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# Performance and body composition of young Nellore bulls slaughtered at different body weights

# Desempenho e composição corporal de novilhos Nelore abatidos com diferentes pesos corporais

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## Abstract

The objective of this work was to evaluate the effect of slaughter body weight on the quantitative characteristics of carcasses and the yield of commercial cuts of young Nellore bulls. Twenty-four non-castrated, 11-month-old, feedlot-fed Nellore bulls were distributed in a completely randomized design, in three treatments: 350 kg, 400 kg or 450 kg of body weight at slaughter (SBW). Slaughter was performed in a commercial slaughterhouse. The data were analyzed by an ANOVA followed by a Tukey test ($p \leq 0.05$). SBW had no relationship with dry matter intake (6.05 kg/day or 75.74 g/kg $BW^{0.75}$), feed efficiency (22.16) or feed conversion (4.67). Average daily gain was different depending on the SBW. Animal slaughtered at 350 kg had gained 1.17 kg/day, whereas animals slaughtered at 400 and 450 kg had gained 1.49 and 1.47 kg/day, respectively. Cold carcass weight increased with SBW (189.50, 209.33, and 242.39, respectively). Other carcass characteristics, like pH at 48 h (5.75), cold dressing carcass (52.61%), chilling losses (1.79%), fat thickness (5.54 mm), marbling (3.34 points), intramuscular fat (6.68%), *longissimus* muscle area (63.10 $cm^2$) and sarcomere length (1.60 μm), were not affected by SBW, but SBW increased cold carcass weight. The treatments had effects on the primary and commercial cut weights. However, the cut yields for the forequarter (39.84%), hindquarter (47.82%) and side-cut (12.34%), and the secondary cuts: chuck (14.38%), hump steak (1.94%), shoulder clod (16.97%), brisket point end (5.56%), neck steak (1.00%), striploin (7.77%), outside flat (5.30%), topside (9.36%), tenderloin (2.16%), flank steak (3.41%), eyeround (2.67%), rump tail (1.20%), rump eye (3.89%), shank (4.44%), knuckle (5.25%) and rump cap (1.40%), were not affected by SBW. SBW did not influence ($p > 0.05$) the commercial cut compositions for all cuts in the forequarter and hindquarter. Finishing young bulls in a feedlot is a strategy to produce beef with reduced feed costs. After all, the slaughter body weight (350, 400 or 450 kg) influenced the quantitative characteristics of the carcass; however, it did not affect the yield of commercial cuts from young Nellore bulls.

**Key words**: Carcass. Commercial cuts. Meat.

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## Resumo

O objetivo do trabalho foi avaliar o efeito do peso corporal de abate sobre as características quantitativas de carcaça e rendimento de cortes comerciais de novilhos Nelore superprecoce. Foram utilizados 24 novilhos Nelore não castrados, com 11 meses de idade, terminados em confinamento, distribuídos em delineamento inteiramente casualizado, em três tratamentos: 350 kg, 400 kg ou 450 kg de peso corporal ao abate (PCA). O abate foi realizado em um matadouro comercial. Os dados foram analisados por ANOVA seguida do teste de Tukey ($p \leq 0{,}05$). O peso corporal ao abate (PCA) não influenciou o consumo de matéria seca (6,05 kg/dia ou 75,74 g/kg $PV^{0,75}$), eficiência alimentar (22,16) e conversão (4,67). O ganho de peso médio diário foi alterado pelo PCA, os animais abatidos com 350 kg ganharam 1,17 kg/dia, enquanto que os abatidos com 400 e 450 kg ganharam 1,49 e 1,47 kg/dia, respectivamente. O peso da carcaça fria aumentou com o PCA (189,50; 209,33 e 242,39, respectivamente). As características de carcaça pH 48h (5,75), rendimentos de carcaça fria (52,61%), perdas por resfriamento (1,79%), espessura de gordura (5,54 mm), marmoreio (3,34 pontos), gordura intramuscular (6,68%), área do músculo *Longissimus* (63,10 $cm^2$) e comprimento do sarcômero (1,60 µm) não foram afetados pela PCA, mas houve aumento do peso da carcaça fria. Os tratamentos tiveram efeito nos pesos dos cortes comerciais primários e secundarios. No entanto, os rendimentos dos cortes: dianteiro (39,84%), traseiro (47,82%), costilhar (12,34%), acem (14,38%), cupim (1,94%), paleta (16,97%), peito (5,56%), capa de contra-file (1,00%), contra-file (7,77%), coxao duro (5,30%), coxao mole (9,36%), file mignhon (2,16%), fraldinha (3,41%), lagarto (2,67%), maminha (1,20%), miolo de alcatra (3,89%), musculo traseiro (4,44%), patinho (5,25%) e picanha (1,40%). O SBW não influenciou ($p > 0{,}05$) a composição dos cortes comerciais para os cortes do dianteiro e do traseiro não sofreram influência dos tratamentos. Terminar novilhos superprecoce em confinamento é uma estratégia para produzir carne de qualidade e pode ser usada para agregar valor à carne bovina. Afinal, o peso corporal ao abate (350, 400 ou 450 kg) influenciou as características quantitativas da carcaça, porém não afetou os rendimentos de carcaça e dos cortes comerciais.


**Palavras-chave:** Carcaça. Carne. Cortes comerciais.

## Introduction

Beef production is a major component of Brazilian agribusiness, producing 9 million tons of carcasses per year and exporting 1.88 million tons to Africa, America, Asia, and Europe (ABIEC, 2017). However, Brazilian meat has a low income in the international market due to the bad reputation of Brazilian beef quality. Thus, it is necessary to develop new strategies to improve the quality of meat produced in Brazil to increase the country's participation in the international market.

Feedlots and young bulls are an alternative production system to the earlier slaughter of animals (14–16 months of age), which presents a higher feed efficiency and meat quality (MAHER et al., 2004; EIRAS et al., 2014). Two points are important in the production of carcasses from young slaughtered animals: the animal slaughter weight and the degree of fatness of the carcass. The beef industry seeks a hot carcass weight between 240 and 340 kg and a carcass fat thickness between 3 and 6 mm, as carcasses must have a minimum amount of subcutaneous fat thickness (3.00 mm) to avoid muscle shortening due to the cold (LAWRIE, 2005).

However, in Brazil, the availability of young bulls (less than 15 months old) with a carcass weight ranging between 240 and 340 kg and subcutaneous fat thickness ranging from 3.00 to 6.00 mm is low. This is due to the genetics of the national herd, which are zebu animals, mainly the Nellore breed. Thus, research that enables the slaughter of young bulls with an ideal degree of fatness and consistent with the requirements of certain markets, which offers better remuneration, is still necessary; meat from smaller carcasses (180–240 kg) is being gradually more accepted by consumers who are looking for a leaner and tender meat.

The effects of slaughter weight on carcass and meat characteristics have been studied under varying conditions, including the effects of environment, genetics, sex, sexual status and age. Young slaughtered animals are more efficient in feed conversion for body weight gain due to the growth of muscle mass and a lower fat deposition. Older animals with higher slaughter weights improve the carcasses' conformation and fat thickness; however, these animals have lower feed conversions. Thus, a higher slaughter weight provides a higher carcass weight, but with a lower gain efficiency (PAZDIORA et al., 2013). Therefore, slaughter weight is of great importance in feedlots, changing the costs and the quality of the final product.

Thus, determining the ideal slaughter weight for animals that meets the requirements of commercialization and distribution systems is essential. A small number of experiments have been carried out under Brazilian conditions to evaluate the effects of different slaughter body weights on the characteristics of the carcass produced by young animals. Thus, the objective of this work was to evaluate the effect of slaughter body weight on the quantitative carcass characteristics and the yield of commercial cuts of young Nellore bulls.

## Material and Methods

*Ethics approval and study location*

This experiment was approved by the Animal Ethics Committee at the Federal University of Sergipe (protocol n° 04/2016). It was carried out at the Santa Cruz Farm, Federal University of Sergipe, Laranjeiras city, Sergipe, northeast Brazil.

*Animals, slaughter and meat sampling*

Twenty-four non-castrated Nellore steers, at approximately 11 months of age and an initial body weight of 287.5 kg, were acquired from the same pasture-rearing property. They were reared under the same feedlot conditions, in collective pens (35 m²/animal). Steers were dewormed using vermifuge with 1% ivermectin as an active ingredient, and had been adapted to the facilities and diet for 15 days. The animals were distributed in a completely randomized design, in three treatments: slaughter body weights of 350 kg, 400 kg or 450 kg.

The basal pellet diet was formulated according to the Nutrient Requirements of Beef Cattle (NRC, 2000) for daily body weight gains of 1.3 kg/day; it consisted of 75% concentrate, 13% soybean hulls, and 12% hay (Table 1). Feed was offered *ad libitum* (5% feed refusal), and the feed intake was recorded daily. The bulls were fed twice daily with orts collected each day to record voluntary intake. The intake was determined by the difference between the quantity offered and the daily orts. Animals had free access to water throughout the entire experimental period. The chemical composition of the diet (Table 1) was analyzed at the Laboratory of Animal Nutrition and Feeding, Department of Animal Science of UFS, according to the Association of Official Analytical Chemists (AOAC, 1990). Total carbohydrates (TC) were estimated according to the equation described by Sniffen et al. (1992): TC (%) = 100 - (% CP + % EE + % ash). The total digestible nutrients (TDN) and dry matter digestibility (DMD) were estimated according to the following equations: TDN = 92.2 – (1.12 x %ADF) (BULL, 1981) and DMD = 88.9 – (0.779 x % ADF) (LINN; KUEHN, 1997).

Slaughter was performed as each group reached the pre-established body weights of 350 kg, 400 kg and 450 kg (after 83.5, 90.5 and 94.0 days in the feedlot, respectively) in a commercial slaughterhouse (Propriá city, Sergipe, northeast Brazil). Truck stocking density was 0.8 ± 0.2 bulls/m², and transport distance was less than 60 km. The bulls were slaughtered following the usual practices of the Brazilian beef industry, according to the Brazilian Regulation of Industrial and Sanitary Inspection of Animal Products (RIISPOA). Afterwards, the carcasses were divided medially from the sternum and spine, resulting in two similar halves, which were weighed to calculate hot carcass weight. Next, the half-carcasses were washed, identified and stored in a chilling chamber at 4 °C, where they remained for a 48 h period. The pH 48 h after chilling was measured in the animals' loin using a meat pH meter (HI 99163®, HANNA, Woonsocket, Rhode Island, USA).

**Table 1.** Ingredients diets composition (%) and chemical composition (%DM) of diet.

| Ingredient | Composition |
|---|---|
| Coast cross hay | 8.0 |
| Oat hay | 4.0 |
| Ground corn | 68.7 |
| Soybean hulls | 13.0 |
| Soybean meal | 3.0 |
| Cana sugar molasses | 0.2 |
| Mineral-vitamin supplement | 3.0 |
| Adsorbents | 0.1 |
| Dry matter | 88.36 |
| Organic matter | 82.42 |
| Ash | 5.94 |
| Crude protein | 14.40 |
| Ether Extract | 11.51 |
| Neutral detergent fiber | 30.87 |
| Acid detergent fiber | 14.29 |
| Non-fibrous carbohydrates | 37.28 |
| Total carbohydrate | 68.15 |
| Total digestible nutrients[2] | 70.92 |
| Dry matter digestibility[3] | 77.76 |

[2]Total digestible nutrients (TDN) = 92.2 – (1.12 x %ADF) (BULL, 1981).
[3]Dry matter digestibility (DMD) = DMD = 88,9 – (0,779 x % ADF) Linn and Kuehn (1997).

Cold carcass weight was determined after slaughter and after the carcass was chilled. Cold carcass dressing (CCD) percentage was defined as the cold carcass weight divided by the final body weight 48 h before slaughter, and calculated by the following equation: CCD = (CCW/FBW) x 100, where CCW = cold carcass weight, and FBW = final body weight.

Forty-eight hours later, after chilling, *longissimus* muscle with bone samples of the cold left half of the carcasses were taken (between the 12th and 13th thoracic vertebra). The samples were identified and stored in plastic bags, then immediately transported to the Laboratory of Meat Technology at the Federal University of Sergipe for later analysis.

*Commercial cuts*

The cold right half of the carcasses was separated into the following primary cuts: hindquarter, which comprehended the posterior part of the carcass, separated from the forequarter between the fifth and sixth rib and the side at an approximate distance of 20 cm from the vertebral column; forequarter, which was composed of the neck, shoulder, foreleg arm, and five ribs; and side-cut, which was composed of the region of the sixth rib and the abdominal muscles.

The cuts were weighed individually, and their proportions were determined in relation to the appropriate half of the cold carcass (disregarding the carcass losses in the cut separations). Afterwards, secondary cuts were obtained according to the Brazilian classification of beef cuts, in which the forequarters were separated into their cuts (shoulder, chuck tender, heart, chuck, neck, and muscle) and the hindquarters were separated into their cuts (tenderloin, striploin, rump, rump cover, topside, flat, knuckle eye round, and muscle). Also, the bone from these components was weighed. The calculations of primary and second cut percentages were obtained by the sum between these cuts. To determinate the physical compositions of the cuts in terms of muscle, fat, and bone, each cut was identified and stored in a plastic bag, then immediately transported to the Laboratory of Meat Technology at the Federal University of Sergipe. The physical compositions of the cuts were determined by the physical separation of the components (muscle, fat, bone, and other tissues).

*Measurements of meat characteristics*

Subcutaneous fat thickness was measured using an ultrasound unit (ALOKA SSD 500V®, Corometrics Medical Systems, Wallingford, CT, USA), equipped with a 3.5-MHz frequency, 172-mm scanning width linear-array transducer. For fat thickness measurements, the bulls were immobilized manually and mucilage was applied for better coupling of the transducer to the skin. The pressure of the transducer head was minimal to avoid compression of the fat. All measurements were performed by the same technician, on the left side, between the $12^{th}$ and $13^{th}$ ribs 24 h before slaughter. After capturing the image, subcutaneous fat thickness was measured using the electronic cursor of the ultrasound.

At the laboratory, photographs were taken to determinate the *longissimus* muscle area (cm²) and marbling. All image analysis and processing procedures to determine the *longissimus* muscle area were done using ImageJ software [http://imagej.nih.gov/ij/] (SILVA et al., 2014). Standardized photograph conditions were prepared (CHAN et al., 2013). An ASUS Z00AD digital camera mounted on a photographic structure (35 cm above the samples), under the lighting of two fluorescent tubes, was used. Following preliminary tests to guarantee that the meat samples appeared entirely in photos, the camera parameters were: standard mode; shutter speed 1/60; aperture size F/12; ISO 210; focal distance 4 mm; no flash. Images were stored and transferred to a computer as JPEG files, and recoded. Marbling was measured on the is *Longissimus* muscle (LM) from the 12th rib by photographic analysis, using the Brazilian scoring system (18 to 16: abundant; 15 to 13: moderate; 12 to 10: mean; 9 to 7: small; 6 to 4: light; and 3 to 1: traces). The percentage of marbling (% IMF, percentage of intramuscular fat) and the number of its particles were calculated for the selected region of interest (ROI) on the cross-section of the muscle using image analysis, and processing procedures were done using ImageJ software [http://imagej.nih.gov/ij/] (LUDWICZAK et al., 2015). Photograph binary images were obtained by implementing semiautomatic thresholding, with the threshold value established individually and subjectively for each image by a trained personnel.

To measure the sarcomere length, chilled samples of the *longissimus dorsi* (1.5 cm long x 1.0 cm wide x 0.5 cm thick) were collected and fixed in 10% buffered formalin for 24 h. Subsequently, the samples were processed for paraffin embedding. Semi-serial, 6-μm-thick longitudinal histological sections were obtained with a microtome. The cuts were distended in a histological water bath at 45 ºC and transferred to labeled slides. The slides were placed on a wood support and incubated at 60 ºC for 24 h to provide greater adherence between the paraffin and the slide. After deparaffinization in an oven at 60 ºC, samples were washed in running water for 2 minutes and treated with an aqueous solution of 0.25% potassium permanganate for 10 minutes, then washed in running water for another 3 minutes. Next, they were immersed in oxalic acid for 5 minutes, removed, and washed in running water again for another 3 minutes, and stained with 10% Mallory phosphotungstic acid-hematoxylin (0.5 g hematoxylin and 1 mL hydrogen peroxide in a total volume of 500 mL) for 24 h. The sections were analyzed in an optical microscope and photographed with an attached capture camera with a 100 times objective and 10 times eyepiece oil-immersion lenses. The formatting of images, scales and measures were performed using Motic Images Plus 2.0 software. Eight animals were assessed per treatment, and the average sarcomere length (μm), obtained by determining the length (μm) of 30 sarcomeres from 25 distinct fibers chosen at random, was calculated in each treatment, generating a total of 200 observations per animal.

*Statistical analyses*

Data were analyzed using the GLM procedure of the SPSS statistical package version 20 (Statistical Package for the Social Sciences, IBM Corporation, Armonk, New York, USA). Data were analyzed using an ANOVA, with slaughter body weight as a fixed effect. Least square means were calculated, and a Tukey test was used to determine significant differences. All statistical differences were considered significant at a level of $p \leq 0.05$.

## Results and Discussion

*Animal performance*

The slaughter body weight of young Nellore bulls finished in feedlots had no relationship ($p > 0.05$) with the days in the feedlot (89 ± 5 days), dry matter intake (6.05 ± 0.09 kg/day or 75.74 ± 2.1 g/kg $BW^{0.75}$), feed efficiency (22.16 ± 1.40), and feed conversion (4.67 ± 0.32) (Table 2). However, these animals consumed a total of 501.8 kg, 548.4 kg and 571.5 kg of feed for the 350, 400 kg, and 450 kg slaughter body weights, respectively, which could lead to an increase in the costs of keeping animals in feedlots.

The average daily gain differed ($p \leq 0.05$) between the different slaughter body weights; the bulls slaughtered at 350 kg gained 1.17 kg/day, while those slaughtered at 400 and 450 kg gained 1.49 and 1.47 kg/day, respectively. The average dry matter intake (6.05 kg/day, 1.75% of body weight) was lower than that reported by Pazdiora et al. (2013), who noted an intake of 8.76 kg/day of DM (2.13% of BW) and an average daily gain of 1.35 kg in young Nellore bulls slaughtered at 450 kg, which is lower than that predicted by BR-CORTE 3.0 (VALADARES FILHO et al., 2016) for non-castrated Nellore steers in feedlots, with 1.37 kg average daily gain with an intake of 8.31 kg/day (2.40% of BW). The dry matter intake of cattle is the result of the complex interaction of various regulator factors, such as those intrinsic to the animal (physical, chemical, psychogenic, metabolic and neurohormonal factors), the environment, and feed. Thus, diet energy density may have regulated intake; it was composed of 88% concentrated feed, corresponding to an estimate of 70.92% and 77.76% total digestible nutrients and dry matter digestibility, respectively (Table 1). The lower intake did not compromise animal performance, with a body weight gain of 1.35 kg/day after 89 days in the feedlot (Table 2); however, in another study of young Nellore bulls, minor performance was noted in animals slaughtered at 423.10 kg after 149 days in a feedlot, with a 1.17 kg/day daily body weight gain (RUBIANO et al., 2009).

**Table 2.** Animal performance and carcass characteristics of Nellore younger bulls finished in feedlot and slaughtered with different body weight.

| | Slaughter body weight (kg) | | | | |
|---|---|---|---|---|---|
| | 350 | 400 | 450 | SEM | p-value |
| Days in feedlot | 83.5 | 90.5 | 94.0 | 4.71 | 0.30 |
| Dry matter intake, kg/day | 6.01 | 6.06 | 6.08 | 0.09 | 0.85 |
| Dry matter intake, g/kg $BW^{0,75}$ | 75.72 | 78.37 | 73.12 | 2.10 | 0.27 |
| Feed efficiency[1], ADG/DMI | 22.24 | 23.76 | 20.47 | 1.40 | 0.25 |
| Feed conversion[2], DMI/ADG | 4.64 | 4.30 | 5.08 | 0.32 | 0.23 |
| Final body weight, kg | 363.25 c | 401.75 b | 454.00 a | 8.16 | ⩽0.01 |
| Average daily gain, kg/d | 1.16 b | 1.49 a | 1.47 a | 0.05 | ⩽0.01 |
| $pH_{48h}$ | 5.77 | 5.70 | 5.77 | 0.02 | 0.18 |
| Cold carcass weight, kg | 189.95 c | 209.33 b | 242.39 a | 4.84 | ⩽0.01 |
| Cold dressing carcass, % | 52.30 | 52.10 | 53.42 | 0.37 | 0.31 |
| Chilling losses, % | 1.76 | 1.98 | 1.63 | 0.08 | 0.18 |
| Fat thickness, mm | 5.42 | 5.31 | 5.88 | 0.73 | 0.26 |
| Marbling, points | 3.21 | 3.56 | 3.25 | 0.92 | 0.73 |
| Intramuscular fat[3], area % | 7.05 | 6.88 | 6.13 | 3.21 | 0.84 |
| Intramuscular fat, number of particles | 256.29 | 229.62 | 254.42 | 102.48 | 0.87 |
| *Longissimus* muscle area, cm² | 60.79 | 63.55 | 64.95 | 3.28 | 0.26 |
| Sarcomere length. μm | 1.58 | 1.62 | 1.60 | 0.52 | 0.99 |

Means followed by the same letters in the rows indicate that there were no differences by Tukey's test ($p \geq 0.05$).
[1]Feed efficiency = ADG/DMI x 100
[2]Feed conversion = DMI/ADG
[3]Relative to *Longissimus* muscle area.

*Carcass characteristics*

The increase in slaughter body weight resulted in an increase in cold carcass weight ($p < 0.05$). However, other carcass characteristics of young Nellore bulls finished in the feedlot, such as the pH at 48 h (5.75 ± 0.18), cold dressing carcass percentage (52.61 ± 0.37%), chilling losses (1.79 ± 0.08%), fat thickness (5.54 ± 0.73 mm) and *longissimus* muscle area (63.10 ± 3.28 cm²), did not differ ($p > 0.05$) by slaughter body weight (Table 2). Young bulls slaughtered at 350 and 450 kg had carcass weights (189.95 and 209.33 kg, respectively) below those recommended by Brazil slaughterhouses (230 kg); however, our results corroborate with those obtained by Santos et al. (2008), who noted a carcass weight of 180.30 kg in crossbred young Charolais-Nellore steers slaughtered at 13 months of age. Regardless, even though the bulls were slaughtered at a final body weight below the recommended value (the recommendation is approximately 500 kg of BW), the minimum carcass weight required (> 180 kg) by the Brazilian system of classification and the classification of bovine carcasses was reached.

Carcass dressing percentage can be affected by several factors, including the age, sex and slaughter weight of the animals (BUREŠ; BARTOŇ, 2012). The carcass dressing percentage indicates the animal's efficiency in transforming feed intake into a carcass, and consequently, into meat. For Zebu cattle, a carcass dressing of around 52% of the final body weight is considered good. This value was equal to the hot carcass dressing percentage verified in the present study (52.61%), and is in agreement with the 52.80% value noted by Pazdiora et al. (2013) for young Nellore bulls slaughtered at 350 kg. Conversely, it was not in agreement with Gomes et al. (2012), who verified that castrated 22-month-old Nellore steers slaughtered at a higher weight (445 kg) showed higher carcass dressing percentages (61.45%) compared to animals slaughtered at a lower weight.

The literature suggested a tendency of increased carcass dressing in animals slaughtered with a higher body weight, as a consequence of the greater deposition of fat in the carcass. However, this study did not reveal a higher fat thickness in Nellore steers slaughtered at a final body weight of 450 kg. When aiming to produce the carcasses of young animals, the precocity of fat deposition is important, because even when aiming for carcasses with smaller amounts of fat, a minimum amount is required (3.00 mm fat thickness) to avoid the darkening of the carcass outside the muscles and the shortening of muscle fibers by the cold, which depreciates the carcass commercial value due to changes in color and softness (LAWRIE, 2005). We observed that when the young Nellore bulls finishing in the feedlot were slaughtered at 350, 400 or 450 kg of body weight, the required minimum fat thickness was reached (5.42, 5.31, and 5.88 mm) for each final body weight. Thus, young bulls fed diets that provide high performances tend to reach a degree of carcass finish early. Nascimento et al. (2015) reported that young Nellore cattle have low body fat, compared to adult animals, since adipose tissue is last to be deposited during the developmental stage of the animal. Therefore, the 5.54 mm fat thickness is this study was due to a diet rich in energy.

Classifying and standardizing carcasses allows for an added value of the meat. Thus, measures such as *longissimus* muscle area or ribeye area loin (REA) can be used to represent the amount of muscle on a carcass, and marbling can be used to evaluate intramuscular fat deposition, which influences meat tenderness (VAZ; RESTLE, 2000). In this study, the young Nellore bulls were finished in a feedlot and slaughtered at 14 months of age, without an effect of slaughter weight (63.10 $cm^2$); this was in agreement with Freitas et al. (2008) for 22-month-old non-castrated Nellore finished in a feedlot (61.23 $cm^2$), and Pazdiora et al. (2013) for young Nellore bulls slaughtered at 350 or 455 kg (52.80 $cm^2$ or 64.90 $cm^2$, respectively). However, it is important to highlight that when animals are slaughtered at a high body weight, the *longissimus* muscle area can be higher. Pazdiora et al. (2013) also showed an increase in *longissimus* muscle area at increased slaughter body weights (52.80 $cm^2$ *versus* 76.70 $cm^2$ for 350 kg *versus* 580 kg).

Our study demonstrated that a reduction in the slaughter weight of young Nellore bulls (up to 350 kg) produced carcasses with similar yields and with weights and fat thickness that are acceptable to the beef industry. On the other hand, heavy slaughter body weight animals presented heavier carcasses and spent more time in the feedlot. Thus, the feasibility of this strategy will depend on the price of commodities (especially corn and soya meal), since feed represents the majority of the costs of finishing animals in feedlots (LUCHIARI FILHO, 2006).

*Meat characteristics*

The marbling (3.34 ± 0.92 points), intramuscular fat (6.68% ± 3.21%), and sarcomere length (1.60 ± 0.52 µm) of young Nellore bulls finished in the feedlot did not differ ($p > 0.05$) by slaughter body weight (Table 2).

Meat marbling was 3.3 points on average, which is considered ‘light’ marbling. The low marbling observed in the current experiment can be explained by the age at slaughter (14 months) and by the genotype (Nellore breed). Beef from the *Bos indicus* sub-species generally have lower marbling scores, compared to *Bos taurus* (ROTTA et al., 2009). Nellore animals slaughtered at 13 months of age probably did not reach physiological maturity, thereby these animals did not start to deposit intramuscular fat. Intramuscular fat also quantifies the fat found between muscle fiber bundles within the ribeye muscle. It is recognized that intramuscular fat (IMF), usually perceived by consumers as marbling, plays an important role in the eating quality of beef, affecting both sensory and physical-chemical properties. IMF can be predicted by image analysis and is considered an indicator for the assessment of marbling level (LUDWICZAK et al., 2015). An intramuscular fat of 6.68% corresponds to 'light' marbling meat, in agreement with the measures of 'light' marbling (3.3 points) obtained by the visual observation of the photos using the Brazilian scoring system.

Visible fat also impacts the purchase intentions of consumers, who associate leaner meats with healthier products (BIALKOVA et al., 2014; BANOVIĆ et al., 2016). Today, consumer behavior is greatly influenced by healthy lifestyle choices (KANG et al., 2015). In general, consumers associate fatter and leaner meats with tastier or healthier products, respectively (BIALKOVA et al., 2014).

Sarcomere length, the smallest contracting unit of muscle, influences meat tenderness. Tenderness is the most important sensory characteristic of beef and directly influences consumer purchasing decisions. In this study, amongst the young Nellore bulls at different finishing stages (slaughter body weights of 350, 400 or 450 kg), no differences in sarcomere length (1.60 μm) were found. Zorzi et al. (2013), also studying Nellore cattle with high and low residual feed intakes finished at 445.00 kg and 22 months of age, found no significant differences in sarcomere length (1.47 μm). Christensen et al. (2011), studying the meat characteristics from young bulls of 15 European breeds, noted that the sarcomere length varied from 1.89 to 2.27 μm. Christensen et al. (2011) also found a negative correlation between sarcomere length and shear force, an important meat texture parameter. However, sarcomere length from *Bos indicus* was expected to be smaller than that from *Bos taurus* animals since European animals (*Bos taurus*) are known to produce more tender meat.

*Commercial cuts*

The slaughter body weight (350, 400, or 450 kg) of fourteen-month-old Nellore bulls finished in a feedlot had an effect on the primary and commercial cut weights ($p \leq 0.05$). However, the cut yields (% or kg/100 kg carcass) were not affected by the treatments ($p > 0.05$), both for the primary cuts: forequarter (39.84%), hindquarter (47.82%) and side-cut (12.34%), and secondary cuts: chuck (14.38%), hump steak (1.94%), shoulder clod (16.97%), brisket point end (5.56%), neck steak (1.00%), striploin (7.77%), outside flat (5.30%), topside (9.36%), tenderloin (2.16%), flank steak (3.41%), eyeround (2.67%), rump tail (1.20%), rump eye (3.89%), shank (4.44%), knuckle (5.25%), and rump cap (1.40%) (Table 3), although, for the knuckle cut, the young bulls slaughtered at 450 kg obtained lower yields than those slaughtered at 350 kg (4.97% *versus* 5.39%; Table 3). We can highlight a tendency for some noble cuts, such as the top side ($p = 0.06$), tenderloin ($p = 0.08$) and rump tail ($p = 0.07$), to have higher yields when young bulls are slaughtered at a lower body weight (350 kg).

**Table 3.** Commercial cuts constituents of Nellore younger bulls finished in feedlot and slaughtered with different body weight.

| | Slaughter body weight (kg) | | | | |
|---|---|---|---|---|---|
| | 350 | 400 | 450 | SEM | p-value |
| Forequarter. Kg | 28.49 b | 30.93 b | 37.52 a | 0.89 | ⩽0.01 |
| Chuck. Kg | 9.91 b | 11.24 b | 13.94 a | 0.44 | ⩽0.01 |
| Hump steak. Kg | 1.29 b | 1.43 b | 2.04 a | 0.10 | ⩽0.01 |
| Shoulder clod. Kg | 12.32 b | 13.13 b | 15.79 a | 0.37 | ⩽0.01 |
| Brisket point end. Kg | 4.98 | 5.12 | 5.76 | 0.17 | 0.13 |
| Hindquarter. Kg | 34.69 c | 37.94 b | 43.43 a | 0.81 | ⩽0.01 |
| Neck steak. Kg | 0.75 | 0.82 | 0.85 | 0.04 | 0.64 |
| Striploin. Kg | 5.64 b | 6.18 b | 7.03 a | 0.17 | ⩽0.01 |
| Outside flat. Kg | 3.81 b | 4.11 b | 4.96 a | 0.12 | ⩽0.01 |
| Topside. Kg | 6.87 c | 7.48 b | 8.32 a | 0.15 | ⩽0.01 |
| Ternderloin. Kg | 1.64 b | 1.69 b | 1.90 a | 0.04 | ⩽0.01 |
| Flank steak. Kg | 2.24 c | 2.66 b | 3.44 a | 0.12 | ⩽0.01 |
| Eyeround. Kg | 1.89 c | 2.15 b | 2.44 a | 0.06 | ⩽0.01 |
| Rump tail. Kg | 0.93 | 0.97 | 1.00 | 0.02 | 0.51 |
| Rump eye. Kg | 2.80 b | 3.08 b | 3.58 a | 0.09 | ⩽0.01 |
| Shank. Kg | 3.27 b | 3.45 b | 4.05 a | 0.08 | ⩽0.01 |
| Knuckle. Kg | 3.87 c | 4.22 b | 4.61 a | 0.08 | ⩽0.01 |
| Rump cap. Kg | 0.99 b | 1.15 a | 1.26 a | 0.03 | ⩽0.01 |
| Side-cut. Kg | 8.67 c | 9.63 b | 11.75 a | 0.29 | ⩽0.01 |
| Forequarter. % | 39.65 | 39.40 | 40.47 | 0.24 | 0.10 |
| Chuck. % | 13.79 | 14.32 | 15.04 | 0.23 | 0.17 |
| Hump steak. % | 1.80 | 1.82 | 2.20 | 0.08 | 0.17 |
| Shoulder clod. % | 17.15 | 16.73 | 17.03 | 0.15 | 0.49 |
| Brisket point end. % | 6.93 | 6.52 | 6.21 | 0.15 | 0.46 |
| Hindquarter. % | 48.28 | 48.33 | 46.85 | 0.18 | 0.24 |
| Neck steak. % | 1.04 | 1.04 | 0.92 | 0.04 | 0.56 |
| Striploin. % | 7.85 | 7.87 | 7.58 | 0.11 | 0.83 |
| Outside flat. % | 5.30 | 5.24 | 5.35 | 0.05 | 0.43 |
| Topside. % | 9.56 | 9.53 | 8.98 | 0.07 | 0.06 |
| Ternderloin. % | 2.28 | 2.15 | 2.05 | 0.03 | 0.08 |
| Flank steak. % | 3.12 | 3.39 | 3.71 | 0.06 | 0.32 |
| Eyeround. % | 2.63 | 2.74 | 2.63 | 0.02 | 0.51 |
| Rump tail. % | 1.29 | 1.24 | 1.08 | 0.03 | 0.07 |
| Rump eye. % | 3.90 | 3.92 | 3.86 | 0.04 | 1.00 |
| Shank. % | 4.55 | 4.39 | 4.37 | 0.05 | 0.50 |
| Knuckle. % | 5.39 a | 5.38 a | 4.97 b | 0.04 | 0.01 |
| Rump cap. % | 1.38 | 1.46 | 1.36 | 0.02 | 0.38 |
| Side-cut. % | 12.07 | 12.27 | 12.68 | 0.11 | 0.07 |

Means followed by the same letters in the rows indicate that there were no differences by Tukey's test ($p \geq 0.05$).

The hindquarter has the noblest and most valued cuts. Thus, a yield of more than 48% for the hindquarter, 39% for the forequarter and less than 13% for the side-cut is advisable (LOPES et al., 2012); the values found in this study for the hindquarter (47.82%) and forequarter (39.84%) fall within this recommendation. The hindquarter, forequarter and side-cut yields observed in our study were similar to those of Pazdiora et al. (2013) for young Nellore bulls, with yields of 51.6% for the hindquarter, 40.4% for the forequarter, and 8.0% for the side-cut for animals slaughtered at 350 kg, and 49.1% for the hindquarter, 40.2% for the forequarter, and 10.6% for the side-cut for animals slaughtered at 455 kg.

Amongst the primary cuts, the side-cut (or back ribs) has the lowest market value. In our study, animals presented a side-cut yield of 12.34%, which is lower than recommended (13%). According to Lopes et al. (2012), abdominal muscle development occurs later than that of other muscles (hind or forequarter muscles); therefore, young animals usually have lower side-cut yields. Lopes et al. (2012) observed larger values for the side-cut of Nellore bulls finished in a feedlot and slaughtered at 24 months of age than those observed in our study (13.20% *versus* 12.34%).

The slaughter body weight of young Nellore bulls finished in a feedlot did not influence ($p > 0.05$) the commercial cut composition (% muscle, % fat, % bone, and % other tissue) for the forequarter (Table 4) and hindquarter (Table 5). For the shoulder clod, the muscle and other tissue percentages differed ($p \leq 0.05$) by the slaughter body weight: the bulls slaughtered at 350 and 400 kg had a higher percentage of muscle (80.66% and 80.75%) and lower percentage of other tissues (3.49% and 2.98%) than those slaughtered at 450 kg (77.13% muscle and 5.37% other tissue; Table 4). The percentages of other tissues were also different ($p \leq 0.05$) in terms of the outside flat, eyeround and rump tail cuts. When the bulls were slaughtered at 450 kg, the percentage of muscle decreased in relation to that of those slaughtered at 350 and 400 kg (Table 5).

**Table 4.** Commercial cuts composition (%) of Nellore younger bulls finished in feedlot and slaughtered with different body weight.

| | | Slaughter body weight (kg) | | | | |
|---|---|---|---|---|---|---|
| | | 350 | 400 | 450 | SEM | p-value |
| Forequarter | | | | | | |
| Chuck | Muscle | 81.56 | 80.58 | 79.77 | 0.60 | 0.28 |
| | Fat | 15.85 | 17.42 | 17.46 | 0.00 | 0.26 |
| | Others | 2.59 | 2.00 | 2.77 | 0.21 | 0.34 |
| Hump steak | Muscle | 80.03 | 81.2 | 80.98 | 0.98 | 0.98 |
| | Fat | 19.97 | 18.88 | 18.90 | 0.96 | 0.98 |
| | Others | 0.00 | 0.00 | 0.12 | 0.03 | 0.15 |
| Shoulder clod | Muscle | 80.66 a | 80.75 a | 77.13 b | 0.62 | 0.01 |
| | Fat | 15.84 | 16.27 | 17.50 | 0.44 | 0.23 |
| | Others | 3.49 b | 2.98 b | 5.37 a | 0.42 | 0.04 |
| Brisket point end | Muscle | 59.67 | 59.70 | 57.39 | 0.89 | 0.49 |
| | Fat | 39.62 | 38.40 | 41.49 | 0.90 | 0.37 |
| | Others | 0.72 | 1.90 | 1.12 | 0.00 | 0.12 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Side-cut | Muscle | 48.55 | 48.92 | 48.98 | 0.19 | 0.86 |
| | Fat | 28.85 b | 28.65 b | 32.36 a | 0.93 | 0.07 |
| | Bone | 16.85 | 16.65 | 16.34 | 0.35 | 0.87 |
| | Others | 5.75 a | 5.78 a | 2.32 b | 0.64 | 0.03 |

Means followed by the same letters in the rows indicate that there were no differences by Tukey's test ($p \geq 0.05$).

For the side-cut, the young bulls slaughtered at 450 kg showed a higher percentage ($p \leq 0.05$) of fat (32.36%) than those slaughtered at 350 kg (28.85%) and 400 kg (28.65%; Table 4). However, the animals slaughtered at 450 kg had 2.32% of other tissues (including the connective tissue), whereas those slaughtered at 350 kg and 400 kg had 5.75% and 5.78% other tissues, respectively. The side-cut (or back ribs) was the only cut with bone (16.61%), and consequently, also had a fat percentage of 29.95%; it was the cut with the lowest amount of muscle (48.82%).

**Table 5.** Commercial cuts composition (%) of Nellore younger bulls finished in feedlot and slaughtered with different body weight.

| | | Slaughter body weight (kg) | | | | |
|---|---|---|---|---|---|---|
| | | 350 | 400 | 450 | SEM | p-value |
| Hindquarter | | | | | | |
| Neck steak | Muscle | 69.02 | 66.45 | 62.46 | 1.27 | 0.06 |
| | Fat | 30.98 | 33.55 | 37.54 | 1.27 | 0.06 |
| | Others | 0.00 | 0.00 | 0.00 | 0.00 | |
| Striploin | Muscle | 74.78 | 74.11 | 73.05 | 0.64 | 0.27 |
| | Fat | 22.24 | 23.22 | 23.09 | 0.80 | 0.61 |
| | Others | 2.99 | 2.67 | 3.86 | 0.44 | 0.54 |
| Outside flat | Muscle | 87.64 | 87.12 | 86.34 | 0.44 | 0.64 |
| | Fat | 10.95 | 12.48 | 11.37 | 0.51 | 0.45 |
| | Others | 1.42 a | 0.40 b | 2.29 a | 0.26 | 0.01 |
| Topside | Muscle | 87.90 | 87.52 | 87.95 | 0.27 | 0.82 |
| | Fat | 10.73 | 11.20 | 10.51 | 0.32 | 0.71 |
| | Others | 1.37 | 1.29 | 1.53 | 0.13 | 0.75 |
| Ternderloin | Muscle | 90.38 | 91.18 | 91.68 | 0.39 | 0.77 |
| | Fat | 8.15 | 7.20 | 6.23 | 0.42 | 0.43 |
| | Others | 1.47 | 1.62 | 2.09 | 0.21 | 0.48 |
| Flank steak | Muscle | 66.15 | 64.64 | 61.45 | 1.06 | 0.10 |
| | Fat | 33.48 | 35.12 | 37.54 | 1.06 | 0.18 |
| | Others | 0.37 | 0.23 | 1.01 | 0.17 | 0.13 |
| Eyeround | Muscle | 85.00 | 83.71 | 85.24 | 0.66 | 0.61 |
| | Fat | 15.00 | 16.29 | 14.25 | 0.67 | 0.47 |
| | Others | 0.00 b | 0.00 b | 0.50 a | 0.08 | 0.01 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Rump tail | Muscle | 83.62 | 81.10 | 81.58 | 0.84 | 0.62 |
| | Fat | 16.33 | 18.63 | 17.45 | 0.84 | 0.71 |
| | Others | 0.05 b | 0.28 b | 0.98 a | 0.15 | 0.02 |
| Rump eye | Muscle | 86.03 | 85.21 | 84.91 | 0.40 | 0.35 |
| | Fat | 11.11 | 11.73 | 12.36 | 0.44 | 0.54 |
| | Others | 2.86 | 3.06 | 2.73 | 0.21 | 0.64 |
| Shank | Muscle | 81.90 a | 82.07 a | 79.22 b | 0.63 | 0.04 |
| | Fat | 11.38 | 11.73 | 11.56 | 0.52 | 0.75 |
| | Others | 6.72 | 6.20 | 9.22 | 0.61 | 0.07 |
| Knuckle | Muscle | 90.36 | 88.73 | 90.29 | 0.51 | 0.33 |
| | Fat | 8.86 | 10.23 | 7.94 | 0.56 | 0.25 |
| | Others | 0.78 | 1.04 | 1.78 | 0.19 | 0.07 |
| Rump cap | Muscle | 77.97 | 76.60 | 73.64 | 0.96 | 0.08 |
| | Fat | 21.69 | 23.16 | 26.03 | 1.02 | 0.08 |
| | Others | 0.34 | 0.24 | 0.34 | 0.14 | 0.43 |

Means followed by the same letters in the rows indicate that there were no differences by Tukey's test ($p \geq 0.05$).

The hindquarter was the primary cut that had a larger amount of muscle (the average of all cuts was 80.8%) than the forequarter cuts (the average of all cuts was 75.0%); this may be one of the reasons that the hindquarter cuts are more valued by consumers. The amount of muscle in a cut is extremely important to consumers, especially those that prefer meat with less fat (a health issue) and more muscle (the edible portion). Tenderloin was the most valuable cut, due to its tenderness and having the highest proportion of muscle (90%) and lowest fat (7.19%) amongst the commercial cuts. Striploin was also a valuable cut for consumers who prefer grilling their meat, despite being a cut with 73.98% muscle and 22.85% fat. Flank steak and brisket point end were the fattest cuts, with 35.38% and 39.84% fat, respectively, and are generally less appreciated by consumers.

## Conclusion

Feedlot animals slaughtered at 350 kg presented lower carcass and commercial cut weights, but similar yields as those slaughtered at 450 kg. The reduction of the slaughter weight of young bulls could be a cost-reducing strategy for farmers, especially when the cost of concentrate per kg of meat produced is not favorable, while still producing carcasses that are well accepted by the Brazilian beef industry.

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## Ethical standards

The manuscript does not contain clinical studies or patient data.

## Conflict of interest

The authors declare that they have no conflict of interest.

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