



Impact of pen space allowance in outdoor feedlot on cattle performance and carcass quality

Fernanda Macitelli^{1,2,*} e Mateus José Rodrigues Paranhos da Costa^{2,3,†}

¹Faculdade de Medicina Veterinária, Universidade Federal de Mato Grosso, Avenida Alexandre Ferronato 1200, 78550-000, Sinop, Mato Grosso, Brazil. ²Universidade Estadual Paulista “Júlio de Mesquita Filho”, Jaboticabal, São Paulo, Brazil. ³Departamento de Zootecnia, Universidade Estadual Paulista “Júlio de Mesquita Filho”, Jaboticabal, São Paulo, Brazil. [†]*In Memoriam*. *Author for correspondence. E-mail: fernanda.benez@ufmt.br

ABSTRACT. Cattle performance and carcass traits as affected by feedlot pen space allowances were investigated. Bulls (N = 1350) of 30 ± 6 months of age and a weight of 392 ± 46 kg were assigned to one of three pen space allowances: 6 (T6), 12 (T12), and 24 (T24) m² animal⁻¹. Individual average daily gain (ADG), hot carcass weight (HCW), fat cover (scored from 1 to 5), carcass bruise occurrences, and meat pH₂₄ were assessed. Treatment T24 showed higher (P < 0.05) ADG than T6 and T12. T6 had lower (P < 0.05) HCW than T12 and T24. T6 had the highest percentage of carcasses (P < 0.05) and scored 3 for fat cover, followed by T24 and T12. In all treatments, pH₂₄ was within the acceptable range for good meat quality, ranging from 5.60 (T24) to 5.63 (T6). The mean of new bruises per carcass was lowest for T24 (P < 0.05) and did not differ between T6 and T12 (P > 0.05). Superficial bruises were more frequent in T24 than in T6 and T12 carcasses (P < 0.05). Muscular bruises were higher in T6 than in T12 and T24 (P < 0.05). Based on the results, reduced space in feedlot pens lessens beef cattle performance and downgrades carcass quality.

Keywords: Bruises; carcass weight; daily gain; pH; welfare.

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Introduction

Space is an essential resource in the adequacy of feedlot pens, and when it is not appropriately defined, it increases the risk of harming animal welfare (Macitelli et al., 2020; Salvin et al., 2023). Limited space in cattle feedlot pens is usually associated with mud accumulation (Mader, 2011; Grandin, 2016; Munilla et al., 2019), increased frequency of agonistic behaviors (Kondo et al., 1989), and a higher risk of predisposing cattle to more severe pathogen effects (Stokka et al., 2001). Space restriction could also result in physiological and psychological stress, negatively affecting cattle performance (Mader, 2011; Grandin, 2016; Munilla et al., 2019); Wechsler, 201; Krawczel et al., 2012). Additionally, due to growing concerns about the welfare of farm animals, high-density feedlots harm consumers' perceptions of the beef cattle production chain (Vanhonacker et al., 2009).

Despite the established relevance of feedlot space to cattle welfare, most studies have been conducted in indoor feedlots, with only a small number of animals kept at high stock densities (Fisher et al., 1997; Gygax et al., 2007; Keane et al., 2017). These conditions do not account for many environmental effects, such as exposure to climatic factors (Van Laer et al., 2014) and social relationships, which differ between large and small groups of animals (Fraser et al., 2013). According to Grandin (2016), the main problems of outdoor feedlots are: (1) muddy pens and the difficulty of keeping cattle clean, (2) heat stress caused by lack of shade in the pens and (3) problems associated with managing large numbers of cattle, besides the high concentration of dust in the air during the dry period, being expected that these problems are aggravated when animals are kept in high density (Macitelli et al., 2020).

Although the dust particles emitted by feedlots are dominated by large particles (Guo et al., 2011), which are relatively simple to control with irrigation systems, it must be considered that feedlot dust particles harbor antibiotic residues, bacteria, and antibiotic resistance genes (McEachram et al., 2015), which increase the risk of health problems to animals and people exposed to this polluted air.

To our knowledge, only a limited number of studies have assessed the impact of space allowance on the performance of beef cattle in commercial outdoor feedlots, but these studies were conducted under different conditions (climate, nutrition, confinement period, and breed) than in our study. This study aimed to assess

the effects of space allowance in outdoor feedlots under tropical conditions on beef cattle performance and carcass and meat quality traits.

Materials and methods

This study was carried out in accordance with Brazilian legislation. It was approved for the Ethical Use of Animals of the Faculty of Agricultural and Veterinary Sciences, São Paulo State University, Jaboticabal-SP, Brazil (Certified n. 025961/13).

Animals, treatments, and facilities

The study was conducted in a commercial feedlot in the municipality of Campo Verde, Mato Grosso State, Brazil (15°32' S and 55°10' W, 736 meters above sea level) from August to November, totaling 111 days in a feedlot. One thousand three hundred and fifty bulls were evaluated, 450 pure Nellore and 900 crossbred Angus or Caracu vs. Nellore cattle. At the beginning of the feedlot period, the animals were approximately 30 ± 6 months old and weighed 392 ± 46 kg on average. The animals were individually identified with numbered ear tags.

All animals were road transported to the farm where the study was conducted two weeks before starting feedlot operations. During this period, cattle were kept on pasture (*Brachiaria ruziziensis*), with free access to mineral supplements and water. Just before entering the feedlot facilities, they were weighed, vaccinated against clostridial diseases, dewormed (Doramectin 1%, Dectomax, Zoetis Brasil, São Paulo, SP, Brazil), and randomly assigned (within breed) to nine batches (150 animals each). The batches were sorted into one of the three treatments, defining one batch of pure Nellore and two of crossbred cattle per treatment.

The treatments consisted of three pen space availability, 6 (T6), 12 (T12), and 24 (T24) m² per animal. These space allowances were defined based on the assumption that 12 m² per animal-1 is the average space available per head of cattle in commercial Brazilian feedlots, compared with halving it (negative control) and doubling it (positive control).

Smooth wire fences enclosed the feedlot pens, and their surfaces (unpaved ground) had approximately 5% slope. The pen areas were defined by changing their lengths, being 18, 36, and 72 m for T6, T12, and T24, respectively. The water troughs were 1.5 meters in diameter (each serving two feedlot pens), and the feed bunk line was 50 meters long in each feedlot pen, resulting in 33 cm per animal.

Diet and feeding management

Cattle were fed two diets in the feedlot: the adaptation diet, offered in the first 25 days of confinement, and the finishing diet, offered from the 26th day until the end of the feedlot period (Table 1). The RLM[®] software (Integra Software, a Brazilian nutritional program that considers age, body weight, sexual condition, genetic group, the nutritional composition and digestibility of Brazilian foods, and the market value of ingredients, aiming for maximum profit) was used to formulate the diets.

Table 1. Composition (% of DM) of the adaptation and finishing diets offered to the cattle in all treatments during the study period.

Ingredients	Adaptation diet	Finishing diet
Corn silage	44.03	14.00
Cotton hulls	00.00	12.50
Corn residue*	07.09	10.20
Milled corn	26.18	40.30
Cotton seed cake	12.67	12.38
Soybean skin	08.13	08.84
Other**	01.90	01.78
Total	100.00	100.00

DM = Dry matter; Dry matter intake = 2.4% live weight. *Residue from corn storage. **14.93% mineral salt, 85% urea, and 0.074% monensin sodium salt.

The animals were fed four times a day, twice in the morning (07:30h and 10:00h) and in the afternoon (14:30h and 16:30h). Before the first feeding of the day, the person responsible for the feed bunk management applied a 5-point feed bunk scoring (Table 2) in each pen. This score was used to determine the amount of food to offer for each pen that day. Generally, the animals received 40% of the total amount of food at the last feeding of each day and 20% at each of the other three feeding times. The average daily gain (ADG) expected for the entire feedlot period was 1.6 kg animal⁻¹.

Table 2. Criteria used for the feed bunk management used to define the amount of food that should be offered for each pen every day.

Score	Feed bunk condition	Cattle behavior	Amount of food
-2	Empty	Most of the animals (more than 50%) standing in front of the feed bunk	Increase 10% the amount of food in relation to the day before
-1	Empty	Few animals (less than 25%) standing in front of the feed bunk	Increase 5% the amount of food in relation to the day before
0	Empty or little quantity of food (5 to 10% of the last feeding). It is possible to see the bottom of the feed bunk	Most of the animals are calm and not expecting the food at the feed bunk	Same amount of food than the last day
1	Little quantity of food. It is not possible to see the bottom of the feed bunk (20% of the last feed)	Half of animals standing and half lying down	Decrease 5% of the amount of food in relation to the day before
2	Full	Most of animals lying and ruminating	Decrease 10% of the amount of food in relation to the day before

Adapted from Pritchard and Burns (2003).

Performance trait

The animals were weighed at the beginning (d0, initial body weight = IBW), after 35 days (d35, intermediate body weight = MBW), and at the end of the feedlot period (final body weight = FBW, measured just before loading the animals for slaughter). Weighing was always done after a 12-hour fast.

The average daily weight gains (ADG) were calculated for three periods: from d0 until d35 ($ADG_i = (MBW - IBW)/dp1$), from d35 until the end of the feedlot period ($ADG_f = (FBW - MBW)/dp2$), and from d0 until the end of the feedlot period ($ADG_t = (FBW - IBW)/dpt$), where dp1, dp2, and dp3 are the number of days covered in each period (35, 51, and 110 days, respectively). Three classes of ADGt were defined, and the percentage of cattle with $ADG \leq 1.6 \text{ kg day}^{-1}$, from 1.61 to 2.39 kg day^{-1} , and $\geq 2.40 \text{ kg day}^{-1}$ were recorded for each treatment.

Cattle were slaughtered in two commercial slaughterhouses, both under the inspection of the Official Veterinary Service of Brazil. The first slaughter was conducted with three batches (one of each treatment) of crossbred bulls, and the second occurred 24 days later when the remaining animals were slaughtered. The hot carcass weights (HCW, kg) were provided by the slaughterhouse.

Carcass and meat quality traits

A trained person recorded the presence of bruises (yes or no) and, when present, the number of bruises per carcass, and their colors and severities. The color of the bruises was classified as fresh (for those presenting as bright red) or old (for those with a yellowish-green color), as described by Gracey and Collins (1992). The bruise severity was scored as superficial, when the damaged area comprises only subcutaneous tissues; muscular, when the damaged area comprises subcutaneous and muscular tissue; and severe, when subcutaneous, muscular tissues, and even bones are damaged, including fractures, as described in the Chilean grading system (INN, 2012). The same trained person used a five-point scale (Brasil, 2004) to score the amount of fat cover on carcasses.

A slaughterhouse technician measured the meat pH24 with a digital pHmeter. The measurements were taken at the 12th rib region (ribeye) in the right half-carcass, which was maintained at about 2°C for 24 hours after slaughter.

Statistical analyses

The database was analyzed using Microsoft Excel, and extreme values were excluded using the criterion of average ± 3 standard deviations. All data were analyzed using SAS software (SAS Inst. Inc. Cary, NC), considering animals as the subjects, and the results were considered statistically different when $P < 0.05$. The normality of data distribution was checked for all continuous dependent variables (IBW, FBW, ADG1, ADG2, ADGt, HCW, and pH24) using the Kolmogorov-Smirnov test.

The analysis of variance was conducted using Proc Mixed to evaluate the effect of treatments (space allowance) on IBW, FBW, ADGi, ADGf, ADGt, HCW, and pH24. The model included the fixed effect of treatment and the random effect of genetic groups. When analyzing FBW and HCW, IBW was included as a covariate in the model. For HCW and pH24 analyses, the slaughterhouse was included as a random effect in the model. Mean comparisons were performed using post-hoc Tukey tests. A chi-square test (using Proc Freq) was applied to assess whether the frequency of fat cover scores of ADGt classes depends on the treatments.

Due to differences in transport distance and conditions between the two slaughterhouses, only the animals slaughtered at the second plant were analyzed for bruises. The effects of the treatments on the number of new, old, and total and superficial, muscular, and severe bruises per carcass were analyzed using the Glimmix procedure, considering the fixed effect of treatment, the random effect of breed, and a Poisson distribution. The effect of treatment on the risk of bruise occurrence was analyzed using a logistic regression (Proc Genmod) with a binomial distribution and a probit link function, assuming an adjacent normal distribution, with T24 as the reference category (RC).

Results and discussion

Performance traits

Significant differences among treatments were observed for FBW ($F_{2, 968} = 9.93$), HCW ($F_{2, 968} = 2.94$), ADGi, ADGf and ADGt ($F_{2, 960} = 13.64$, $F_{2, 959} = 64.14$, $F_{2, 970} = 17.68$, respectively), but not for IBW ($F_{2, 970} = 0.46$). The ADGi was lower for T24 and did not differ between T6 and T12. On the other hand, T24 showed higher FBW, ADGf, and ADGt means than T12 and T6 (Table 3). There was no difference between the HCW means of T24 and T12, which were greater than the T6 mean. The percentages of animals in each ADG class also differed significantly among treatments for ADGt (DF = 42, $\chi^2 = 106.63$), as shown in Figure 1.

Table 3. Means (\pm SE) of the cattle performance traits when kept in outdoor feedlot pens under three space allowances (6, 12, and 24 m² animal⁻¹).

Variables	Space allowances		
	6 m ² animal ⁻¹	12 m ² animal ⁻¹	24 m ² animal ⁻¹
IBW (kg)	389.16 \pm 9.37	390.11 \pm 9.34	386.74 \pm 9.36
FBW (kg)	526.76 \pm 10.12 ^c	535.45 \pm 9.96 ^b	538.22 \pm 10.10 ^a
ADGi (kg d ⁻¹)	2.19 \pm 0.08 ^a	2.14 \pm 0.08 ^a	1.91 \pm 0.08 ^b
ADGf (kg d ⁻¹)	1.30 \pm 0.12 ^c	1.40 \pm 0.12 ^b	1.71 \pm 0.12 ^a
ADGt (kg d ⁻¹)	1.60 \pm 0.08 ^c	1.69 \pm 0.08 ^b	1.77 \pm 0.08 ^a
HCW (kg)	291.85 \pm 1.29 ^b	294.42 \pm 1.23 ^a	295.17 \pm 1.25 ^a

SE (Standard error), initial body weight (IBW), final body weight (FBW), average daily gain in the first period (ADGi, from d0 to d35), average daily gain in the second period (ADGf, from d36 until d110), average daily gain for the total experimental period (ADGt, from d0 until the d110), and hot carcass weight (HCW). Means followed by the same letters in the lines did not differ statistically (Tukey test, $P < 0.05$).

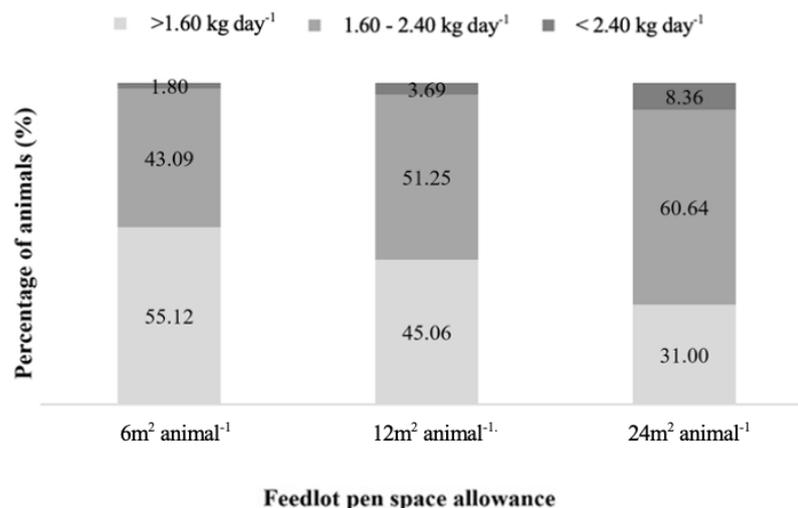


Figure 1. Percentages of outdoor feedlot cattle kept under three space allowances (6, 12, and 24 m² animal⁻¹) according to the ADGt classes (≤ 1.60 kg day⁻¹; from 1.61 to 2.39 kg day⁻¹, and ≥ 2.40 kg day⁻¹).

It is well known that many factors affect cattle ADG, including pen space allowances for feedlot cattle (Andersen et al., 1997; Fisher et al., 1997; Gyax et al., 2007; Herva et al., 2009; Park et al., 2020). Our results corroborated these previous findings, showing that ADG differed between treatments across all feedlot periods, with a lower ADGi mean for T24 than for T6 and T12, and higher ADGf and ADGt means for T24 than for T6 and T12.

The observed reduction in ADG after the adaptation phase in the feedlot was not expected. Newly arrived feedlot cattle often face numerous stressors that alter their behavior and physiological state, leading to reduced performance (Loerch & Fluharty, 1999). However, changes in weather conditions during our study,

resulting in increased rainfall during the second period, likely contributed to the reduction in ADG. Rainfall increases mud accumulation in the feedlot pens (Macitelli et al., 2020), leading to reduced food consumption and cattle performance (Mader, 2011; Grandin, 2016; Munilla et al., 2019). Our results also show that high density in feedlots harms individual performance of beef cattle, as indicated by the ADGf and ADGt means and the distribution of weight gain observed for T6 animals, compared with T12 and T24 animals. We should also consider that reducing space allowance in feedlot pens can impair cattle health and cause behavioral disorders, also negatively affecting cattle performance (Andersen et al., 1997; Gygas et al., 2007).

Although weight gain is widely used as a performance indicator, it is also important to regard the distribution of weight gain as a piece of complementary information, since, with this information, it will be possible to compare the homogeneity of ADG between batches and to identify the percentages of animals at the lower extreme of the ADG curve.

In this study, all treatments were under the same conditions, varying only in density. Our results show that 69.00% of animals in T24, 54.94% in T12, and 44.89% in T6 had a higher average daily weight gain than expected ($>1.60 \text{ kg/day}^{-1}$; Figure 1). According to the production cost calculation, animals should gain at least 1.30 kg/day ; otherwise, they would incur losses. Most of the 156 animals that did not meet the expected ADG were housed in T6 and T12 (41.03% and 44.23%, respectively).

These results corroborate the outcomes from previous studies showing that the reduced space in indoor feedlots negatively affects cattle performance (Ingvarsten & Andersen, 1993; Fisher et al., 1997; Gygas et al., 2007; Keane et al., 2017; Park et al., 2020) and feed conversion ratio (Cortese et al., 2020), strengthening the idea that the individual space in feedlots is an essential resource for beef cattle.

Carcass quality traits

No carcass was scored as 4 or 5 for fat cover, and only one case of severe bruise was recorded, being excluded from the statistical analyses. The percentages of carcasses receiving fat cover scores 1, 2, or 3 varied significantly among treatments ($DF = 4$, $\chi^2 = 12.89$, Figure 2), with a higher percentage of score three occurring in T6, followed by T24 and T12 (50.54, 42.28, and 39.16%, respectively).

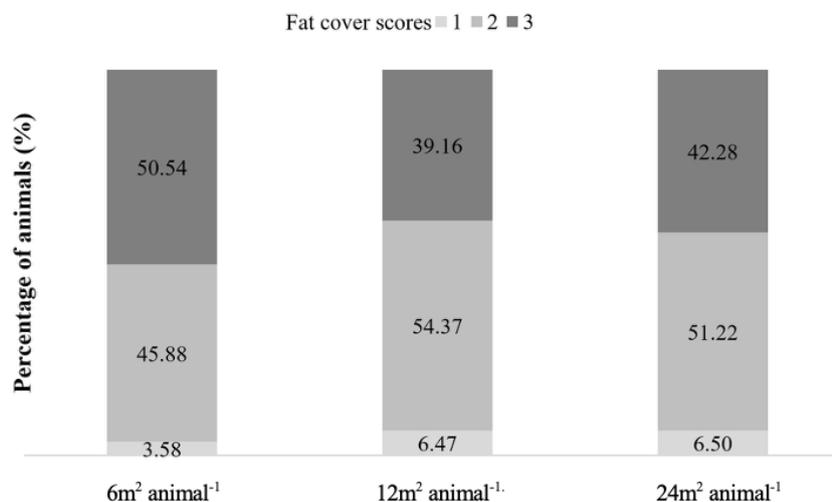


Figure 2. Percentages of carcasses for each fat cover scored according to the three space allowances (6, 12, and 24 m² animal⁻¹) in an outdoor feedlot.

The number of new ($F_{2, 737} = 11.99$), old ($F_{2, 738} = 8.55$) and total ($F_{2, 737} = 14.58$) bruises per carcass differed among treatments. The mean number of new bruises per carcass was lowest for the T24 and did not differ between the T6 and T12. The mean number of old and total bruises per carcass was highest for T12, but T24 and T6 did not differ (Table 4). The odds ratios of new and total bruises differed among treatments, as shown in Table 5. We observed an increased risk of new and total bruises for T6 and T12. However, the risk of old bruises did not differ among treatments.

The number of superficial ($F_{2, 737} = 20.13$) and muscular bruises ($F_{2, 737} = 4.32$) differed among treatments. T24 had the lowest mean of superficial bruises per carcass, followed by T6 ($N = 0.48$) and T12 ($N = 0.65$), respectively; and T6 had the lowest mean of muscular bruises per carcass, with T24 and T12 not differing from each other (Table 6). The odds ratios of superficial and muscular bruises differed between treatments ($P <$

0.05). There was a pronounced increase in the risk of superficial bruises for T6 and T12 compared to the reference class (T24). On the other hand, the risk of muscular bruises was lower for T6 (Table 7).

There were differences among treatments for meat pH ($F_{2, 960} = 5.40$), with the highest mean observed for T6 (5.63 ± 0.03), followed by T12 and T24 (5.61 ± 0.03 and 5.60 ± 0.04 , respectively), which did not differ from each other ($P > 0.05$).

Table 4. Adjusted (\pm SE) and observed means (between brackets) of the numbers of new, old, and total bruises per carcass of beef cattle kept in outdoor feedlots under three space allowances (6, 12, and 24 m² animal⁻¹).

Bruises categories	Space allowance		
	6 m ² animal ⁻¹	12 m ² animal ⁻¹	24 m ² animal ⁻¹
New	-0.38 \pm 0.17 ^a (0.50)	-0.20 \pm 0.16 ^a (0.60)	-0.91 \pm 0.18 ^b (0.30)
Old	-2.10 \pm 0.18 ^b (0.12)	-1.23 \pm 0.11 ^a (0.29)	-1.58 \pm 0.14 ^b (0.20)
Total	-0.14 \pm 0.15 ^b (0.62)	0.22 \pm 0.14 ^a (0.90)	-0.36 \pm 0.15 ^b (0.51)

SE (Standard error). Means followed by the same letters in the lines did not differ statistically (Tukey test, $P < 0.05$).

Table 5. Odds ratios and respective confidence intervals of new, old, and total bruises occurrences per carcass of beef cattle kept in an outdoor feedlot under three space allowances (6, 12, and 24 m² animal⁻¹).

Bruises categories and space allowances	N	%	Odds ratio	Confidence Intervals	χ^2
New					
6 m ² animal ⁻¹	246	49.59	1.68	1.13 – 2.46	6.72*
12 m ² animal ⁻¹	266	60.53	1.77	1.20 – 2.64	8.02*
24 m ² animal ⁻¹	229	30.00	1.00	RC	.
Old					
6 m ² animal ⁻¹	246	12.19	0.68	0.41 – 1.17	1.92
12 m ² animal ⁻¹	266	29.32	1.51	0.95 – 2.41	3.05
24 m ² animal ⁻¹	229	20.00	1.00	RC	.
Total					
6 m ² animal ⁻¹	246	61.78	1.40	0.92 – 2.03	3.23*
12 m ² animal ⁻¹	266	89.85	1.72	1.20 – 2.46	8.52*
24 m ² animal ⁻¹	229	50.00	1.00	RC	.

χ^2 test, all $P < 0.05$. N = total number of evaluated animals; (%) = percentage of animals with bruises, and RC = reference class.

Table 6. Adjusted (\pm SE) and observed means (between brackets) of the number of superficial and muscular bruises per carcass of beef cattle kept in an outdoor feedlot under three space allowances (6, 12, and 24 m² animal⁻¹).

Bruises severity	Space allowances		
	6 m ² animal ⁻¹	12 m ² animal ⁻¹	24 m ² animal ⁻¹
Superficial	-0.10 \pm 0.18 ^b (0.48)	0.17 \pm 0.16 ^a (0.65)	-0.79 \pm 0.19 ^c (0.25)
Muscular	-2.00 \pm 0.19 ^b (0.14)	-1.48 \pm 0.15 ^a (0.23)	-1.40 \pm 0.15 ^a (0.25)

SE (Standard error). Means followed by the same letters in the lines did not differ statistically (Tukey test, $P < 0.05$).

Table 7. Odds ratios and respective confidence intervals of superficial and muscular bruises occurrences per carcass of beef cattle kept in an outdoor feedlot under three space allowances (6, 12, and 24 m² animal⁻¹).

Bruise categories and space allowance	N	%	Odds ratios	Confidence intervals	χ^2
Superficial					
6 m ² animal ⁻¹	381	37.00	2.37	1.55 – 3.60	15.99*
12 m ² animal ⁻¹	403	35.70	2.72	1.13 – 2.46	23.48*
24 m ² animal ⁻¹	399	24.89	1.00	RC	.
Muscular					
6 m ² animal ⁻¹	381	10.97	0.50	0.30 – 0.83	7.27*
12 m ² animal ⁻¹	403	21.43	0.81	0.51 – 1.27	0.84
24 m ² animal ⁻¹	399	15.28	1.00	RC	.

χ^2 test, all $P < 0.05$. N = total number of carcasses evaluated; (%) = percentage of carcasses with bruises; RC = reference class.

Several factors affect fat deposition in cattle carcasses, and the source and concentration of dietary energy are considered the most relevant, especially during the finishing period (Drackley et al., 2014). Once the animals of all treatments tested in this study received the same diet, other factors caused the differences in carcass fat cover between treatments. Interestingly, despite T6 showing the lowest ADFf and ADGt, a higher percentage of cattle from this treatment scored 3 for fat cover than T12 and T24.

Carcass fat cover is indirectly associated with meat quality because it controls the rate of temperature drop and the activity of enzymes that convert glycogen into lactic acid, lowering meat pH (McGilchrist et al., 2012). Despite significant differences among treatments in carcass fat cover and meat pH, all results were within the acceptable range for good carcass and meat quality (European Union, 2007; Brasil, 2017).

Based on our results, we suggest that the stress caused by the space restriction altered the metabolism of energy nutrients, corroborating findings from several previous cattle studies reporting elevated blood glucocorticoid concentrations in animals kept under limited-space conditions (Friend et al., 1979). These results conflict with what is expected of adipose tissue metabolism and distribution, as we expected lower fat cover in T6 cattle. However, as pointed out by Peckett et al. (2011), the acute and long-term effects of glucocorticoids on adipose tissue lipolysis remain unclear.

A well-standardized fat cover is desired. However, it depends on many factors, including diet and genetics, and is affected by stress-induced metabolic disorders. As already reported (Finger et al., 2012; Lee et al., 2014), chronic stress conditions increase adipocyte numbers, mainly in visceral fat deposition, which suggests a lower efficiency of the animal in utilizing the diet to deposit tissues that are profitable. To our knowledge, there is no result about how chronic stress may increase fat accumulation in beef cattle adipocyte cells. The studies addressing this subject were conducted mainly with rats and humans because of the direct relationship between abdominal fat and metabolic and cardiovascular diseases in humans (Finger et al., 2012; Lee et al., 2014). Thus, there is a need to conduct further studies on the association between indicators of chronic stress and those related to visceral and fat-cover deposition in cattle.

Another variable used to assess the carcass quality was the occurrence of bruises. We expected that T6 cattle would show the highest number of old and muscular bruises in the carcasses since it is known that space restriction potentially increases physical contact and, consequently, the frequency of agonistic behavior (Lindberg, 2001; Rodenburg & Koene, 2007), as also described by Kondo et al. (1989), who reported a significant negative correlation between space allowance and agonistic behavior in feedlot cattle. However, this was not the case, probably because, as reported by Macitelli et al. (2020), T6 and T12 cattle reduced their locomotion over time. A higher percentage of T6 cattle showed health problems and hoof alterations (three times that of T12 and twice that of T24), as well as deeper mud in the pens. Therefore, we assume that, because T6 cattle were not physically well, this diminished the frequency and intensity of agonistic interactions, thus reducing the risk of old and muscular bruise occurrences. On the other hand, T24 cattle had greater space allowance and better health (Macitelli et al., 2020) and thus were more efficient at avoiding social confrontations, thereby reducing the risk of bruising. T12 cattle were apparently in an intermediate situation, in which the space did not allow them to prevent agonistic encounters, despite being in better physical condition than those from T6.

Then, we could suppose that the lower number of new and superficial bruises observed in T24 cattle was associated with their apparent tranquility during pre-slaughter handling procedures. Nevertheless, we should also consider other factors, not controlled in this study, that are relevant to consider when recording new bruises' occurrence and severity, such as poor pre-slaughter handling and transport, inadequate facilities design, and cattle with an excited temperament (Strappini et al., 2010; Paranhos da Costa et al., 2012; Schwartzkopf-Genswein et al., 2012).

Muscular bruise occurrences were higher for T12 and T24 than for T6, which could reduce HCW. According to Huertas et al. (2015), bruises cause economic losses since, when muscular and severe, they are trimmed from the carcasses, downgrading meat cuts. Bruises directly affect consumer perception of meat quality (Strappini et al., 2009) because bruised meat decomposes quickly (Chambers & Grandin, 2001), leading to poor taste and a shorter shelf life.

Conclusion

It is concluded that pen space allowance for beef cattle kept in outdoor feedlots has a role in their performance and carcass quality. Reduced space in outdoor feedlot pens lessens cattle performance and downgrades carcass quality.

Data availability

Contact the authors if you are interested in the data collected during the study.

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Associate Editor in charge:

Leandro Dalcin Castilha

ORCID: <https://orcid.org/0000-0003-4799-2839>