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Spatial variability of the occurrence of lesions on cattle carcasses in association with pre-slaughter factors in the forest–savannah transition zone

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ABSTRACT - This study mapped cattle carcass lesions and associated the isoline maps with the occurrence factors of these lesions. Isoline maps were drawn by common kriging. The associated occurrence factors were the layout of the boards in the crowding tub (CT), characteristics of the hauling truck (general state and the presence of loose and/or sharp boards), broken boards in the corral (BBC), type of road covered (TRC), and animal falls upon unloading at the slaughterhouse (FAUS). The BBC showed a higher number of carcass lesions in the rib region. The data on FAUS and deterioration of hauling trucks fit an exponential model, with more carcass lesions in the rib and hindquarters, and plate regions, respectively. The data on spaced boards in the CT and TRC (mixed) showed greater carcass lesions in the rib region. Therefore, this method provides important information about the spatial distribution of lesions in bovine carcasses, and the drawing sheet used is adequate to represent such lesions.

Keywords: carcass quality, geostatistics, slaughterhouse

1. Introduction

The Brazilian cattle herd is considered the largest commercial herd in the world, with over 214 million head (IBGE, 2019). The beef industry is one of the pillars of the Brazilian economy. In quantitative terms, Brazil's international prominence in beef production is evident. However, meat quality is influenced by several aspects, including bruises due to inadequate facilities, mishandling, and incorrect transportation, which are evidenced after slaughtering (Assis et al., 2011). In Brazil, beef cattle are mainly transported by two-axle trucks on roads of poor condition (Mendonça et al., 2019), which is considered the main risk factor for the occurrence of carcass injuries (Schwartzkopf-Genswein et al., 2012), increasing when the transport time exceeds two hours (Polizel Neto et al., 2015), in addition to a significant increase in stress and eventual death of cattle (Romero and Sánchez, 2012). Therefore, the last 24 hours before slaughter plays a prominent role in carcass bruising (Andrade et al., 2008). Given the economic impact of such losses, it is important to seek measures that help to understand them; one way to accomplish this is to study spatial variability by using lesion occurrence maps, as is performed in other agricultural activities (Oliver et al., 2013).

Analyzing the spatial dependence of the data provides a means by which to obtain the respective mappings of the drawing sheet studied through kriging. Kriging is the method of interpolation responsible for estimating the values of regular points and adjusting the model for the spatial variance behavior of the data (Oliver et al., 2013).

Considering the impact of carcass lesions on meat production in Brazil, the objective of this work was to analyze the occurrence of lesions on the carcass associated with pre-slaughter factors using spatial variability.

2. Material and Methods

During the rainy and dry seasons, pre-slaughter management data were collected on 23 rural properties in six municipalities in a forest-savannah transition zone located in Tocantins State, Brazil, referring to 414 bovines of both sexes and different breeds and weights. Sampling of the properties was entirely at random. The following variables were determined: layout of the boards in the crowding tub, presence of broken boards in the farms' pens, loose and/or sharp boards in the hauling truck, general state of the hauling truck (n = 21) used from the farm to the slaughterhouse, road type, and falls of animals upon unloading at the slaughterhouse. The number of animals per truck was 18.81. Time of transportation and journey distance ranged 10–454 min and 5–245 km, respectively, with an average of 134 min and 78 km.

The layout of the boards in the crowding tub was classified by measuring the distance between the boards that composed it, which was juxtaposed (less than 15 cm) or spaced (greater than 15 cm). The general state of the hauling trucks was observed. Depending on the physical structure of the cabin and fence trailer, and whether or not the truck was in good condition for transporting animals, hauling trucks were classified as either conserved or deteriorated. It was determined if the hauling trucks and the farms' pens had at least one loose/sharp board that could come into contact with the animals. The road conditions during transportation of animals from the property to the slaughter facility were classified into mixed pavement (part of the transport occurred on a road with asphalt pavement and part on a road without asphalt pavement) or asphalt pavement only. The occurrence of animal falls upon unloading was determined at the arrival at the slaughter facility and pen assignment. The effect of these variables, in addition to transport time, distance that the animals were transported, sex, and horns on the percentage of bruising occurrence was described by Brito et al. (2019).

All animals were slaughtered in the same slaughterhouse, and the measurement of carcass lesions occurred under refrigeration and federal inspection in Araguaína, TO, Brazil. Carcass lesions were recorded in the routine inspection lines of "H" carcasses (examination of the medial and lateral faces of the caudal part of the half carcass), "I" (examination of the medial and lateral faces of the cranial part of the half carcass), and in DIF (Departamento de Inspecção Final; where the lesions are evaluated by a veterinarian). The number and locations of lesions were recorded on a specific drawing sheet for each animal (Figure 1). The drawing sheet used had an area of 225 cm^2 (15 × 15 cm), consisting of six columns and 11 rows, for a total of 66 squares.

Spatial variability was characterized by semivariogram, with spherical, exponential, gaussian, and linear models; the parameters nugget, range, and sill were determined. The nugget effect is the value of the semivariance for the distance zero and represents the random component of the variation, the sill is the value of the semivariance where the curve stabilizes over a constant value, and the range is the maximum distance to which spatial dependence occurs. The model was chosen

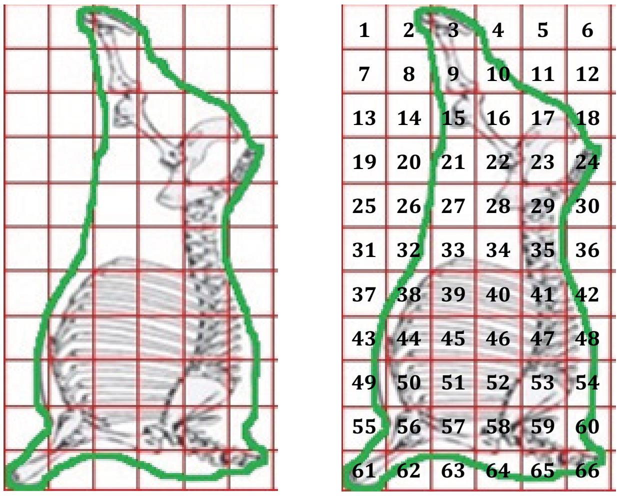


Figure 1 - Drawing sheet for the recording of carcass lesions.

by evaluating the smallest sum of squares of the residuals, highest coefficient of determination (R^2), and highest degree of spatial dependence (DSD). Semivariograms were calculated with an amplitude of 90°.

The spatial dependence model is known through the semivariogram (Oliver et al., 2013). According to Matheron (1963), the semivariogram is defined by the equation:

$$\gamma\,(h) = \frac{1}{2N(h)} \sum_{i=1}^{n(h)} \{[z(x_i) - z(x_i + h)]\}^2$$

in which $\gamma\ (h)$ = semivariogram, $N(h)$ = number of pairs of samples separated by distance h, $z(x_i)$ = variable value at point x, $z(x_i + h)$ = value of the variable at the point $(x_i + h)$, and h = distance between points x_i and $x_i + h$.

The DSD was calculated based on the percentage ratio between the nugget effect (Co) and the sill, given by the sum of Co and the structural variation (C) [DSD = C/(Co + C) × 100]. The DSD is considered to be strong above 75%, values from 25% to 75% determine a moderate DSD, and results below 25% represent a weak DSD; wherein DSD = 0, the nugget effect is pure (Cambardella et al., 1994; Oliver et al., 2013).

The value interpolation was performed by means of ordinary kriging, represented in contour maps. Kriging estimates non-sampled areas using semivariogram structural properties made from sampled sites. It is important to emphasize that it is only possible to construct isoline maps from variables with DSD. Isoline maps were constructed using the software GS+®.

3. Results

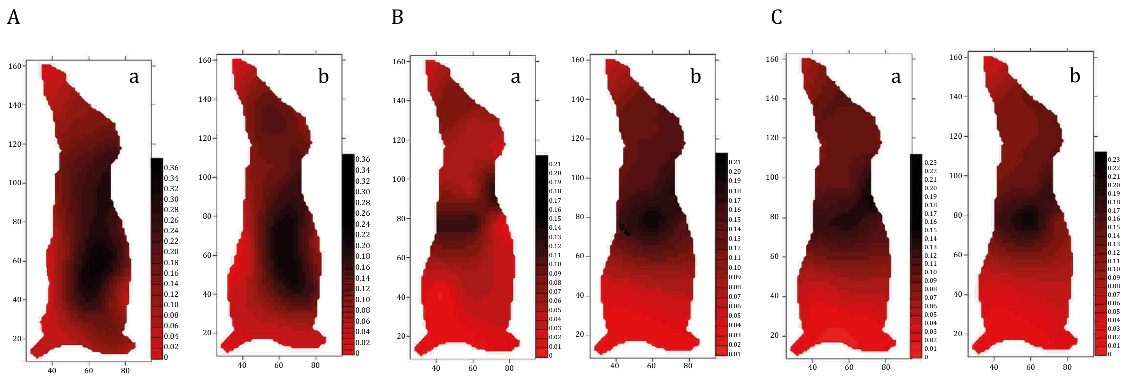
In total, 61.6% of evaluated cattle showed at least one lesion. There were 1542 grade 1 lesions (93.8%) and only 102 grade 2 lesions (6.2%), averaging 3.97 lesions per animal. The analysis of models and estimated parameters of semivariograms showed spatial dependence of the variables studied (Table 1).

The range values were greater than the spacing value between the samples, allowing for interpolation, since the samples were spatially correlated. The semivariogram for broken boards in the farm pens, in both classes (absent and present) (Table 1), were adjusted to the Gaussian model, which means that lesions were homogeneously distributed (Figure 2A). The exponential model adjusted the semivariograms of variables for animal falls (both classes), hauling truck (deteriorated), and

Table 1 - Parameters and models of semivariograms adjusted for pre-slaughter factors

Variable	Class	Model	Parameter					
			Co	Co+C	Ao	R^2	C/Co+C	DSD
Broken boards in the farm pens	Absent	Gaussian	0.000010	0.003930	43.64	0.750	0.997	Moderate
	Present	Gaussian	0.000010	0.010820	44.51	0.840	0.999	Strong
Boards in the crowing tub	Juxtaposed	Exponential	0.000008	0.002696	72.30	0.651	0.997	Moderate
	Spaced	Spherical	0.004200	0.011100	106.70	0.890	0.620	Strong
Hauling-truck	Preserved	Spherical	0.001230	0.004410	77.90	0.630	0.721	Moderate
	Deteriorated	Exponential	0.003210	0.012820	192.60	0.820	0.750	Strong
Loose and/or sharp boards in the hauling truck	Absent	Pure nugget effect						
	Present	Pure nugget effect						
Road cover	Paved	Spherical	0.000082	0.001344	24.30	0.096	0.930	Weak
	Mixed	Spherical	0.003140	0.010340	129.20	0.880	0.696	Strong
Animal falls	Absent	Exponential	0.000680	0.005450	153.60	0.800	0.870	Strong
	Present	Exponential	0.008380	0.021760	195.60	0.800	0.610	Strong

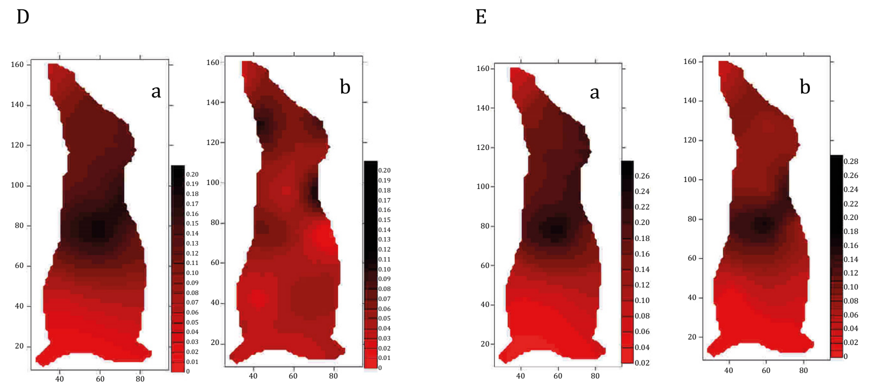
Co - nugget effect; Co+C - sill; Ao - Range; R^2 - coefficient of determination (%); C/Co+C - contribution of the nugget effect; DSD - degree of spatial dependence.



A) Board broken in the corral: presence (a) and absence (b).

B) Layout of the boards in the crowding tub: juxtaposed (a) and spaced (b).

C) General state of the hauling truck: preserved (a) and deteriorated (b).



D) Type of road: mixed (a) and only asphalt (b).

E) Animal falls: present (a) and absent (b).

Darkly colored areas indicate a higher frequency of lesions.

Figure 2 - Spatial distribution of lesions on cattle carcasses.

boards in the crowding tub (juxtaposed). The semivariograms adjusted to the spherical model were for road cover (both classes), hauling truck (preserved), and boards in the crowding tub (spaced) (Table 1).

A pure nugget effect occurred for loose and/or sharp boards in the hauling truck (Table 1). These data were discontinuous, and the isoline maps could not be assembled. The adjusted model, range, nugget effect, and sill were used in interpolation by ordinary kriging, generating maps of occurrence probability of lesions in the bovine carcass area.

The distribution of lesions on the carcasses occurred in similar locations for both classes of the variable broken boards in farm pens, with higher intensities (darker areas of the map) occurring in the rib region (Figure 2A). However, for the variable layout of the boards in the crowding tub, it presented noticeable differences in the isoline maps, mainly in the rib region where the incidence of injuries was greater when the boards were spaced (Figure 2B).

On hauling-truck maps (Figure 2C), it can be observed that animals transported in deteriorated trucks showed a greater frequency of injuries in the plate region than animals transported in preserved trucks, which showed a greater frequency of lesions in the loin region compared with other sites (Figure 2C). According to the maps of road type (Figure 2D), the lesions in animals transported on a mixed road are concentrated in the final region of the ribs, whereas in animals transported only on roads with asphalt pavement, injuries appeared scattered. The isoline maps showed differences in the location of carcass lesions between the cattle groups that suffered falls and those that did not upon unloading at the slaughterhouse, with more lesions in the ribs and hindquarters occurring in the animals that fell (Figure 2E).

4. Discussion

The percentage of injured animals (61.6%) in this study was within the range of values (54.2–84.3%) observed by Mendonça et al. (2018) in Pelotas, Rio Grande do Sul, and Andrade et al. (2008) in Corumbá, Mato Grosso do Sul, Brazil. Nevertheless, the number of lesions per animal in this study (3.97) was higher than that observed by the aforementioned authors, who reported values of 2.74 and 2.23, respectively. Carrasco-García et al. (2020) observed that 71.6 and 4.6% of carcasses showed two and three bruises, respectively, and only 2% showed more than three bruises. The higher number of lesions per animal in the current study may indicate higher stress during the pre-slaughter period. According to Mendonça et al. (2018), the number of lesions on the carcass can be influenced by many pre-slaughtering factors that induce stress on the animals, such as cattle handling, loading facility, animal-load density in the truck, and transport and uploading time. In addition, annual mean air temperature in the North of Tocantins is higher (>26 °C) when compared with Pelotas (16–18 °C) and Corumbá (24–26 °C) (Alvares et al., 2013). Also, in environments with temperatures above the thermal comfort zone, as evidenced in this work, cattle tend to use more thermoregulation mechanisms during transport, which are associated with behaviors that may predispose them to injuries (Gallo et al., 2005).

Another aspect reported in the literature that may contribute to the higher occurrence of bruising and, consequently, injuries is the fact that the roads where the animals are transported are in bad conditions (Eldridge et al., 1988). In northern Brazil, the region where the test was carried out, it is common for most roads to be in poor condition for a good part of the year, due to the large volume of rain and the lack of periodic maintenance.

The semivariogram expresses the spatial behavior of the variable and shows the size of the zone of influence around the sample, the variation in the different areas (in this case, the carcass), and the continuity of the studied characteristic (Landim, 1998). The nugget effect reflects the analytical error, an unexplained variation from one point to the other, which may result from measurement errors or microvariation not detected as a function of the sampling distance used (Cambardella et al., 1994; Oliver et al., 2013). However, it is impossible to quantify the contribution of measurement errors or variability.

According to Grandin and Deesing (2014), cattle have a panoramic view (up to 330°) and refined hearing, which allow them to monitor the environment efficiently. Thus, the greater space between boards in the crowding tub increases the cattle's field of view, and they tend to divert their attention to the outside, which stresses them and makes them more reluctant during the boarding process as they feel threatened, possibly leading to more injured animals.

Animals transported in deteriorated trucks presented more injuries, likely due to the lack of obligatory regular maintenance of these vehicles. Thus, poor truck conditions tend to increase animal movement during transportation, leading to more carcass injuries compared with proper trucking conditions (Mendonça et al., 2019).

In a study carried out by a team of researchers from the University of Colorado in the United States (Kline et al., 2020), using a different tool from the one used in this work, they evaluated the prevalence, location, and possible causes of injuries in bovine carcasses from unloading to trimming. Kline et al. (2020) reported that several factors associated with the conditions of the animal's transport compartment or trailer, such as trailer compartment density, trailer type, and trailer condition, influence the prevalence and location of lesions in bovine carcasses. However, the aforementioned authors reported that studies evaluating the location of lesions are scarce in the literature.

In the present work, considerations about the trailer compartment density and trailer type are not possible, as these parameters were standardized in the present study. However, the prevalence data found by Kline et al. (2020) with trailer compartment density and trailer type conditions similar to this study were close. Trailer condition factor was evaluated in this work similarly to much of the specialized literature on the subject (Kline et al., 2020; Lee et al., 2017; Mendonça et al., 2019; Romero et al., 2013), and several factors related to trailer conditions are associated with increased prevalence and location of lesions in bovine carcasses.

Andrade et al. (2008) analyzed the occurrence of lesions in 121 bovines in Brazil and reported that 12.2% of the carcass lesions occurred in the rib region as an effect of the transport conditions, a lower value than that observed in this study. Animals that fell upon unloading at the slaughterhouse had a greater incidence of injuries compared with those that did not, as was observed by Mendonça et al. (2018). The higher number of lesions in the ribs and hindquarters may be due to the concentration of the entire weight of the animal in this region when it is lying down in lateral decubitus. Work conducted by Braggion and Silva (2004) with 99 bovines reported that 10.20% of the lesions occurred in the rib region. The isoline map presented a relative proportion of lesions in the round region, where the commercial high-value meat cuts are located, such as, topside, knuckle, eye of round, and outside round. A study by Petroni et al. (2013) evaluated 898 bovines slaughtered in Brazil, and the carcasses showed 3032 lesions, 64.1% of them observed in the round region.

5. Conclusions

The maps obtained with a spatial distribution pattern in this study provide a better understanding of the different areas of occurrence of carcass lesions. The occurrence of injuries when systematized with the variables loose/broken truck boards did not present spatial dependence. In the other variables, it is possible to explain the spatial variability through the tested method and the drawing sheet used is suitable for this. The pre-slaughter factors studied influence the spatial variability of lesions on bovine carcasses. In the future, the use of spatial variability associated with technologies such as digital photo capture and processing could provide tools to correct factors that may increase the occurrence of injuries both in slaughterhouses and on farms.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: L.F. Sousa, A.T. Ramos and J.L. Ferreira. Formal analysis: L.F. Sousa. Funding acquisition: L.F. Sousa. Investigation: E.F. Brito, A.T. Ramos, J.M.B. Vendramini and J.L. Ferreira. Methodology: L.F. Sousa. Project administration: L.F. Sousa. Visualization: L.F. Sousa. Writing – review & editing: L.F. Sousa, E.F. Brito, R.E. Mora-Luna, P. Moriel and J.M.B. Vendramini.

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References

Alvares, C. A.; Stape, J. L.; Sentelhas, P. C.; Moraes Gonçalves, J. L. and Sparovek, G. 2013. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22:711-728. https://doi.org/10.1127/0941-2948/2013/0507

Andrade, E. N.; Silva, R. A. M. S.; Roça, R. O.; Silva, L. A. C.; Gonçalves, H. C. and Pinheiro, R. S. B. 2008. Ocorrência de lesões em carcaças de bovinos de corte no Pantanal em função do transporte. Ciência Rural 38:1991-1996. https://doi.org/10.1590/S0103-84782008000700030

Assis, D. R.; Rezende-Lago, N. C. M.; Marchi, P. G. F. and D´Amato, C. C. 2011. Perdas diretas ocasionadas por abscessos e hematomas em carcaças de bovinos. Revista Portuguesa de Ciências Veterinárias 106:47-51.

Braggion, M. and Silva, R. A. M. S. 2004. Quantificação de lesões em carcaças de bovinos abatidos em frigoríficos no Pantanal Sul-Mato-Grossense. Comunicado Técnico, 45. Embrapa Pantanal, Corumbá.

Brito, E. F.; Sousa, L. F.; Ramos, A. T.; Sousa, D. M. F.; Costa, B. M. P. and Ferreira, J. L. 2019. Pre-slaughtering factors related to bruises on cattle carcasses in the micro-region of Araguaína, Tocantins, Brazil. Semina: Ciências Agrárias 40:3553-3564. https://doi.org/10.5433/1679-0359.2019v40n6Supl3p3553

Cambardella, C. A.; Moorman, T. B.; Novak, J. M.; Parkin, T. B.; Karlen, D. L.; Turco, R. F. and Konopka, A. E. 1994. Field-Scale variability of soil properties in Central Iowa Soils. Soil Science Society of America Journal 58:1501-1511. https://doi.org/10.2136/sssaj1994.03615995005800050033x

Carrasco-García, A. A.; Pardío-Sedas, V. T.; León-Banda, G. G.; Ahuja-Aguirre, C.; Paredes-Ramos, P.; Hernández-Cruz, B. C. and Veja Murillo, V. 2020. Effect of stress during slaughter on carcass characteristics and meat quality in tropical beef cattle. Asian-Australasian Journal of Animal Sciences 33:1656-1665. https://doi.org/10.5713/ajas.19.0804

Eldridge, G. A.; Winfield, C. G. and Cahill, D. J. 1988. Responses of cattle to different space allowances, pen sizes and road conditions during transport. Australian Journal of Experimental Agriculture 28:155-159. https://doi.org/10.1071/ea9880155

Gallo, C.; Warriss, P.; Knowles, T.; Negrón, R.; Valdés, A. and Mencarini, I. 2005. Densidades de carga utilizadas para el transporte de bovinos destinados a matadero en Chile. Archivos de Medicina Veterinaria 37:155-159. https://doi.org/10.4067/S0301-732X2005000200010

Grandin, T. and Deesing, M. J. 2014. Genetics and behavior during handling, restraint, and herding. p.115-158. In: Genetics and the behavior of domestic animals. 2nd ed. Grandin, T. and Deesing, M. J., eds. Elsevier Inc. https://doi.org/10.1016/B978-0-12-394586-0.00004-4

IBGE - Instituto Brasileiro de Geografia e Estatística. 2019. Pesquisa da pecuária municipal. Efetivo dos rebanhos, por tipo de rebanho. Available at: <https://sidra.ibge.gov.br/tabela/3939>. Accessed on: Jun. 24, 2021.

Kline, H. C.; Weller, Z. D.; Grandin, T.; Algino, R. J. and Edwards-Callaway, L. N. 2020. From unloading to trimming: studying bruising in individual slaughter cattle. Translational Animal Science 4:txaa165. https://doi.org/10.1093/tas/txaa165

Landim, P. M. B. 1998. Análise estatística de dados geológicos. UNESP, São Paulo.

Lee, T. L.; Reinhardt, C. D.; Bartle, S. J.; Vahl, C. I.; Siemens, M. and Thomson, D. U. 2017. Assessment of risk factors contributing to carcass bruising in fed cattle at commercial slaughter facilities. Translational Animal Science 1:489-497. https://doi.org/10.2527/tas2017.0055

Matheron, G. 1963. Principles of geostatistics. Economic Geology 58:1246-1266. https://doi.org/10.2113/gsecongeo.58.8.1246

Mendonça, F. S.; Vaz, R. Z.; Cardoso, F. F.; Restle, J.; Vaz, F. N.; Pascoal, L. L.; Reimann, F. A. and Boligon, A. A. 2018. Pre-slaughtering factors related to bruises on cattle carcasses. Animal Production Science 58:385-392. https://doi.org/10.1071/AN16177

Mendonça, F. S.; Vaz, R. Z.; Vaz, F. N.; Leal, W. S.; Silveira, I. D. B.; Restle, J.; Boligon, A. A. and Cardoso, F. F. 2019. Causes of bruising in carcasses of beef cattle during farm, transport, and slaughterhouse handling in Brazil. Animal Science Journal 90:288-296. https://doi.org/10.1111/asj.13151

Oliver, M. A.; Bishop, T. F. A. and Marchant, B. P. 2013. Precision agriculture for sustainability and environmental protection. Routledge. Taylor & Francis, United Kingdom. https://doi.org/10.4324/9780203128329

Petroni, R.; Bürger, K. P.; Gonçalez, P. O.; Rossi, G. A. M.; Vidal-Martins, A. M. C. and Aguilar, C. E. G. 2013. Ocorrência de contusões em carcaças bovinas em frigorífico. Revista Brasileira de Saúde e Produção Animal 14:478-484. https://doi.org/10.1590/S1519-99402013000300009

Polizel Neto, A.; Zanco, N.; Lolatto, D. C. J.; Moreira, P. S. A. and Dromboski, T. 2015. Perdas econômicas ocasionadas por lesões em carcaças de bovinos abatidos em matadouro-frigorífico do norte de Mato Grosso. Pesquisa Veterinária Brasileira 35:324-328. https://doi.org/10.1590/S0100-736X2015000400002

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

Romero, M. P. and Sánchez, J. V. 2012. Bienestar animal durante el transporte y su relación con la calidad de la carne bovina. Revista MVZ Córdoba 17:2936-2944. https://doi.org/10.21897/rmvz.264

Schwartzkopf-Genswein, K. S.; Faucitano, L.; Dadgar, S.; Shand, P.; González, L. A. and Crowe, T. G. 2012. Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: A review. Meat Science 92:227-243. https://doi.org/10.1016/j.meatsci.2012.04.010