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BREED AND CARCASS CHARACTERISTICS ON LOSSES BY BRUISES AND MEAT PH IN BEEF OF STEERS AND CULLING COWS

CARACTERÍSTICAS RACIAIS E DE CARCAÇA NAS PERDAS POR CONTUSÕES E NO PH FINAL DA CARNE DE BOVINOS MACHOS CASTRADOS E FÊMEAS DE DESCARTE

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Abstract
This study aimed to evaluate the effects of the genetic group, maturity, and fatness score of cattle on losses by bruises and final pH value of the carcass of steers and cows. The number of bruises and the final pH value of the carcasses were evaluated as response variables in function of the genetic group, the physiological maturity, and the fatness score. Increases of 174.6 and 159.4% cases of bruises were found when maturity evolved from deciduous to eight teeth for males and females, respectively. The carcasses with moderate fat showed a higher number of bruises than scarce-fat carcasses only in males. Bruises increased by 37.93 and 23.52% for the zebu animals compared with taurine cattle, for males and females, respectively. As regards the pH values, there were variations between sexes, with females having, on average, higher pH, which differed between zebu and taurine cattle. Two-teethed males displayed higher pH values than four-teethed animals, while four and six-teethed females presented higher values than the others. Physiological maturity, fatness score, and genetic group influence losses by bruises in bovine carcasses, with older animals being more susceptible to bruises. Zebu animals being are also more susceptible. Females are more susceptible to final pH alterations in the carcass, mainly in the carcasses of zebu animals.
Keywords: animal welfare; carcass classification; meat quality.

Resumo
Objetivou-se avaliar os efeitos de grupo genético, maturidade e escore de gordura de acabamento de bovinos sobre perdas por contusões e valor do pH final da carcaça de bovinos machos e fêmeas. O

número de contusões e o valor final do pH das carcaças foram avaliados como variável resposta em função do grupo genético, da maturidade fisiológica e do escore de gordura de acabamento. Acréscimos de 174,6 e 159,4% no número de contusões foram verificados quando a maturidade evoluiu de animais dentes de leite para oito dentes para machos e fêmeas, respectivamente. Apenas carcaças de machos com gordura mediana apresentaram maior nível de lesões que gordura escassa. Ocorreram aumentos de 37,93 e 23,52% de contusões para os animais zebuínos, quando comparados a taurinos, para machos e fêmeas, respectivamente. Com relação aos valores de pH, ocorreram variações entre os sexos, tendo as fêmeas, na média, pH mais elevado diferindo entre zebuínos e taurinos. Machos de dois dentes apresentaram valores mais elevados que os de quatro dentes, enquanto as fêmeas de quatro e seis foram superiores às demais. As perdas por contusões em carcaças bovinas são influenciadas pela maturidade fisiológica, o escore de gordura e pelo grupo genético e os animais mais velhos são mais susceptíveis às contusões, assim como os animais zebuínos também são mais susceptíveis. Fêmeas são mais susceptíveis às alterações no pH final das carcaças, principalmente quando a carcaça é proveniente de animais zebuínos.
Palavras-chave: bem-estar animal; classificação de carcaças; qualidade de carne.

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Introduction

Brazil has a prominent place in the world scenario as a big producer and exporter of beef, with considerable increases in the amounts consumed in the internal market and exports. The females have a fundamental relative importance of representing 49.3% of the cattle slaughtered in Brazil and they are destined only for the internal market(1).

The growing consumption of meat resulting from the increasing number of developing countries, or even as a consequence of the better income of populations, generates great concern about the quality and certification of these products. Animal protein consumers demand better production conditions that are sustainable and that reduce animal suffering, associating quality with animal welfare and food safety(2).

Together, these factors induce the production of carcasses of better quality, better reproductive rates, and better productive responses, with consequent economic gains(3). Therefore, it is up to the producers to fit the consumer's demands, seeking to provide an end product that meets the ever-demanding markets, which are also those that pay best(4).

The pre-slaughter stress caused by inadequate management and transport conditions increases losses by bruises on the animal(5), as well as an improper transformation of muscle into meat, reducing the product quality and its shelf life at retailers(6). Animals under stress have physiological mechanisms of adaptation to adverse conditions(7); however, the energy cost of these mechanisms may result in the partial or total absence of muscle glycogen, leading to a decrease in the formation of lactic acid and rapid establishment of the rigor mortis. For Lawrie(8), the combination of these

events modifies the standard conversion of muscle into meat, making the meat tougher and darker — the so-called DFD (dark, firm, dry) meat.

Stressful situations intensify according to sex[9], species, breed, and bloodline[10,11]; category and age[12]; body size, anatomical conditions and fatness[13,14]; and transport and finishing system[15,5].

Thus, reducing the animal stress is a measure of great importance because, in addition to losses in meat quality, stressed animals are more prone to physical injuries, with consequent economic losses. The present study aimed to evaluate the genetic group, maturity, and fatness score of males and females on losses by bruises and final pH value measured 24 h after slaughter.

Material and methods

The dataset consisted of the record of 2,794 carcasses of cattle slaughtered between August and November in a meat-packing plant under federal inspection (S.I.F 1733) located in the central region of Rio Grande do Sul State, Southern Brazil. We used in this study carcasses from castrated steers (1,580) and female (1,214) cattle originating from the purchase of the company for slaughter and industrialization. The Ethics Committee On Animal Welfare of UFPel approved this study (CEEA No. 8794 - 2013).

Animals came from several regions and were transported through different types of vehicles, roads, topographies, and distances; thus, they represented the most diversified production systems and characterized the cattle marketing. Carcasses of steers and culling cows from the herds were used in this study. Cows were culled due to advanced age, reproductive problems or they were considered a surplus from herd replacement, having a similar market value to steers.

Upon being unloaded at the packing plant, animals were housed in separated corrals according to their origin and divided by sex. Also at unloading, the genetic group of the animals was evaluated, and cattle were classified as taurine and zebu cattle. Taurine animals have a predominance of animals from the batches with European phenotypic characteristics, compact muscle mass, strong bone structure, thick hide, small dewlap, long hair, a strong head with medium length chamfer, medium-sized ears, long and arched ribs, and either the presence or the absence of horns. Zebu cattle had the predominance of animals from the batches with zebu phenotypic characteristics, hump, short and fine hair, dark skin, a head shaped like a coffin, medium to long ears, straight chamfer, black and dilated nose, either the presence or the absence of horns, and a large dewlap starting below the jaw and ending at the navel.

Animals followed the logistics of the packing-plant slaughter line. After the hide had been removed, all carcasses were identified individually according to the sequential number of the slaughter order, which at that moment became the identification reference of each carcass. This identification allowed to later relate the pH and bruising data (dependent variables) to the data provided by the carcass classification system. These data refer to the following independent variables: breed characterization, animal age, and fatness score within each sex.

Injuries or bruises on the carcasses were quantified by counting them on the slaughter line immediately after the hide had been removed from the animals; values were recorded on spreadsheets according to the numerical sequence of the carcasses. Animal maturity was evaluated by dentition, after the heads were removed from the carcasses, and classified as: deciduous teeth, two teeth (presence of front incisors), four teeth (presence of front incisors and first intermediates), six teeth (presence of front incisors and first and second intermediates), and eight teeth (complete set of incisors with presence of corner teeth), according to the carcass classification of the Ministry of Agriculture, Livestock, and Food Supply (MAPA), under normative instruction No. 9, of May 4th, 2004[16].

Fatness score was evaluated by technicians from the company and from breed associations, maintaining the patterns established by Ordinance No. 612/89, proposed by the MAPA, as follows: score 1 (absent, < 1 mm), score 2 (scarce, 1 to 3 mm), score 3 (moderate, 3 to 6 mm), score 4 (uniform, 6 to 10 mm), and score 5 (excess, > 10 mm).

The final pH of the carcasses was measured 24 h after slaughter, on the longissimus dorsi muscle at a depth of four centimeters. This measurement was obtained using a portable digital pH meter (ASKO SX 811) calibrated according to the specifications; an average value was calculated between both half-carcasses.

The total number of carcass bruises and the final pH of the carcasses were subjected to analysis of variance using SAS[17] statistic software, and when significant ($P<0.05$) means were compared by the t test of LSMEANS package at a 5% significance level. The total pre-slaughter fasting time (transport time and rest in the slaughterhouse pens) were inserted as covariates in the model. To verify the normality of the data, the Shapiro Wilk test was performed, and when significative, data with ±3 SD were excluded from the mean. Analyses were performed separately for males and females, according to the following model:

$$Y_{ijklmn} = BC_i + AM_j + \mathrm{BC} * AM_{ij} + CF_k + BC * CF_{ik} + AM * CF_{jk} + \beta \times CW_{ijkl} + \beta \times PF_{ijklm} + e_{ijklmn}$$

where Yijklm = dependent variables number of bruises and final pH; BCi = effect of breed characterization i (i: 1 = taurine, 2 = zebu); AMj = effect of animal maturity j (j: 1 = deciduous teeth, 2 = two teeth, 3 = four teeth, 4 = six teeth, 5 = eight teeth); BC*AMij = effect of the interaction between animal maturity and breed characterization; CFk = effect of carcass fatness score k (k: 1 = absent, 2 = scarce, 3 = moderate, 4 = uniform, 5 = excess); BC*CFik = effect of the interaction between carcass fatness score and breed characterization; AM*CFij = effect of the interaction between animal maturity and carcass fatness score; β is the covariate associated with the carcass weight and pre-slaughter fasting (CW and PF) and eijklmn is the residual term. Because the BC*AM, BC*CF, and AM*CF interactions had a low magnitude, they were removed from the final model.

Results and discussion

Analyses were performed separately for males and females, and data were presented by sex as a function of the independent variables (Table 1). Analyzing the overall results, females had 170.0% more

bruises when compared with males, averaging 0.91 and 2.46 bruises per carcass, respectively.

Of the 2,794 carcasses evaluated, 947 carcasses of males and 526 of females did not have any bruises, representing 60.0 and 43.3%, respectively. This finding demonstrates the greater susceptibility of females to get bruised in the pre-slaughter period.

The analysis of the mean values for bruises on the carcasses revealed that both sexes displayed an increase accompanying the maturity advance, with no significant differences from deciduous teeth up to four teeth and up to two teeth, for males and females, respectively. Bruises increased by 174.6 and 159.4% as animals matured from deciduous teeth to eight permanent teeth, for males and females, respectively. These increases in relation to sex and the advancement in maturity are probably because females and older animals are more reactive to adversity and new situations when boarding the vehicle, during transport, and at unloading[18], as well as the greater presence of horns, which causes bruising on animals[19].

According to Vaz et al.[19], females are slaughtered at an older age than males; in this case, culling cows represented, in the last year, 49.3% of the cattle slaughtered in Brazil[1]. Many studies have reported a greater incidence of injuries in females compared with males. Grandin[20] mentioned that the higher prevalence of injuries in females is due to the reproductive management to which cows are subjected on farms; it may also be due to their larger weight and body size[13].

Table 1. Means and standard errors for number of bruises per carcass of male and female cattle according to maturity, fatness score, and genetic group

	Bruises			
Characteristic	***N***	**Males**	***N***	**Females**
Maturity (Dentition)				
Deciduous teeth	424	0.63±0.17^{c}	437	1.43±0.40^{c}
2 teeth	442	0.81±0.17^{c}	143	1.52±0.42^{c}
4 teeth	335	0.83±0.18^{c}	88	2.12±0.43^{b}
6 teeth	223	1.19±0.19^{b}	59	2.62±0.47^{b}
8 teeth	156	1.73±0.20^{a}	487	3.71±0.39^{a}
Fatness score				
2 – Scarce	306	0.93±0.09^{b}	97	1.74±0.22^{a}
3 – Moderate	1113	1.15±0.05^{a}	858	1.65±0.10^{a}
4 – Uniform	161	0.99±0.13^{ab}	259	1.65±0.15^{a}
Genetic group				
Taurine	1026	0.87±0.16^{b}	686	2.04±0.39^{b}
Zebu	554	1.20±0.17^{a}	528	2.52±0.39^{a}

a,b,c in the same column differ (P<0.05) within each characteristic.

In the present study, carcasses with a fat score absent or excessive were not observed, probably because of the purchasing criterion of the industry, which avoids the acquisition of animals with absent or excess fat because they do not present good quality carcass. The fatness score (P>0.05) in females did not affect the number of bruises per carcass. However, males presented a difference between the moderate and scarce fatness classes, which did not differ from the others. The lack of differences (P>0.05) between fatness score ranges in the carcasses of females on the number of bruises corroborates the findings by Voisinet et al.[21], who demonstrated that bruising in females is a consequence of temperament because they are more reactive, and that the fat cover has no influence.

The higher number of animals with adequate fatness (moderate) can be explained in part by the larger number of carcasses evaluated, as they are the objective of industrial purchase[22]. Simarly, the high number of bruises is due to the conformation of the animals, that present a higher fatness degree and have less space in vehicles and corrals, being more prone to being hit. Evaluating 15,002 carcasses of Nellore crossbred animals in Minas Gerais State and investigating the probable causative agents of bruises, Silva et al.[5] found that injuries originate from several potential factors, and the subcutaneous fat score influences their occurrence, in which carcasses with higher fatness scores (> moderate) had more injuries when compared with carcasses whose fatness was scarce or absent.

The genetic group showed 37.93 and 23.52% more bruises for zebu cattle when compared with those animals of taurine origin, for males and females, respectively. About carcass bruising, among the many causative factors, the genetic group has an influence on their occurrence, with animals with zebu phenotypes having greater changes of bruising due to their reactivity to adversities from management and facilities. For Delgado and Santos[23], the biological type of the animal defined by the breed characteristics or by breeds that are in its genetic composition is the key point of management and is decisive to the final quality of the meat product.

The relative analysis of the mean values showed greater amplitudes among males, whereas in females, despite the lower variation, absolute numbers are higher and with less dispersion, and they have more bruises when compared with males. Regardless of the category or age of the animals, Civeira et al.[24] found no differences (P<0.05) in the comparison between males and females, evaluating the frequency of injuries. Mendonça et al.[25], however, measured injuries on bovine carcasses and observed that males were 58% less likely to be bruised than females; 64% of the females displayed at least one injury, whereas in males this value was only 44%.

The pH values, measured after 24 h of chilling, were lower than 5.8, meaning they were within the limits required by the Federal Inspection Service for international sale, irrespective of maturity, fatness score, and breed characterization of the cattle (Table 2).

Although the meat quality alters as cattle grow older due to changes in muscle composition and metabolic characteristics[26], in this study the pH measurements in both genders did not increase or decrease accompanying the maturity of animals. The pH decline increases as the animals age, but final pH values remain very similar[27].

Table 2. Means and standard errors for final pH of carcasses of males and females according to maturity, fatness score, and genetic group

	Carcass final pH			
Characteristic	**N**	**Males**	**N**	**Females**
Maturity (Dentition)				
Deciduous teeth	424	5.52±0.01^{ab}	437	5.52±0.03^{b}
2 teeth	442	5.53±0.01^{a}	143	5.50±0.03^{b}
4 teeth	335	5.50±0.02^{b}	88	5.56±0.03^{a}
6 teeth	223	5.51±0.02^{ab}	59	5.59±0.03^{a}
8 teeth	156	5.51±0.02^{ab}	487	5.51±0.03^{b}
Fatness score				
2 – Scarce	306	5.49±0.01^{a}	97	5.53±0.02^{a}
3 – Moderate	1113	5.50±0.00^{a}	858	5.53±0.01^{a}
4 – Uniform	161	5.48±0.01^{a}	259	5.52±0.01^{a}
Genetic group				
Taurine	1026	5.51±0.01^{a}	686	5.53±0.03^{b}
Zebu	554	5.52±0.01^{a}	528	5.55±0.03^{a}

a,b,c in the same column differ (P<0.05) within each characteristic.

In males, the highest pH values were observed in two-teethed animals (5.53), differing (P<0.05) only from those with four teeth, but with no differences between the other maturities. In females with four and six teeth, pH values were higher than in the other maturities. Older animals were expected to show higher pH values, since they are usually more reactive than younger animals, depleting their muscle glycogen reserves faster. Although the statistical analysis did not compare males and females, on the average of the different maturities, females (5.54) showed higher pH values than males (5.51), which is probably due to the greater reactivity of the former in relation to males[5]. Working with zebu females divided into eight groups, Leite et al.[28] found only one of these to be in the ideal pH range (below 5.8), which was due to the inappropriate management pre-slaughter, influencing the animal welfare parameters.

Fatness scores did not interfere (P>0.05) with the pH of the carcass measured on the longissimus dorsi. Vaz et al.[19] studied Braford cows with eight teeth and found that the fat cover degree was not a decisive factor for carcass pH, with no differences observed (P>0.05), and at all fat degrees the pH was within the ideal range for meat of good quality. Variations in pH are related to pre-slaughter stress, and more marked differences are observed on animals with different sexual conditions[8], under different pre-slaughter managements, or from different genetic groups, which may in turn alter the stress status prior to stunning[28].

The breed characterization showed pH values within the ideal range (below 5.8). In males, no difference was found (P>0.05) in the final pH of the carcasses of animals characterized as of taurine origin or zebu, with respective values of 5.51 and 5.52. Bianchini et al.[26] studied young non-castrated zebu, continental, and crossbred steers and found appropriate declines in pH and temperature, without variations between genetic groups, but found variations in temperature and pH in the different muscles. Within the females, however, animals characterized as zebu showed higher pH values than the taurine ones (P<0.05), indicating higher susceptibility to stress of animals with this genetic inheritance[11].

Conclusions

Physiological maturity, fatness score, and genetic group are factors responsible for losses by bruises and final pH value in cattle carcasses. Factors influencing the occurrence of bruises and alterations in the final pH of carcasses act differently in males and females. While physiological maturity acts independently of the sex, with older animals bruising more often, the fatness score influences only males, with a higher number of bruises on carcass with moderate fat scores.

It should be stressed that although the pH values were within the ideal range for beef exports, females showed greater susceptibility to qualitative alterations in pH in zebu carcasses in relation to the taurine breeds, which was not observed in males. Regardless of the characteristics evaluated, females appeared to be more susceptible to losses by bruises and variation in the final pH value.

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