

legislation for animal welfare protections (Caporale et al., 2005) with consumers that have high expectations for farmed animal welfare (Martelli, 2009; Alonso et al., 2020). In a systematic review of studies exploring public attitudes and perceptions towards farm animal welfare, nearly three-quarters of the included studies were conducted in Europe (Clark et al., 2016) emphasizing the relative importance that this area of the world may place on aspects of welfare.

Interestingly, the North American and South American regions combined only accounted for approximately one-third of the research studies yet countries within these regions are some of the largest beef producers in the world; the United States and Brazil are the top two beef producing nations globally, together accounting for over a third of the world's beef production (Canadian Beef, 2021; OECD, 2022), and coincidentally were the top two countries in North and South America in studies included in this review. Studies in large commercial slaughter facilities, like many of those found in North and South America, are challenging to coordinate and can be expensive to execute. The authors speculate that funding mechanisms for research of this nature across countries could be different in number of opportunities, sponsor interests, and grant amounts contributing to these geographic differences.

Conversely, studies originating from developing geographic regions such as Africa and Asia were underrepresented in this scoping review. This gap in animal welfare research in these regions is likely due to many factors such as economic status of specific countries and cultural or religious predispositions of how animals should be treated (Abdulhaleem, 2022). Public concern for animal welfare comes predominantly from urbanized populations and is inversely proportional to the population size engaged in agriculture, which is this case is many of these developing countries as populations are heavily engaged in agriculture (Harper and Henson, 2001). Public and consumer concern can positively drive legislation to achieve some minimum standards of welfare conditions (Désiré et al., 2002; Asebe et al., 2015; Alonso et al., 2020; Abdulhaleem, 2022), however, many developing countries within the regions of Africa and Asia do not have the same concern for animal welfare as education and awareness of the topic is limited (Abdulhaleem, 2022). Additionally, many developing countries do not have the resources to provide animal care to the standards that developed countries are able to do (Rahman et al., 2005). Sinclair et al. (2017) explored attitudes of stakeholders in Asia towards animal welfare during slaughter and transport and found that government laws, religion, and peer attitudes towards welfare were among the greatest ranked influencing factors. These examples should not be generalized to every developing country, but this discussion may help clarify some of the differences in welfare research attention across regions.

Oceania encompasses a geographically, socially and economically diverse region, where concerns for animal welfare vary greatly (Rahman et al., 2005). Studies conducted in Oceania had low representation in this review and all studies were conducted in Australia. New Zealand and Australia have strong legislation at the government and community level that work to improve and regulate animal welfare, however, several countries (e.g., Tonga, Wallace and Futuna) are in desperate need for development and updates in animal welfare legislation, as well as practicing veterinarians to implement animal related policies and practices (Rahman et al., 2005). Rahman et al. (2005) also explains that many populations in oceanic countries, like other developing countries, lack awareness of animal welfare issues.

Efforts are being made to narrow the gap in animal welfare legislation, awareness, and research across demographic regions of the globe by increasing the online availability of animal welfare guidelines and best practices (Bayne and Turner, 2019). The accessibility of these resources can contribute to the development of standards and practices in developing countries, however, some developing countries lack the resources to efficiently adopt practices of already developed countries, and therefore these countries will need to evolve their own standards based on their own priorities (Rahman et al., 2005).

4.3 Alternative slaughter methods

Alternative slaughter was identified as a process that followed religious slaughter laws, used a head restraint during stunning, performed electrical stunning, or slaughtered and processed animals outside of a permanent facility. Ten papers were identified as studies categorized as alternative slaughter: religious slaughter (n = 6; Bourguet et al., 2011; Ahsan et al., 2014; Bozzo et al., 2018; Alam et al., 2020; Abubakar et al., 2021; Imlan et al., 2021), electrical stunning followed by exsanguination (n = 1; Minka and Ayo, 2007), on-farm and mobile slaughter (n = 2; Hultgren et al., 2020; Hultgren et al., 2022) and conventional slaughter with a head restraint (n = 1; Ewbank et al., 1992).

4.3.1 Religious slaughter

The welfare of animals during religious slaughter has been extensively discussed (Adams and Sheridan, 2008; Anil, 2012; Downing, 2015; Farouk et al., 2016). Due to the nature of religious slaughter (i.e., in most instances, no stun delivered prior to exsanguination), welfare concerns have been identified including an increase of stress for the animals (Bozzo et al., 2018), casting procedures (Ahsan et al., 2014), incorrect knife use (i.e., dull or small; Ahsan et al., 2014; Alam et al., 2020) and sensibility (Alam et al., 2020). Some of the studies in this category explored different aspects of religious slaughter impacts on cattle welfare, such as: a general focus on welfare outcomes during the religious slaughter process (i.e., not treatment comparisons; Ahsan et al., 2014; Alam et al., 2020);

a comparison of welfare outcomes in cattle experiencing religious slaughter as compared to conventional slaughter (e.g., stunning with a captive bolt stunner prior to exsanguination; Bourguet et al., 2011; Bozzo et al., 2018); and a comparison of different restraint devices used during religious slaughter on welfare outcomes (Imlan et al., 2021). All of these studies included one or more of the following measurements to aid in welfare assessment: blood parameters, electroencephalography (EEG) analysis, post-exsanguination animal responses (e.g., signs of insensibility), behavioral reactions to lairage conditions, electrical prod use, pre-slaughter handling (e.g., slipping and falling), and characteristics of the neck cut that could impact welfare (e.g., cuts and stabs). The last study in this category examined the relationship between transport distance and stocking density on the trailer and cortisol response and EEG parameters of animals slaughtered using religious methods (Abubakar et al., 2021). Several of the same or similar welfare outcomes were measured as those found the formal analysis portion of this review. For example, antemortem behaviors and blood parameters were measured frequently throughout these studies and the studies included in the review.

Although a direct comparison between welfare outcomes in studies utilizing religious slaughter methods as compared to non-religious methods was not performed, it is worth noting that some of the results reported in these studies did cause concern for animal welfare. For example, religiously slaughtered animals had an increase in blood parameters such as cortisol (Bozzo et al., 2018) indicating increased stress, and observed corneal reflex (Bourguet et al., 2011) indicating sensibility post-slaughter as compared to conventionally slaughtered cattle. Some pre-slaughter handling techniques of animals during the religious slaughter process also raises welfare concern due to practices such as casting; Ahsan et al. (2014) observed animals pushed onto hard concrete, dragging by tails, bounding of all four legs for several minutes' pre-slaughter, and vocalization during casting and post-cut. Consideration should be given to how the actual slaughter method (e.g., stunning and exsanguination, exsanguination only, etc.) could impact results when exploring other pre-slaughter management practices.

4.3.2 On farm and mobile slaughter

On-farm and mobile slaughter has become an area of interest, mainly due to the stress transportation induces on cattle which is avoided in on-farm scenarios, and it is anticipated that more research will be conducted in this area as this type of processing becomes more popular (Johnson et al., 2012; Friedrich et al., 2015; Hultgren et al., 2020; Hultgren et al., 2022). Hultgren et al. (2022) studied slaughter by rifle from a distance (ranging 6-12 m), focusing on blood parameters and pre and post slaughter behaviors (e.g., walking, exploring, sniffing, and vocalizing) as indicators of stress. Hultgren et al. (2020) conducted a study to assess the stress related behaviors in a mobile slaughter scenario compared to a stationary slaughter plant. The measurements recorded in this study focused on the actions of the animal handlers (e.g., touching, hitting, prodding, and tail-twisting) and subsequent animal responses (e.g., slipping, backing up, and vocalizing). The study concluded that more handling actions by stockmen, such as during the transportation process, increased stress behaviors in animals (Hultgren et al., 2020).

4.4 Limitations

These studies were evaluated solely on the pre-slaughter factors that they measured and the resulting indicators of welfare, this review did not compare methodology for measuring these factors or welfare indicators. This sector of the beef industry requires continued improvement and advancement from researchers on narrowing down which pre-slaughter factors are the most impactful and which measures of animal welfare provide the most accurate depiction of the animal's current state. This review only covered the pre-slaughter phase of the beef industry, therefore past experiences, stressors, and challenges faced by animals in these studies varied and therefore may have affected their responses to stressors during the pre-slaughter phase. In addition to the vast difference in measures assessed across studies, several studies also proved difficult to compare as cattle populations varied in their characteristics such as breed, age and sex, and place of origin. Although studies included in this review were conducted in differing geographic regions, the exclusion of non-English papers likely limits the fully robust global potential of this review.

4.5 Conclusions

Undoubtedly, fundamental factors such as the effects of transport conditions, reactions of the animals to novel environments and underlying commercial pressures that impose 'speed' on workers at the plant (Wigham et al., 2018), all contribute to animal welfare impacts. It is both essential and imperative for beef processors, producers and industry stakeholders to understand the direct relationships between management decisions and beef cattle welfare. This review highlights that there are several pre-slaughter management factors that contribute to animal welfare, as well as several measurable outcomes to assess fed beef cattle welfare at slaughter. A majority of management factors affecting beef cattle welfare were centered around transportation and animal handling, and frequently assessed indicators of welfare included physiological and behavioral measures. The results of this review continue to demonstrate that animal welfare is complex and identifying precise events or stages in the pre-slaughter phase

that generate the most notable outcomes is difficult as the impacts are likely multifactorial and dynamic. Systematically compiling these factor and outcome measures, as well as their relationships, is essential to provide an accurate description of hazards to fed beef cattle welfare and hazard occurrence within the pre-slaughter sector of the industry. Animal welfare surveillance activities during the pre-slaughter management period may provide a framework that not only enables the timely detection of hazards and threats, but also identifies approaches that either support or drive different risk management strategies to be adopted by the public and private sectors (Losada-Espinosa et al., 2018). From this review, there is substantial evidence demonstrating that a majority of events in the pre-slaughter phase inflict multiplicative stressors on an animal that negatively impact their welfare. However, the results from this review also provide a collection of welfare indicators that can be used to facilitate further research on examining how new and existing management factors impact cattle welfare.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MD, PS and LE-C conceived and designed the study. JB advised on the methodology and provided technical advice. MD conducted the formal search and analysis and led the writing of the original draft; LE-C and LD contributed to the original draft writing. PS, LE-C, LD and JB provided editing and review of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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