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Effects of transport on water buffaloes (*Bubalus bubalis*): factors associated with the frequency of skin injuries and meat quality

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Abstract It is well known that transporting livestock is stressful for the animals and a primary cause of skin lesions. The effects of transport on the water buffalo (*Bubalus bubalis*) have not been studied extensively despite reports of high incidences of trauma during and after these mobilizations. The present review article analyzes the frequency of skin injuries suffered by water buffaloes during transport and several key contributing factors. It also discusses the consequences of injuries on the quality of carcasses. Important aspects identified include inappropriate vehicle design that does not comply with the dimensions recommended by international institutions (e.g., height, type of flooring, characteristics of the ramp), handling methods, and the ability of stockpeople to manage water buffaloes, all of which impact the incidence of injuries. Our analysis of these elements will contribute to identifying critical control points and areas of opportunity while also suggesting strategies to ensure the welfare of these animals during transport and the quality of water buffalo products and by-products.

Keywords: animal welfare, antemortem, bruises, carcass, injuries, transport

1. Introduction

Transport is a process that all livestock destined for meat or milk production experience at least once in their lifetime (Schwartzkopf-Genswein et al 2016). In the case of the water buffalo (*Bubalus bubalis*), this event usually occurs at the end of the productive cycle when the animals are transported to a cattle market or slaughterhouse (Chandra and Das 2001a; Mota-Rojas et al 2020a; Mota-Rojas et al 2021abc; Rodríguez-González et al 2022). During transport, buffaloes and other animals are exposed to numerous stressful factors: movement, noise, unfamiliar odors, overcrowding, handling, inadequate rest, changes in social hierarchies, extreme environmental conditions, and restricted access to food and water (Chambers and Grandin 2001; Gallo et al 2001; Mota-Rojas et al 2005, Mota-Rojas et al 2010ab; Salesse 2017; Padalino et al 2018; Carrasco-García et al 2020). These conditions can produce dehydration and fatigue (Alam et al 2010a). The design of the vehicle and excessive use of electric prods and other harmful objects during on-loading and off-loading increase the risk of lesions, while factors like driving techniques, vehicle swaying, sudden braking (Broom 2008), loading density, trip duration, and road conditions can also affect the welfare of these animals (Strappini et al 2009; Mota-Rojas et al 2010ab, Alam et al 2010b; Lemcke 2015; Valkova et al 2021; Castro de Jesús et al 2021). Identifying the precise causes of lesions is, however, a challenging task because elements inherent to this species may also exert a significant influence (Kline et al 2020). Among these aspects, we can mention age, gender (Alam et al 2010b), and levels of fat coverage. Finally, the conditions in which the animals were raised and lairage times before slaughter (Strappini et al 2010) may also affect indices of injuries (Napolitano et al 2020).

Today, the wounds that occur during transport are considered an indicator of reduced welfare (Gallo et al 2001; Mota-Rojas et al 2010ab; Romero et al 2012), which can have significant economic repercussions because excessive trimming of carcasses may be required to remove bruised meat. Moreover, injuries can trigger biochemical and organoleptic changes in the meat due to the action of biogenic amines (cadaverine, putrescine, histamine) that accelerate putrefaction (Cruz-Monterrosa et al 2017; Mota-Rojas et al 2021abc). Obviously, these effects reduce the

yields and value of carcasses, generating millions of dollars in losses (Kline et al 2020).

Against this background, the objective of this study is to analyze the effect of factors involved in the handling of water buffaloes throughout the transportation process – beginning with on-loading and ending with off-loading– on the incidence and types of lesions these animals suffer and their impact on carcasses and the quality of the meat products and by-products. We set out to determine critical control points and areas of opportunity to improve the transport of water buffaloes.

2. Classification of *ante-mortem* contusions

The factors to which water buffaloes are exposed during on-loading at the farm and off-loading at a market or abattoir constitute the etiology of the presentation of injuries during transport. Key aspects identified in this regard to date include loading density, confinement in vehicles of inadequate size, and the training of stockpeople (Mendonça et al 2018). Alam et al (2010b) analyzed and compared the indices of skin injuries post-transport in 192 Indian water buffaloes and 368 bovines (*Bos indicus*, Hariana, exotic, and local breeds) at a cattle market in Bangladesh. They found that the buffaloes had a higher index of skin injuries than the cattle (89 *vs*. 84%) and that abrasions were the main type of lesion in 73% of the animals. These percentages are similar to those reported by Gregory et al (2008), who identified skin injuries in 99 and 84% of buffaloes and cattle, respectively. Later work by Alam et al (2020) determined that the frequency of lesions in water buffaloes (75.4% of 138 animals) was higher than that reported for Hariana cattle (68.4%). These results have led some authors to affirm that the differences in the number of lesions that occur in water buffaloes can be attributed to certain morphological differences between this species and conventional cattle, differences that include the size of the hooves (Bertoni et al 2020) and cranium (Özkan et al 2019). The study of Murrah buffalo cows by Alapati et al (2010) affirms that the transverse lumbar processes are narrower and pointier than in female bovines and that the buffaloes' ribs have a more pronounced curvature. While these differences may well be associated with the frequency of lesions during transport, the structure of the vehicle and loading density also impact indices of injuries (Garcia et al 2019; Ferreira et al 2020).

Other authors report that the frequency of lesions in water buffaloes can result from inadequate handling during on-loading before transport (Alam et al 2020). One objective of handlers, of course, is to minimize on- and off-loading times. Because buffaloes are more sluggish than conventional bovines, stockpeople often strike them with sticks or make excessive use of instruments like electric prods (Alam et al 2010b). While it has been demonstrated that using these instruments reduces on- and off-loading times (41 ± 30 seconds per head) (Chandra and Das 2001a), they can cause skin lesions and damage the carcass, causing economic losses.

Grandin (2010) observed that striking animals with sticks are more harmful than using electric prods on this issue. According to numerical scores from the Welfare Quality Network (WQN, 2009) related to establishments in the slaughtering industry, instruments like sticks and prods should only be used on animals that refuse to move. An industry-standard holds that only 5 to <25% of animals need to be moved using electric prods (Grandin 2012).

The injuries mentioned above have been analyzed and classified in the following eight categories: abrasions, lacerations, penetrating wounds, ulcerations, bleeding sores, swelling with hyperkeratosis, and scar tissue. Figure 1 presents a schematic view of the percentage of lesions that water buffaloes suffer according to Alam et al's classification (2010b).

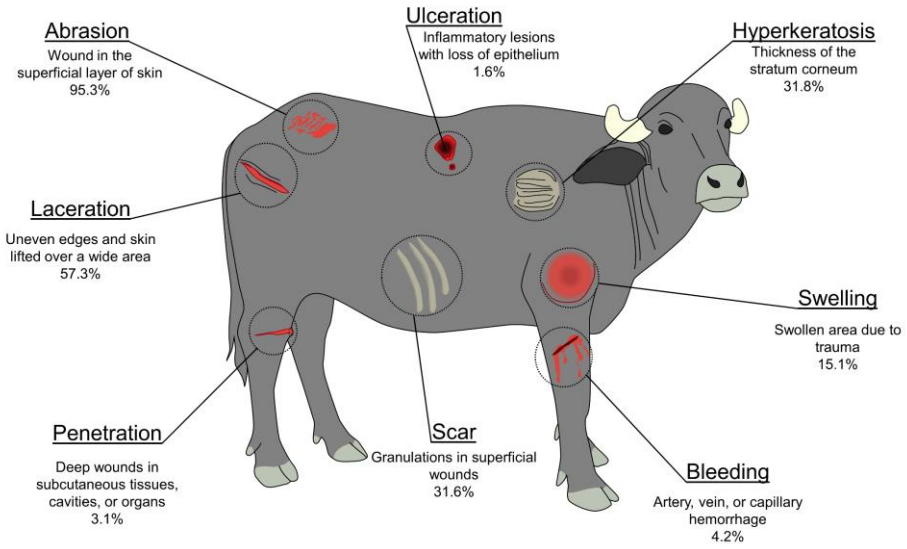

Figure 1 Frequency (in percentages) of eight types of skin injuries in water buffaloes (*B. bubalis*) during transport. Information from Alam et al's classification (2010b).

Alam et al's (2010b) study identified abrasions (95.3%) as the most frequent type of lesion in buffaloes, followed by lacerations (57.3%) and swelling with hyperkeratosis (31.8%). The injuries with the lowest incidences were ulcerations, penetrating wounds, and bleeding sores (1.6, 3.1, and 4.2%, respectively). Meanwhile, Chandra and Das (2001a) proposed an evaluation scale for the severity of bruising in animals before slaughter based on the Australian Carcass Bruising Scoring System. That scale considers the surface area (from <5 to >10 cm) and type of tissue affected –skin, surface muscles, deep muscles, muscle lesions that ooze blood– to classify injuries as small, small-deep, medium, heavy, and heavy-deep. Those authors evaluated 244 bruises found in 100 water buffaloes. The most common ones were small-deep at 59.0%, followed by the medium at 19.3%.

But injury type and frequency depend, as well, on the corporal zone evaluated. In both water buffaloes and conventional cattle, studies of injuries have focused on 11 zones: the head, neck, forelimbs, thorax, abdomen, hips, buttocks, hindlimbs, external genitalia, back, and tail (Alam et al 2010b). On average, the highest incidence of injuries of all types occurred in the buttocks region. For example, the highest percentage of abrasive lesions (61.9%) was identified there, followed by the hips, back, and hindlimbs (48.4, 47.3, and 25.5%, respectively). Lacerations were also more common in the buttock region (17.7%), back (16.1%), hips (15.6%), and forelimbs (9.9%). No bleeding sores were observed in the neck or thorax, while the tail area was free of swelling injuries. These results are similar to those reported for water buffaloes transported on a short trip –20 km for 30 min– at a velocity of 40 km/h and an approximate density of 0.6 m^2 per animal. In that case, most of the bruises occurred in the pelvic members (43.4%), abdomen, and udder region (21.3%). Percentages in the shoulders, neck, back (16.0%) and perianal region (11.1%) were lower (Chandra and Das 2001a). Figure 2 presents a comparison of the data described for buffaloes to reports on conventional cattle regarding the frequency of laceration injuries.

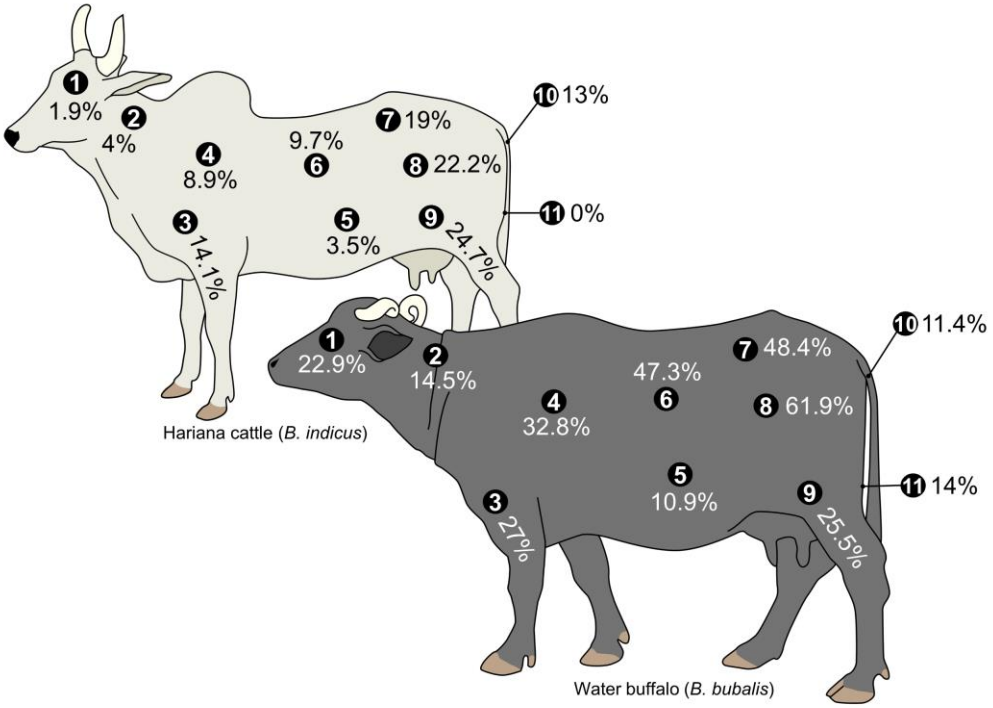

Figure 2 Comparison of the frequency of lacerations in cattle (*Bos indicus*) *vs*. water buffaloes (*Bubalus bubalis*) according to the body regions identified by Alam et al (2010b). 1, head; 2, neck; 3, forelimbs; 4, thorax; 5, back; 6, abdomen; 7, hips; 8, buttocks; 9, hindlimbs; 10, tail; 11, external genitalia.

Alam et al (2010b) and Kober et al (2014) reported percentages of abrasions in buffaloes that are as much as 33.6% higher than in cattle. The data from both of those studies show that buffaloes had higher percentages of lacerations (57.3 and 70.5% *vs*. 32.3 and 28.5%). Concerning bleeding sores, the indices for buffaloes were also higher than in cattle (2 and 4.3% *vs*. 4.2 and 9%), with a difference of just over 50%. Swelling injuries were also over twofold more common in buffaloes than cattle (15.1 and 23.1% *vs*. 4.9 and 3.8%). However, the incidences of scarring found in these studies suggest that cattle suffer this type of injury more often (59.5 and 66.5%) than water buffaloes (31.6 and 41%).

One reason why the frequency of lesions in the tail area was higher in buffaloes than conventional cattle can be attributed to inadequate handling by stockpeople who used sticks excessively to strike the buffaloes on the hips, buttocks, and perineal region to force them to move. This may reflect the impact of a cultural factor since water buffaloes and their products have less value at the market than cattle and their products (Alam et al 2010b). Meanwhile, lesions on the animals' backs and sides could be related to the vertical

sliding doors that control entry into the stunning box (Mota-Rojas et al 2020b).

Other reports have focused on the frequency of injuries in the nose and tail areas. One study of 192 water buffaloes found that 54% had their noses perforated, a condition that can produce injuries because the ropes passed through them may chafe or tear the nostrils. According to the classification of injuries mentioned above, the most common types cited in these studies were lacerations (58.3%), ulcerations (34%), bleeding sores (4.8%), and scarring (2.9%) (Alam et al 2010c).

In most of these cases, one of the major causes identified was poor vehicle design, as the inside of the trucks had sharp objects against which animals could rub or collide. Animals transported under these conditions often show yoke marks around their shoulders and neck because they lean on or rub against the vehicle's sides. Rough driving has been cited as a cause of 59% of injuries, while high loading densities, tying animals to the vehicle's walls by the nose, legs, or neck, and chafing are other elements that can inflict abrasions and lacerations on buffaloes during transport (Alam et al 2010b). In addition, falls during transports and attempts to jump or escape from the vehicle have been reported as causes of lesions. One study of 100 buffaloes attributed the frequency with which animals lost their balance, tripped, slid, or were unable to remain standing in the vehicle to poor driving techniques characterized by constant, sudden braking, bumping, high/speed cornering, and sudden acceleration (Chandra and Das 2001b). Similarly, falls during off-loading was seen to be caused by ramps with slippery floors. The critical point for implementing measures to prevent accidents of this kind is reached when over 1% of animals slip or fall during movement (Grandin 2010).

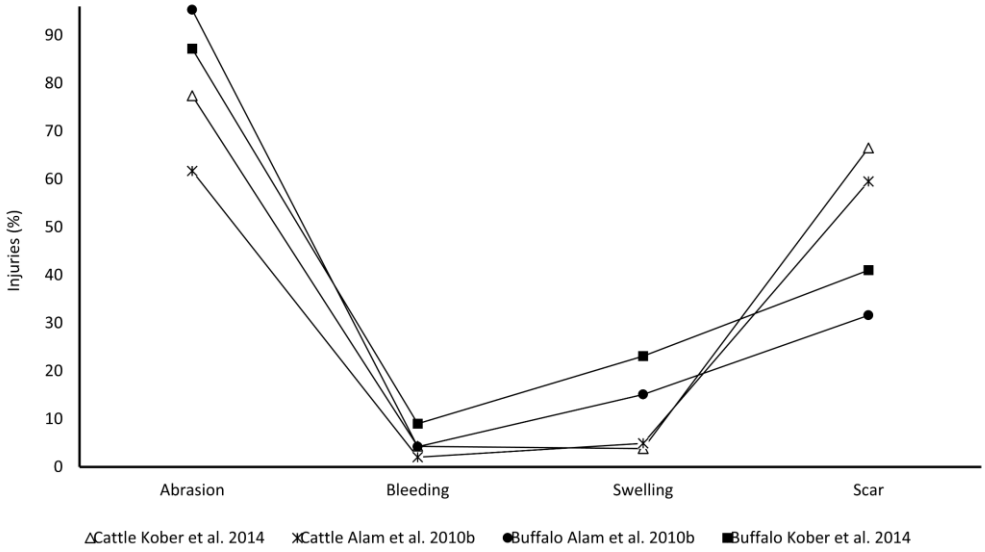

Figure 3 Percentage of lesions reported by Alam et al (2010b) and Kober et al (2014) in water buffaloes (*Bubalus bubalis*) and cattle (*Bos indicus*).

Strappini et al (2013) evaluated bruising in Black and Red Friesian crossbred cows by filming the animals during on-loading, transport, off-loading at an abattoir, lairage, and entry into the stunning box. Their results showed that of the 100% (1792) of potential events that could cause bruising, 91.2% occurred during lairage before slaughter, 5.4% in the stunning box, 2.5% during on-loading, and 0.4 and 0.5% during transport and off-loading, respectively. That study further showed that 99.7% of the bruising that occurred during on-loading, 75% of the injuries suffered during off-loading, and 51.5% of the lesions inflicted in the stunning box were attributable to human-animal interaction. Observations in the reception areas showed that 23% of bruising occurred when the animals were pricked with a stick, while the analysis of the stunning box revealed that blows with blunt objects caused 36% of the bruising that occurred there. In contrast, 99.7% and 71.4% of lesion events during lairage and transport, respectively, were related to animal-animal interaction, including head-butting, horn-butting, and being stamped on or mounted.

Finally, Grandin (2017) pointed out that the reliability of assessments of injuries by region or severity requires that the stockpeople involved be trained to recognize recent bruising and identify its etiology. No scoring system exists for the water buffalo like the ones that have been developed for bovines (*B. taurus*, *B. indicus)* (McKeith et al 2012) and swine (Nielsen et al 2014), but this does not exempt stockpeople from implementing the measures required to ensure adequate handling in accordance with the characteristics of each species, or from correctly identifying the injuries that animals suffer and their causes.

3. Evaluation of *post-mortem* lesions

Assessing bruising is an activity performed routinely at abattoirs to determine the condition of cattle before slaughter. Various scoring systems have been elaborated to evaluate carcasses based on a thorough visual examination

to define the location, extension, color, shape, and severity of bruising (Strappini et al 2009). Bruises are defined as soft tissue injuries due to crushing which ruptures capillaries and causes deposits of blood and serum to form, but without dermal discontinuity (Trigo 2017; Mendonça et al 2018). Bruising is reported to be one of the principal reasons for discarding meat tissues during *post-mortem* butchering (Chandra and Das 2001a). As mentioned above, the prevalence of bruising depends on multiple conditions, not only on-loading, off-loading, transport in the vehicle, and trip distance, but also characteristics of the animals, such as sex, temperament, age, the presence of horns, even genotype (Bethancourt-Garcia et al 2019). Unfortunately, information on *post-mortem* analyses of water buffalo carcasses is scarce, though studies like the one by Strappini et al (2012) describe the general aspects of bruises in dairy cows on farms and at cattle markets. Those authors reported the results of *post-mortem* assessments of bruising in accordance with the following criteria: anatomical site, severity, form, size, and color, using the ACBSS protocol (Australian Carcass Bruising Scoring System) and the Chilean bruising carcass-grading standard.

Their report states that the carcasses of animals sold at a cattle market had 3.8 bruises per head, compared to just 2.5 for the animals transported directly from farms. These findings could reflect the quality of human-animal interaction during multiple trips (at least, farm-to-market and market-to-abattoir), on- and off-loading operations, and additional periods of manipulation (e.g., rest periods during trips). That study identified the tip of the ischium (pin) as the area most often affected by bruising (26.5% of all events), likely due to collisions against the sides of the vehicle or other structures inside and to the use of herding tools like sticks or prods. The second-most affected area was the back (21.8%), probably because of collisions with overhead structures in the vehicle or with the guillotine doors that control entry into the stunning box. These results identify areas of opportunity for implementing measures to ensure compliance with the parameters proposed for evaluating animal welfare at slaughterhouses (Mota- Rojas et al 2020c).

In complementary analyses, those researchers evaluated the shape, size, severity, and coloration of the bruises found. Concerning shape, the categories were circular (delimited circumference), linear (straight line), tramline (two parallel lines), mottled, and irregular. This classification found that, 91% of bruises were irregular, 3.8% lineal, 3.1% circular, and 1.9% tramline. Significantly, the latter shape was seen only in animals that had been transported from cattle markets and likely reflected the use of wooden sticks.

The size of the bruises was assessed by diameter and classified as small (>2 to <8cm), medium (8 to <16 cm), and large (16 cm and over). The authors determined that 60.4% were small, 32% medium, and only 7.6% large.

In terms of severity, 66.2% of the bruises were classified as grade 1 (only subcutaneous tissue damage). There were no reports of grade 3 injuries marked by bone and muscle damage. Still, a relation was determined with respect to the amount of fat coverage in the animals, as those with scarce coverage were more susceptible to bruising.

Regarding color, the authors considered that reddish coloration indicated a fresh bruise, a bluish or dark color, an old bruise, and a yellowish shade, a very old lesion. Results showed that 70% of bruises were bright red in color, leading the researchers to deduce that they were caused during transport, off-loading, or lairage at the abattoir or were due to some other form of handling performed between 24 and 48h before slaughter. Another 29.4% of the hematomas were blue or dark in color, while only 0.2% were yellowish, reflecting longer evolution times. However, the authors were careful to note that because this is a subjective measure, it may provide high reliability. They suggested that a more exact assessment might be achieved by correlating these observations with pre-slaughter events to identify the precise moments when bruising occurs (Strappini et al 2012).

The results summarized above show that one critical point for dealing with bruising is determining where it occurs (on the farm, during transport, at the market, in the abattoir). This is of key importance because, as Alam et al (2010b) emphasize, the fact that buffaloes are more susceptible to bruising than bovines could mean that an increase in the number of stressful events will elevate the indices of DFD (dark, firm, dry) meat (Carrasco-García et al 2020) due to the higher pH levels caused by the lack of anaerobic glycolysis and the consequent production of lactic acid that has been associated with chronic stress caused by the accumulated effects of necessary *ante-mortem* processes, such as fasting, on-loading, off-loading, transport, and inadequate handling (e.g., the use of harmful objects, shouting) (Napolitano et al 2020).

Kline et al (2020) conducted studies of individual cows, bulls, and finished steers from the stages of off-loading through to *ante-mortem* processing at several abattoirs. The animals examined had been transported to the slaughterhouses in two different kinds of vehicle: straight-deck and double-deck trailers. Results showed that the cattle transported on the lower deck of the double-deck truck presented more bruising than those carried on the upper deck (46.8 *vs*. 33.2%), especially in the dorsal area. That difference may have been due to collisions against the overhead frame of the truck during on-loading. The posterior evaluation of the carcasses determined a greater frequency of bruising along the dorsal midline and in the rump region. Possible causes of this distribution were vehicle design, inadequate use of doors, and the size of the animals. That study clearly showed that the type of vehicle affects the probability of bruising (Figure 4) and produced findings similar to those in Alam et al (2010b), who stressed that rubbing against the interior vehicle walls increases the frequency of lesions in buffaloes.

Figure 4 (A) and (B) load density and type of vehicle used to transport water buffaloes with upper tubular structures at least 30 cm above the height of the animals (dimensions recommended by the FAWC, 2019). (C) comparison of vehicles used for transport. Regardless of other characteristics, the recommended height and dimensions must be maintained to avoid injuries during on- and off-loading.

Other reports point to an increase in bruising in vehicles with a trailer, since the larger the vehicle, the greater the centrifugal force in the center of the box, which can cause animals to lose their footing, increasing the risk of falls (Mendonça et al 2018). Studies of this aspect of animal transport have analyzed the factor of load density in efforts to determine optimal parameters in relation to the size and weight of the animals involved. Results suggest that animals weighing 400, 450, and 500 kg require 1.16, 1.26, and 1.35 m^2 of space, respectively, to prevent the injuries that can occur as they try to maintain their balance and postures that reduce stress, fatigue, and falls during transport (FAWC 2019; González et al 2012). Excessively high loading densities (see Figure 4B) leave the animals with less space to adopt secure postures, so they may be unable to place their hooves in a stable way that prevents slipping or falling. Moreover, it increases the likelihood that animals will be stomped on by others (Garcia et al 2019). At the opposite extreme, excessively low loading densities (see Figure 5A) can make it more difficult for animals to keep their footing during transport because they cannot support themselves against their congeners, though they will have greater space to regain their balance or stand up if they fall (Figure 4A).

Other physical features of the vehicle can also directly impact the frequency of injuries. Work by Alam et al (2010b) found that another area of the animals often affected by bruising is around the buttocks. This is probably due to the presence of open bars, hinges, bolts, or screws in the vehicle's doors (Mendonça et al 2018), against which this area of the animal's body could collide (Figure 5B).

Figure 5 Skin injuries in water buffalo due to transport. (A) during off-loading, falls can occur because the ramps are too steep or the floors slippery. (B) lacerations in the caudal area are often observed in buffaloes. (C) a group of buffaloes awaiting slaughter with signs of bilateral lacerations near the hock. Injuries to the hindlimbs are frequent due to falling or vehicle design.

Finally, it is important to mention that certain characteristics of the animals themselves can contribute to bruising, including, as mentioned previously, the amount of fat coverage. However, studies have also demonstrated that sex can influence incidences of bruising (Garcia et al 2019; Bethancourt-Garcia et al 2019). For example, one comparative study of water buffaloes and cattle found a higher prevalence of abrasions in females (93.2%) than males (69.7%) (Alam et al 2010b). This effect may be due to certain maternal behaviors that females exhibit –like trying to defend their offspring– and/or to past abuse since females tend to be more susceptible to maltreatment by stockpeople (Garcia et al 2019).

4. Perspectives

The corpus of literature on lesions and evaluations of critical points during the transport of water buffaloes is limited. The studies cited in this review article reveal the need to identify essential points of control before, during, and after transportation and develop strategies to develop and implement more adequate handling processes that consider such factors as the number of animals, vehicle type, and travel times, among others. We also require etiological studies of the injuries that buffaloes suffer during transport. These are the only measures that will make it possible to reduce the frequency of bruising, improve the welfare of water buffaloes, and decrease economic losses (Napolitano et al 2020).

Therefore, it is important to rigorously analyze not only the handling procedures adopted by stockpeople, but also events that occur inside the vehicle, such as collisions against structures during transport, the frequency of falls, vehicle speed, and allowances for rest periods during long journeys. The design of the vehicle is another key factor in preventing injuries. One recommendation is to improve transport by ensuring that vehicles have curved corners, non-slip flooring, and flat floors or have a slightly upward sloped. A second recommendation is that the ramps used for on- and off-loading should not exceed a 20° slope (Broom 2008).

Regarding options to reduce indices of bruising, other authors have suggested the need to implement professional training programs. Training stockhandlers to design transit zones where they can move animals more fluidly with no need for sticks or electric goads is a simple strategy that can improve on- and off-loading (Broom 2008). Better supervision, improved handling techniques (Brennecke et al 2020), the implementation of new strategies, enhanced design of structures and vehicles, and personnel training are all factors that must be evaluated in the field of water buffalo production units (Strappini et al 2013). In addition, improving handlers' knowledge and understanding of the water buffalo's characteristics, temperament, and behavior is another way to prevent injuries. It is important, as well, to train stockpeople to identify when animals are feeling stressed by their surroundings simply by observing changes in behavior during movement, such as freezing, backing off, attempts to escape, or constant vocalizing (Broom 2000).

Concerning this important point, protocols have been developed that include preventive measures, monitoring processes, and the optimization of operations to reduce the prevalence of injuries. One goal in this field is to control the factors that most significantly impact animal welfare. The importance of these efforts is increasingly being reflected in the demands of final consumers that are having a strong economic impact on the meat industry (Gallo and Huertas 2016; Velarde and Dalmau 2012). A second aim is to elaborate universal standards for water buffalo welfare that contemplate every phase of the movement, that is, from on-loading to pre-stunning. There is a clear need for stricter and more complete norms than the ones established in the legislation of individual countries (Grandin 2010).

Specific protocols do not yet govern water buffalo production for animal welfare. However, Wigham et al's (2018) analysis of documents related to animal welfare assessments at cattle production units, during transport, and before/during slaughter suggests that an ideal protocol would include measures that reflect sensitivity to the need for concrete changes will improve welfare. In this regard, they emphasize the need to train and continuously evaluate the performance of stockpeople because inadequate human-animal interaction is one of the factors that most severely impacts animal welfare (Costa et al 2006; Sandstrom 2009; Strappini et al 2013). Finally, implementing internationally recognized and approved certifications and programs will have a positive economic impact by fomenting continuous improvements to improve animal welfare, reduce incidences of injuries, and enhance the characteristics of carcasses and meat products.

5. Conclusions

The frequency of injuries during the transport of water buffaloes is an indicator of the level of the animals' welfare. The lesions suffered include abrasions, lacerations, penetrating wounds, ulcerations, bleeding sores, swelling with hyperkeratosis, and scarring. The corporal regions most susceptible to injury in this species are the buttocks, hips, back, and nose. It is important to emphasize that the vehicles used to transport buffaloes are usually adapted to *Bos taurus* and *Bos indicus* cattle, not buffaloes. Though similar, these two species have significant differences, both morphological –e.g., narrower, bony projections in the buffalo's lumbar transverse processes– and behavioral, that impact the incidences of injuries. Other key factors that impact indices of lesions are inadequate handling by stockpeople and the excessive use of instruments to move the animals.

Trauma caused during transport is associated with bruising in *post-mortem* tissues. Evaluating the coloration of bruises is a technique that can help determine the antiquity of lesions because it changes from bright red to bluish-dark and then yellow during the healing process. However, assessments of this kind do not provide high reliability because color changes may also depend on factors like an animal's age, sex, species, tissues, and amount of subdermal fat. Other approaches to evaluating bruises focus on shape

(circular, linear, tramline, mottled, irregular), severity (low, medium, high), size (small, medium, large), and the depth of injuries.

Therefore, strategies proposed to reduce or prevent injuries in transported animals and their significant physicochemical and economic repercussions on the meat produced suggest designing vehicles appropriately for this species, providing adequate training for stockhandlers, and establishing –and enforcing– transport norms and regulations that consider the characteristics of the water buffalo. All these measures will promote better practices that improve the quality of transport for these animals.

Conflict of Interest

The authors declare that they have no conflict of interest.

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