Risk factors infuencing bruising and high muscle pH in Colombian cattle carcasses due to transport and pre-slaughter operations

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Abstract

The aim of this study was investigate risk factors as possible causes for bruising and high muscle pH under commercial operating conditions in Colombia. Data was recorded for 86 journeys referring to 1179 animals. Carcasses were analyzed in terms of muscle pH and bruises (site, size, severity and shape). Our results indi-cate that truck load density, stops during transportation of cattle and the lairage time at the plant increased the risk of bruises appearing on carcasses. A lairage time of 18 to 2 h at the plant increased the prevalence of bruises 2.1 times compared to lairage periods of between 12 and 18 h. Furthermore, intermittent stops during transit are a risk factor for the increase in the incidence of bruises. However, the transport time (up to h) was not related to the presence of bruises and high muscle pH. Finally, steers were found to have less risk of presenting a high muscle pH.

*Keywords:*Transport; Pre-slaughter operations Bruises; Higher muscle pH ebu cattle; Colombia

1. Introduction

Animal transport and pre-slaughter operations are an essential component of the farming industries (Ljungberg, Gebresenbet, & Aradom, 2007). Particularly in the case of cattle, widespread, exten-sive pasture-based systems result in the need to move animals to central points, whether for sale or slaughter. Livestock may be transported within properties, between properties, and between a property and sale yard, abattoir, feedlot, and pre-export assembly depot (Fisher, Colditz, Lee, & Ferguson, 2009). Transport and pre-slaughter conditions may vary according to the way in which the animals are sold. Some cattle are sold and shipped directly from the farm to the slaughter plant, minimizing the effect of operating procedures. Others are sold through private dealers who have their own facilities for handling and transporting animals from the farm or market to the slaughterhouse (Schwartzkopf-Genswein et al., 2012). Animals are also sold at live auction markets, which involves longer transport times, loading and unloading, and multiple handling procedures, and the likely mixing with unfamiliar animals (Weeks, McNally, & Warris, 2002).

Handling and transport are stressful for the animals and have implications for their welfare. Along with ethical aspects, humane treatment of animals throughout the production chain is an important component in the uality and safety of meat (Lambooij, vander Werf, Reimert, & Hindle, 2012). Improper handling and transportation are also responsible for stress-induced meat uality problems, such as shrinkage of the carcass, higher pH, DFD meat and damage to the carcass through bruising (Chandra & Das, 2001). A bruise is a focal discoloration of the carcass surface, caused by an extra-vascular collection of blood, following trauma to the body by the impact of a blunt instrument (Capper, 2001). 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 inef ciency and neglect within a pre-slaughter chain (Strappini, Frankena, Metz, Gallo, & emp, 2010). Ef cient detection of carcass bruising can be used as a tool in the evaluation of a program of critical control points (Miranda-de la Lama et al., 2009).

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Transportation and the associated increase in handling are neces-sary components of the Colombian beef production chain. Beef production in Colombia is largely extensive and primarily based on Bos indicus and Bos taurus B. indicus cattle, where B. indicus is repre-sented by Commercial ebu and Brahman cattle, and B. taurus breeds are Angus, Senepol, Simmental, and local breeds (Blanco Orejinegro, Romosinuano, and Sanmartinero) (Vergara, Elzo, & Ceron-Mu oz, 2009). Actually, the country ranks as the fourth largest Latin American beef producer with a commercial herd of 27.7 million heads (FAOSTAT, 2010). Advances in embodied technologies, lower labor costs, and a large domestic market have fostered the development of large beef-processing operations (Estevez-Moreno et al., 2009). How-ever, the livestock sector is currently undergoing a process of selective modernization in production conditions and in its pre-slaughter logistic process. Although the stressful effects of pre-slaughter prac-tices on livestock have been comparatively well studied in some re-gions of the world, in Latin America and, in particular, in Colombia, the subject has received limited attention. Colombian commercial systems that include indirect sales via cattle markets or auctions, prolonged transportation, long and poor lairage conditions may result in an even greater prevalence of carcass bruising and DFD meats (Romero, Sánchez, & Gutiérrez, 2011). However, little information is available regarding the impact of transport and pre-slaughter opera-tions on animal welfare and on carcass uality in Colombia. It is there-fore interesting to examine the operating procedures of a typical export plant in order to identify any detrimental effects that said oper-ations may have on animal welfare and meat uality, to be able to recommend appropriate changes in handling routines that could min-imize the biological cost to animals during the pre-slaughter process and thus improve the uality of the product. The aim of this study was investigate risk factors as possible causes for bruising and high muscle pH, observed under commercial operating conditions in Colombia.

2. Material and methods

The study was carried out in the department of Cordoba (northern Colombia, in the Caribbean region) from July to September 2011 at a typical slaughter plant for export in Monteria (8 5 0 N, 75 53 0 W), which complies with the stipulations of Decree 1500, May 2007, which created the Of cial System of Meat Inspection, Surveil-lance and Control for all meat and meat products and establishes the sanitary and safety re uirements for primary production, slaughtering, processing, storage, transport, sales, import and export of all meat and meat products. Monteria is characterized by having a tropical dry forest climate with a mean annual rainfall of 1.156 mm and mean annual temperature of 28 C. It is situated at approximately 18 m above sea level, particularly along the Sin river valley.

2.1. Study description

Data was recorded for 86 journeys referring to 1179 animals (predominant ebu breeds, especially Brahman and possible crosses) with a live weight of 55.83 3.15. All of the animals came from farms and auction markets in the departments of Córdoba and Sucre (northern Colombia). Of the cattle assessed 7 . (877/1.179) were males and the remaining 25.6 (302/1.179) females. With regard to commercial categories, 38.8 (n 58) of the livestock was classed as young bulls (intact males, between 1 and 3 years of age), 3 (n 00) as steers (castrated males, between 1 and 3 years of age), 20.3 (n 239) as cows (females older than 3 years of age), 5.3 (n 63) heifers (females between 1 and 3 years of age) and 1.6 (n 19) as bulls (males over 3 years of age). Several variables related to transport and pre-slaughter conditions (including lairage), were recorded over a three-month period (Fig. 1).

2.1.1. Transport conditions and slaughter plant

The livestock trucks used during this study complied with Colom-bian standards for cattle transport and were of the type most com-monly used in Colombia (1 –16 animals capacity). They were 10-ton capacity, two-axle vehicles with a rigid chassis (combined wood and steel), passive ventilation and a canvas roof. The slaughter plant for export assessed in our study operates from Monday to Saturday (0600–1 00 h) and has a slaughtering capacity of 500–600 animals/day at a rate of 0– 5 animals/h. The concrete un-loading ramps have nonslip oors that are about as wide as the livestock trailers. They are connected by a series of corridors to a lairage area that has 260 m2 of pens (3.65 m wide 20 m long) with Polyshade roo ng (high density polyethylene screen) and nonslip concrete oors. Animals from different livestock trucks are not mixed at the plant and each group is housed in separate pens. Water is freely available, but there is no access to feed. A concrete curved passageway leads from the lairage area to a stunning box (1.80 m high 0.90 m wide 2.53 m long) with a head xation sys-tem. Access to the

box is through a guillotine door and a revolvingiron exit door. After being stunned by a non-penetrating captive bolt, the cattle are slaughtered, suspended by a hind leg, bled, and trans-ferred to the production line to begin the process of removing the head, feet, skin, viscera, and the uartering of the carcass.

2.1.2. Bruising assessment

The protocol for the post-mortem evaluation was based on the Australian Carcass Bruising Scoring System, ACBSS (Anderson & Horder, 1979) and the Chilean bruising carcass-grading standard (INN, 2002). Parameter of shape of bruises was added. We de ne a bruise as a lesion where tissues are crushed with a rupture of vascular supply and an accumulation of blood and serum, without discontinu-ity of the skin. The assessment of carcasses for the presence of bruises and bruise characteristics was carried out by a meat grader and veterinarian with ve years of experience. This observer was placed after the de-hiding point and before the carcass-splitting point on the slaughter line, allowing the entire carcass—hanging by both hind legs—to be easily observed.

In the case of each carcass, rstly the presence of bruises (yes or no) was recorded. If bruises were present, the number of bruises per carcass and the number of bruises per anatomical site were assessed. Next, each bruise present on the carcass was evaluated by registering its anatomical site, size, severity and shape. The original ACBSS score sheet for half a carcass was extended to allow complete re-cording of bruises for the entire carcass. The anatomical site of the bruise was recorded according to the ACBSS, and the carcass was divided into seven areas: anatomical location 1 lateral side of the hind leg, 2 abdominal wall, 3 thoracic wall, front leg, 5 loin, 6 Tuber is uiadicum and its muscular insertions, 7 Tuber coxae and its muscular insertions (Fig. 2) and 8 multiple area affected.

The size of the bruise was assessed on the basis of its diameter according to the ACBSS: small: b8 cm, medium: b16 cm, large: 16 cm. When a bruise was not circular, the diameter was measured as the longest length of the lesion. To assist with the visual appraisal of the bruises, a disc indicating circular areas of 2, 8 and 16 cm was used. The severity of the bruise was rated by the observer according to the Chilean bruising grading classi cation (INN, 2002): grade 1: only subcutaneous tissue affected grade 2: as grade 1, but with mus-cle tissue affected grade 3: as grades 1 and 2, but with the presence of broken bones. The shape of the bruise, de ned as the characteristic pattern or form of a bruise, was classi ed according to previous studies (Weeks et al., 2002). The following shapes were differentiated: circular: a bruise shaped like or nearly like a circle linear: a non-circular bruise with one dimension (length) longer than the other (width) tramline: two parallel linear bruises separated by a paler undamaged area mottled: the bruised area appears spotted or blotched and irregular: a bruise without clear dimensions and with uneven edges. Bruises smaller than 2 cm, blemished injection sites, and reddening lesions that looked like bruises, located on the left hind leg (more likely caused after stunning by the tightening of the shackle chain) were not recorded (Strappini et al., 2013).

2.1.3. pH measurements

To determine carcass pH 2 h post-mortem (pHu) of the M. longissimus, a portable pH meter (tted with a penetration electrode pH/mV/temperature meter (Model I 150, I. . Scienti c Instruments, Loveland, CO) was used, which was inserted into a small incision in the left side of the carcass (1 th/15th rib interface). The pH meter was re-calibrated at the same temperature of the operation room (5 C) after every ve samples, using two standard buffer solutions at pH 7.0 and .0. Carcasses showing pH2 values greater than 5.8 were classi ed as DFD. Meat was considered as being of normal uality when pH2 was b5.8.

2.2. Statistical analysis

Multivariable logistic regression analyses were performed on absence/presence of bruised carcasses using STATA software, version 12.0 (College Station, Texas, EU). Grade 2 and 3 bruises were merged with grade 1 bruises in one category. The general model was:

$$Y = \frac{e^{(\beta o + \sum \beta i Xi)}}{1 + e^{\beta o + \sum \beta i Xi}}$$

Where the probability of the presence of bruise, 0 is the intercept, i are the regression coef cients, Xi are the explanatory variables included in the analysis. Additionally, another similar model was run on subsets of the data using the records that included information on pH, taking into account two categories: carcasses with apH b 5.8, and carcasses with a pH 5.8. Each analysis began with a univariable analysis of each predictor variable to explore data. A full model containing all predictor variables was then used to estimate their effects and signi cance. Non-signi cant variables were removed one by one from the model, starting with the variable showing the highest overall P value. The model was re-run and the presence of confounding was assessed by comparing the estimates of the new model with those of the previous model. Confounding was deemed present when estimates changed by at least 25 confounders were forced in the model irrespective of their signi cance in order to obtain less biased estimates. Finally, relevant interaction terms were added to the model. The goodness-of- t of the models was checked by the Hosmer–Lemeshow statistic test. Effects of the predictor variables on the presence of bruises were expressed in terms of the odds ratios (OR) and their 95 con dence intervals (CI). An OR that is greater (smaller) than 1 indicates that the bruise is more (less) likely to be present in a speci c category of the predictor variable compared to the reference category.

3. Results

Table 1 gives detailed information of the pre-slaughter conditions evaluated. 85.3 (1006/1179) of the animals came from 23 farms and the remaining 1 .7 (173/1179) from four auction markets located in twelve municipalities of the departments of Córdoba and Sucre (northern Colombia). Mean transport time was 1.97 0.0 h. Load densities complied to current health legislation re uirements (87.2), which establish acceptable densities to be between 3 and 00 kg/m2, depending on the weight of the cattle (ICA, 2007). Lairage time at the plant was more than 12 h (18.9 0.13 h)(MPS, 2007a).

3.1. Bruise assessment

Upon examination 37.5 (2/1179) of the carcasses displayed bruising, with a mean of 2.71 bruises/carcass (1198/ 2). No signi -cant differences were observed in the prevalence of bruises according to the origin of the livestock (farms versus auction markets). In the case of cattle from farms 38.6 (388/1006) of the carcasses displayed bruising whilst in cattle from auction markets this gure was 31.2 (5 /173) (P b 0.05). Signi cant differences (P b 0.01) were observed in the proportion of bruises between males (1.2) and females (26.5). The bruises were predominantly of a small size and chie y located in the ischial and coccygeal tuberosities, affecting muscle tissue to a large extent (Grade 2 bruising). The shape of fre uent bruises was oval or irregular (Table 2).

The gender variable was not assessed in the multivariate analysis due to collinearity with the type of animal variable. Estimates of the odds ratios (OR), with their respective 95 con dence intervals, indicate that truck load density, stops during transport and lairage time at the plant increased the risk of bruises on carcasses in the present study (Table 3). In spite of the fact that the truck load densi-ties complied with Colombian legislation, said densities increased the risk of bruises on the livestock assessed (P b 0.01). The lairage time of cattle at the plant (18–2 h) increased prevalence of bruising 2.1 times, compared to lairage periods of between 12 and 18 h. Intermit-tent stops in the journey to the plant are a risk factor for the presence and/or increase in the incidence of bruises on carcasses (OR 1.7 P b 0.01).

3.2. pH measurements

Recording of pH2 was carried out on 1176 carcasses. 37.3 (0/1176) of the carcasses were found to have a pH 5.8. Carcasses of livestock arriving from markets or auctions had a higher pH than those coming from farms (5.8 0. vs 5.7 0.0 , respectively P b 0.01). The commercial livestock type had a signi cant effect on pH (P b 0.01, Fig. 3). Heifers (OR 2.5), young bulls (OR 2.5), bulls (OR 1.2) and cows (OR 2.), showed a greater risk of presenting dark cutting beef than in the case of steers. Truck stops during livestock transport were found to have a directly proportional relationship to the presence of dark cutting (P b 0.01). An increase in the density of cattle loads increased the risk of dark cutting carcasses (OR 1.0, P b 0.01)(Table).

4. Discussion

Producers, retailers and other food chain actors increasingly recognize that consumer concerns for good animal welfare represent a business opportunity that could be pro tably incorporated into their commercial strategies (Velarde & Dalmau, 2012). In this context, Colombia embarked upon the process of updating its public health laws with a from the farm to the table approach, which included guidelines on the welfare of beef cattle during production and throughout the pre-slaughter supply chain. Furthermore, the Colombian Beef Supply Chain Council (2010) has announced a com-petitive supply chain agreement for 2010–2019 and considers good animal welfare practices to be imperative to obtain uality meat. In spite of the fact that Colombian legislation has laid down pre-slaughter animal welfare re uirements, the degree to which they are actually implemented is low, personnel are poorly trained, transport conditions are not specialized and the slaughter plants are not designed with function criteria in mind (Guarín, 2008). Our results are an initial approach to the modern export-oriented slaughter sys-tems in Colombia. The plant assessed is the country s most modern slaughter plant and the rst to be certi ed to 1500 standards (MPS, 2007b), as well as one in which animal welfare principles are observed during pre-slaughter handling. The current study is the rst to report on pre-slaughter characteristics and their relationship to bruise prevalence and the uality of beef carcasses in Colombia.

.1. Bruise assessment

Bruises are a good indicator of problems during transport (Miranda-de la Lama, Monge, et al., 2011), in-transit accidents (Miranda-de la Lama, Sep lveda, et al., 2011), livestock marketing (Weeks et al., 2002), loading and unloading (Minka & Ayo, 2007) and stunning (Chandra & Das, 2001). The prevalence of bruises (37.5) on the carcasses assessed in our study is considered moderate bearing in mind that the cattle studied are commercial ebu cross-breds handled under extensive farming conditions, raised with little human contact and known to have a nervous temperament during pre-slaughter (Solano, Galindo, Orihuela, & Galina, 200), which makes them more likely to suffer lesions and bruising. The medium prevalence of bruises in our study could be due to the implementa-tion of animal welfare principles at the plant that we assessed, through training of personnel, commitment of management, and audits carried out on handling practices. In addition to innovations in the design of the plant for unloading animals, the pre-slaughter lairage areas and passageways leading to stunning have nonslip oors and are solid and curved which makes handling more ef cient and reduces the need to use electric goads and other instruments that produce lesions. Studies carried out in Brazil on ebu breeds in com-mercial conditions, found a higher prevalence of bruises (8 .5 and 9 .3) however, in these cases the cattle were subjected longer transport times, (12 h), they underwent river transport and less carcasses were assessed (n 88 and 209, respectively) (Andrade, Ro a, Silva, Gon alves, & Pinheiro, 2008 Andrade, Silva, & Ro a, 2009). Other studies carried out on B. taurus cattle in Chile, Uruguay and Mexico found a higher prevalence of bruises, and demonstrated their economic impact (Huertas, Gil, Piaggio, & van Eerdenburg, 2010 Miranda-de la Lama, Leyva, et al., 2012 Strappini et al., 2010).

Our results indicate that males showed a greater proportion of bruising compared to females (1.2 vs 26.5). These results do not coincide with those reported in other studies (Hoffman & L hl, 2012). The differences could be explained by the fact that the largest groups of male animals that suffered bruising was that formed by young bulls and adult bulls (5 .1), that is, by uncastrated animals. This characteristic may cause them to be more reactive in unstable social settings due to the social mix that occurs during pre-slaughter lairage, which increases aggressiveness and the probability of suffer-ing an injury (Mounier, Dubroeuc , Andanson, & Veissier, 2006). With regards to the origin of animals variable (farm versus auction market), bruises were chie y located in the ischial/coccygeal tuberos-ities and were classed as grade 2, predominantly oval bruises. These lesions may have been caused by loading and unloading procedures, transport and to group mixing (Romero et al., 2011), and may also be due to the fact that this anatomical area has less tissue density and fat cover (Strappini, Metz, Gallo, & emp, 2009). Conventionally, higher numbers of bruised carcasses are reported for marketed ani-mals than for animals transported directly from the farm (Weeks et al., 2002). A recent epidemiological study carried out in Chile has shown that animals from auction markets are at higher risk of being bruised than animals coming directly from farms (OR of 1. Strappini et al., 2010). However, this tendency was not observed in our study. A possible reason for this result could be related to the few animals evaluated from action market compared with farm origin.

Short journeys are a characteristic of Colombian export slaughter plants, because they are located in areas with great livestock produc-tion, unlike the slaughter plants for the national market that receive animals that have been transported for more than 10 h (Romero & Sánchez, 2012). In our study transport times were short and an increase in duration did not increase the risk of a higher incidence of bruising. These results partially coincide with other studies carried out in Latin America. For example, a study carried out in Uruguay, in 12 export slaughter plants found that 60 of livestock from short journeys had at least one lesion (Huertas et al., 2010). Similar results were reported in Mexico, with 92 prevalence of bruises on animals with transport times of less than 1 h (Miranda-de la Lama, Leyva, et al., 2012). These ndings indicate that in this region, bruises may be principally conditioned by other risk factors related to poor handling practices, high densities, badly designed installations, poor state of roads and the mixing of animals from different origins during lairage (Marahrens et al., 2011 Miranda de- la Lama, Salazar-Sotelo, et al., 2012).

In our study, in spite of the fact that load densities for transport complied with Colombian health legislation re uirements (MPS, 2007b), this variable signi cantly increased the risk of bruising. In Colombia cattle are transported in trucks with a wooden and metal chassis which take 1 or 15 animals. During transport the animals are separated into two groups by a wooden or metal fence that divides the truck into two compartments. It is uite probable that the animals housed in the rear section of the truck are more suscep-tible to suffering falls during transport, possibly due to too much space for the animals in the truck which makes them more liable to lose balance, fall, suffer knocks against the body and or get trodden on. However, studies conducted in Chile, in which load densities were higher (approximately 50 kg/m2), suggest that the greater the load density, the greater the number of bruises (Gallo, Lizondo, & nowles, 2003), which leads us to infer that the presence of lesions is related with both high and low densities, it being thus advisable to work with mean densities that are in accordance with the weight of the animals to be transported, such as those suggested by Colombian legislation (ICA, 2007).

In spite of short transport times, pre-slaughter lairage times were very long (18 h) and indeed this variable was identi ed as a risk factor for bruising on the carcasses assessed. Although the instal-lations used to house animals seem to be ade uate, an increase in the time they remain there could be a stress factor that can result in nervousness, reactivity, aggressiveness and an increase in lesions in animals. Several studies in the region indicate that pre-slaughter lairage should be reduced as much as possible and should be between 3 and 6 h (Tadich, Gallo, Bustamante, Schwerter, & Van Schaik, 2005). Some authors sustain that the uality of pre-slaughter lairage is more important than the lairage time itself (Villarroel et al., 2001). Howev-er, in Latin America, such uality conditions are dif cult to implement since infrastructure and operational efforts focus on slaughter and on obtaining carcasses. It is important and necessary to raise the aware-ness of slaughter plant management as to the importance of having good conditions for the pre-slaughter lairage period and optimising the animals lairage time at the plant.

Intermittent stops during transport are a risk factor for the presence and/or the increase in the incidence of bruises. In Colombia these stops are typically 30 to 60 min and are used by drivers to check the cattle, rest, eat and to pass health controls (Romero & Sánchez, 2011). These types of stops are very fre uent in fairly unstructured transport systems with intensive schedules for picking up cattle, which means that the divers have intensive working days and irregular rest periods that exposes them to health problems and even traf caccidents (Miranda-de la Lama, Sep lveda, et al., 2011). Our results indicate that stops in journeys of less than h should be eliminated or reduced.

.2. pH measurements

At a commercial level the last pH measurement taken is one of the most important reference values to measure the uality of meat (Villarroel et al., 2001) and it is related to the depletion of glucogen reserves and the release of lactate caused by stressful handling during pre-slaughter operations (Amtmann, Gallo, Van Schaik, & Tadich, 2006). A pH 5.8, together with a dark color and high water reten-tion are characteristics of DFD meats. Our results indicate that 37 of the animals studied had a pH 5.8, as well as a positive correlation between the pH2 and the presence of bruises. Some authors have suggested that there is an association between stressful conditions during the pre-slaughter stage, bruises and a high pH (Strappini et al., 2010). It is normally assumed that pH2 values of more than 5.8 are related to dark, dry, rm meats (DFD). Our results are similar to those reported in Mexico (Leyva-García, Figueroa-Saavedra, Sánchez-López, Pérez-Linares, & Barreras-Serrano, 2012), but with higher values than those reported in Chile (Amtmann et al., 2006).

In Latin America commercial systems that include indirect sales via markets or auctions are a potential risk for animal welfare as they trig-ger notable stress and reactivity in cattle which in turn seriously affects the uality of their meat (Gallo & Tadich, 2008), due the fact that the animals are subjected to double transport, fasting, long lairage, new en-vironments, violent handling and social mixing (Paranhos da Costa, Huertas, Gallo, & Dalla Costa, 2012). In our study the impact of such conditions is evident in the high pH levels of such animals compared to those transported directly from the farm to the slaughter plant. Tak-ing this into account, auction markets should be gradually eliminated or at least undergo audits with a view to obtaining certi cation for good animal welfare practices.

Our study found that there was a signi cant effect on pH according to the commercial category of the livestock evaluated. In comparison to the rest of the commercial categories, steers were found to have less risk of presenting a high pH. These results partially coincide with those reported by Jeremiah, Tong, and Gibson (1991), who found sig-ni cant differences in pH values between steers and bulls, the highest pH values being those of bulls due to the fact that, unlike steers, they have not been castrated. This fact makes them more excitable animals and more likely to experience greater glucogen consumption due to muscular contraction and hypersecretion of catecholamines before slaughter, which would increase the nal pH (Sornay & Legras, 1978). In our study, female animals also showed high pH values compared to steers, which would indicate that the females also display a high level of reactivity during the pre-slaughter period. These results high-light the need to draw up protocols for actions that can be taken in re-lation to each commercial category of animal.

Intermittent stops during a journey are highly stressful for cattle, even more so than loading and unloading (Chacón, García-Belenguer, Villarroel, & Maria, 2005). In our study, vehicle stops during transit have a directly proportional relationship to the presence of high pH2 . These results reinforce the idea that stops during transport are highly stressful for animals and can generate reactivity and social con icts, which leads to a greater presence of bruising. In the case of the load density variable, the results indicate that the greater the density of animals is, the greater the risk of high pH2 . Numerous studies have shown that high densities during transport are very stressful for ani-mals due to the fact that they cannot chose the best position to keep their balance during vibrations and movements (nowles, Brown, Edwards, Philips, & Warris, 1999 Tarrant, 1990). In Latin America, high densities of animals during transport are common practice with a view to reducing operating costs (Paranhos da Costa et al., 2012).

5. Conclusions and implications

Our results indicate that truck load density, stops during trans-portation of cattle and the lairage time at the plant increased the risk of bruises appearing on carcasses. Likewise, in spite of the fact that load densities were in line with Colombian legislation, they increased the risk of bruising. A lairage time of 18 to 2 h at the plant increased the prevalence of bruises 2.1 times com-pared to lairage periods of between 12 and 18 h. Furthermore, intermittent stops during transit are a risk factor for the presence and/or increase in the incidence of bruises on carcasses. However, the transport time was not related to the presence of bruises and high muscle pH. Finally, steers were found to have less risk of presenting a high muscle pH.

It is important to underline that this study found only a moderate prevalence of bruises on carcasses if our results are compared to those reported in other countries in the region. This is obviously a strong argument in favor of this type of certi ed plant. However, there is still the obvious need to reinforce transport structures, reduce lairage times at slaughter plants, provide more training for personnel involved in handling livestock in the cattle supply chain and improve the teach-ing of aspects of animal welfare at all academic and research levels.

REFERENCES

[1] Amtmann, V. A., Gallo, C., Van Schaik, G., & Tadich, N. (2006). Relaciones entre el manejo antemortem, variables sanguíneas indicadoras de estrés y pH de la canal en novillos. Archivos de Medicina Veterinaria, 38, 259–26 .

[2] Anderson, B., & Horder, J. C. (1979). The Australian Carcass Bruises Scoring System. ueensland Agriculture Journal, 105, 281–287.

[3] Andrade, E. N., Ro a, R. O., Silva, R. A. M. S., Gon alves, H. C., & Pinheiro, R. S. B. (2008). Preval ncia de les es em carca as de bovinos de corte abatidos no Pantanal Sul Mato-Grossense transportados por vias uviais. Ci ncia e Tecnologia de Alimentos, 28( ), 822–829.

[4] Andrade, E. N., Silva, R. A. M. S., & Ro a, R. O. (2009). Manejo pré-abate de bovinos de corte no pantanal, Brasil. Ar uivos de ootecnia, 58(222), 301–30 .

[5] Capper, C. (2001). The language of forensic medicine: the meaning of some terms explained. Medicine Science Law, 1, 256–259.

[6] Chacón, G., García-Belenguer, S., Villarroel, M., & Maria, G. A. (2005). Effect of transport stress on physiological responses of male bovines. Deutsche Tier rztliche Wochenschrift, 112, 65– 69.

[7] Chandra, B. S., & Das, N. (2001). The handling and short-haul transportation of spent buffaloes in relation to bruising and animal welfare. Tropical Animal Health and Production, 33, 155–163.
[8] CNCCB (2010). Acuerdo de Competitividad Cadena Cárnica Bovina 2010–2019. Bogotá, Colombia: Consejo Nacional de la Cadena Carnica Bovina.
[9] Estevez-Moreno, L. X., Santana, A. D., Camacho, C. G., Gutiérrez, J., Gómez, M. V., García, G., Rozo, M. C., & Ballesteros, H. (2009). Competir e innovar: la ruta de la industria bovina. Agenda prospectiva de investigación y desarrollo tecnológico para la cadena cárnica bovina en Colombia. Bogotá, Colombia: Ministerio de Agricultura y Desarrollo Rural, FEDEGAN, CORPOICA, Universidad Nacional de Colombia.
[10] FAOSTAT (2010). Online database of the Food and Agriculture Organization of the United Nations. (on line). http://faostat.fao.org— Production— livestock primary. (Web site: http://faostat.fao.org/site/573/DesktopDefault.aspx?PageID 573 ancor).
[11] Fisher, A. D., Colditz, I. G., Lee, C., & Ferguson, D. M. (2009). The in uence of land transport on animal welfare in extensive farming systems. Journal of Veterinary Behavior: Clinical Applications and Research, , 157–162.
[12] Gallo, C., Lizondo, G., & nowles, T. (2003). The effects of journey and lairage time on steers transported to slaughter in Chile. Veterinary Record, 152, 361–36 .
[13] Gallo, C., & Tadich, T. A. (2008). Chapter 10: South America. In M. C. Appleby, V. Cussen, L. Garcés, L. Lambert, & J. Turner (Eds.), Long distance transport and welfare of farm animals (pp. 261–287) (1st ed.). Wallingford, U : CABI.
[1] Guarín, A. (2008). Carne de cuarta para consumidores de cuarta. Revista de Estudios Sociales, 29, 10 –119.
[15] Hoffman, L. C., & L hl, L. (2012). Causes of cattle bruising during handling and transport in Namibia. Meat Science, 92, 115–12 .
[16] Huertas, S. M., Gil, A. D., Piaggio, J. M., & van Eerdenburg, F. J. C. M. (2010). Transporta- tion of beef cattle to slaughterhouses and how this relates to animal welfare and carcass bruising in an extensive production system. Animal Welfare, 19, 281–285.
[17] ICA, Instituto Colombiano Agropecuario (2007). Reglamento sobre las condiciones sanitarias y de inocuidad del ganado bovino y bufalino en la producción primaria. Diario O cial de la Rep blica, Resolución N 0023 1.
[18] INN, Instituto Nacional de Normalización, Chile (2002). Canales de Bovino. De niciones y Tipi cación. Norma Chilena O cial NCH. 1306 Of. 02.
[19] Jeremiah, L. E., Tong, A. . W., & Gibson, L. L. (1991). The usefulness of muscle color and pH for segregating beef carcasses into tenderness groups. Meat Science, 30, 97–11 .
[20] nowles, T. G., Brown, S. N., Edwards, J. E., Philips, A. J., & Warris, P. D. (1999). Effect of young calves of a one-hour feeding stop during a 19-hour road journey. Veterinary Record, 1 , 687–692.
[21] Lambooij, E., vander Werf, J. T. N., Reimert, H. G. M., & Hindle, V. A. (2012). Compartment height in cattle transport vehicles. Livestock Science, 1 8, 87–9 .
[22] Leyva-García, I. A., Figueroa-Saavedra, F., Sánchez-López, E., Pérez-Linares, C., & Barreras- Serrano, A. (2012). Impacto económico de la presencia de carne DFD en una planta de sacri cio tipo Inspección federal (TIF). Archivos de Medicina Veterinaria, , 39– 2.
[23] Ljungberg, D., Gebresenbet, G., & Aradom, S. (2007). Logistics chain of animal transport and abattoir operations. Biosystems Engineering, 96, 267–277.
[2] Marahrens, M., leinschmidt, N., Di Nardo, A. D., Velarde, A., Fuentes, C., Truar, A., Otero, J. L., Fede, E., & Dalla Villa, P. (2011). Risk assessment in animal welfare—especially referring to animal transport. Preventive Veterinary Medicine, 102, 157–163.
[25] Minka, N. S., & Ayo, J. O. (2007). Effects of loading behaviour and road transport stress on traumatic injuries in cattle transported by road during the hot-dry season. Live- stock Science, 107, 91–95.
[26] Miranda-de la Lama, G. C., Leyva, I. G., Barreras-Serrano, A., Pérez-Linares, C., Sánchez-López, E., María, G. A., & Figueroa-Saavedra, F. (2012a). Assessment of cattle welfare at a commercial slaughter plant in the northwest of Mexico. Tropical Animal Health and Production, , 97–50 .
[27] Miranda-de la Lama, G. C., Monge, P., Villarroel, M., Olleta, J. L., Garcia-Belenguer, S., & María, G. A. (2011a). Effects of road type during transport on lamb welfare and meat uality in dry hot climates. Tropical Animal Health and Production, 3, 915–922.

[28] Miranda-de la Lama, G. C., Salazar-Sotelo, M. I., Pérez-Linares, C., Figueroa-Saavedra, F., Villarroel, M., Sañudo, C., & María, G. A. (2012b). Effects of two transport systems on lamb welfare and meat quality. Meat Science, 92, 554–561.
[29] Miranda-de la Lama, G. C., Sepúlveda, W. S., Villarroel, M., Olleta, J. L., García-Belenguer, S., & Maria, G. A. (2011b). Livestock vehicle accidents in Spain: causes, conse- quences, and effects on animal welfare. Journal of Applied Animal Welfare Science, 14, 109–123.
[30] Miranda-de la Lama, G. C., Villarroel, M., Olleta, J. L., Alierta, S., Sañudo, C., & María, G. A. (2009). Effect of the pre-slaughter logistic chain on meat quality of lambs. Meat Science, 83, 604 609.
[31] Mounier, L., Dubroeucq, H., Andanson, S., & Veissier, I. (2006). Variations in meat pH of beef bulls in relation to conditions of transfer to slaughter and previous history of the animals. Journal of Animal Science, 84, 1567–1576.
[32] MPS, Ministerio de la Protección Social de Colombia (2007a). Reglamento técnico que crea y reglamenta el Sistema oficial de inspección, vigilancia y control de la carne. Diario Oficial de la República, Decreto No 1500.
[33] MPS, Ministerio de la Protección Social de Colombia (2007b). Reglamento técnico sobre los requisitos sanitarios y de inocuidad de la carne y productos cárnicos comestibles de las especies bovina y bufalina. Diario Oficial de la República, Resolución No 2905.
[34] Paranhos da Costa, M. J. R., Huertas, S. M., Gallo, C., & Dalla Costa, O. A. (2012). Strate- gies to promote farm animal welfare in Latin America and their effects on carcass and meat quality traits. Meat Science, 92, 221–226.
[35] Romero, M. H., & Sánchez, J. A. (2011). Implicaciones de la inclusión del bienestar animal en la legislación sanitaria colombiana. Revista Colombiana de Ciencias Pecuarias, 24, 93–101.
[36] Romero, M. H., & Sánchez, J. A. (2012). Bienestar animal durante el transporte y su relación con la calidad de la carne bovina. Revista MVZ Córdoba, 17, 2936–2944.
[37] Romero, M. H., Sánchez, J. A., & Gutiérrez, C. (2011). Evaluación de prácticas de bienestar animal durante el transporte de bovinos para sacrificio. Revista de Salud Pública, 13(4), 684–690.
[38] Schwartzkopf-Genswein, K. S., Faucitano, L., Dadgar, S., Shand, P., González, L. A.,& Crowe,
[39] T. G. (2012). Road transport of cattle, swine and poultry in North America and its im- pact on animal welfare, carcass and meat quality: a review. Meat Science, 92, 227–243.
[40] Solano, J., Galindo, F., Orihuela, A., & Galina, C. S. (2004). The effect of social rank on the physiological response during repeated stressful handling in Zebu cattle (Bos indicus). Physiological & Behavior, 82, 679–683.
[41] Sornay, J., & Legras, P. (1978). Cartography of pH in beef carcass: quality, colour, conservation. Revue Technique Veterinaire de l'Alimentation, 17, 18–23.
[42] Strappini, A. C., Frankena, K., Metz, J. H. M., Gallo, B., & Kemp, B. (2010). Prevalence and risk factors for bruises in Chilean bovine carcasses. Meat Science, 86, 859–864.
[43] Strappini, A. C., Metz, J. H. M., Gallo, C., Frankena, K., Vargas, R., De Freslon, I., & Kemp, B. (2013). Bruises in culled cows: when, where and how are they inflicted? Animal, 7, 485–491.
[44] Strappini, A. C., Metz, J. H. M., Gallo, C. B., & Kemp, B. (2009). Origin and assessment of bruises in beef cattle at slaughter. Animal, 3(5), 728–736.
[45] Tadich, N., Gallo, C., Bustamante, H., Schwerter, M., & Van Schaik, G. (2005). Effects of transport and lairage time on some blood constituents of Friesian-cross steers in Chile. Livestock Production Science, 93, 223–233.
[46] Tarrant, P. V. (1990). Transport of cattle by road. Applied Animal Behaviour Science, 28, 153–170.
[47] Velarde, A., & Dalmau, A. (2012). Animal welfare assessment at slaughter in Europe: moving from inputs to outputs. Meat Science, 92, 244–251.
[48] Vergara, O. D., Elzo, M. A., & Ceron-Munoz, M. F. (2009). Genetic parameters and genetic trends for age at first calving and calving interval in an Angus-Blanco Orejinegro- Zebu multibreed cattle population in Colombia. Livestock Science, 126, 318–322.
[49] Villarroel, M., Maria, G. A., Sierra, I., Sanudo, C., Garcia-Belenguer, S., & Gebresenbet, G. (2001). Critical points in the transport of cattle to slaughter in Spain that may compromise the animals' welfare. Veterinary Record, 149, 173–176.
[50] Weeks, C. A., McNally, P. W., & Warris, P. D. (2002). Influence of the design of facilities at auction markets and animal handling procedures on bruising in cattle. Veterinary Record, 150, 743–748.