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Case report

Electro-thermal injuries in ruminants caused by electrical equipment during pre-slaughter operations: Forensic case reports from an animal welfare science perspective

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ABSTRACT

The use of electrical equipment for herding and moving livestock (electric batons) or for stunning animals before slaughter (electric stunners) is widespread in the livestock and meat industries worldwide. The use of these equipment is restricted to specific procedures and/or exceptional circumstances that justify their rational use. However, these restrictions can be underestimated or disregarded due to ignorance, inexperience, incompetence or irresponsibility on the part of users, resulting in pain and suffering to the animals and, in some cases, electro-thermal injury. This report presents four forensic cases of electro-thermal injuries identified during *post-mortem* animal welfare assessments in slaughterhouses in Colombia, Mexico and Spain. Electro-thermal injuries caused by contact (accidental or intentional) of equipment electrodes with skin and subcutaneous tissue are presented. Although our cases are isolated events detected over a 5-year period, they provide a useful visual guide for technicians and veterinarians interested in the differential diagnosis between bruises and electro-thermal injuries. The differentiation of the equipment causing the injuries allows the identification and control of critical points for animal welfare along the pre-slaughter logistic chain and the elimination of inappropriate animal handling practices.

1. Introduction

A key objective of animal welfare science is to develop tools and protocols to objectively assess the conditions in which animals have lived and died during the various stages of rearing, transport and slaughter [1]. In this sense, the forensic evaluation of carcasses at the slaughterhouse level can be used to understand how animals have adapted their farm environment, or if they have been subjected to poor quality practices or mistreatment along the pre-slaughter chain. Traditionally, animal welfare assessment in the slaughterhouse is based on quantitative examination of carcasses for bruising prevalence and other characteristics such as location, severity and shape [2]. Recently, there is a tendency to study typical patterns to characterise damage profiles related to logistics and handling of livestock [3]. A bruise can be defined as a lesion that lies beneath an intact epidermis and consists of an extravascular accumulation of erythrocytes that has leaked from blood vessels damaged by mechanical impact [4]. Carcass bruising is one of the earliest, most common, and easily recognizable signs of poor welfare during transport and pre-slaughter operations and can signal escalating inefficiency and neglect within the pre-slaughter chain [5]. Efficient detection of carcass bruising can be used as a tool in the evaluation of a program of critical control points at slaughterhouse level [6]. However, bruise assessments tend to focus on measuring injuries that, due to their size, compromise the quality and price of the carcass. In addition, assessments should be rapid and non-invasive, as in many cases it is difficult to distinguish between bruises and other injuries of similar appearance caused by other agents, such as electricity.

The appearance of injuries of electro-thermal origin is due to the resistance offered by body tissues when they receive a certain electric current [7]. The greater the resistance of the tissues, the greater the thermal energy produced at the point of entry of the current, causing greater damage [8]. Skin, covered with hair or wool, is the most resistant tissue in the animal body, followed by bones, tendons and fat, tending to heat up and coagulate rather than transmit the current [9]. Nerves, muscles and blood have a lower resistance because of their high electrolyte and water content, being good conductors of electricity [10]. Lower skin resistance results in deeper burns that are more likely to affect internal organs. Whether the skin is relatively dry or moist,

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electricity passes through high resistance skin tissue and then spreads through underlying tissues with lower resistance [11]. In humans, electro-thermal skin burns are characterised by being yellow-grey, depressed or with punctate areas with central necrosis, multiple or very deep at the points of contact [12]. These injuries are usually small in size over the body surface of the first contact (punctate) and are often only the beginning of a large, non-obvious deep tissue lesion, commonly referred to as the iceberg sign [13]. Cutaneous injuries often reproduce the shape of the conductor, especially when it is a metal object with a specific shape [14]. In livestock, the hair and its colouration make it difficult to observe electro-thermal burns, so the evaluation of this type of injuries can only be done post-mortem and at the sub-cutaneous level when the skin is removed.

In the livestock and meat industry, some equipment are used that administer electric shocks of varying intensity, voltage and frequency, such as electric batons or prods (to mobilize animals), and electric stunners (to produce loss of consciousness of the animals before exsanguination during slaughter procedures). Electric prods or batons deliver an electrical charge through two contact points, or electrodes attached to the end of a stick when pressed against the animal's body [15]. These devices typically deliver a low, non-incapacitating voltage; the electrical current passes primarily between the two electrodes, with current limited to the rest of the body. This causes pain and localized contraction of the underlying skeletal muscle and is commonly used on goats, sheep, cattle and pigs, although its use on horses is prohibited [16]. The use of the electric batons is very popular among livestock farmers, operators and slaughter house personnel because they consider them necessary to handle animals and because there is an idea that it does not cause tissue injuries [17]. Instead, electrical stunning is commonly used in small ruminants wherein an electric current is passed through the electrodes applied on the forehead of the animal to produce instantaneous insensibility by the induction of cardiac arrest and epileptic form of activity in the brain. Two types of electric stunners are commonly used for goats and sheep: head-only and head-to-body [18]. Both systems consist of an electrical control box to produce the appropriate supply and an electrode system to deliver current to the animal [19]. Used correctly with specialised equipment, electrical stunning is considered to be an effective and humane method because it induces an immediate loss of consciousness and allows painless slaughter [19].

The competitiveness of the meat industry depends to a large extent on the imposition of demanding schedules that have a direct impact on the handling, transport and slaughter of livestock [20]. In this sense, farmers, transporters and slaughterhouse operators are forced to handle a large number of animals in a short window of time, which particularly affects the quality of treatment given to the animals by the handlers [21]. Difficulty in moving livestock is a major source of frustration for handlers and appears to be responsible for much of the rough handling that occurs, particularly the use of electric prods [22]. It is therefore important to implement protocols based on the detection of characteristic injuries consistent with improper or malicious use of the various electrical equipment that may be used in pre-slaughter operations. Therefore, the aim of this article is to analyse four case reports showing patterns of subcutaneous electrothermal injuries on carcasses of domestic ruminants caused by use of different types of electrical equipment.

2. Cases reports

Four cases of electro-thermal injuries compatible with the use of electrical devices in domestic ruminants are presented, detected during several visits to authorized slaughterhouses as part of other studies in Mexico, Colombia and Spain. The reported cases were accumulated over the last 5 years. Unlike a traditional forensic examination, a slaughterhouse post-mortem examination has certain methodological and time constraints. This is due to the fact that carcasses are usually not kept in the slaughterhouse for more than 24 h, the impossibility of taking tissue samples in some slaughterhouses, the trimming of injuries (removal of evidence) and the conditions of the assessment (i.e. chain speed, interaction with operators, cold chambers). These limitations can be compensated for by: i) intensive inspections of the various links in the logistics chain to identify objects, subjects and risk practices; ii) consolidation of a high-quality photographic archive; and iii) use of slaughterhouse traceability systems, which can provide valuable logistical and operational information.

2.1. Carcass assessment methodology

The post-mortem carcass assessment was based on a protocol for the assessment of bruising in cattle by Strappini et al. [23], adapted to small ruminants. The carcasses were always evaluated by the same researcher. The carcasses of each reported case were examined between 30 min and 2 h post mortem (hot carcass) to avoid possible effects related to the transfer of red blood cells from the lesion to the surrounding tissues, as occurs in bruising [23]. However, in all cases the carcasses were re-observed and measured 24 h post-mortem if the size and appearance of the lesions did not change, allowing us to conclude that they were burns and not bruises. It is important to note that the presence of livores and other post-mortem phenomena associated with circulating blood during death, as seen in humans and animals [24], are usually not visible in slaughtered animals because they are bled immediately after stunning. The carcasses were divided into seven anatomical areas: 1 = head and neck, 2 = foreleg, 3 = thoracic and abdominal wall, 4 = hind leg, 5 = *tuber isquiadicum* and its muscular insertions (butt/pin), 6 = *tuber coxae* and its muscular insertions (hip), and 7 = loin. Where an electro-thermal lesion was present, it was compared with other lesions (e.g. bruises, injections) on the carcass, averaged, its location on the carcass and its characteristics (outline, colour and evidence of contact with the electrodes) were recorded. Other animals of the same origin were also examined for similar lesions. In addition, the facilities and equipment were inspected in order to try to associate the electrical instruments compatible with the electro-thermal lesion found. Each lesion present on the carcass was assessed by recording its anatomical location, size and severity. The size of the electro-thermal injury was assessed on the basis of its diameter, where bruises between 1 and 5 cm were considered small, those between 5 and less than 8 cm were considered medium, and those greater than 8 cm were considered large. As part of our research group's case collection methodology, each case is documented in a forensic template and another case analysis template developed by the Subspecialty in Animal Welfare Science, Ethics and Law (AWSEL) of the European College of Animal Welfare and Behavioural Medicine (ECAWBM).

2.2. Cases related to abusive use of electrical devices

In this subsection, we report the presence of electro-thermal subcutaneous injuries compatible with the misuse of electric batons (cases 1 and 2) and electric stunning device (case 3). These three cases are compatible with injuries affecting animal welfare because they cause pain and suffering during the pre-slaughter operations (i.e. during loading at the farm, transport, unloading at the abattoir and slaughter).

2.2.1. Case 1

This case was detected during the monitoring and study of a journey from northern to central Mexico (1250 km of journey) in a pot-belly truck with 500 heavy hair lambs (40–50 kg live weight). Throughout the loading operations at origin (assembly centre), we found that the handlers were especially violent in handling and indiscriminately used two electric batons (a large one recommended for cattle and a smaller one for pigs) to speed up the weighing and loading of the animals into the truck. The journey lasted 21 h, with 3 h loading, 17 h driving (with a 40-min stop for rest and driver change) and 40 min unloading. Upon arrival at the abattoir, the animals were quietly unloaded without the

use of electric batons or sticks. After 16 h of rest in the pre-slaughter holding area (with access to water and feed upon arrival), the lambs were taken to the mechanical stunning and bleeding area. At the time of inspection in the cold chamber, we found a carcase with lesions compatible with 4 linear bruises caused by blows with a blunt object (Fig. 1, a). However, in a lamb carcass catalogued without bruises (due to the small size of the injuries), subcutaneous injuries were found in pairs in the dorsal-lumbar region; they were macular, erythematous, rounded, between 2 and 5 mm, well circumscribed, with central puncture, separated by about 4 cm (Fig. 1, b). From the arrangement of the injuries in pairs and the distance between the punctate injuries clearly differentiated by the use of a large and a small baton, it could be established that they were compatible with thermo-electrical injuries produced by the two electrodes present in the two electric batons used (Fig. 1, c, d, e). It is estimated that the subcutaneous damage was inflicted between 33 and 36 h before the animal was slaughtered at the local slaughterhouse. Commercially available electric cattle prods are usually battery-powered and discharge relatively high-voltage currents of between 3000 and 5000 volts. The use of electric batons is usually indicated only in the following cases: a) the animals have enough space to move; b) when the animals are not moving (balking); c) the physical integrity of the operator is at risk; and d) if other methods have already been used and have failed. Manufacturers warn that they should not be used on the eyes, muzzle, ears, anus, genitals or belly, being the hock region the most indicated due to its poor vascularization and musculature. Some manufacturers have fungiform electrodes to avoid carcass injuries, although the device reported in our study are circular electrodes.

2.2.2. Case 2

During a visit to a Colombian slaughterhouse, we found a handmade electric baton at the entrance area of the stunning box, which consisted of a metal rod at one end inside a polyvinyl chloride or PVC insulator, connected at one end to a cable that fed a 20 V truck battery and at the other end to an electrode consisting of a washer and a hexagonal head screw (Fig. 2, a). The corridor had a water spray system to attenuate the effect of the heat on the animals and to shower them before slaughter, although this also improved the current conductivity of the handmade device. The handler told us that the device was used to prevent two animals from entering the stunning box at once, as the long corridor made it difficult to contain the animals from running in groups. Handlers were positioned on one side of the aisle in an adjoining elevated area, which allowed them to restrain animals using the handmade device and also to move them by administering direct current to the hocks when they refused to move. At the time of inspection in the cold chambers, we did not find any carcasses with lesions on the hocks, but we did find lesions in the shoulder-elbow area. These lesions were compatible with bruising caused by blows from a blunt object, probably a stick (Fig. 2, b).

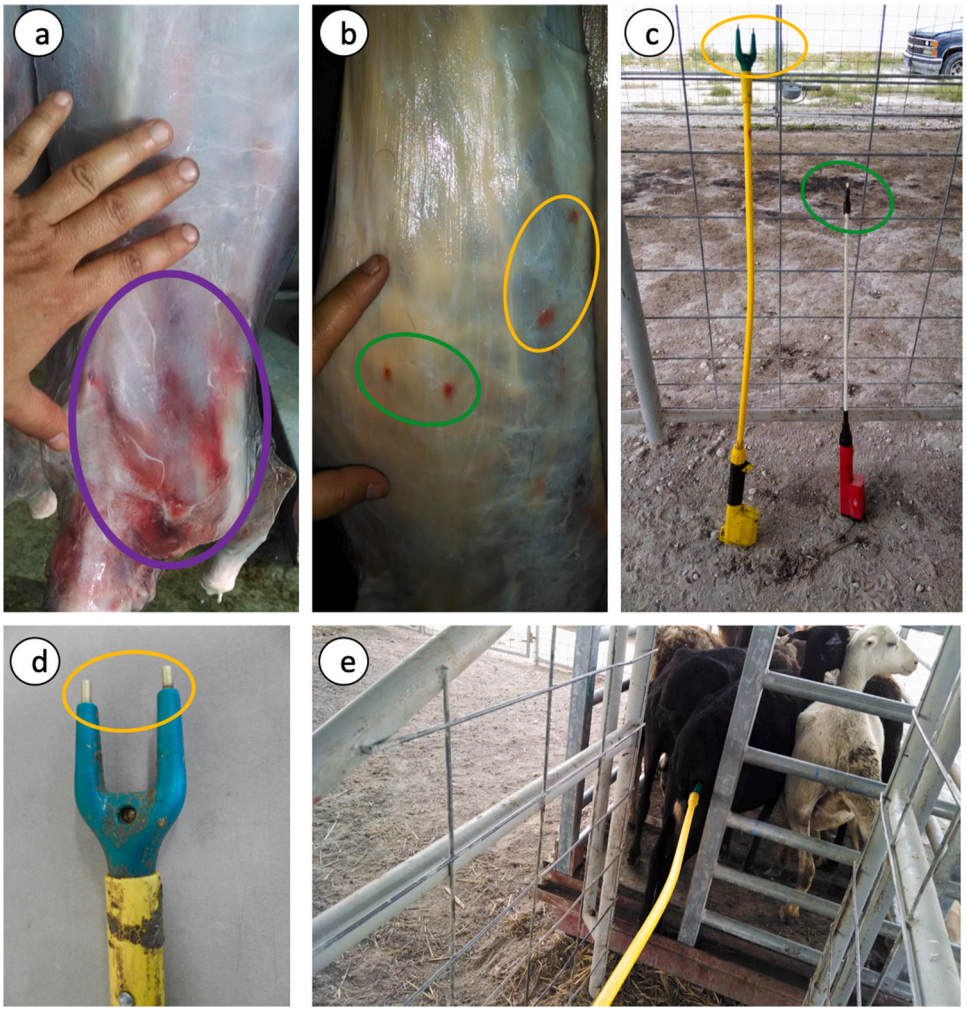

Fig. 1. Case 1: Differential diagnosis of lesions on the dorsal region between two sheep carcasses: (a) four bruises (purple circle) caused by blunt trauma during pre-slaughter handling; (b) two pairs of electrical lesions compatible in shape and distance with the electrodes of the two electric poles used, the large one recommended for cattle (yellow circle) and the small one specific for sheep (green circle); (c) the two electric prods used to unload the hair lambs; (d) the electrodes of the electric prod used for cattle; and (e) graphic evidence of the use of the electric prods used to load the animals at origin.

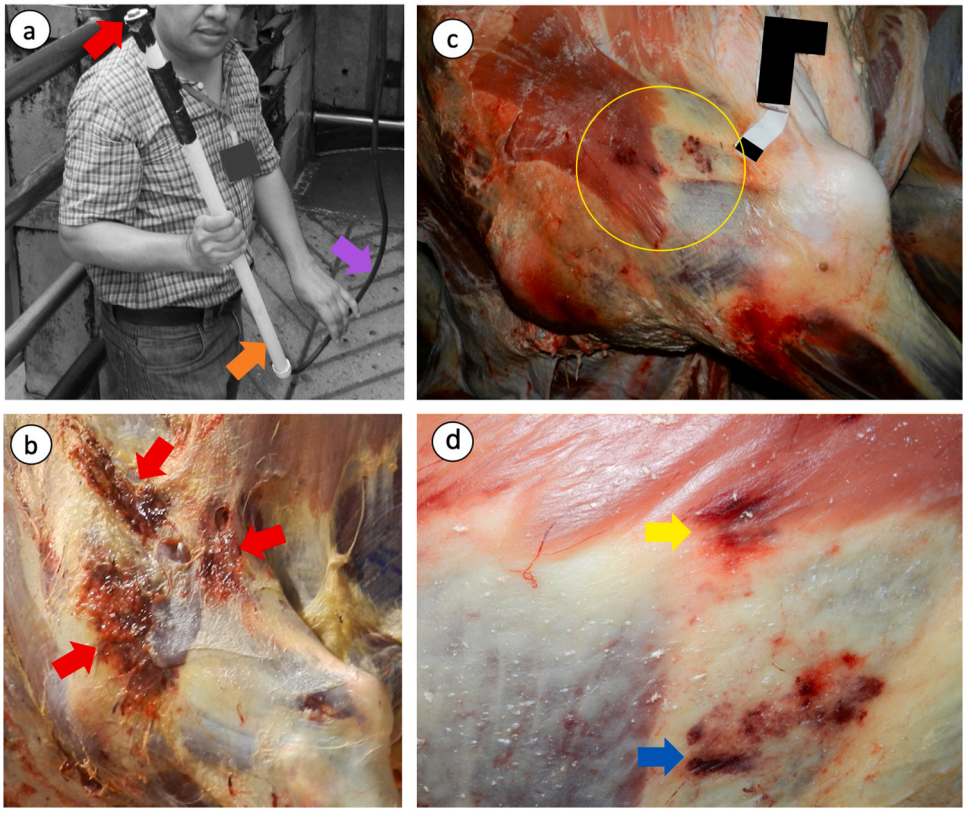

Fig. 2. Case 2: Differential diagnosis of lesions in the shoulder-elbow region between two carcasses: (a) three bruises (red arrows) caused by projections or blows during pre-slaughter operations; (b) four thermoelectric lesions (yellow circle); (c) Handmade electric baton based on a metal rod at one end inside a polyvinyl chloride or PVC insulator (orange arrow), connected at one end to a cable (purple arrow) feeding a 20 V truck battery and at the other end to an electrode consisting of a washer and a hexagon head screw (red arrow); and (d) Note the electric injuries (yellow arrow) and the thermal injuries (blue arrow).

However, one carcass had 4 lesions compatible with the use of the handmade electric baton described by the handler.Each lesion was characterised by a variation between erythematous subcutaneous injuries due to electrical contact and thermal injuries, both resulting from inhomogeneous contact of the electrode on the skin and hair, perhaps due to a bad design of the device (Fig. 2, c, d). The handlers and operators were convinced that the electric current had no consequences on the carcass, although they reported that the device was a bit unsafe for them, especially on days when many animals are slaughtered. The photographs of the injuries were quite shocking to them and have been used in subsequent trainings to stop the use of these types of handmade devices, and replace them with the more welfare friendly methods (i.e. flags). Except in export slaughterhouses, such devices are relatively common in beef slaughterhouses in Colombia, although their use is being phased out due to new, stricter animal welfare standards starting in 2021.

2.2.3. *Case 3*

As part of a study to validate post-mortem indicators in a slaughterhouse in Spain, we made several visits to evaluate carcasses of light lambs. The animals were moved from the waiting aisle to the stunning area by herding, then the operator (using an electric head stunner with water spray) stunned them. Then they were slaughtered and incorporated into the chain to begin the process of bleeding, evisceration, skin

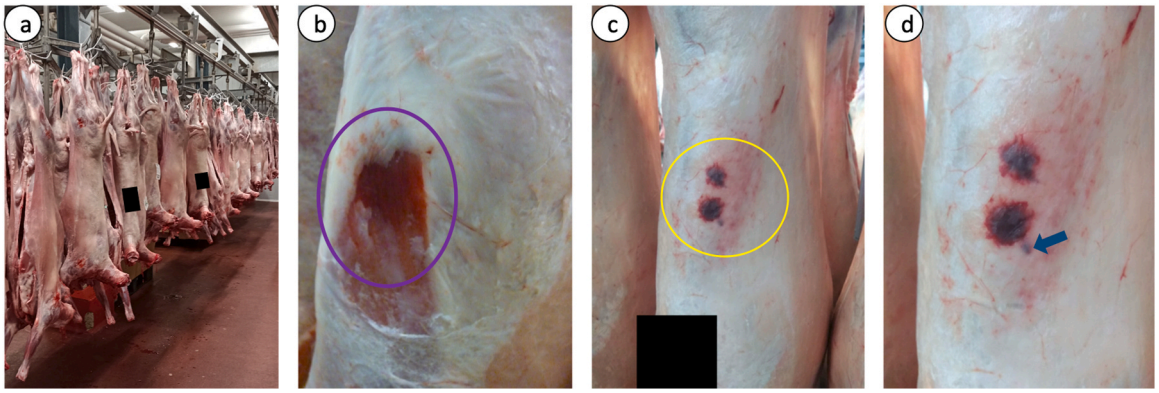

Fig. 3. Case 3: Differential diagnosis of lesions in the loin region in two carcasses: (a) carcasses evaluated in the cold chamber; (b) the first with a bruise from blunt trauma (purple circle); (c) the second with a pair of concentric circular electrothermal lesions compatible with the electrodes of an electric stunner (yellow circle); and (d) with the surrounding area visibly inflamed and hyperemic and the presence of a peripheral thrombus (blue arrow).

removal and obtaining the carcass. Once the carcasses were sent to the cooling chamber (Fig. 3, a), the animals were evaluated in terms of bruises with the protocol described in **Section 2.1** . Only two carcasses were found with injuries out of the 50 carcasses evaluated. The first carcass examined had a bruise compatible with trauma caused by a blow with or against a blunt object (Fig. 3, b); this injury was used to establish the differential diagnosis in comparison with the other carcass with injuries. The second carcass examined had two concentric injuries (each with a diameter of approximately 2.5 cm) with coagulative necrosis of tissue in the dorsal-lumbar region (each one depressed internaly and surrounded by a ring in the periphery) and the surrounding tissue was inflamed and hyperemic (Fig. 3, c, d), both lesions are consistent with thermoelectric burns. In this slaughterhouse and on farms in the region, no electric batons are used due to European Union Protected Geographical Indications (PGI) standards, but both burns appeared to have been inflicted simultaneously and apart from each other (the distance between the two lesions was no more than 1.5 cm). In appearance they coincide with the electrical stunning device. As in Case 4, we were unable to witness the stunning operations. These injuries, however, appear to be abusive since they are distant from the head and correspond to a sustained administration of current on a high resistance tissue (dry skin and wool) that concentrates thermal energy and results in the burns reported in this case.

2.2.4. Legal implications

The use of electric prods or batons has been tolerated at the international regulatory level, although recently the legislation of many countries has begun to limit their use to certain species or specific circumstances (i.e. when no other method of handling works) or to prohibit their use by stages in the production chain (i.e. farm and/or transport and/or slaughterhouse), as recommended by the World Organisation for Animal Health [25]. The European Union is a world reference in animal welfare legislation, which in the case of electric prods during transport is regulated by Council Regulation (EC) No 1/2005 of 22 December 2004 (Article 35), which authorises the use of electric prods on adult cattle and pigs only if the animals *"refuse to move and only if they have space in front of them to move forward"* and *"shocks shall not last more than one second, shall be appropriately spaced and shall be applied only to the muscles of the hindquarters"* [26]. In the case of the Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing, Article 15 prohibits their use for all species in the slaughterhouse [27]. In Case 1, the electro-thermal injuries found on the sheep carcass show non-compliance with the Mexican official standard NOM-051-ZOO-1995 on the humane treatment of animals during transport, which prohibits the use of these devices on sheep, goats and horses [28]. In addition, NOM-033-SAG/ZOO-2014 on slaughterhouse handling prohibits their use on horses, sheep, goats, pigs and calves, but not on adult cattle [29]. In Case 2, injuries to the cattle carcass compatible with the use of a handheld electrical baton in the slaughterhouse are not yet prohibited. However, recent Colombian legislation prohibits their use on the farm Resolution 253 of 2020 [30] and during transport Resolution 20223040006915 of 2022 [31]. While Case 3, shows that electro-thermal injuries are compatible with the prohibited use of the stunner, the EU Regulation on the Protection of Animals at the Time of Slaughter (EC No 1099/2009 of 24 September 2009) prohibits in Article 15 *"the use of electrical currents that do not stun or kill animals under controlled conditions for the purpose of immobilization, in particular any application of electrical current that does not affect the brain"*. Furthermore, in Annex I on stunning methods (Chapter 1), on electrical methods states in the key points that *"electric shocks shall be avoided before stunning"* [27].

2.3. Case related to macroscopic evidences of electrical stunning

In this subsection, we report only one case (Case 4) corresponding to the presence of subcutaneous injuries in the skull rostral area of several electrically stunned kids. This case did not have a direct impact on the welfare of the animals, as they were stunned immediately before slaughter. However, the detection of these injuries can be an indicator of the quality of the stunning procedures in terms of conductivity and frequency of shocks. Contrary to the previous section, this case does not correspond to an abusive use of the equipment, although the prevalence of these electro-thermal injuries can be used to evaluate the percentage of animals with injuries, similar to what is done in mechanical stunning audits in cattle.

2.3.1. Case 4

In the south of Spain, the consumption of kids and suckling lambs (30-day-old lambs) throughout the year is a well-established tradition . However, in the north of the country it is possible to find these animals at the slaughterhouse specially during the Christmas season, because the rest of the year light lambs (between 60 and 90 days old) are consumed. Unlike the carcasses of light lambs, the carcasses of suckling lambs include the head as a distinguishing feature for easy identification by consumers. The handling of suckling lambs is usually calm and efficient due to their young age, as well as their commercial value, and carcass bruising is rare. In a study to validate post-mortem indicators in a slaughterhouse in northern Spain, we carried out two visits to evaluate small ruminant carcasses. The animals passed from the waiting aisle to the stunning area using an automated restrainer where they were stunned with a head-to-back stunning devicewith water spray (Fig. 4, a) and then their throats were slit and they were incorporated into the chain to begin the process of bleeding, evisceration, skin removal and obtaining the carcass.

During the first visit (early December) we found 6 carcasses of kids (evidence of antlers, small presence of hair, concave rostral profiles and small triangular tails; which are characteristic of the species and local goat's breeds), without any injuries on the head (Fig. 4, b, c) or the rest of the carcass. On the second visit (21 December), we found 8 carcasses of kids and 3 of lambs (acorns, wool remains, convex rostral profiles and long tails; which are characteristic of the species and local sheep breeds), all of them with injuries on the rostral part of the head at the level of the frontal bone, and no injuries on the carcass (Fig. 4, d). The subcutaneous injuries were haemorrhagic, linear in shape, 8 cm long and 1.5 cm wide, with a dark red colouration in the middle, suggesting the existence of clots and thrombi, which are compatible in size and distance between electrodes with the electric stunner used in the slaughterhouse (Fig. 4, e, f). Most modern stunning equipment operates at power ratings above 200 V, and for kids and lambs it is recommended to apply a current of 1.0 A for at least three seconds [19]. This type of device combines two electrodes with a water spray system to help reduce contact resistance and improve current flow. In addition, they decrease the likelihood of damaging the animal's skin by reducing the heating effect of the current at the back-electrode site [19].

2.3.2. Legal implications

The Spanish legislation to regulate the slaughter of farm animals in terms of animal welfare is Royal Decree 37/2014, from 24 January 2014 [32]. This decree aims to facilitate the application of European Union legislation EC No. 1099/2009, from 24 September 2009. Annex I of this decree defines the authorized stunning systems, which include two electrical methods applicable to goats and sheep: stunning limited to the head and stunning by means of electric shock to the head and trunk. In Case 4, the electro-thermal injuries found in the rostral area of the kid are compatible with the lack of control of the key points indicated in Annex I (Chapter 1) of electrical stunning methods, where one of the key parameters that must always be considered in this type of procedure and in Chapter 2, the minimum current to be used is 1 A for goats and sheep [27].

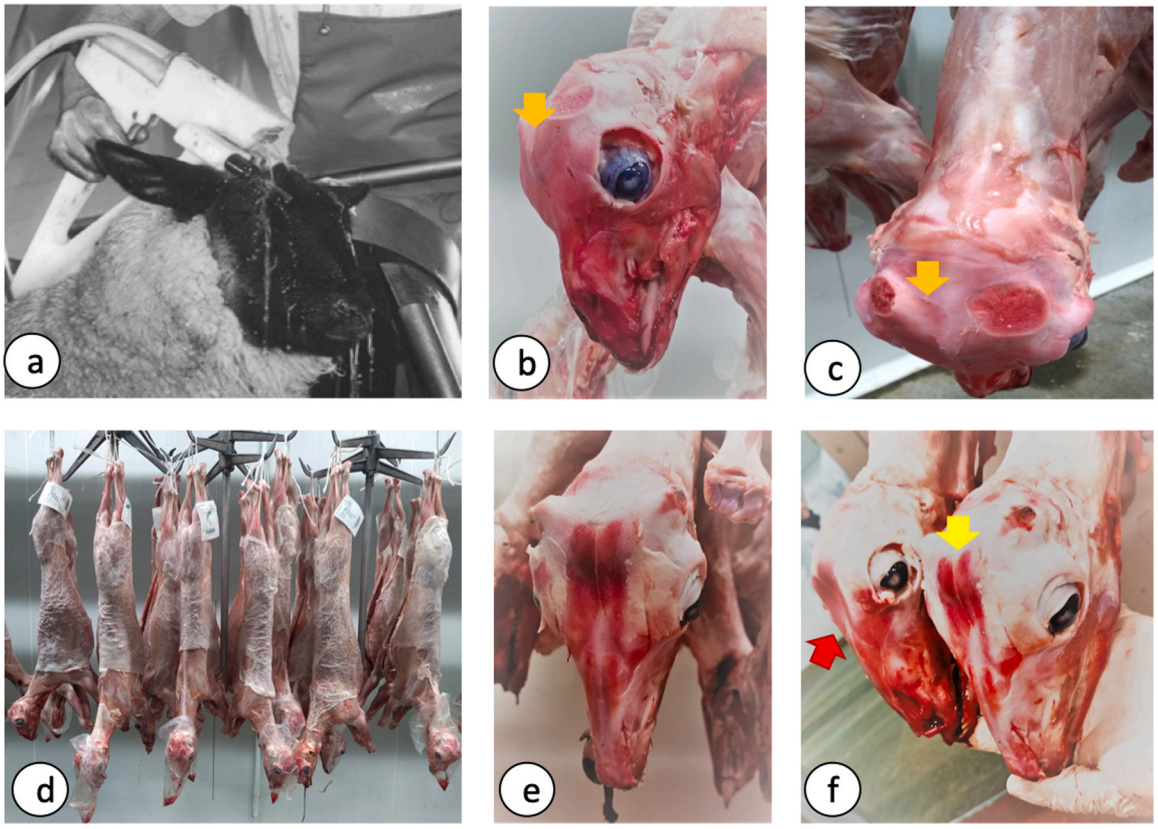

Fig. 4. Case 4: (a) Operation of the head-to-back electric stunner, note the correct positioning of the electrodes and water spray during stunning procedure (photograph from the Humane Slaughter Association, [18]); (b, c) electrically stunned kid with no apparent injuries (orange arrow); (d) carcasses evaluated in the cold chamber; (e) kid with a couple of thermo-electrical lesions compatible with the electrodes of the electrical stunner (yellow arrow) on the rostral surface in the area of the temporal bone; and f) lamb (red arrow) and kid (yellow arrow) with rostral thermo-electrical lesions attributed to electrical stunning mark.

3. Discussion

Animal welfare science is rapidly emerging as a distinct branch of veterinary medicine, particularly due to the increasing awareness of animal suffering [33]. Most forensic evidence regarding the human-animal relationship has been reported in companion animals (i.e. [34]) or farm animals (i.e. [35]), particularly in criminal cases. However, although it is assumed that pre-slaughter handling of farm animals can be rough and cause bruising, there is little forensic evidence to distinguish between the different causes of accidental, negligent or abusive handling injuries [36]. In this context, our case reports highlight two important aspects of forensic veterinary practice at the abattoir level. The first, which relates to the detection of abusive or negligent use of specific electrical equipment, can be demonstrated by post-mortem inspection of carcasses by detecting characteristic patterns and shapes of subcutaneous electro-thermal injuries. The second is to establish a differential diagnosis between electro-thermal injuries and bruising caused by handling.

3.1. Electric batons

Commercial electric cattle batons have been available worldwide since 1939 (the first brand was Hot-Shot®) for use on farms and in abattoirs [37]. Although there is no obvious basic design, the operating principles are common to all models [38]. Electric batons have been developed for the primary purpose of causing pain to animals and humans to control their behaviour. Part of the experience of pain is because they stimulate primary afferent nociceptors, which are a group of specialised cells that terminate in the skin and signal different forms and intensity of pain to the brain [37]. Since the 1960 s, the use of the electric cattle batons has become widespread among police, military and paramilitary forces around the world [10]. In fact, forensic reports of evidence of injuries caused by these devices are from human torture cases (children, [39]; adults, [16]). In animals, they have only been reported at the experimental level [14], but not under farm or slaughterhouse conditions. In this sense, our cases show clear and objective evidence of injuries caused by these devices, in order to detect misuse of these devices. Several studies have shown that the use of electric batons on cattle is inefficient and increases anxiety and fear in animals, resulting in attempts to escape, jump and fall [40,41]. Some meat-exporting countries (e.g. Argentina, Canada) have regulations or standards governing their efficacy, how they are used and in which species (e.g. European Union). Although there are no restrictions on their sale, there are in fact a large number of brands and models available for purchase on-line. It is striking, however, that in the case of popular sticks (including the brands mentioned in this report), the power and capacity specifications are omitted from the list of electrical equipment for sale online. In the case of hand-made devices, they are also very heterogeneous in terms of design and capacity and, unlike factory-made electric batons, pose an important risk to users.

3.2. Electric stunners

Electric stunning was first used commercially on pigs at the beginning of the last century and became widespread from 1930 onwards [42]. Its popularity as a method of stunning and/or slaughter is due to its effectiveness in producing immediate unconsciousness, its ease of use and its economic viability [43]. The administration of electric current causes the secretion of greater amounts of epinephrine than a typical environmental stressor [44]. The increased epinephrine is not perceive

by an unconscious animal, but an inappropriately stunned animal will have an increased heart rate, feel pain, anxiety, stress and fear during the procedure [45]. It can also cause electro-thermal burns (thermal necrosis) to the skin if contact is made by a puncture-shaped electrode, although if the electrode has a larger contact area it will not cause visible skin injuries [7]. However, Case 4 shows that this is not necessarily true and that there are other factors to consider such as the contact time with the electrode, the pressure of the electrode on the skin and adequate wetting of the frontal and temporal areas of the head during the procedure. Miranda-de la Lama et al. [46], found that lambs had a higher prevalence of carcass bruising during the winter season; the authors attributed this difference to an increase in the number of animals slaughtered due to the high demand for these meats at Christmas, to the detriment of the quality of animal handling. Although we were not present during the stunning procedures, it is possible to infer that the stunning of these animals was done with a poor flow of water by stunner system, which increased tissue resistance and caused the thermo-electrical injuries described. Another possible explanation is that the current used was inappropriate, using a current for light lambs and not for suckling animals. It is possible that this has happened in this case. Finally, the puncture electro-thermal injures in Case 3 demonstrate the potential for subcutaneous damage that can be inflicted on lambs by careless use of stunning equipment. Both cases provide important evidence to be used in the training of operators correct and responsible for stunning.

4. Conclusions

The present report shows that it is possible to detect cases of misuse, neglect or abuse of electric batons in domestic ruminants at the post-mortem level. It is clear that the use of electrical batons needs to be effectively regulated in use and specification, although they should be phased out because of their ability to cause subcutaneous damage. While stunning equipment is an essential tool for humane slaughter, our cases demonstrate the need to monitor their use in abattoirs to avoid accidents or inappropriate use. Our report shows that it is possible to distinguish macroscopically between bruising and electro-thermal injury. This differentiation may help to identify operational problems, neglect and/or mistreatment of animals in the pre-slaughter chain, with the aim of improving handling practices, awareness and operator training.

Ethical approval

No live animals were used in this study.

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CRediT authorship contribution statement

Genaro C. Miranda-de la Lama: Conceptualization, Methodology, Validation, Investigation, Writing- Original draft preparation, Visualization, Supervision, Writing- Reviewing and Editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] N. Losada-Espinosa, L.X. Estévez-Moreno, M. Bautista-Fernández, F. Galindo, A.Z. M. Salem, G.C. Miranda-de la Lama, Cattle welfare assessment at the slaughterhouse level: Integrated risk profiles based on the animal's origin, pre-slaughter logistics, and iceberg indicators, Prev. Vet. Med. 197 (2021) 105513, https://doi.org/10.1016/j.prevetmed.2021.105513.

[2] K. Barington, K. Skovgaard, N.L. Henriksen, H.E. Jensen, Optimising the sampling procedure for forensic investigation of bruises on pigs, 153–153, Vet. Rec. 187 (2020), https://doi.org/10.1136/vr.105625.

[3] G.C. Miranda-de la Lama, C.A. González-Castro, F.J. Gutiérrez-Piña, M. Villarroel, G.A. Maria, L.X. Estévez-Moreno, Horse welfare at slaughter: A novel approach to analyse bruised carcasses based on severity, damage patterns and their association with pre-slaughter risk factors, Meat Sci. 172 (2021) 108341, https://doi.org/10.1016/j.meatsci.2020.108341.

[4] T. Sawaguchi, B. Jasani, M. Kobayashi, B. Knight, Post-mortem analysis of apoptotic changes associated with human skin bruises, Forensic Sci. Int. 108 (2000) 187–203, https://doi.org/10.1016/S0379-0738(99)00210-8.

[5] A.C. Strappini, K. Frankena, J.H.M. Metz, B. Gallo, B. Kemp, Prevalence and risk factors for bruises in Chilean bovine carcasses, Meat Sci. 86 (2010) 859–864, https://doi.org/10.1016/j.meatsci.2010.07.010.

[6] M.H. Romero, L.F. Uribe-Velásquez, J.A. Sánchez, G.C. Miranda-de la Lama, Risk factors influencing bruising and high muscle pH in Colombian cattle carcasses due to transport and pre-slaughter operations, Meat Sci. 95 (2013) 256–263, https://doi.org/10.1016/j.meatsci.2013.05.014.

[7] J. Husheer, M. Luepke, P. Dziallas, K.-H. Waldmann, A. von Altrock, Electrocution as an alternative euthanasia method to blunt force trauma to the head followed by exsanguination for non-viable piglets, Acta Vet. Scand. 62 (2020) 67, https://doi.org/10.1186/s13028-020-00565-9.

[8] B. Becour, Conducted electrical weapons or stun guns: a review of 46 cases examined in casualty, Am. J. Forensic Med. Pathol. 34 (2013) 142, https://doi.org/10.1097/PAF.0b013e31828873d6.

[9] C. Schulze, W. Peters, P. Baumgärtner, P. Wohlsein, Electrical injuries in animals: causes, pathogenesis, and morphological findings, Vet. Pathol. 53 (2016) 1018–1029, https://doi.org/10.1177/0300985816643371.

[10] N.S. Dhaniwala, D. Swapnil, M.N. Dhaniwala, Effects of electrical injury on musculoskeletal system: a case report, MOJ Orthop. Rheumatol. 11 (2019) 160–162, https://doi.org/10.15406/mojor.2019.11.00493.

[11] D. Dechent, T. Emonds, D. Stunder, K. Schmiedchen, T. Kraus, S. Driessen, Direct current electrical injuries: a systematic review of case reports and case series, Burns 46 (2020) 267–278, https://doi.org/10.1016/j.burns.2018.11.020.

[12] R.M. Fish, Electric injury, part I: treatment priorities, subtle diagnostic factors, and burns, J. Emerg. Med. 17 (1999) 977–983, https://doi.org/10.1016/S0736-4679(99)00127-4.

[13] Y. Najmi, P. Kumar, A retrospective analysis of electric burn patients admitted in King Fahad Central Hospital, Jizan, Saudi Arabia, Burns Open 3 (2019) 56–61, https://doi.org/10.1016/j.burnso.2018.12.002.

[14] L. Danielsen, H.K. Thomsen, O. Nielsen, O. Aalund, K.G. Nielsen, T. Karlsmark, I. K. Genefke, Electrical and thermal injuries in pig skin — evaluated and compared by light microscopy, Forensic Sci. Int. 12 (1978) 211–225, https://doi.org/10.1016/0379-0738(78)90006-3.

[15] H. Hillman, Electrical devices used by prison officers, police and security forces, Med., Confl. Surviv. 19 (2003) 197–204, https://doi.org/10.1080/13623690308409691.

[16] C. Liu, J. Weintraub, M.E. Kakalis, Torture by administration of electric shocks: The case of PG, Torture J. 31 (2021) 113–116, https://doi.org/10.7146/torture.v32i3.129471.

[17] D. Gellatly, D.M. Meléndez, S. Marti, D. Moya, X. Yang, J.S. Church, K. S. Schwartzkopf-Genswein, 319 Effects of repeated exposure to either energized or non-energized prods on the behavioral responses of beef cattle to handlin, J. Anim. Sci. 97 (2019), 7–7.

[18] M. Kiran, B.M. Naveena, M. Smrutirekha, P. Baswa Reddy, B. Rituparna, Y. Praveen Kumar, S. Ch. Venkatesh, Rapole, Traditional halal slaughter without stunning versus slaughter with electrical stunning of sheep (Ovis aries, Meat Sci. 148 (2019) 127–136, https://doi.org/10.1016/j.meatsci.2018.10.011.

[19] HSA, Electrical Stunning of Red Meat Animals, , 2016. ⟨https://www.hsa.org.uk/downloads/publications/electricalstunningdownload-updated-2016-logo.pdf⟩ (Accessed January 24, 2023).

[20] G.C. Miranda-de La Lama, M. Villarroel, G.A. María, Livestock transport from the perspective of the pre-slaughter logistic chain: a review, Meat Sci. 98 (2014) 9–20, https://doi.org/10.1016/j.meatsci.2014.04.005.

[21] N. Losada-Espinosa, G.C. Miranda-De la Lama, L.X. Estévez-Moreno, Stockpeople and animal welfare: compatibilities, contradictions, and unresolved ethical dilemmas, J. Agric. Environ. Ethics 33 (2020) 71–92, https://doi.org/10.1007/s10806-019-09813-z.

[22] M. Dokmanović, A. Velarde, V. Tomović, N. Glamočlija, R. Marković, J. Janjić, M.Ž. Baltić, The effects of lairage time and handling procedure prior to slaughter on stress and meat quality parameters in pigs, Meat Sci. 98 (2014) 220–226, https://doi.org/10.1016/j.meatsci.2014.06.003.

[23] A.C. Strappini, J.H.M. Metz, C. Gallo, K. Frankena, R. Vargas, I. De Freslon, B. Kemp, Bruises in culled cows: when, where and how are they inflicted? Animal 7 (2013) 485–491, https://doi.org/10.1017/S1751731112001863.

[24] S. Niederegger, J. Schermer, J. Höfig, G. Mall, Case report: Time of death estimation of a buried body by modeling a decomposition matrix for a pig carcass, Leg. Med. 17 (2015) 34–38, https://doi.org/10.1016/j.legalmed.2014.08.007.

[25] WOAH. Terrestrial Animal Health Code. Section 7 - Animal Welfare, 29th ed..,, World Organization for Animal Health,, Paris, France, 2021. ⟨https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/⟩ (accessed August 28, 2023).

[26] European Union, Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97. Official Journal of the European Union, L276., n.d.
[27] European Union, Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing. Official Journal of the European Union, 303, 1–30., n.d.
[28] NOM, NOM-051-ZOO-1995, Trato humanitario en la movilización de animales, n. d. https://www.gob.mx/senasica/documentos/nom-051-zoo-1995.
[29] NOM, NOM-033-SAGZOO-2014. Métodos para dar muerte a los animales domésticos y silvestres. Norma Oficial Mexicana, n.d. https://www.gob.mx/profepa/documentos/norma-oficial-mexicana-nom-033-sag-zoo-2014-metodos-para-darmuerte- a-los-animales-domesticos-y-silvestres.
[30] Diario Oficial, Resolución 253 de 2020. Por la cual se adopta el Manual de Condiciones de Bienestar Animal propias de cada una de las especies de producción del sector agropecuario: bovina, bufalina, aves de corral y animales acuáticos. Ministerio de Agricultura y Desarrollo Rural. Republica de Colombia., n.d.
[31] Diario Oficial, Resolución 20223040006915 de 2022. Por la cual se adopta el Manual de Procedimientos para el Transporte, manejo y movilización de Animales en Pie y se dictan otras disposiciones. Ministerio de Transporte - Instituto Colombiano Agropecuario – ICA. Republica de Colombia., n.d.
[32] BOE, Real Decreto 37/2014, de 24 de enero, por el que se regulan aspectos relativos a la protección de los animales en el momento de la matanza. Boletín Oficial del Estado BOE 2014, 28. 7178–7183, n.d.
[33] N.M.A. Parry, A. Stoll, The rise of veterinary forensics, Forensic Sci. Int. 306 (2020) 110069, https://doi.org/10.1016/j.forsciint.2019.110069.
[34] F.A. Salvagni, A. de Siqueira, A.R. Fukushima, M.F. de A. Landi, H. Ponge-Ferreira, P.C. Maiorka, Animal serial killing: The first criminal conviction for animal cruelty in Brazil, Forensic Sci. Int. 267 (2016) e1–e5, https://doi.org/10.1016/j.forsciint.2016.08.033.
[35] R.J. Blundell, Peter Richards-Rios, The forensic pathology of the sexual abuse of a group of chickens, J. Comp. Pathol. 199 (2022) 75–80, https://doi.org/10.1016/j.jcpa.2022.09.010.
[36] K. Barington, T.B. Nielsen, R.S. Andersen, H.E. Jensen, Forensic necropsies of cattle: a study of Danish cases from 2010 to 2021 and a guideline for forensic examination of cattle, J. Comp. Pathol. 201 (2023) 57–62, https://doi.org/10.1016/j.jcpa.2022.12.012.
[37] T.L. Whiting, Pain in human and non-human animals caused by electricity, Can. Vet. J. 57 (2016) 883–886.
[38] M.N. Robinson, C.G. Brooks, G.D. Renshaw, Electric shock devices and their effects on the human body, Med Sci. Law 30 (1990) 285–300, https://doi.org/10.1177/106002809003000403.
[39] A. Frechette, M.E. Rimsza, Stun gun injury: a new presentation of the battered child syndrome, Pediatrics 89 (1992) 898–901.
[40] E.A. Pajor, J. Rushen, A.M.B. de Passillé, Aversion learning techniques to evaluate dairy cattle handling practices, Appl. Anim. Behav. Sci. 69 (2000) 89–102, https://doi.org/10.1016/S0168-1591(00)00119-2.
[41] J.J. Mcglone, R.L. Mcpherson, D.L. Anderson, Moving Devices for Finishing Pigs: Efficacy of Electric Prod, Board, Paddle, or Flag, Prof. Anim. Sci. 20 (2004) 518–523, https://doi.org/10.15232/S1080-7446(15)31357-7.
[42] E. Lambooy, Electrical stunning of sheep, Meat Sci. 6 (1982) 123–135.
[43] M. Müller, The electric stunning of pigs from the standpoint of the meat industry and animal protection, 451.e1-454, Vet. J. (1900) 88 (1932), https://doi.org/10.1016/S0372-5545(17)39616-5.
[44] R. Warrington, Electrical stunning: a review of the literature, Vet. Bull. 44 (1974) 617–635.
[45] A.Z. Zivotofsky, R.D. Strous, A perspective on the electrical stunning of animals: are there lessons to be learned from human electro-convulsive therapy (ECT)? Meat Sci. 90 (2012) 956–961, https://doi.org/10.1016/j.meatsci.2011.11.039.
[46] G.C. Miranda-de la Lama, L. Rivero, G. Chacón, S. Garcia-Belenguer, M. Villarroel, G.A. Maria, Effect of the pre-slaughter logistic chain on some indicators of welfare in lambs, Livest. Sci. 128 (2010) 52–59, https://doi.org/10.1016/j.livsci.2009.10.013.