



Implications, trends, and prospects for long-distance transport in cattle. Review



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Abstract:

The growth of international trade and population has increased the demand for animal protein in developing and emerging countries, which has led to a considerable increase in the number of animals bred, transported, and processed worldwide. As a result, transport distance and duration have increased, which has driven specific improvements in livestock infrastructures, such as trucks with greater autonomy and load capacity, adapted to the biological needs of animals; reduction of operating costs; and liberalization of animal health restrictions that facilitate international trade. In this review, was conduct an integrated, detailed, and updated analysis of long-distance transport. Considering that the current trend is to increase transport duration, logistical scales, and mixed transportation, it is necessary to develop evaluation and decision-making systems with tools and protocols that minimize the biological cost in cattle.

Key words: Animal welfare, Long-distance transport, *Bos indicus*, *Bos taurus*, Meat quality.

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Introduction

Transport is an inevitable stage in the life of a production animal with various purposes, such as breeding, fattening, sale, slaughter, reproduction, and entertainment⁽¹⁾. Several studies indicate that transport is a strange, invasive, aversive, and very physically demanding procedure for animals⁽²⁾; including unfamiliar stimuli such as sound, visual, and olfactory cues; social mix; vibration; temperature variations; risk of injury; spatial restriction; fasting, and limited access to water⁽³⁾. The direct effect of transport has implications for animal welfare and health, as well as for meat quality⁽⁴⁾. Currently, the growing interest in food safety and quality in meat production chains seeks to incorporate sustainable production commitments and promote animal welfare in the search for a new concept of quality^(5,6). The modern globalization and the increasing demand for animal protein have considerably increased the number of animals bred, transported, and processed for slaughter worldwide⁽⁷⁾. The development of more complete and efficient supply chains facilitates international trade, thanks to improvements in livestock infrastructure, such as more autonomous trucks and specialized designs, reduction of operating costs, and liberalization of animal health restrictions⁽⁸⁾. In this context, long-distance transport is a strategic element of the livestock industry.

In some countries, due to climatic conditions, internal production is limited, and the importation of live cattle is necessary to supply the meat markets. In others, the breeding and fattening centers are distant from each other, due to feed availability and climatic conditions; here animals are born and bred in grazing zones, due to the availability of low-cost forage, and are sent for completion to intensive fattening centers. Other countries prefer to import live cattle since, for religious reasons, animals must be alive at the time of Kosher or Halal slaughter^(9,10). Other cross-border livestock flows take place due to the attraction of added value, such as the certification offered by the United States Department of Agriculture (USDA) through the labeling of “improved beef,” which promotes the export of live cattle from Canada for slaughter in the United States of America (USA), with very long journeys resulting in high losses⁽¹¹⁾. Additionally, the specialization by species of many slaughterhouses located at strategic points near the marketing channels has increased the travel distance from the farm to these slaughterhouses⁽¹²⁾.

It is crucial to point out the economic importance of live animal exportation, which provides many direct and indirect jobs in the transport, logistics, and storage sectors. However, it is highly likely that large-scale regional planning would allow for the redistribution of slaughter centers close to production sites, in such a way that transport duration would be reduced, in addition to seeking the gradual replacement of the export of live cattle to meat export⁽¹³⁾. In Latin America, due to the geography, commercial terms, and distribution of livestock production centers, long-distance transport is the rule rather than the exception. Regulations in these countries tend to be much laxer in terms of distance compared to European regulations. This review evaluates long-distance transport of cattle from the perspective of different countries with very particular situations given by different factors such as the geographical location of the country; pre-transport processes; vehicle design, loading density, and microenvironment; as well as current research on the risks associated with the driver and the effects that each of these factors may have on the beef chain.

Typology of long-distance transport

Long-distance transport includes repopulation, living, and slaughter transport. Historically, cattle for immediate slaughter has dominated the trade, but in the new century, there has been a rapid growth in the number of “half fattened” cattle for further value-adding before slaughter through fattening and finishing, including males in the dairy sector. Therefore, it is increasingly common to transport cattle several times during their lives⁽¹⁴⁾, estimating 296 million head of beef cattle transported worldwide during 2005, some of them transported more than once⁽¹¹⁾. The main transport reasons include sale for herd repopulation, change of owner, search for cheaper or more abundant sources of supply (pasture and water), breeding or replacement of livestock for reproduction, the supply of intensive fattening units, auctions, livestock shows and fairs⁽¹⁾. The inappropriate grouping and management of livestock, primarily those extracted from extensive systems, results in animals with high levels of stress at the beginning of transport. During prolonged groupings, it is advisable to give the animals time to recover in the pre-loading pens. It is important to emphasize that animals with little human contact or aggressive temperament will be more susceptible to stress and have a higher chance of injuring handlers due to an excessive response or fear-induced aggression^(9,15). Although there are not enough data, it has been proposed that previous experience may affect the fear response of animals and may be responsible for the variable results reported in transport studies⁽¹⁵⁾. However, other studies have shown that more docile cattle lose less weight during transport and tend to recover faster once they continue with their production cycle⁽¹⁶⁾.

In the past, cattle transport for reproductive purposes was required for breeding; however, with new biotechnologies, this transport became impractical. The starting point was artificial insemination in domestic species, which originated in 1779, while embryo transfer was reported as another successful technique in 1890⁽¹⁷⁾, and in 1973, *in vitro* fertilization⁽¹⁸⁾. Worldwide, more than 750,000 embryos are produced annually from superovulated donors, and more than 450,000 embryos are produced using *in vitro* techniques⁽¹⁷⁾. Although these technologies were developed for breeding purposes, the number of livestock transported for reproductive purposes must have decreased considerably from the 18th century, when artificial insemination began. Moreover, exhibitions, fairs, and actions continue to require the physical presence of livestock, which demands constant transport. At the international level, there are efforts to eliminate this practice using the internet or television-based systems⁽¹⁹⁾, an example of this are auctions in Europe, the USA, and recently in Argentina, Brazil, and Colombia; in these auctions, animal transport only occurs once you have a secured buyer. However, this field has not yet been studied, and the available information is scarce, so it represents an important area of study as part of the current livestock industry, where the use of technology facilitates the commercialization of livestock. There is a tendency to decrease or disappear unnecessary animal handling.

Repopulation transport includes movements between countries, between farms of the same country, or within the same property⁽²⁰⁾. For example, Mexico is the largest trading partner of the USA introducing live animals, the trade consists of animals with a minimum of blood from zebu breeds to supply fattening units or feedlots from that country⁽²¹⁾. Moreover, the supply and domestic consumption of Mexico depends on the cattle from the southeast tropical and subtropical regions and Central American countries⁽²²⁾, this supply consists of the long-distance transport of animals, of which there is still little information. Further research in repopulation transport, especially in animal health and welfare repercussions is required; this will provide the competent authorities with the background information required to establish rules and regulations on the conditions before, during, and after transport, in addition to considering aspects such as the ideal state of an animal to be transported, maximum transport duration, and water and food restriction depending on the region⁽²³⁾.

International regulatory trends

Livestock transport is an important concern of governments, animal protection organizations, and consumers in general, due to the perception of an absence of welfare in this link of the chain, as well as the possible consequences on the quality and product

safety⁽²⁴⁾. A bad image during transport or accident management creates a negative perception of the transport activities⁽²⁵⁾. There are well-intentioned regulations with possible negative consequences for animals; regulations on cattle transport do not always consider fundamental aspects for their welfare⁽²⁶⁾. For example, under Canadian regulation, livestock can be deprived of water for up to 57 h. Animals may also be deprived of food for up to 81 h during transport to a federal slaughterhouse⁽¹¹⁾.

The European Community has the most demanding legislation in the world regarding the transport of cattle in terms of animal welfare; it establishes a maximum duration of 14 hours of travel, followed by an hour of rest to drink water, being able to continue with another 14 h travel. This sequence can be repeated when the animals have been unloaded, fed, provided with water, and rested for at least 24 h^(27,28). Despite the latter, more than a million citizens of the European Community requested, demanded, a general transport duration limit of 8 h. The European Parliament adopted a statement that upholds an 8-hour limit for cattle transport⁽³⁾. The World Organization for Animal Health (OIE) developed guidelines for the welfare of livestock during transport; however, the signatory countries and the livestock export sector are not obliged to comply with them⁽²⁹⁾. With very opposite scenarios, countries like South Africa, Kenya, and some European countries have well-developed legislation on the welfare and transport of livestock. In contrast, Central and South American countries have a weak legislative framework, with a low level of compliance where knowledge of the legislation is absent, even among stakeholders⁽³⁰⁾.

Stress factors associated with long-distance transport

Factors associated with the pre-transport process

Transport-related activities begin with the grouping of animals; in some countries, the grouping can begin 48 hours before loading, since livestock is dispersed over large territorial extensions. The number and duration of various handling practices before loading; such as mixing of animals, food and water deprivation; represent a challenge that predisposes animals to dehydration and energy expenditure⁽³¹⁾.

Animals in detrimental conditions lack the same capacity to withstand long-distance transport. There are guidelines, similar to those used in Europe, to determine if an animal is fit for transport. An animal can travel if: it walks normally, carrying its weight evenly in its four legs; it is healthy, without visible disease or injury that could harm it during transport; it can stay with the group during loading and unloading; it has at least one functional eye,

and it is not on late pregnancy⁽¹⁵⁾. Loading is more stressful for animals than the unloading process; however, the physical integrity risks of the animal are similar in both cases⁽³²⁾. Animal loading, as well as the early stages of transport, cause high levels of stress; after this period, animals can adapt to transport conditions; however, after 12 hours, animals get tired and compromise their health, which is why transport should be interrupted^(33,34). Stressors will initiate a series of reactions in the organism, with the activation of the sympathetic-adrenomedullary system and the hypothalamic-pituitary-adrenal axis, causing an increase in the levels of catecholamines and glucocorticoids⁽³⁵⁾, in addition to marked effects on the immune system, clearly visible in animals transported for repopulation purposes. Other repercussions can manifest several weeks after travel, such as lack of growth, low weight gain, and mortality, especially in young or recently weaned animals⁽³⁶⁾.

Most research on the effects of transport and its regulations has focused on transport duration; for example, in Canada, the maximum transport time is 52 hours before arriving at destination; in the USA transport should not take longer than 28 hours, and in the European Union the maximum transport time is 30 hours. However, few studies have focused on the total time in which animals are confined in vehicles, waiting before departure, transport time, type of road, number and duration of stops, waiting for unloading, among others^(37,38). Factors such as the cost of transportation; truck specifications and design; loading density, vibrations, and movement; microclimate conditions; climatic and geographic conditions; route planning; factors associated with the driver and risk of accidents must be considered as a whole within transport logistics⁽⁸⁾.

Transport design

Livestock transport vehicles must be designed, built, and maintained in order to protect the animals from inclement weather, extreme temperatures, adverse changes in climatic conditions, and injury. Overall, there are four types of specialized vehicles: small trucks (≤ 3 t), individual units (>13 m long), semitrailers, and double semitrailers⁽³⁾. For a vehicle to guarantee greater animal comfort during transport, it is recommended to include drinking and ventilation systems, species-customized ramps, roof, non-slip flooring, lateral walls that prevent any part of the animal from leaving the truck, removable partitions to separate smaller and easier to handle groups, lateral inspection doors, and temperature control⁽³⁹⁾. However, the design of the truck and its impact on welfare has been poorly studied⁽⁴⁰⁾. In Central and South America, trucks can be articulated or not, generally without a roof, with metal or wooden structures⁽¹³⁾. In Latin American countries, there are laws that try to protect animals by avoiding animal cruelty and unnecessary suffering. There is also legislation on the transport of animals for consumption in most countries. However, it deals

mainly with sanitary and public health requirements (vehicle cleaning, antemortem animal health inspection, and postmortem meat inspection), instead of animal welfare, such as the case of Paraguay, Peru, Colombia, Ecuador, Argentina, Venezuela, and Uruguay⁽¹³⁾. In Brazil, there is no specific legislation regulating the transport of farm animals, although most of the government agencies and large slaughterhouse companies are aware of the OIE recommendations. In Mexico, the Official Mexican Standard “NOM-051-ZOO-1995 for Humane practices in animal transport” covers different animal species, but is not up-to-date and has weak and not very specific stipulations in terms of transport design. In North America, including Mexico, livestock is generally transported in pot-belly trailer trucks⁽⁴¹⁾; these vehicles have an aluminum cover and five compartments: compartment 1 (nose), compartment 2 (belly), compartment 3 (back), compartment 4 (deck), and compartment 5 (doghouse)⁽⁴²⁾. In Europe, single or semitrailer trucks are the most common⁽⁴³⁾. The choice of vehicle will generally depend on the type and quantity of livestock, the specific demands of the market, the duration of transport, and the geographical region⁽³⁾.

Loading density

From an economic point of view, loading density can increase or decrease operating costs per unit⁽⁴⁴⁾. The space required per animal during transport can be represented in three ways: ($\text{m}^2/100 \text{ kg}$), (kg/m^2), and by the amount of surface used by each one (m^2/animal). Other studies⁽⁴⁵⁾ concluded that the Space Allowance ($\text{SA}=\text{m}^2/\text{animal}$), and an allometric coefficient that includes live weight of the animal ($k=\text{ED}/\text{PV}^{0.6667}$), was a better indicator of available space for comparisons between studies in homogeneous weight batches. The area per animal is proportional to its surface area; a 400 kg cow should be transported in an area of 1.16 m^2 ⁽⁴⁵⁾.

Drivers or unit operators must be careful about the space availability in their trucks and know the characteristics of the species to be transported (horned or hornless; waste, fattening, dairy, recently weaned animals, among others); this, together with climate limitations, allows defining or altering the recommended loading density⁽⁴⁶⁾. When the loading density is of fewer animals per square meter, animals have more room to lie down, but if the way of driving or the road conditions are poor, it will be easier for the animals to lose their balance⁽⁴⁷⁾. A study reported that with a density of $170 \text{ kg}/\text{m}^2$ (below the $360 \text{ kg}/\text{m}^2$ recommended by the Farm Animal Welfare Council of the USDA), animals tend to lie down during transport⁽⁴⁸⁾. Eldridge and Winfield⁽⁴⁹⁾ examined the effects of different densities on long-distance transport, and although there were no effects in the ultimate pH (pHu) in beef, the incidence of bruises was higher with the lower and higher densities.

Vibration, movement, and livestock exhaustion

During transport, animals are exposed to vertical, lateral, and horizontal vibrations. Unpaved roads or roads with strong wind currents transmit a more significant amount of vibrations, animal's sensitivity increases after long standing periods⁽⁵⁰⁾, causing fatigue and displacement of their gravity center, which leads to falls and injuries⁽⁵¹⁾. Additionally, animals make a more considerable effort seeking for a place to lean on the truck during braking⁽⁵²⁾. Long-distance transport is so physiologically demanding that it tends to affect the neutrophil/lymphocyte (N/L) ratio, which increases the probability of opportunistic infections⁽⁵³⁾. Gebresenbet *et al*⁽⁵⁰⁾ placed vibration sensors in a truck with an air suspension system and observed that the highest vibration level on animals was 2.27 ± 0.33 m/s² when driving in gravel roads at 70 km/h. Horizontal and lateral vibrations were lower on animals located perpendicular to the road direction. Avoiding rough, gravel, or dirt roads can reduce the exposure to vibrations, as well as using a truck that is serviced and operated by trained drivers.

The pre-transport stages produce additional energy expenditure in order to meet transport demands; however, the long periods of fasting to which the animals are subjected will have negative effects on the muscle glycogen concentration, leading to a high pHu, which will result in Dark, Firm, and Dry (DFD) meat^(34,54,55). Recent reports describe the Fatigue Cattle Syndrome (FCS), animals that develop mobility problems shortly after reaching a slaughterhouse, similar to that reported in pigs. Cattle present clinical signs of tachypnea and respiratory distress, animals may also present lameness, stiff gait, or supine position in the absence of evidence indicating injury or illness, in addition to elevated concentrations of lactate and creatine kinase (CK)⁽⁵⁶⁾.

Temperature, microclimate, and ventilation

Theoretical estimates indicate that in a typical trailer with a recommended density for 500 kg cattle, the heat produced inside would be 13,400 watts, which is why a ventilation system is required⁽⁴⁾. There are two ventilation systems: passive ventilation (openings) and active ventilation (fans). Passive ventilation is given by openings throughout the truck and depends on the movement and speed of the truck⁽⁵⁷⁾. Active ventilation is controlled by sensors and uses extractor fans in air inlets and outlets⁽⁷⁾.

The microclimate inside the truck (temperature, relative humidity, and temperature and humidity index) is affected by the macroclimate, loading density, and airflow, as well as by animal respiration, transpiration, and secretions. Microclimate has a broad and potential impact on animal welfare, especially in adverse environmental conditions. Long-distance transport increases the probability of exposing animals to different climatic regions⁽⁵⁸⁾. For example, during the transport between Canada and the USA, temperature ranges from -42 to 45 °C⁽³⁷⁾. In extreme climatic conditions, the temperature inside the truck varies greatly, so the driver must be careful to open or close the ventilation openings. In warm climates, ventilation is hampered by air density, and the use of temperature and humidity recording devices is recommended so that the driver can make decisions during transport⁽³⁶⁾. The driver must also avoid stopping the truck for long periods since the internal temperature increases rapidly due to the external temperature, lack of ventilation, and the temperature emitted by the cattle. Under these temperature conditions, in trips longer than a day, cattle suffer an important weight loss⁽⁵⁹⁾. In cold climates, the incidence of post-transport morbidity and in-transit injuries caused by the freezing of sensitive body parts may increase⁽⁴⁶⁾. In these climates, straw bedding is recommended to improve animal comfort and to maintain a warmer temperature. High humidity conditions should be avoided during cold or hot climates since it has detrimental effects on the thermoregulatory capacity of animals^(60,61). Depending on the increase in body temperature, the upper critical point for sheep and cattle is around 24-26 °C. Most mammals die when body temperature reaches 42-45 °C, which is above the normal body temperature by about 3 to 6 °C⁽⁶²⁾. The accumulation of ammonia represents a risk in high densities and poor ventilation conditions since it correlates with temperature and air humidity⁽⁶²⁾.

Risk factors associated with the driver

The driver's ability to control the truck affects the quality of driving. Acceleration, braking, cornering, and driving techniques affect the ability of animals to maintain a stable posture, increasing excitability, reactivity, and injury⁽⁶³⁾. Moreover, the leading causes of road accidents during livestock transport in Spain, the USA, and Mexico are related to fatigue and poor decision-making by the driver, which results from long working hours, poor route design, and changes in sleep cycles⁽²⁵⁾. An analysis of articulated truck failures and accidents identified that the most common form of driver-associated accidents is related to an error in decision-making while driving⁽⁶⁴⁾. For example, the number of accidents during livestock transport in Mexico is unknown; drivers in this country frequently travel at high speeds, which affects the ability of the driver to deal with truck control in curves and other obstacles that may arise on the road⁽¹¹⁾.

Other factors included the age of the driver, due to the combination of experience and good health, the ideal age to drive trucks is between 28 and 54 yr old, drivers under the age of 27 obtained higher accident/fatality ranges, which increases again in drivers older than 63 yr⁽⁶⁵⁾. Alcohol consumption, fatigue, and chronic health problems such as being overweight or obese, are other factors associated with the driver^(66,67). In a study performed in Spain, most accidents involved pig (57 %), cattle (30 %), poultry (8 %), and sheep (5 %) transport⁽²⁵⁾; while in another study performed in the USA and Canada, Woods and Grandin⁽⁶⁸⁾ found that cattle (56 %) and pigs (27 %) were the most affected species. Of these accidents, 59 % occurred between 2400 and 0900 h, most of them were overturns, similar to what was observed in a study carried out in Mexico, where overturns were the most common type of accident (58.8 %) in long-distance transport of cattle⁽⁶⁷⁾; these were retrospective studies based on the analysis of newspaper reports, news, and driver surveys^(67,68). In this type of accident, the surviving animals are usually stunned and disoriented; they can also suffer pain, states of fear and anxiety, which complicates their handling and increases the risk of secondary accidents⁽³⁾.

Therefore, driver training should be a priority in the logistics chain, covering aspects of animal behavior and welfare, as well as factors related to the mechanical operation of their trucks⁽⁴⁶⁾. The livestock industry must take action to reduce fatigue and, therefore, the risk of accidents, which results in the loss of human and animal lives, besides significant economic losses in the logistics chain of animal transport. The only effective strategy to prevent fatigue accumulation is an ergonomic interaction of the vehicle design, besides ensuring that drivers consistently get good quality and adequate sleep⁽⁶⁶⁾.

Routes and geography

Geographic conditions have a strong influence on livestock production systems and on the opportunities to commercialize it. In some cases, the geographic location of a country allows or hinders international exchanges and requires a variety of different types of transport⁽⁶⁹⁾. In countries like Chile, it is not possible to reduce livestock transport duration due to its unique geography and few adequate routes, with transport durations of up to 63 h⁽³⁶⁾. Brazil is another example, with long transport periods due to its territorial extension⁽⁶⁾ and the global trend of reduction and specialization of slaughterhouses⁽¹²⁾. Brazil's road network system is over 1.6 million km long, and transport conditions vary depending on geographic characteristics. Roads are usually unpaved and in poor condition, a situation that worsens especially in the rainy season, increasing transport duration, the number of broken trucks, broken bridges, and road accidents⁽¹³⁾.

Impacts on welfare and productivity

The effect of long-duration transport on livestock is an important economic and animal health issue. This type of transport, as occurs in the Chilean Patagonia, causes significant loss of body weight⁽³⁶⁾, prolonging the physical recovery of livestock at the final destination.

Live weight loss, mobility, and mortality

Live weight loss in cattle is probably the most significant economic effect of transport. In a study with a group of heifers transported 518 km (8 h), with a maximum ambient temperature of 32.2 °C, live weight decreased by 6 % after transport⁽⁴⁸⁾. Weight loss is the most notorious effect at first, but a primary factor is the recovery time elapsed before starting to generate weight gain in animals transferred to fattening centers. Loerch and Fluharty⁽⁷⁰⁾ reported that a feed and water deprivation period above 72 h in addition to an eight-hour transport reduces the total ruminal protozoa. Moreover, animals subjected to long-distance transport can suffer dehydration, especially in warm-dry or very cold climates, when the airflow inside the truck is high. Providing small amounts of nutrients or electrolytes with correct tonicity immediately before and after transport, reduces tissue dehydration and the catabolism of muscle proteins, glycogen, and lipids, as well as reducing acid-base and electrolyte imbalances⁽⁷¹⁾.

Another concern is the risk of disease or death due to the variable climatic conditions and toxin exposure, among other factors⁽⁵⁾. During transport, animals can get sick or die; these effects can occur several weeks after arriving at the destination. One of the most important diseases in cattle from intensive systems is the bovine respiratory disease. This disease usually affects young cattle, although it also increases due to the transport process to fattening units. In the USA, the bovine respiratory disease affects 14.4 % of the cattle that enter the fattening units⁽⁷²⁾. The immune response of transported cattle is usually suppressed by the high concentrations of cortisol associated with stress⁽⁷³⁾, so the disease usually manifests days or weeks after arrival.

The injuries suffered during transport must be specially cared for; it is crucial to attend open wounds and keep in observation the animals that present difficulties in moving. Injured animals should receive anti-inflammatory and pain-relieving treatments to facilitate their recovery. The Fatigue Cattle Syndrome should be considered in the case of animals

with mobility problems immediately after transport⁽⁵⁶⁾; this syndrome is accentuated in *Bos indicus* cattle, which is more temperamental and tends to lie down and "surrender" in trucks with high populations⁽¹⁾, presenting greater difficulty in adapting to confinement conditions. However, there is little information about this syndrome, and studies do not show consistent information, further information is needed. Transport mortality is a reflection of a severe welfare problem; this includes animals dead on arrival (DOA) and animals without apparent injuries (Non-ambulatory, non injured - NANI) that die at a later time⁽⁷⁴⁾. Mortality records during transport in commercial and experimental conditions have shown that mortality increases with high or very low temperatures, long-distance transport, or in the transport of very young animals^(75,76). Transport mortality is variable and depends on different factors. Animals that lose 10 % of their body weight during transport are more likely to die or become non-ambulatory animals. Mortality also increases with lower space availability in the transport vehicle^(37,38).

Bruising

Injuries and damage to the carcass caused by improper transport practices, or long-distance transport will affect the severity of bruising and, therefore, the quality of the carcass and meat. Based on the current market requirements, animal transport must avoid this type of damage. A carcass with less damage suggests better welfare conditions and, therefore, a higher ethical quality of the product. In the canal, bruising can be associated with different factors. During an experiment, the amount of bruising was higher in females than in males; also, the most severe injuries were found in old cows and not in heifers, which could be because most of these cows have a lower body condition (less muscle and subcutaneous fat). In this study, transport-related bruises were observed in a "dark red" color and therefore considered to be less than or equal to 24 h in age, bruises were found on the sides, around the hip bones (ischial tuberosity), probably due to the contact that the cattle have with the sidewalls of the vehicle; bruising increased with higher animal densities⁽³¹⁾.

In males, the mating behavior and headbutts, which are common behaviors in beef cattle, are related to an increase in bruising, especially in holding pens⁽⁷⁷⁾; in this study, the appearance of this behavior could not be related to bruising.

Strategies to reduce stress on long-distance transport

The production and transport of live cattle will continue to be stimulated by the growing human population⁽⁷⁸⁾, but with the integration of activities within the logistics chain, it would be possible to obtain the following advantages: 1) distance and time reduction through route optimization; 2) improve animal welfare; 3) expand the market area for producers; 4) decrease operating costs and increase competitiveness; 5) reduce carbon dioxide (CO₂) emissions; 6) improve traceability for authorities and consumers; 7) narrow the participation between producers, distributors, merchants, and consumers; 8) promote the exchange of knowledge, experience, and information⁽⁷⁹⁾. Important members of the industry have begun to introduce their own policies to reduce stress and improve the welfare conditions of animals for slaughter.

Pharmacology applied to transport

Several studies have allowed the implementation of strategies that improve the conditions of animals during long-distance transport. Different studies recommend the use of some ingredients and drugs such as dexamethasone to support the treatment of some problems associated with transport^(34,80). There is evidence that Mg can reduce the effects of pre-slaughter stress and improve the quality of meat because it suppresses neuromuscular stimulation⁽⁸¹⁾ and, when added to the diet, results in the attenuation of the secretion of glucocorticoids and catecholamines⁽⁸²⁾. Tryptophan (Trp) is the precursor of serotonin, which regulates numerous biological functions, including temperature, pain sensitivity; feeding, sexual, and aggressive behavior⁽⁸³⁾; although its effects during transport have not been studied, preparations containing tryptophan are marketed worldwide as calming agents to treat excitable horses⁽⁸⁴⁾.

It is important to administrate a fluid and electrolyte therapy during and after transport⁽¹⁾, a study demonstrated that providing cattle with electrolytes before slaughter improves carcass yield, without affecting the pHu, color, or water holding capacity⁽⁸⁵⁾; electrolytes also reduce dehydration and weight loss associated with transport⁽⁸⁶⁾. Moreover, allostatic modulators (AM), which contain substances such as ascorbic acid, acetoxybenzoic acid, sodium chloride, and potassium chloride, have been shown to mitigate the stress caused by the capture and handling of cattle during transport. A diet supplemented with 10 g of an AM, fed before slaughter for 30 d, showed anti-inflammatory properties, decreased stress levels determined by physiological parameters, and increased meat color stability at 24 and 28 d *post-mortem*⁽⁸⁷⁾.

Conclusions

Distance in transport is a strategic component of the global food and agriculture, and meat production economy. However, it is necessary to develop guidelines and technologies in terms of handling, operation, and logistics aimed to improve the welfare and health conditions of cattle. The impact of stress on biological functions, behavior, and suffering of animals has been underestimated in the past. Nowadays, it is important to integrate animal welfare into a broad concept of quality in animal production. Therefore, it is essential to invest in improvements aimed to establish logistics programs that have animal welfare as the axis of an operational quality program, in addition to legislation that regulates long-distance travel based on scientific evidence, and vehicle designs that adjust to different climatic conditions, as well as to the characteristics and behavior of each species.

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