



Review Article

Impact of Inappropriate Transport on the Welfare and Cut Quality of Broilers: A Review

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Abstract

Since Brazil is one of the largest consumers and exporters of broiler chickens, poultry farming plays a crucial role in the Brazilian economy. However, the consumer market increasingly demands practices compatible with animal welfare. The pre-slaughter processes (handling and transport) are especially challenging for professionals of this industry. This review of the literature was aimed to highlight important aspects to improve welfare of birds during these processes. The importance of stressors such as environmental temperature, humidity, population density of vehicles and transport and failures in catching animals was discussed in this review. During harvesting, thermal stress and management failures cause a large proportion of birds to present carcass defects, such as injuries, fractures, Pale Soft and Exudative and an increase in the rate of Dead on Arrival. The high population density and inadequate distribution of animals in the transport compartment can result in the formation of heat and humidity islands and reduce ventilation efficiency, causing thermal stress to occur. Deaths can occur at any stage up to the slaughterhouse, however long journeys under inadequate transport conditions, road quality and temperature is more like to cause deaths. Logistics adaptations in the transport system and better-quality control and identification of risk factors are essential to avoid injuries and mortality of birds during transport.

Key words: Broiler, DOA, mortality, pre-slaughter operations, stress

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INTRODUCTION

Brazil is one of the world's largest producers of food, whether of animal or plant origin. In 2020, 29.7 million cattle, 6.0 billion chickens and 49.3 million pigs were slaughtered, in addition to producing 3.96 billion dozens of chicken eggs and selling more than 25.5 billion liters of milk¹. According to USDA² statistical data estimations (2024), Brazil's chicken meat production will reach 15.1 million metric tons by 2025, an increase of 1% from the previous year. To maintain its position as one of the world's leading producers of animal products, the country must adapt to new consumer demands and animal welfare has become an increasingly important asset for consumers worldwide. There is thus a need to consider these aspects in order to guarantee the welfare of these animals³.

Broiler production represents a highly profitable facet of the agricultural sector in the Brazilian economy. An important welfare issue in the poultry industry is related to the pre-slaughter handling (water fasting, catching, conditioning) and transport^{4,5}. Notably temperature and humidity during transport can be important stressors for the birds and have a heavy impact on the producer's profits⁶.

The quality of the birds' carcass, as well as the mortality rate, are directly affected by the stressors potentially present during pre-transport handling, transport and waiting time at the slaughterhouse. The pre-transportation period and the period of transport to the slaughterhouse are particularly involved in the occurrence of lesions in the carcass and an increase in the pre-slaughter mortality rate⁶. The risk of mortality and the occurrence of lesions in broilers are multifactorial. The formation of microclimates inside the transport vehicle, thermal stress, asphalt quality, travel time, catching and population density are just some of the factors that negatively impact the welfare of birds. Among all these factors, susceptibility to heat stress appears to be the most critical risk factor⁷. The environment created inside transport vehicles, together with the stress of the animals, favors the occurrence of carcass contamination, rejection of carcass parts due to injuries and the occurrence of "Dead on Arrival" (DOA) animals⁶. Considering that this is the final phase of the production chain in poultry farming, such losses cannot be recovered and represent a considerable burden on the producer's total profit⁸.

According to what has been presented so far, this study aimed to review the main factors in the transportation of broiler chickens that negatively influence the welfare of these animals and ways to prevent these factors were proposed.

MATERIALS AND METHODS

The following platforms were used to conduct the searches: PubMed, Google Scholar, ResearchGate and ScienceDirect. No time restriction was adopted as the search criteria. The following keywords were used: "Animal welfare", "Broilers", "DOA", "Injuries", "Management", "Mortality", "Handling", "Pre-slaughter operations" and "Transport". The exclusion criterion adopted was the lack of relevance to the chosen topic or duplication of information. As shown in Fig. 1, a total of 45 publications were included, covering the period from 1993 to 2024, which address ethical, physiological, productive and welfare aspects in the transportation of broiler birds and pre-slaughter handling. The pertinent data were extracted from the articles and synthesized to write this literature review (Fig. 2).

LITERATURE REVIEW

Carcass lesions and dead-on-arrival (DOA)-indicators of bird welfare during handling and transportation: Traumas originating during handling or transportation can result in Dead-on-arrival (DOA). These are two important indicators of bird welfare during these pre-slaughter phases and highlight the importance of adequate management during the pre-slaughter handling and transportation to ensure the quality and welfare of the birds^{9,10}.

Within the lesions observed at slaughter we can cite skin lesions such as bruising on the wings, breast and legs¹¹ and fractures. According to a study conducted in Norway from 2012 to 2013, 25 percent of birds declared dead on arrival, trauma was the most likely pathological cause of death. For 7% of the dead poultry, trauma was the most probable cause of death. The vertebral fracture rate was 3.6%, the skull fracture rate was 1.2%, the wings fracture rate was 0.5% and the femur and tibia fracture rate was 1.5%¹².

DOA is one of the ultimate indicators of animal welfare but also for the poultry industry, because of the financial losses caused by the condition. In this article, we will discuss different stressors potentially observed during the pre-slaughter phases that can influence the lesions and DOA.

Capture and pre-transport handling: Capturing birds is an important step in transportation and directly impacts chicken carcass quality and price. At this stage the birds are most exposed to stress, fractures, bruises and contusions.

Although, automated capture can be available, the most common in Brazil is manual capture, however, it is reported that manual capture is the method causing the most damage

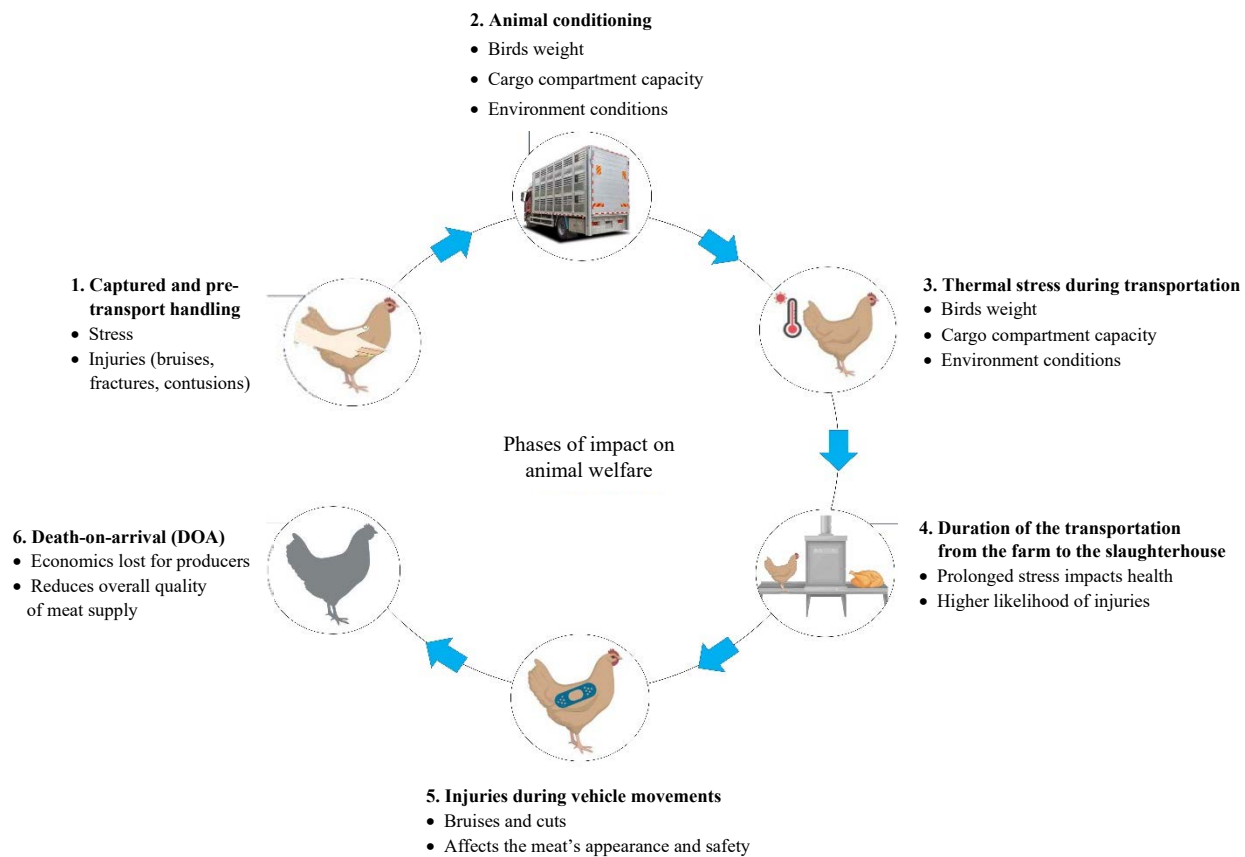


Fig. 1: Schematic representation of materials and methods

to the animals¹³. In addition, different capture maneuvers can affect the percentage of DOA and birds with bruised wings or breasts^{14,15} and interfere with the welfare of the animals, compromising the carcass and the quality of the meat. Therefore, it is essential that the catchers are trained and qualified employees¹⁶. Also, in order to reduce stress on the birds and provide a gentler capture, the ideal time for this stage is at night, because the temperature is milder and also because the animals' visual capacity decreases. It is advisable to use blue light to reduce the movement of the birds, facilitating capture¹⁷.

It is a requirement of the Brazilian Association of Animal Protein (ABPA) that the catching team must have a person responsible for ensuring the birds are handled carefully and are not mistreated.³ In order to minimize trauma caused during capture, the ABPA recommends that no more than two birds be captured at a time. It is also recommended that, during the capture process, transport boxes should be used to divide the birds into groups, which makes capture and restraint easier, resulting in a lower incidence of skin lesions

due to the agitation caused by the restraint. In addition, birds that already have health problems, fractures or injuries that compromise their welfare should not be transported³. There isn't a specific, publicly available database tracking every injury that occurs to broiler chicken during slaughter in Brazil. However, Souza *et al.*¹⁸ carried out a study between 2010 and 2015 in 3 states of southern Brazil, the purpose of this study was to investigate the use of carcass seizure data as indicators for animal welfare monitoring in broiler slaughterhouses in Brazil and to identify areas for improvement to increase data reliability, the results showed that fractures and bruises together represented the most prevalent welfare violations followed by skin lesion or inflammation.

Animal conditioning: The population density in the compartments of the transport vehicle depends on the weight of the birds, the capacity of the cargo compartment and the climatic and environmental conditions¹². The increase in population density in the vehicle is directly proportional to the increase in temperature and heat conservation in the cargo

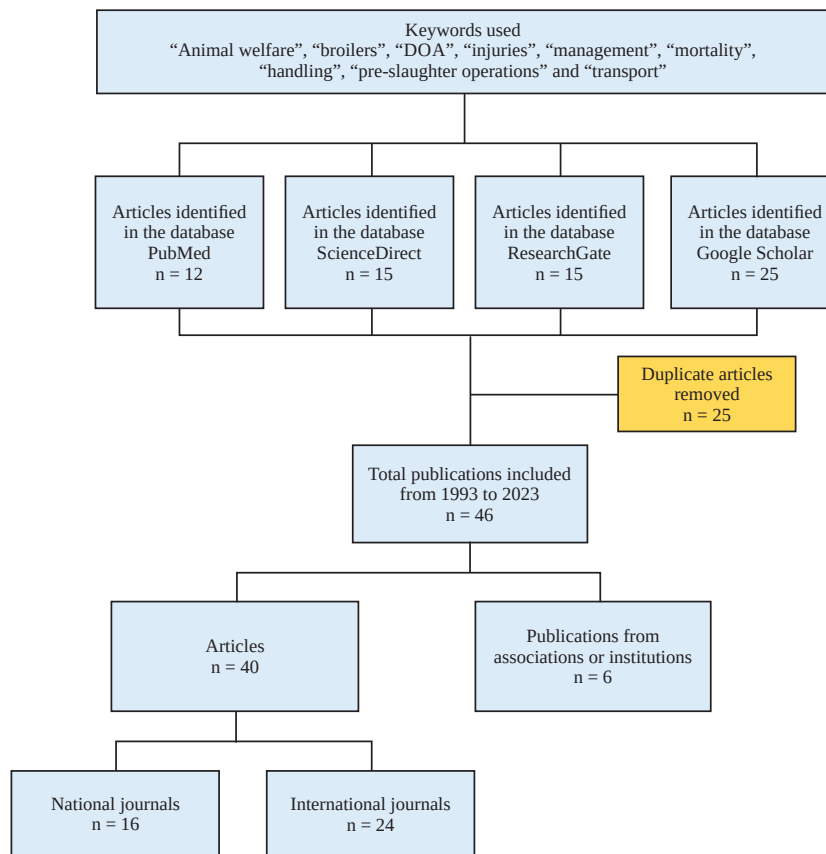


Fig. 2: A visual representation of the different titles and themes of the literature review

compartment, since there is greater generation of metabolic heat and a reduction in ventilation inside the compartment¹⁹.

In cold climate regions, the generation of metabolic heat due to high population density is desirable. Although the results are not representative for commercial models, it is reported that the metabolic heat produced by birds allowed to move during transport in cold environments that can reduce the rate of DOA due to hypothermia^{19,20}. However, if there is no adequate distribution of heat, there may be deaths due to thermal stress associated with hyperthermia^{12,21}.

It is important to emphasize that birds are more sensitive to thermal stimuli after being caught due to the stress generated by handling²², therefore any changes caused by population density will have a significant impact on the welfare and health of the animals. Temperature and humidity dynamics related to the accumulation of animals also impact social changes. As birds seek thermal comfort in certain areas of the transport compartment, they can aggregate or accumulate at certain points, resulting in carcass lesions⁷. The

grouping of different batches, with their own social hierarchies, can also lead to the appearance of lesions due to disputes²³.

Heat stress during transportation: During transportation, temperature is one of the most important parameters and the one that most affects the rate of animals Dead on Arrival (% DOA), in addition to increasing losses and condemnation of carcasses due to the formation of Pale Soft and Exudative (PSE) meat. Both temperature extremes (heat and cold) are capable of inducing thermal stress in animals.

In broiler chickens, the effect of temperature variation on weight loss has been demonstrated. For example, it was shown that a temperature of 29°C for 12 hrs induced a weight loss of 6.20%. This weight loss was reduced to 3.75% when the temperature decreased by 7°C for the same duration. However, a decrease of 18°C did not induce further improvement, as the weight loss was stable at 3.82% and 18°C²⁴.

Also, according to studies conducted in France and Canada, the age and size of the animals can influence the rate of DOA. When the birds are small, the mortality rate is higher. The shape of the body, the body weight and the coverage provided by the long feathers insulate the older birds from the cold^{19,25,26}.

The production of metabolic heat during transport creates thermal gradients, influenced by the action of the wind, resulting in a heterogeneous distribution of temperature throughout the truck load. Therefore, maintenance of temperature in transport vehicles is multifactorial. Most trucks that transport poultry do not have their own temperature regulation apparatus, depending directly on external environmental conditions and population density to ensure the thermal comfort of the transported animals^{8,27}.

Another point of interest is the variation in temperature depending on the location inside the transport truck. Animals that are transported in the most central areas of the cargo compartment receive less ventilation than those transported in the most external regions. As a result, birds in the most central regions retain more heat and accumulate more moisture, since there is little air movement to dissipate the accumulated moisture^{9,27}. In some cases, the movement of the truck and the aerodynamics of the cargo compartment allow some of this metabolic heat and moisture to be dissipated, however this depends directly on the arrangement of the transport boxes and population density of the cargo compartment⁹.

If the moisture and metabolic heat are not efficiently removed, regions of thermal concentration are formed. With the formation of these regions, there is a high probability of heat stress occurring in the birds¹². It is important to note that broiler birds have undergone a selective genetic process that exerted great pressure on muscle growth characteristics, however this same selective pressure negatively affected the ability of these birds to tolerate and compensate for heat²⁸.

The main mechanism by which chickens eliminate heat is through the evaporation of water through the respiratory tract and latent heat loss through the skin. These mechanisms are directly affected by the ambient temperature and humidity. At high temperatures, the respiratory rate increases and the bird may become panting²⁹. There is a great loss of latent heat in birds exposed to a temperature of 25°C and a humidity of 71%, while a bird exposed to 30°C and 90% relative humidity will lose almost all of its heat through the respiratory evaporation mechanism³⁰.

In addition to tachypnea, we can observe wing spreading, birds with their beak open, heads lowered and attempts to touch the chest to the floor of the enclosure as behavioral

adaptations to combat heat stress⁷. Birds that reach a body temperature close to 46°C present deep breathing, with reduced respiratory movements. This internal temperature is considered lethal for birds, causing death by hyperthermia. The moment of death is preceded by metabolic changes and panting. An increase in serum levels of uric acid, sodium and potassium is noted. Metabolic alkalosis occurs after hyperventilation, as carbon dioxide is lost during the attempt to dissipate heat^{7,12}.

These factors highlight the need for strategies to minimize thermal stress and improve transport conditions, aiming to reduce mortality and improve meat quality³¹. In Brazil, the impact of heat stress on broilers during transportation due to the country's climate conditions is highlighted^{6,12} and some measures can be implemented to reduce thermal stress in birds during this period. During the summer, it is common practice to bathe chickens with water before traveling to the slaughterhouse, which reduces the DOA rate (0.12 to 0.17%) when compared to transportation without bathing on hot days (0.16 to 0.27%)²⁷. This factor is also influenced by the speed at which the vehicle moves, the quality of the road, the ambient temperature and relative humidity, which can impair heat loss due to latency⁶. The afternoon is reported to be the period with the highest temperatures and, consequently, the greatest losses associated with thermal stress. Therefore, it is recommended that birds not be transported during this period⁶. Furthermore, by using expected temperature and humidity indexes (Mean Enthalpy Comfort index) for predicting the degree of thermal comfort to be expected, the logistics and planning of the arrangement of animals in the cargo compartment can be improved⁷.

Duration of transportation to the slaughterhouse: Studies indicate that transport distances influence bird mortality and up to 40% of deaths during transport are attributed to stress with a significant relationship between distance traveled and mortality^{27,32}. In addition, as far as is known, there is a negative correlation between the transportation time from the farm to the slaughterhouse and the welfare of broiler chickens, which can be evidenced by the increase in the percentage of dead-on-arrival birds¹². Factors that prolong the journey include the time to refuel the transport vehicles, the distance between the slaughterhouse and the farm, the quality of the road on the planned route and, finally, the logistics and capacity of the slaughterhouse to receive and slaughter the birds⁷.

Several factors are determining factors for the relationship between transportation time and loss of animal welfare and carcass quality. A longer journey results in a longer fasting period for the birds to be slaughtered. Prolonged fasting

periods favor metabolic reactions that affect glycogen reserves in addition to promoting increased animal stress¹². According to Fu *et al.*³³, transport time for broilers cannot exceed 3 hrs. Therefore, the logistics of the journey must be planned carefully in order to prevent prolonged fasting or temperatures outside their comfort zone^{34,35}.

As long journeys are likely to expose birds to other problems that may occur during transport, animals with insufficient physiological capacity to cope with stressors have a higher chance of dying^{19,24}. If there are problems in the catching process that cause injuries and fractures to the birds, the animals will have an increased level of stress due to the discomfort of the injuries during transportation³⁴.

Stress induced by temperature, ventilation, vehicle movement and humidity are also influenced by the length of the journey. Several resources are used to mitigate the problems generated by these factors, such as, for example, the baths mentioned above, which, combined with ventilation and the physiological mechanisms of heat dissipation of the birds, were able to reduce the rate of DOA and PSE^{27,36}. However, this only applies to longer transports, since in short journeys the mechanisms of heat dissipation combined with high humidity, hinder the physiological mechanisms of heat exchange of the birds⁶.

Although heat stress is a major concern, it is also important to consider cold stress. The speed of the transport vehicle directly influences the microclimate between the crates where the broilers are transported and therefore, increasing the speed favors air flow and reduces the temperature inside the vehicle, especially in the front and upper crates^{13,34}.

After arriving at the slaughter site, the distance traveled must be considered when determining the waiting time for slaughtering the batch of birds. According to Silva and Vieira³⁷, the stress caused by long-distance journeys, between 24 and 51 km, can be regulated by a period of 1 to 3 hrs in a properly air-conditioned waiting room, during which time the animals would be able to regulate their physiological mechanisms, preventing deaths and changes in carcasses. Journeys over 50 km require a short interval between arrival and slaughter, considering that in these cases the birds have already reached a state of irreversible stress due to the depletion of energy reserves. Therefore, a long wait and birds weakened by the journey would only result in more deaths and economic losses. In journeys carried out at night or on days with mild weather, a shorter rest period before slaughter can also be considered to compensate for the stress of the journey³⁷.

Vehicle movement: The distance traveled by the vehicle from the farm to the slaughterhouse, as well as heat stress, has a direct relationship with the occurrence of injuries and mortality in broiler chickens. Although, this relationship includes factors such as temperature, air circulation in the vehicle and humidity, there are inherent aspects of the quantity and intensity of movements in the transport vehicle that negatively affect broiler chickens⁷.

During the transport of broiler chickens to the slaughterhouse, vibrations are produced, either from the structure of the vehicle itself or from the interaction between the vehicle and the road. When the frequency of these vibrations approaches the resonant frequency of the "whole-body vibrations" of the birds, the resulting interactions generate an increase in the body temperature of the individuals. Transport vehicle movement is also affected by the quality of the road. This increase in body temperature, together with the temperature of the environment, directly affects the occurrence of heat stress in broiler chickens¹².

In addition, vibrations directly affect the instability of the birds, regardless of whether they are sitting or standing. The constant challenge caused by vehicle vibrations increases the muscular activity of broilers, who seek postural correction. An increase in serum Creatine Kinase (CK) concentrations has been observed in broilers subjected to vibrations, a reflection of the postural instability generated by vibrations³⁸. In addition, high serum cortisol levels in birds subjected to vibrations suggest that there is a stress factor directly related to vibrations³⁹. In general, birds that are transported in the back of the truck tend to suffer greater stress from vibrations⁴⁰. According to Abeyesinghe *et al.*⁴¹, exposure to intense vibrations for a period of 1 hr is sufficient to cause a reduction in muscle pH, a reduction in serum glucose levels and death. There is also a risk of transport crates falling, since continuous vibrations can cause the containment of the transport crates to loosen⁴².

A relationship has also been observed between the distance traveled from the farm to the slaughterhouse and the occurrence of movements that are adverse to the welfare of the chickens. Roads with asphalt defects such as cracks, potholes, uneven patches and undulations generate greater movement of cargo in the transport vehicle, increasing the occurrence of trauma and injuries to the animals being transported^{8,12}. In general, the areas with the highest incidence of injuries are on the breast and wings of the animals, both of which are desirable parts for human consumption^{43,44}. Injuries related to muscle tension can also be found and these can be particularly associated with vibration during transport^{12,19}. The chest and wings can also be injured due to handling problems

during breeding and capture errors during transportation, respectively⁷. Some injuries such as fractures are also related to the breed or strain of chickens. According to Budgell and Silversides⁴⁵, commercial lines have about 10% of fractures during loading and transport, compared to 0 and 3.5% in rustic lines.

CONCLUSION

In several studies, management and control measures are described for the numerous adverse conditions broiler birds are subjected to before slaughter. This review of the literature highlighted the different points of attention and the importance of proper handling of broiler birds before slaughter in order to guarantee the quality of the chicken meat, minimizing discomfort, contamination and ensuring the welfare of the animals. In addition, we identified several improvements that could be made so the birds are transported in the best possible conditions. Among them: transport must be adapted to local climate conditions, always respecting the tolerance threshold of the animals being transported, seeking better control of environmental variables; training the workforce, adjustments in transport logistics, correct adaptation of the transport vehicle in terms of ventilation and population density are some of the main parameters that must be constantly updated and improved. Finally, it is important to emphasize that ensuring the health and welfare of the animals throughout the entire poultry farming process is also one of the best ways to ensure survival during the pre-slaughter phase.

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