

Pre-slaughter factors associated with severe bruising in different primary commercial cuts of bovine carcasses¹

Fatores pré-abate associados à contusões severas em diferentes cortes comerciais primários de carcaças bovinas

Javier Alexander Bethancourt Garcia², Ricardo Zambarda Vaz^{3*}, Fabiano Nunes Vaz⁴, João Restle⁵ and Fábio Souza Mendonça⁶

ABSTRACT - The incidence of bruising in bovine carcasses is a consequence of several potentially stressful and aggressive factors to which the animals are subjected during pre-slaughter handling. The aim of this study was to identify pre-slaughter factors associated with the severe bruising in different regions of the bovine carcass. The study evaluated 5,028 batches of slaughtered cattle from 154,100 animals. The carcasses were analysed for gender, handling on the farm, condition of farm infrastructure, type of truck, distance and journey time from the farm to the slaughterhouse, loading density and time of year in which the animals were slaughtered. The results showed that the sidecut and forequarter are the areas most affected by bruising, with females being the most vulnerable. Loading densities above excess of 401 kg m⁻² cause an increase in the number of bruises. The use of larger vehicles results in an increase in bruising, as does the use of poor farming facilities. A decrease in the number of bruises was seen for journey times of more than three hours. All the variables under evaluation are potential causes of injury to bovine carcasses. As such, improving the handling conditions and facilities for loading cattle, as well as reducing the stress of transport, are factors which determine a smaller number of bruises in bovine carcasses.

Key words: Welfare. Loading density. Management. Transport.

RESUMO - A incidência de contusões nas carcaças bovinas é consequência de distintos fatores potencialmente estressantes e agressivos a que são submetidos os animais durante o manejo pré-abate. Este estudo teve como objetivo identificar os fatores pré-abate associados a lesões de contusões severas observadas em diferentes regiões da carcaça dos bovinos. Foram avaliados 5.028 lotes de bovinos abatidos referentes a 154.100 animais. As carcaças foram analisadas quanto a: sexo, manejo na fazenda, condição da infraestrutura da fazenda, tipos de caminhão, distâncias e tempo de transporte da fazenda ao abatedouro, densidade da carga e estações do ano em que ocorreu o abate dos animais. Os resultados demonstraram que a região da ponta de agulha e do dianteiro são as zonas mais afetadas com a incidência de contusões sendo as fêmeas as mais vulneráveis. Densidades de cargas acima de 401 kg m⁻² ocasionam incremento no número de contusões. A utilização de veículos de maior tamanho promove o acréscimo de contusões, assim como a utilização de instalações da fazenda precárias. Em tempos de transportes superiores a três horas foi observado um decréscimo no número de contusões. Todas as variáveis avaliadas são potenciais causadoras de lesões nas carcaças bovinas. Deste modo, melhorar as condições de manejo e instalações nos carregamentos dos bovinos bem como diminuir o estresse de transporte são fatores determinantes de menores números de contusões em carcaças bovinas.

Palavras-chave: Bem-estar. Densidade de carga. Manejo. Transporte.

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*Author for correspondence

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²Universidade Federal de Pelotas, Rio Grande do Sul/UFPEL, Pelotas-RS, Brasil, javierbethancourt_@hotmail.com (ORCID ID 0000-0001-8479-5856)

³Departamento de Zootecnia e Ciências Biológicas, Universidade Federal de Santa Maria, Rio Grande do Sul/UFSM, Palmeira das Missões-RS, Brasil, rzvaz@terra.com.br (ORCID ID 0000-0003-4505-1277)

⁴Universidade Federal de Santa Maria, Rio Grande do Sul/UFSM, Santa Maria-RS, Brasil, fabianonunesvaz@gmail.com (ORCID ID 0000-0002-7252-2778)

⁵Universidade Federal de Goiás, Goiás/UFG, Goiânia-GO, Brasil, jorestle@terra.com.br (ORCID ID 0000-0002-6103-4074)

⁶Universidade Federal de Pelotas, Rio Grande do Sul/UFPEL, Pelotas-RS, Brasil, fabio_mendc@hotmail.com, (ORCID ID 0000-0003-2477-0360)

INTRODUCTION

Animal welfare and the quality of the produced meat are directly linked to each of the activities in the production chain, from the birth to the slaughter of the animals. This subject has recently become of public, economic and political interest, mainly due to changes in the profile of meat consumers, who have begun to inquire how the animals are bred, fed and slaughtered (LOSADA-ESPINOSA *et al.*, 2017; MIRANDA-DE LA LAMA *et al.*, 2017; NJISANE; MUCHENJE, 2017).

There are scientific and normative studies that recommend the implementation of good animal welfare practices and handling alternatives (GRANDIN, 2014; ROMERO *et al.*, 2017). However, individual differences between animals, herds and pre-slaughter handling systems, and their interaction (MENDONÇA *et al.*, 2019) mean that there is a need for constant research in the subject.

Recent studies describe how the absence of animal welfare programs on properties increases bruising, which is significantly associated with various factors such as gender (MENDONÇA *et al.*, 2018), transport (MENDONÇA *et al.*, 2019; SILVA; BERTOLONI; RIBEIRO, 2016), the handling employed on the property and irregularities in the maintenance of equipment and facilities (ROMERO *et al.*, 2017), as well as the lack of training of the personnel who handle the cattle (HULTGREN *et al.*, 2014). Economic losses due to bruising in bovine carcasses are significant (ANDRADE *et al.*, 2008; MENDONÇA *et al.*, 2016, 2019), since the affected meat must be discarded. Furthermore, meat from injured animals or even from those slaughtered under poor welfare conditions, loses its principal characteristics for consumers, and decomposes rapidly, becoming unsuitable for human consumption (YOUNGERS *et al.*, 2017). Commercial cuts of beef follow a quality standard, where the presence of bruises requires the piece to be recut, with a loss of economic value and a reduction in profitability within the production chain (MENDONÇA *et al.*, 2016). The aim of this study was to determine losses in primary commercial cuts of bovine carcasses due to severe injuries caused during pre-slaughter handling.

MATERIAL AND METHODS

The research was approved by the Ethics Committee for Animal Experimentation, CEEA, of the Federal University of Pelotas, under case number 23110.008794/2013-31 (Pelotas, Rio Grande do Sul, Brazil, CEEA case number 8794 CEEA).

Details of the slaughterhouse

The slaughterhouse, Frigorífico Silva Indústria e Comércio Ltda., is located in the central region of the state of Rio Grande do Sul, Brazil (53°77'97" W and 29°78'18" S). The climate in the state is humid subtropical, with an average annual temperature of 19 °C and an average rainfall of 1688 mm. The slaughterhouse operates from Monday to Friday (08:00 - 17:00) and has a slaughter capacity of 600 cattle per day (80 animals/hour) and is regulated by the Federal Inspection Service (SERVIÇO DE INSPEÇÃO FEDERAL - S.I.F 1733).

Description of the study

The study evaluated a total of 5,028 batches of cattle, with an average of 30.64±10 animals (ranging from 10 to 54 animals), totalling 154,100 carcasses, 60% male and 40% female, with a mean body weight on arrival at the slaughterhouse of 467.12±56.38 kg and 451.75±48.11 kg respectively, slaughtered from January to December 2013. The slaughtered animals were of different ages, evaluated according to dentition: milk teeth (17,296 males and 9,949 females), two teeth (21,846 males and 10,233 females), four teeth (19,430 males and 10,094 females), six teeth (17,680 males and 10,999 females) and eight teeth (16,208 males and 20,365 females).

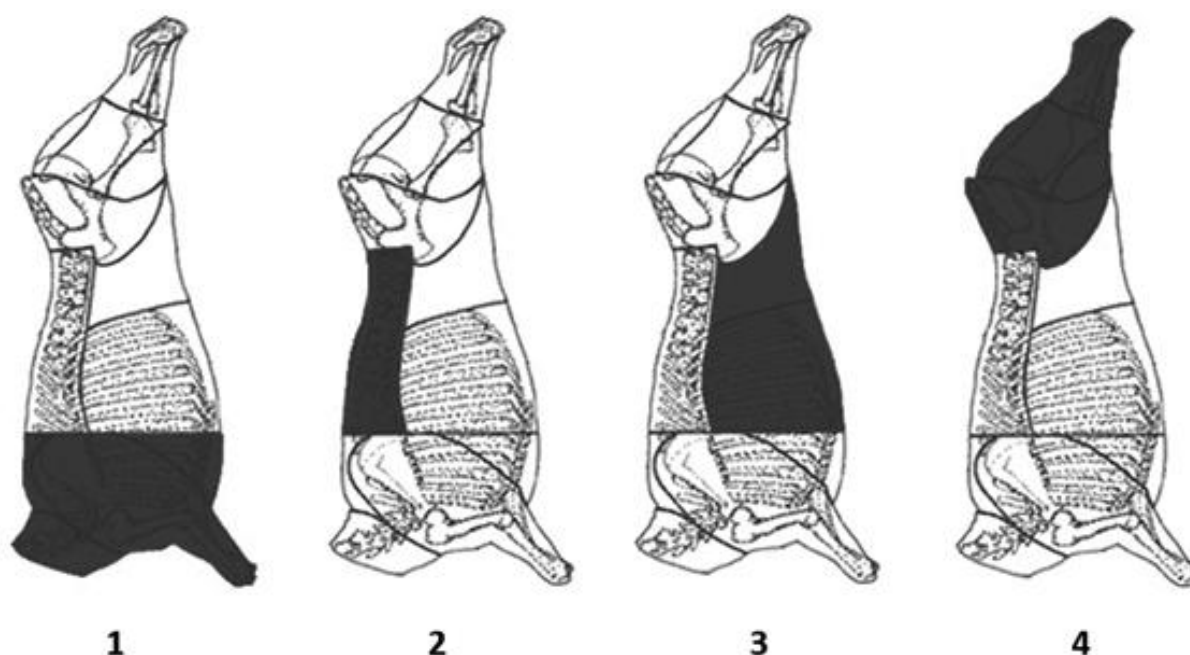
The animals were acquired from different mesoregions in Rio Grande do Sul, where they were bred in production systems characteristic of the region. The predominant genetic groups included British breeds (Aberdeen Angus and Hereford) and their crosses with zebu (Nelore, Bhraman) and continental breeds (Charolais, Limousin). The genetic group was not considered in the evaluations as a probable cause of bruising due to confusion in both the production systems and in the consignments sent for slaughter, especially when the herd came from producers that only finished the cattle. As such, there are hardly any homogeneous batches, with zebu animals, or even animals of synthetic breeds, often being mixed in with batches of European and British animals.

Evaluation of bruising

Bruises were routinely identified by health-care agents from S.I.F., and were counted according to the affected region of carcass: forequarter, loin, sidecut and round (Figure 1). Only severe bruises, for which it was not necessary to have affected the bone structure, were counted - adapted from the National Standards Institute, Chile (INSTITUTO NACIONAL DE NORMALIZACIÓN, 2002). Such bruises determine the complete or partially loss of the cut, influencing its market value.

The variables considered as causing bruising were gender (R), condition of the loading yards and ramp at the

Figure 1 - Cutting the carcase to register bruises. 1 = forequarter 2 = loin, 3 = sidecut, 4 = round (BRAZILIAN ASSOCIATION OF MEAT-EXPORTING INDUSTRIES, 2019)



farm (CF), handling on the farm (HF), type of transport truck (TK), load density (LD) and season of year (TY). In addition, the journey time (JT) and distance travelled by the truck (DT) were counted from loading the animals at the property to arrival at the slaughterhouse.

In order to estimate the effect of CF and HF, the methodology established by Mendonça *et al.* (2018) was used, which classified as Good, Fair or Poor the boarding facilities (yard and ramp) and the level of aggressive handling that might present a risk of injury to the animals in the yard or on the ramp. These evaluations were determined by staff at the slaughterhouse who intermediate in negotiations and accompany loading of the animals together with the drivers. There were several training sessions for these activities, with the evaluations being marked in the travel log and signed by the staff and a representative of the property, who was present when loading.

To evaluate the effect of TK, six types of vehicle were used: extended double-axle truck + trailer, double-axle truck + trailer, single-axle truck + trailer, articulated double-axle truck, double-axle truck and single axle truck. These vehicles achieved a mean stocking density of 48, 43, 37, 37, 27, 18 animals respectively, considering an animal unit of 450 kg. All the vehicles belonged to the same carrier and were therefore similar as regards bodywork maintenance,

interior design, driver training, engine power and general truck mechanics.

The effect of LD was evaluated using the ratio of the total weight of the load (kg) to the area of the truck (m^2), grouped into the following classes: $<370 \text{ kg m}^{-2}$, from 371 to 400 kg m^{-2} , 401 to 430 kg m^{-2} and $>431 \text{ kg m}^{-2}$.

TY were consistent with the seasons of the year in the Southern Hemisphere, classified as summer, autumn, winter and spring.

DT was determined as the truck mileage (km) from the property to the slaughterhouse, and grouped into three classes: $\leq 150 \text{ km}$, from 151 to 250 km and $\geq 251 \text{ km}$. JT was counted in hours (hs) from the time the truck left the farm to unloading the animals at the slaughterhouse, and grouped into the following classes: $<1 \text{ hr}$, from 1 to 3 hs, 3 to 6 hs and $>6 \text{ hs}$.

Statistical analysis

The analysis was carried out using the R Software, establishing Poisson regression models for each region of carcass. In order to fit the models, the STEPWISE selection procedure was used, starting with the one-by-one addition of the variables under evaluation (Forward Selection); the model being defined by means of the Akaike Information Criterion (AIC), which can be represented by following equation:

$$\log\left(\frac{Y_{ijklmnopr}}{1 - Y_{ijklmnopr}}\right) = \alpha + G_i + TY_j + CF_k + HF_l + TK_m \quad (1)$$

$$+ LD_n + DT_o + JT_p + \beta xN_{ijklmnopq} + e_{ijklmnopr}$$

where: $Y_{ijklmno}$ is the number of lesions per region of carcass, α is the intercept of the model, G_i is the effect of i^{th} gender of the animal ($i=1$ male, $i=2$ female); TY_j is the effect of the j^{th} season of the year ($j=1$ summer; $j=2$ autumn; $j=3$ winter; $j=4$ spring), CF_k is the effect of the k^{th} condition of the loading yards at the farms ($k=1$ good; $k=2$ fair, $k=3$ bad); HF_l is the effect of the l^{th} handling condition at the farm ($l=1$ good; $l=2$ fair, $l=3$ bad); TK_m is the effect of the m^{th} type of truck used for transport ($m=1, \dots, 6$); LD_n is the effect of the n^{th} loading density of the truck ($n=1, \dots, 4$ classes); DT_o is the effect of the o^{th} distance travelled ($o = 1, \dots, 3$ classes); JT_p is the effect of the p^{th} journey time ($p=1, \dots, 4$ classes); β is the covariant associated with the number of animals per batch (N) and $e_{ijklmnopr}$ is the residual term.

The mean number of bruises per class were compared by Tukey's test using the Pairwise procedure of the SPSS/lmeans package at a significance level of 5%.

RESULTS AND DISCUSSION

In the total of 154,100 carcasses evaluated, 7,865 serious injuries were found, accounting for 5.1% of bruises.

As for the cuts, the most damaged was the sidecut region, followed by the forequarter, loin and round, with values of 53.6, 23.9, 13.6 and 8.9% of the injuries respectively.

For each carcass cut, a decreasing model was prepared based on the degree of importance established by the AIC for the variables causing bruising in the carcass (Figure 2).

Gender was the main variable in causing injury to the sidecut, forequarter and loin, and the third factor in importance for the round, for which the condition of the yards and ramps was the principal factor; this was also a variable with great potential for causing injury to the forequarter and loin of the animals.

When fitting the models, the distance and time of transport, although potentially the causes of severe injury, had the smallest influence on bruising in all regions of the carcass, with the other variables having a moderate effect.

Females presented a higher frequency of bruising than did males (Figure 3), with percentages of 79.13% and 20.87% respectively. The mean number of injuries per batch in the females was higher than in the males ($P < 0.05$), irrespective of the region of carcass (Table 1).

The larger amount of bruising in females compared to males is possibly due to their reactivity. This greater reactivity is a consequence of maternal

Figure 2 - Historical logistic regression for defining the Poisson Model by stepwise selection methodology using the Akaike information criterion (AIC) in the different regions of the carcass

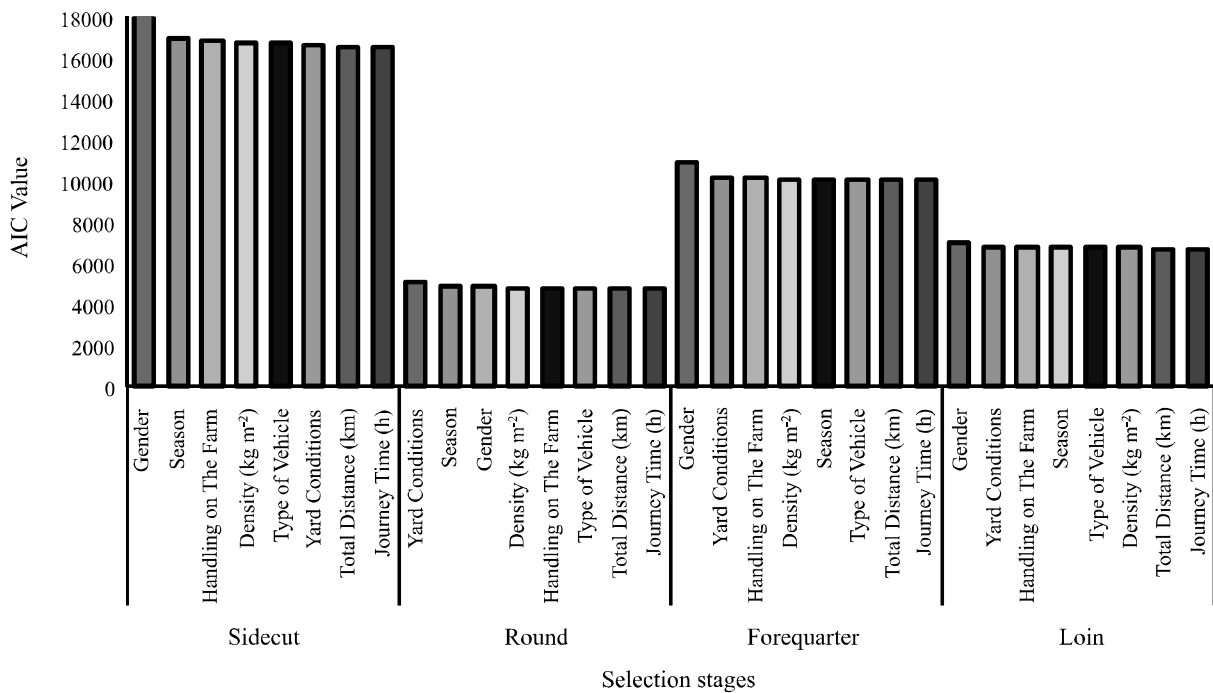


Table 1 - Number of carcasses, mean values with standard errors and total injuries per batch for the independent variables that display a significant effect on the total number of injuries in the regions of the sidecut, round, forequarter and loin; based on Poisson analysis

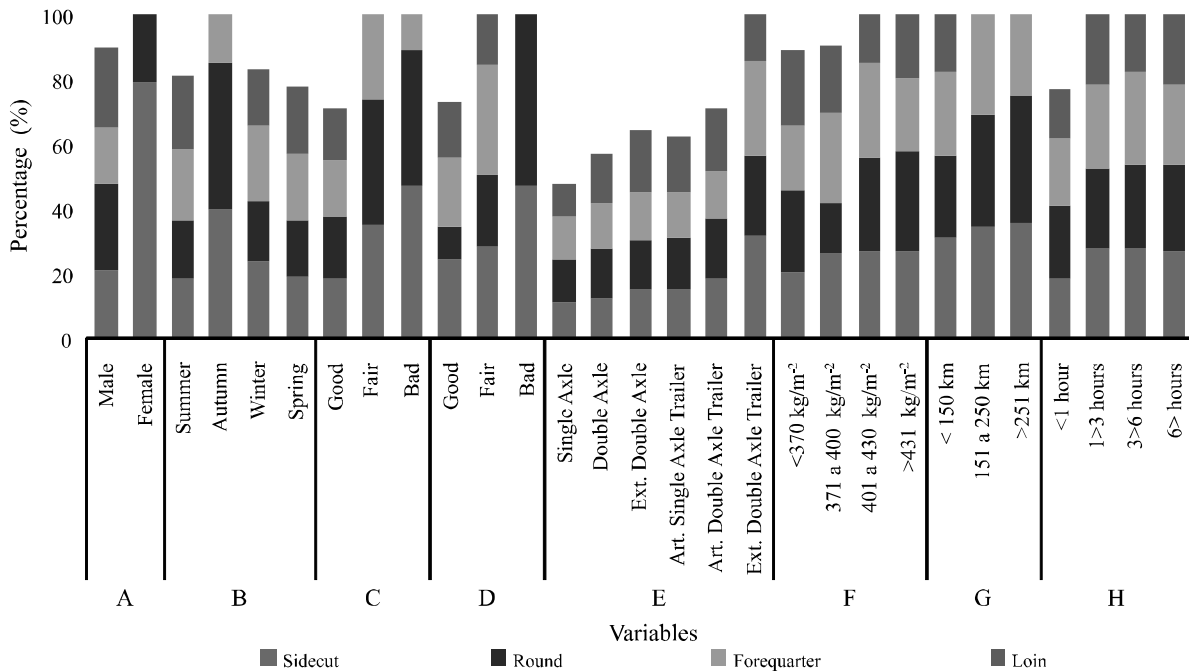
Area of the carcass						
Variable	N	Sidecut	Round	Forequarter	Loin	Total Bruising
Gender						
Females	2079	2.13 ± 0.11 a	0.43 ± 0.05 a	1.20 ± 0.09 a	0.56 ± 0.06 a	4.32 ± 0.77
Males	2949	0.57 ± 0.03 b	0.16 ± 0.02 b	0.26 ± 0.02 b	0.19 ± 0.02 b	1.18 ± 0.18
Total	5028	2.7 ± 1.10	0.59 ± 0.19	1.46 ± 0.66	0.75 ± 0.26	5.5 ± 2.22
Seasons of the Year						
Summer	1203	0.97 ± 0.06 b	0.26 ± 0.04 b	0.61 ± 0.05 b	0.38 ± 0.05 b	2.22 ± 0.31
Autumn	971	1.84 ± 0.11 a	0.59 ± 0.08 a	0.79 ± 0.07 a	0.57 ± 0.07 a	3.79 ± 0.60
Winter	1071	1.06 ± 0.06 b	0.20 ± 0.02 c	0.51 ± 0.04 c	0.23 ± 0.03 c	2.00 ± 0.39
Spring	1783	0.79 ± 0.04 c	0.15 ± 0.02 d	0.39 ± 0.03 d	0.23 ± 0.03 c	1.56 ± 0.28
Total	5028	4.66 ± 0.46	1.20 ± 0.20	2.30 ± 0.17	1.41 ± 0.16	9.57 ± 0.97
Management on the Farm						
Good	3381	0.72 ± 0.03 c	0.17 ± 0.02 b	0.36 ± 0.02 b	0.18 ± 0.02 c	1.43 ± 0.25
Fair	1498	1.25 ± 0.06 b	0.32 ± 0.03 a	0.63 ± 0.04 a	0.37 ± 0.04 b	2.57 ± 0.42
Bad	149	1.50 ± 0.12 a	0.33 ± 0.06 a	0.77 ± 0.09 a	0.52 ± 0.08 a	3.12 ± 0.52
Total	5028	3.47 ± 0.40	0.82 ± 0.09	1.76 ± 0.21	1.07 ± 0.17	7.12 ± 0.86
Density (kg m ⁻²)						
<370	1259	0.66 ± 0.04 d	0.18 ± 0.02 c	0.31 ± 0.03 c	0.22 ± 0.03 c	1.37 ± 0.21
371 - 400	889	1.15 ± 0.07 c	0.16 ± 0.02 c	0.62 ± 0.05 b	0.27 ± 0.04 c	2.20 ± 0.44
401 - 430	1269	1.29 ± 0.07 b	0.35 ± 0.04 b	0.73 ± 0.06 a	0.39 ± 0.05 b	2.76 ± 0.43
>431	1611	1.53 ± 0.09 a	0.45 ± 0.06 a	0.68 ± 0.05 ab	0.50 ± 0.06 a	3.16 ± 0.50
Total	5028	4.63 ± 0.37	1.14 ± 0.14	2.34 ± 0.19	1.38 ± 0.13	9.46 ± 0.78
Type of Vehicle						
Single Axle	422	0.57 ± 0.05 d	0.16 ± 0.03 c	0.31 ± 0.04 e	0.22 ± 0.04 d	1.26 ± 0.18
Double Axle	2118	0.91 ± 0.05 c	0.22 ± 0.03 bc	0.41 ± 0.03 d	0.30 ± 0.03 c	1.84 ± 0.30
Extended Articulated						
Double Axle	298	1.12 ± 0.09 b	0.22 ± 0.46 bc	0.51 ± 0.06 c	0.29 ± 0.05 c	2.14 ± 0.40
Single Axle With Trailer	770	1.59 ± 0.11 a	0.30 ± 0.05 b	0.84 ± 0.08 b	0.43 ± 0.06 b	3.16 ± 0.58
Double Axle With Trailer	777	1.14 ± 0.07 b	0.19 ± 0.03 c	0.53 ± 0.04 c	0.21 ± 0.02 d	2.07 ± 0.44
Extended Double Axle						
With Trailer	643	1.75 ± 0.15 a	0.70 ± 0.13 a	1.06 ± 0.13 a	0.72 ± 0.12 a	4.23 ± 0.49
Total	5028	7.08 ± 0.43	1.79 ± 0.20	3.66 ± 0.28	2.17 ± 0.19	14.7 ± 1.07
Farm Infrastructure						
Good	3489	0.79 ± 0.04 c	0.08 ± 0.01 c	0.34 ± 0.02 c	0.17 ± 0.02 c	1.38 ± 0.31
Fair	1258	1.06 ± 0.06 b	0.28 ± 0.03 b	0.64 ± 0.05 b	0.36 ± 0.04 b	2.34 ± 0.35
Bad	281	1.61 ± 0.11 a	0.75 ± 0.10 a	0.79 ± 0.08 a	0.57 ± 0.07 a	3.72 ± 0.46
Total	5028	3.46 ± 0.42	1.11 ± 0.34	1.77 ± 0.23	1.10 ± 0.20	7.44 ± 1.18

Continuation Table 1

Total Distance (km)						
<150	1081	0.89 ± 0.05 b	0.15 ± 0.02 b	0.33 ± 0.03 b	0.26 ± 0.03 b	1.63 ± 0.33
151 - 250	1115	1.26 ± 0.08 a	0.34 ± 0.05 a	0.74 ± 0.07 a	0.36 ± 0.04 a	2.70 ± 0.43
>251	2832	1.21 ± 0.07 a	0.36 ± 0.05 a	0.72 ± 0.06 a	0.38 ± 0.05 a	2.67 ± 0.39
Total	5028	3.36 ± 0.20	0.57 ± 0.13	1.79 ± 0.23	1.00 ± 0.06	7.00 ± 0.61
Length of Journey (hours)						
<1	69	1.05 ± 0.18 bc	0.40 ± 0.15 a	0.70 ± 0.17 a	0.29 ± 0.11 b	2.44 ± 0.34
1>3	762	1.37 ± 0.08 a	0.37 ± 0.05 a	0.77 ± 0.06 a	0.43 ± 0.05 a	2.94 ± 0.45
3>6	2117	1.09 ± 0.04 b	0.19 ± 0.01 b	0.49 ± 0.02 b	0.32 ± 0.02 b	2.09 ± 0.39
6>	2080	0.95 ± 0.04 c	0.16 ± 0.01 c	0.37 ± 0.02 c	0.29 ± 0.02 b	1.77 ± 0.34
Total	5028	4.46 ± 0.18	1.12 ± 0.12	2.33 ± 0.19	1.33 ± 0.07	9.24 ± 0.50
General Total Bruising (number)	5028	4216	703	1876	1070	7865

Letters in a column within the same cause of injury differ (P<0.05) by Tukey's test

Figure 3 - Frequency of bruising in the different regions of the carcass. gender (A), seasons (B), animal handling on the farm (C), conditions of the yards (D), type of truck (E), loading density (F), distance (G), journey time (H)



behaviour expressed over time, a result of the need to defend their offspring, and therefore be more reactive to all types of management; in addition, memorisation of mistreatment received by the animals is more evident in females than in males, as mentioned by Fernandes *et al.* (2017). It is therefore advisable to select less reactive animals in order to avoid injury, as well as work accidents concerning the people involved in the handling and which result in economic losses to the

meat production chain, as per the study by Haskell, Simm and Turner (2014).

The sidecut ribs region is more vulnerable in both males and females due to its being exposed and more susceptible to collision with the structures in which animals are handled. This is more noticeable in females, which have greater arching of the ribs, a result of the type of feeding and the distension necessary for the animals

to achieve maximum voluntary consumption, as well as the larger space in the internal cavity during the gestation period (STRAPPINI *et al.*, 2010). Exposure of the sidecut is a predominant factor in injuries, due to poor handling and inadequate infrastructure (MENDONÇA *et al.*, 2018).

The season was an important factor in the incidence of bruising, especially in the region of the sidecut and round. Animals slaughtered in the autumn had a higher average number of injuries in all regions of the carcass ($P < 0.05$), with values of 1.84, 0.59, 0.79 and 0.57 injuries per batch for the sidecut, round, forequarter and loin respectively (Table 1). Whereas animals slaughtered in the spring displayed a lower mean number of injuries ($P < 0.05$) for all cuts, with values of 0.79, 0.15 and 0.39 injuries per batch, except for the loin ($P > 0.05$), where the number for spring was similar to that of winter, with 0.23 lesion per batch.

The higher occurrence of severe bruising in the autumn irrespective of the cut is due to the demographic region under study, which mainly presents extensive grazing, with oscillations in animal performance due to a smaller supply in both quantity and quality. This fact results in slower production cycles with increases in the age of the animals at slaughter. Mendonça *et al.* (2017), when studying animal age at slaughter and its relationship with the number of bruises, found that increased age is a determining factor in increasing the number of bruises in bovine carcasses. This same time of the year coincides with the end of the reproductive period of the herds and the diagnosis of gestation, when production systems generally sell for slaughter cattle which are not pregnant or unfit for reproduction.

Similar results were expressed by Gallo *et al.* (2000), who found 143.3% more bruising in bullocks slaughtered during the autumn-winter, for which there were 73 bruises, or 70.8% of animals with bruising, compared to those slaughtered during the spring-summer, with 30 bruises, giving 29.2% of injured animals. These authors noticed an association between the period of slaughter and the time of transport, finding an increase of 26 and 40 bruises, accounting for 24.25 and 38.33% in absolute and relative numbers of bruises respectively, with a respective increase in transport time from 3 to 24 hours. In a study carried out in Nigeria, Minka and Ayo (2007) found that cattle transported during the dry season with average temperatures of 38.3 °C had a greater number of bruises on the carcass (34 bruised carcasses). These authors found 43% of injured carcasses between 10:00 and 12:00, which is associated with stress factors that affect both the resistance of the animals during travel and their health.

The number of bruises increased as the handling worsened during loading (Table 1). The number of bruises was higher in the sidecut and loin regions under bad handling, followed by fair handling, and in smaller numbers under good handling. For the round and forequarter, there was no difference between fair and good handling. However, for all cuts, the worst handling received by the animals was the major cause of injury.

The large number of bruises seen in the different regions of the carcass shows deficiencies in handling cattle destined for slaughter, which influence animal welfare. Improper handling of the animals determines a lower quality for the final meat product, besides increasing the biological risks for the consumer (HULTGREN *et al.*, 2014). In Brazil, most beef cattle are extensively reared and man-animal interaction is reduced, representing a great challenge to the animals. In such a scenario, suitable handling, that provides greater tranquillity for the animals, reduces bruising of the carcass, an important indication of the improvements in animal welfare (HUERTAS *et al.*, 2010; MENDONÇA *et al.*, 2018).

The condition of the infrastructure was a determining factor in the occurrence of bruising. Facilities considered to be bad caused an increase in the mean occurrence of bruising. As these conditions improved, the number of bruises decreased linearly ($P < 0.05$), irrespective of the region of carcass.

Inadequate handling during animal-loading activities is shown, since cuts such as the sidecut and loin presented an increase in the number of bruises. The bruising of these cuts is evidence of bad treatment and inadequate installations, as due to their anatomical location, these cuts are more exposed to collision, especially where the installations are unsuitable, in addition to injuries caused directly by the handlers.

Mendonça *et al.* (2018), when introducing variables that result in injury into models in order to predict their effects, found that for all cuts, gender was the main cause of carcass injury. For the loin, the variables of handling and property infrastructure, were the principal causes, suggesting that during loading and irrespective of gender, the animals are mistreated by the people involved, this being worse when the handling structure is inadequate (MENDONÇA *et al.*, 2018). As such, it is important to train the people who take part in the entire production process (MELO *et al.*, 2016). Bertoloni *et al.* (2012) show the lack of training of workers involved in handling the animals to be an obstacle when transporting cattle, especially in terms of loading and unloading, where many employees use pieces of wood, tree branches, belts and electrical equipment, among others, with the aim of speeding up the animals' movement, causing agitation, disorderly movement of the herd and consequent falls.

Increases in the loading density of the transport vehicles caused a greater number of carcass injuries, irrespective of the cut. Densities greater than 431 kg m⁻² promoted an increase in severe injuries in all cuts except the forequarter, for which a LD of over 400 kg m⁻² was similar to densities greater than 431 kg m⁻² (0.73 and 0.68 injuries per batch respectively). In general, although the carcasses still suffered severe injury, densities up to 400 kg m⁻², irrespective of the type of vehicle, were less prejudicial, causing fewer losses due to injury.

Higher loading densities determine animal welfare in pre-slaughter handling (GALLO *et al.*, 2000). Under such circumstances, although the animals get more support from the other animals in the group for maintaining their balance, there are fewer open areas for the animals to take up a position where they feel more secure and that might result in a fall. In this case, if a fall occurs, the lack of empty space makes it almost impossible for the animal to get up, travelling for a long time lying down and being trampled by the other animals.

On the other hand, under light loads (less than 370 kg m⁻²), even if the animals lose their balance and have less support from the other animals of the group during the journey, they have enough space to regain their balance or, in the case of a fall, space to regain their feet and avoid being trampled by other animals in the group (MENDONÇA *et al.*, 2018). A similar number of bruises on bovine carcasses were registered by Mendonça *et al.* (2018), considering all grade I, II and III injuries (INSTITUTO NACIONAL DE NORMALIZACIÓN, 2002) when working with extreme densities at values <370 or greater than 430 kg m⁻². Gonsález *et al.* (2012) recommend that loads transported at high densities should be driven by more-careful drivers, who check the condition of the animals at shorter intervals.

The number of injuries was greater in vehicles with a higher loading capacity and equipped with a trailer. The lowest number of bruises was registered in smaller-sized trucks with a consequently lower animal-loading capacity.

An increase in bruising was seen in the sidecut for vehicles with trailers. Larger vehicle sizes increase the centrifugal force at the centre of the truck body, resulting in a greater loss of balance and increasing the risk of falls. This is intensified when large vehicles are used to transport animals of different batches or from different properties, grouping together animals that have no formed hierarchy (BERTOLONI *et al.*, 2012), causing stress and increased fighting, characterised by high levels of cortisol (SÍMOVÁ *et al.*, 2016). In addition, the stress caused by the air temperature (environmental factor) tires the animals, making them

weak and increasing the number of falls (MITTHELL; KETTLEWELL, 2008). Longer vehicles hinder the flow of air, causing anxiety to the animals (LAMBOOIJ *et al.*, 2012).

Distances of 151 to 250 km or above caused more bruising than did distances of up to 150 km (P<0.05). However, increases in journey time did not show a clear relationship with the number of bruises. Greater bruising was found for journey times of between one and three hours.

Animal stress caused during transport has been widely related to distance/journey time, where long distances are more likely to compromise animal welfare, increasing the risk of bruising (MIRANDA-DE LALAMA *et al.*, 2017; MPAKAMA; CHULAYO; MUCHENJE, 2014). However, it is important to point out that distance is not an isolated factor, but it is the associated conditions that have the greatest effect on animal welfare.

Factors such as thirst, hunger, muscle fatigue and extreme temperatures are made worse by the length of the journey, compromising the health and welfare of the animals (NJISANE; MUCHENJE, 2017). In addition to these factors, transportation may also influence animal welfare through the type of vehicle (MENDONÇA *et al.*, 2018) and high loading density (ROMERO *et al.*, 2013), with negative repercussions on carcass quality. Furthermore, bruises can be induced by stress, the result of the interaction of these variables with people who do not have the necessary knowledge of animal behaviour and who help in loading and unloading the trucks, which represents an unusual activity for the animals (SILVA; BERTOLONI; RIBEIRO, 2016; SÍMOVÁ *et al.*, 2016). Another factor may be a lack of truck maintenance, which increases the risk of bruising, especially from the truck doors (ANDRADE *et al.*, 2008) and rough handling (STRAPPINI *et al.*, 2013).

The similar behaviour for the number of bruises regarding the distance and length of journeys, where an increase in bruising did not follow an increase in these factors, suggests that bruising occurred at the beginning of the journey or before loading, and is a result of the handling at weighing or loading. Similar results are reported by Mendonça *et al.* (2018).

For Tarrant, Kenny and Harrington (1988), there are various factors associated with transportation that interact and influence bruising. These authors suggest that even short journeys, when under non-ideal conditions, are more detrimental than long journeys with excessive journey times but at ideal densities and when care is taken in loading and transporting the animals.

The greater number of bruises associated with short journey times may be due to the initial stress of the animals during the early stages of transportation, when

they are less able to maintain their balance and are more susceptible to slipping (MENDONÇA *et al.*, 2018).

CONCLUSIONS

1. Female cattle are more susceptible to carcass injury resulting from handling during transportation than are males, with the sidecut and forequarter being the most affected cuts;
2. Slaughter during autumn results in a greater number of carcass injuries, whereas during the spring, the number of injuries is lower;
3. An increase in loading density and vehicle size increases the number of carcass injuries in cattle;
4. Travel distances under 150 kilometres cause less bruising in relation to longer distances;
5. Journeys lasting between one and three hours produce the most carcass injuries in cattle;
6. The increase in cuts of meat being discarded in slaughterhouses due to injuries in different regions of the carcass is evidence of poor pre-slaughter handling and the use of unsuitable facilities.

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