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Carcass characteristics and non-carcass components of young ½ Purunã x ½ Canchim bulls fed rations with three concentrate contents

Características de carcaça e componentes não-carcaça de tourinhos ½ Purunã x ½ Canchim alimentados com rações contendo três teores de concentrado

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Abstract

Improving the quality and energy content of rations increases performance in feedlot cattle, resulting in higher weight at slaughter, better carcass quality and a higher yield of non-carcass components. The purpose of this study was to evaluate the effect of increasing concentrate content in the ration on the carcass traits and weight of non-carcass components of young bulls finished in a feedlot. Eighteen young crossbred ½ Purunã x ½ Canchim bulls were used, with an average body weight (BW) of 278 kg and 12 months of age at the start of the experiment. The experimental design was completely randomized with three treatments and six replicates, where the treatments were the contents of 0.71, 0.97 and 1.24% BW day^{-1} of concentrate in the ration, on dry matter (DM) basis. Corn silage was used as roughage and was provided *ad libitum* during the experiment. The young bulls were kept in the feedlot for 168 days and slaughtered at 17 months of age. There was a linear effect of concentrate content on the slaughter weight (SW) and hot carcass weight (HCW), which increased from 433 to 485 kg and from 248 to 280 kg between 0.71 and 1.24% BW in DM day^{-1} of concentrate. This represented an increase of 9.87 kg in SW and 6.16 kg in HCW for each 0.10% BW in DM day^{-1} of concentrate added to the ration. The hot carcass yield, rib eye area, subcutaneous fat thickness and the proportions of bone, muscle and fat in the carcass were not affected by the concentrate content and showed mean values of 57.3%, 79.6 cm^2, 3.20 mm, 14.88%, 65.21% and 20.67%, respectively. There was a linear effect of concentrate content on the carcass temperature after cooling, which increased from 8.1 to 9.0 ^{o}C between 0.71 and 1.24% BW in DM day^{-1} of concentrate. An increase of 0.16 ^{o}C in the post-cooling carcass temperature for each 0.10% BW in DM day^{-1} of concentrate added to the ration was observed. The weight of internal organs and the perirenal and internal fat deposition were not affected by the concentrate content. The inclusion of 1.24% BW in DM day^{-1} of concentrate in the ration is recommended to obtain high SW and high HCW. Below this level, the carcass tissue composition and weight of non-carcass components are not modified.
Key words: Beef cattle. Feedlot. Hot carcass weight. Post-cooling temperature. Slaughter weight.

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Resumo

A melhoria da qualidade e do aporte energético da ração proporciona alto desempenho aos bovinos confinados, resultando em elevado peso ao abate, melhor qualidade da carcaça e alto rendimento dos componentes não-carcaça. Objetivou-se com este estudo avaliar a influência do aumento do teor de concentrado da ração nas características de carcaça e no peso de componentes não-carcaça de tourinhos terminados em confinamento. Foram utilizados 18 tourinhos mestiços ½ Purunã x ½ Canchim, que iniciaram o experimento com 278 kg de peso corporal (PC) e 12 meses de idade, em média. O delineamento experimental foi inteiramente casualizado com três tratamentos e seis repetições, em que os tratamentos foram os teores de 0,71; 0,97 e 1,24% PC dia^{-1} de concentrado na ração, em base de matéria seca (MS). A silagem de milho foi utilizada como volumoso e fornecida à vontade durante o experimento. Os animais permaneceram confinados por 168 dias e foram abatidos com 17 meses de idade. Houve efeito linear dos teores de concentrado no peso ao abate (PA) e no peso de carcaça quente (PCQ), que aumentaram de 433 para 485 kg, e de 248 para 280 kg entre os teores de 0,71 e 1,24% PC em MS dia^{-1} de concentrado. Isso correspondeu ao aumento de 9,87 kg no PA e de 6,16 kg no PCQ dos tourinhos a cada 0,10% PC em MS dia^{-1} de concentrado adicionado à ração. O rendimento de carcaça quente, a área de olho de lombo, a espessura de gordura subcutânea e as proporções de osso, músculo e gordura da carcaça não foram influenciados pelos teores de concentrado, apresentando valores médios de 57,3%, 79,6 cm^2, 3,20 mm, 14,88%, 65,21% e 20,67%, respectivamente. Houve efeito linear dos teores de concentrado na temperatura da carcaça após o resfriamento, que aumentou de 8,1 para 9,0 ºC entre os teores de 0,71 e 1,24% PC em MS dia^{-1} de concentrado. Registrou-se aumento de 0,16 ºC na temperatura pós-resfriamento da carcaça a cada 0,10% PC em MS dia^{-1} de concentrado adicionado à ração. O peso dos órgãos internos e a deposição de gordura perirrenal e interna não foram influenciados pelos teores de concentrado. A inclusão de 1,24% PC em MS dia^{-1} de concentrado na ração é indicado para a obtenção de alto PA e alto PCQ em tourinhos. No entanto, abaixo deste teor de concentrado a composição tecidual da carcaça e o peso dos componentes não-carcaça não são alterados.

Palavras-chave: Bovinos de corte. Confinamento. Peso ao abate. Peso de carcaça quente. Temperatura pós-resfriamento.

Introduction

The beef cattle industry in Brazil is characterized, for the most part, by production systems in tropical pastures dominated by zebu cattle - *Bos taurus indicus* (FERRAZ; FELÍCIO, 2010; EIRAS et al., 2016). However, in the climatic conditions of the southern part of the country, these animals perform less well than taurine cattle - *Bos taurus taurus*. Moreover, taurine cattle and their crosses with zebu cattle produce more tender meat with a higher fat content (MAGGIONI et al., 2012). With the modernization of beef cattle production and the increasing demand for food for the world population, the search for young animals with higher potential for muscle development has intensified. These animals can produce carcasses with weights ranging from 225 to 250 kg that show good conformation, a minimum fat thickness of 3 mm and a high proportion of marketable meat (RODRIGUES et al., 2008; PRADO et al., 2015a).

Finishing cattle in feedlot is an important strategy to meet the demands of consumers. However, it is difficult to achieve the carcass fat covering required by the abattoir and meat packing industry in finishing systems for young animals. A way to overcome this is to add concentrate to the ration in sufficient quantity to produce good quality carcasses, without adversely affecting the economic result of feedlot finishing. In the meat production chain, feeding systems and feed composition can influence the carcass and meat traits of cattle, affecting the purchase of this product by consumers (ROTTA et al., 2009).

The content of concentrate in the ration also affects the weight of the internal organs (FERREIRA et al., 2000; MISSIO et al., 2009). The weight of these components at the time of slaughter exerts a strong influence on carcass yield, since heavier viscera increase the revenue of the abattoirs that sell these components to the animal feed industries, while the price paid to the producer for the carcass is lower (SILVEIRA et al., 2013).

Given the above, the purpose of this study was to evaluate the effect of three levels of concentrate in the ration on carcass characteristics and weight of the internal organs of young ½ Purunã x ½ Canchim bulls finished in a feedlot.

Material and Methods

The experiment was carried out at the Model Farm Experimental Station of the Agricultural Institute of Paraná, in Ponta Grossa, State of Paraná, Brazil. Eighteen young ½ Purunã x ½ Canchim bulls were used, with a body weight (BW) of 278 ± 18 kg (mean ± standard deviation - SD) and aged 12 months at the start of the experimental period.

Before the experiment, the animals were kept in collective feedlot pens for 65 days for adaptation to the experimental management. During the adaptation period and the experiment, animals were weighed every 28 days after a 16-hour fast. The ration was composed of corn silage and protein concentrate (Table 1). The silage was supplied *ad libitum*, keeping daily leftovers between 5 and 10% of the amount supplied, on fresh matter (FM) basis, so as not to limit the roughage intake. The concentrate was supplied at a ratio of 0.88% PC day^{-1}, on dry matter (DM) basis. The ration was split into two daily meals that were provided at 8 and 14 hours.

The chemical analysis of corn silage and concentrate was carried out at the Animal Nutrition Laboratory (LNA), Federal University of Paraná (UFPR), for determination of DM, crude protein (CP), ether extract (EE), lignin, ash, calcium, phosphorus, magnesium and potassium contents according to the procedures of the AOAC (1990); the neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined as described by Van Soest et al. (1991). The non-fiber carbohydrates (NFC) content was calculated using the equation: 100 - (CP + EE + NDF + ash). Total digestible nutrients (TDN), digestible energy (ED) and metabolizable energy (ME) were calculated according to Weiss et al. (1992).

At the end of the adaptation period, the animals were placed in individual pens with concrete floors on a roofed feedlot, where they were randomly assigned to the experimental treatments. The pens were 4 m long x 2 m wide and were provided with troughs for roughage, concentrate and mineral supplement, and a water tank with an automatic float ball valve.

The experimental design was completely randomized with three treatments and six replicates (animals). The treatments were characterized by three levels of concentrate in the ration, which corresponded to 0.71, 0.97 and 1.24% BW day^{-1} on DM basis. Adjustments of the amount of concentrate supplied were performed at 28-day intervals, based on the post-fasting BW of animals. The corn silage supply was kept *ad libitum* in the three experimental rations, following the same management adopted in the adaptation period. The mineral supplement in the concentrate (Table 1) was also supplied *ad libitum* in the trough during the experimental period. The availability of mineral supplement was monitored daily, maintaining a minimum quantity of 100 g day^{-1} in the trough to meet the bulls' mineral requirements in the growth and finishing phases (NRC, 2000).

Rations were isonitrogenous, and the CP content was adjusted by the addition of urea to the rations. At the start of the experiment, the animals received 30 g day^{-1} of urea for four days. At the end of this period, the urea contents were adjusted in the three experimental rations, which were formulated to provide an average daily gain of 1.20 kg day^{-1} according to the NRC (2000). Leftovers of silage and concentrate in the trough were collected and

Table 1. Proportion of ingredients in the protein concentrate and contents of dry matter, nutrients and energy of protein concentrate and corn silage used in the experimental rations.

Component[I]	Protein concentrate	Corn silage
Ingredients		
Ground corn (g kg DM^{-1})	730.0	
Soybean meal (g kg DM^{-1})	250.0	
Mineral supplement (g kg DM^{-1})	20.0	
Dicalcium phosphate (g kg DM^{-1})	9.0	
Sodium chloride (g kg DM^{-1})	9.0	
Mineral premix (g kg DM^{-1})[II]	2.0	
Nutritional composition		
Dry matter (g kg FM^{-1})	883.9	266.0
Crude protein (g kg DM^{-1})	204.7	64.0
Ether extract (g kg DM^{-1})	46.4	30.4
Neutral detergent fiber (g kg DM^{-1})	134.6	549.0
Acid detergent fiber (g kg DM^{-1})	48.3	327.0
Lignin (g kg DM^{-1})	12.8	61.6
Non-fiber carbohydrates (g kg DM^{-1})	564.0	310.7
Ash (g kg DM^{-1})	50.3	45.9
Calcium (g kg DM^{-1})	4.2	2.8
Phosphorus (g kg DM^{-1})	5.8	2.5
Magnesium (g kg DM^{-1})	2.0	1.9
Potassium (g kg DM^{-1})	8.3	9.2
Total digestible nutrients (g kg DM^{-1})	841.8	606.3
Digestible energy (Mcal kg DM^{-1})	3.27	2.59
Metabolizable energy (Mcal kg DM^{-1})	2.68	2.12

[I]DM: dry matter; FM: fresh matter

[II]Guaranteed analysis - Macrominerals: 140 g kg^{-1} calcium, 80 g kg^{-1} phosphorus, 12 g kg^{-1} magnesium, 140 g kg^{-1} sodium and 12 g kg^{-1} sulphur; Trace minerals: 189 mg kg^{-1} cobalt, 1,520 mg kg^{-1} copper, 1,770 mg kg^{-1} iron, 144 mg kg^{-1} iodine, 1,240 mg kg^{-1} manganese, 19 mg kg^{-1} selenium and 4,650 mg kg^{-1} zinc.

weighed daily before the morning meal. The daily dry matter intake (DMI) of the experimental rations was calculated based on the amounts of silage and concentrate supplied and of leftovers, and the DM contents of these foods and of leftovers, as reported by Bren et al. (2014).

The experimental period lasted 168 days and animals were slaughtered at 17 months of age, on average. Before slaughter, the animals were kept fasted for 16 hours and weighed to record the body weight at slaughter (SW). The slaughter and evisceration procedures were performed, and the weights of the flank steak (rib portion formed by internal abdominal oblique muscle), tongue, tail, heart, liver, kidneys, perirenal fat and internal fat (mesenteric and omental) were recorded. After dressing, the carcasses were weighed to record the hot carcass weight (HCW) and the hot carcass yield was obtained using the following equation: HCY = (HCW/SW) x 100. The carcasses were divided lengthwise into two halves, identified, weighed and taken to cooling chambers, where they remained at 1°C for 24 hours.

During the *rigor mortis* period, the pH and temperature were measured in the lateral side of the left half of the carcass, having as evaluation points the chuck + shoulder in the forequarter, and the loin and round in the hindquarter. The pH was measured using a portable digital pH meter (Digimed®, model DME-CF1), with a penetrating glass electrode (model J0105BDR). The temperature was measured with an electronic thermometer (Digital Termo®), equipped with a penetrating metallic sensor. Ten sequential measurements were taken at each sampling point, with a 2-hour interval between each measurement up to 8 hours *post-mortem*, and 3-hour interval between each measurement from 8 to 23 hours *post-mortem*.

After cooling, the following measurements were obtained in the right half of the carcass according to Prado et al. (2015a): carcass length (CL), measured using a measuring tape, and comprising the distance between the anterior border of the pubic bone and the medial cranial border of the first rib; leg length (LL), measured using a wooden compass with metal tips and a measuring tape, and comprising the distance between the anterior border of the pubic bone and the midpoint of the tarsometatarsal joint; cushion thickness (CT), also measured using the wooden compass and measuring tape, and comprising the distance between the lateral and medial sides of the upper portion of the cushion.

The *longissimus* muscle was exposed between the 12th and 13th ribs of the left half of the carcass to measure the rib eye area (REA) and the subcutaneous fat thickness (SFT), since such measurements obtained directly from the muscle or *in vivo* by ultrasound have a high correlation with the carcass composition of taurine cattle (CREWS JÚNIOR, 2001). The contour of the transverse section of the *longissimus* muscle was traced on parchment paper and later scanned in a computer for REA measurement in AutoCAD software (version 2000). The SFT comprised the mean of two measures of fat thickness obtained with a caliper at two distinct points on the lateral side of the *longissimus* muscle.

In the section of the *longissimus* muscle comprising the 10th, 11th and 12th ribs, the bone, muscle and fat were physically separated and each fraction was weighed separately. The proportions of these tissues (PB_{LOIN}, PM_{LOIN} and PF_{LOIN}, respectively) were used to estimate the tissue composition of the 9th, 10th and 11th ribs using the following equations proposed by Müller (1987): bone proportion: $PB_{RIBS} = 2.117 + (0.860 \times PB_{LOIN})$; muscle proportion: $PM_{RIBS} = 6.292 + (0.910 \times PM_{LOIN})$; and fat proportion: $PF_{RIBS} = 1.526 + (0.913 \times PF_{RIBS})$. From PB_{RIBS}, PM_{RIBS} and PF_{RIBS}, the tissue composition of the carcasses was estimated using the following equations described by Hankins and Howe (1946): bone proportion: $PB = 4.30 + (0.61 \times PB_{RIBS})$; muscle proportion: $PM = 15.56 + (0.81 \times PM_{RIBS})$; and fat proportion: $PF = 3.06 + (0.82 \times PF_{RIBS})$.

With the exception of pH and temperature of the carcasses in the *rigor mortis* period, data were analyzed by regression (PROC REG), in which the concentrate content in the ration was considered the independent variable. The analyses were performed up to the second order (quadratic), according to the model:

$$\hat{Y}_{ij} = \beta_0 + \beta_1 Ai_1 + \beta_2 Ai_2 + \gamma_{ij} + \varepsilon_{ij},$$

where: $\hat{Y}_{ij}$ = value of the dependent variable for the *j*th animal in the *i*th concentrate content; β_0 = regression intercept; Ai = independent variable; β_1 = linear regression coefficient for the dependent variable; β_2 = quadratic coefficient of regression for the dependent variable; γ_{ij} = regression deviations; ε_{ij} random error.

Data regarding the pH and temperature of the carcasses in the *rigor mortis* period were analyzed in a mixed model with repeated measures on time (PROC MIXED), where the concentrate content in the ration, evaluation times during the cooling period (0, 2, 4, 6, 8, 11, 14, 17, 20 and 23 hours) and their interactions were the fixed effects, and the animal was the random effect. The model used was:

$$\hat{Y}_{ijk} = \mu + C_i + An_{j(i)} + T_k + CT_{ik} + e_{ijk},$$

where: $\hat{Y}_{ijk}$ = value of the dependent variable in the *k*th time, for the *j*th animal in the *i*th concentrate content; μ = mean value of the dependent variable (constant); C_i = effect of the *i*th concentrate content in the ration; $An_{j(i)}$ = random effect of animal nested within concentrate content; T_k = effect of the *k*th evaluation time in the cooling period; CT_{ik} = effect of the interaction between times of evaluation and concentrate content; e_{ijk} = random error. The most appropriate covariance structure for the variables analyzed was defined according to the Corrected Akaike (AICC) and Bayesian (BICC) information criteria. The means were fitted to the statistical model (PROC LSMEANS) and when the fixed effect of evaluation times was significant, the means were compared by the Fisher's test. When the interaction between fixed effects was significant, the effect of concentrate content was evaluated within each evaluation time by regression analysis (PROC REG), which was performed up to the second order (quadratic); the evaluation times were compared within each concentrate level by Fisher's test.

Statistical analyses were performed in the Statistical Analysis System, version 9.0 (SAS, 2002). The significance level was set at 5% for all analyses.

Results and Discussion

Concentrate content had a significant effect (P <0.05) on SW and HCW, with a linear increasing effect with the inclusion of concentrate in the ration (Table 2). There was an increase of 9.87 kg in SW and 6.16 kg in HCW with an increase of 0.10% BW in DM day^{-1} of concentrate in the ration. These results differ from those observed by Prado et al. (2015b), who evaluated the carcass traits of Purunã cattle fed ration with concentrate contents similar to the present study and found higher values for SW and HCW in animals fed 1.00% BW in DM day^{-1} of concentrate (491 and 256 kg), and similar values between 0.73% (449 and 226 kg) and 1.27% BW in DM day^{-1} (464 and 246 kg) of concentrate.

Table 2. Means and standard error of the mean (SEM) for slaughter weight and carcass traits of young ½ Purunã x ½ Canchim bulls fed rations with three concentrate contents during the finishing phase.

Variable[I]	Concentrate[I] (% BW in DM day^{-1})			SEM	*P*-value[II]	
	0.71	0.97	1.24		L	Q
SW (kg)[III]	433	454	485	10	0.0182	0.7944
HCW (kg)[III]	248	258	280	6	0.0160	0.5957
HCY (%)	57.28	56.92	57.79	0.45	0.6237	0.5508
Carcass length (cm)	123.4	125.7	126.4	0.8	0.1141	0.6311
Leg length (cm)	64.4	64.9	66.1	0.4	0.0507	0.6578
Cushion thickness (cm)	25.8	26.4	26.8	0.3	0.1987	0.7945
Rib eye area (cm²)	74.2	80.5	84.2	2.4	0.1039	0.2576
SFT (mm)	3.00	3.08	3.00	0.17	0.9981	0.8298
Proportion of bone (%)	15.12	15.63	13.89	0.35	0.1265	0.1222
Proportion of muscle (%)	64.19	64.54	66.91	0.64	0.0723	0.4629
Proportion of fat (%)	21.37	20.28	20.36	0.67	0.5603	0.6997

[I]BW: body weight; DM: dry matter; SW: slaughter weight; HCW: hot carcass weight; HCY: hot carcass yield; SFT: subcutaneous fat thickness
[II]Probability for linear (L) and quadratic (Q) regression
[III]Regression equation: SW = 361.059 + 98.714*C (R^2 = 0.99)
HCW = 202.174 + 61.604*C (R^2 = 0.99)
C: addition of concentrate to the ration (% BW in DM day^{-1}).

Increasing the concentrate in the ration improved the performance of the young bulls (1.05 to 1.31 kg day^{-1}; BREN et al. 2014), resulting in a higher SW with the inclusion of 1.24% BW in DM day^{-1} of concentrate (Table 2). Bren et al. (2014) evaluated the performance of the animals used in the present study and verified that those receiving 1.24% BW in DM day^{-1} of concentrate had a higher feed intake (8.58 kg DM day^{-1}) than those receiving 0.71 and 0.97% BW in DM day^{-1} of concentrate (7.49 and 7.70 kg DM day^{-1}). This implied a higher daily energy and protein intake by the young bulls that received 1.24% BW in DM day^{-1} of concentrate (TDN = 6.13 kg day^{-1}, CP = 1.09 kg day^{-1}), followed by those receiving 0.97% (TDN = 5.49 kg day^{-1}; CP = 0.96 kg day^{-1}) and 0.71% BW in DM day^{-1} of concentrate (TDN = 5.11 kg day^{-1}; CP = 0.88 kg day^{-1}). Thus, the higher SW and HCW values of young bulls that received 1.24% BW in DM day^{-1} of concentrate were determined by their higher energy and protein intake.

There was no effect (P> 0.05) of the concentrate contents on HCY (Table 2), which presented a mean value of 57.3%. This value was higher than that reported by Pinto et al. (2015), who found mean values of 55.1% in young bulls of similar genetic group, fed with 0.65, 0.99 and 1.33% BW in DM day^{-1} of concentrate and slaughtered at 16 months of age with 470, 487 and 479 kg BW, respectively. The main factor that affects carcass yield is the gastrointestinal tract content, which declines with the increase of concentrate content in the diet (FERREIRA et al., 2000; SILVA et al., 2002). Although the gastrointestinal content of the young bulls was not measured, the silage and concentrate intake reported by Bren et al. (2014) showed that there was a reduction of 8.3% in silage intake and a 62.7% increase in concentrate intake, on DM basis, with an increase from 0.71 to 1.24% BW in DM day^{-1} of concentrate. This represents a change of 68:32 to 54:46 in the roughage: concentrate ratio of the experimental rations; however, this change did not affect the carcass yield of the young bulls.

The morphometric characteristics CL, LL and CT were not influenced (P> 0.05) by the concentrate content (Table 2), presenting mean values of 125.1, 65.1 and 26.3 cm, respectively. Pinto et al. (2015) also found no effect of the concentrate content of the ration on these traits in young ½ Purunã x ½ Canchim bulls slaughtered at 16 months of age. These authors reported a higher value for CL, and values close to those obtained in the present study for LL and CT, corresponding to 129.3, 66.9 and 25.9 cm, respectively. The CL and LL are poorly influenced by nutrition and genetics, with age having the most influence on changes in these traits (ROTTA et al., 2009). For CT, the increase in concentrate content in the ration was not sufficient to promote increased muscle deposition in this region.

There was no effect (P> 0.05) of concentrate content on REA and SFT (Table 2), which presented mean values of 79.6 cm^2 and 3.0 mm. Rodrigues et al. (2008) evaluated young ½ Purunã x ½ Canchim bulls fed rations containing 640, 670 and 705 g kg DM^{-1} of TDN, and slaughtered at 22 months of age at a BW of 461, 465 and 497 kg, respectively, and found no effect of energy content on REA and SFT, with mean values of 71.7 cm^2 and 4.7 mm. Pinto et al. (2015) also found no effect of the concentrate content on REA and SFT of young ½ Purunã x ½ Canchim bulls slaughtered at 16 months of age, and recorded mean values of 72.0 cm^2 and 4.3 mm for these traits.

The REA is an indicator of body composition, as it reflects the development or deposition of muscle mass in the carcass of cattle (CREWS JÚNIOR, 2001). The SFT values are within those recommended by the abattoirs, which adopt a thickness between 3.0 and 6.0 mm as standard (RODRIGUES et al., 2008), in order to avoid dehydration and darkening of the musculature during cooling and to add commercial value to the carcass (SILVA et al., 2015). The similarity of these traits between the contents of concentrate that were evaluated indicates that the young bulls presented carcasses with similar composition, independently of the ration.

The lack of effect (P> 0.05) of the concentrate content on the estimated proportions of bone, muscle and fat of the carcass (Table 2) reinforces the similarity of its composition between the rations. The mean values recorded for these traits were 14.88, 65.21 and 20.67%, respectively. These results are close to those of Rodrigues et al. (2008), who reported 14.78, 62.67 and 23.36% for the proportions of bone, muscle and fat. Prado et al. (2015a) evaluated young ½ Purunã x ½ Canchim bulls slaughtered at 16 to 22 months of age and a mean BW of 445 kg and observed a lower proportion of muscle and higher proportions of bone and fat than those obtained in the present study, with values of 59.40, 15.25 and 25.95%, respectively. Variations in the carcass tissue composition may be related to the genetic group and the age of the animals, as well as to the chemical characteristics of the ration (ROTTA et al., 2009; MISSIO et al., 2010). In the present study, the bulls were from the same genetic group and had the same age between the treatments, but there was an increase in energy and protein intake between 0.71 and 1.24% BW in DM day^{-1} of concentrate in the ration. In this condition there was an increase in the performance and SW, but this did not cause changes in the body composition of young bulls.

There was an interaction (P <0.05) between concentrate content and cooling times on the carcass pH (Table 3). Up to 4 hours of cooling, the carcasses of young bulls that received 0.97 and 1.24% BW in DM day^{-1} of concentrate had a more pronounced drop in pH compared to those receiving 0.71% BW in DM day^{-1} of concentrate. There was a linear decreasing effect of the concentrate content on carcass pH at 4 hours of cooling, which reinforces the more pronounced reduction of this trait in bulls fed 0.97 and 1.24% BW in DM day^{-1} of concentrate. This was probably related to the greater availability of glycogen in muscle tissue at the time of slaughter, due to the higher energy intake from these experimental rations. In fact, the increase in concentrate content of the ration increases the availability of glycogen in the muscle at the time of slaughter, as reported by Favaro et al. (2016). The level of glycogen in the muscle affects the pH drop in the carcass during cooling (KUSS et al., 2010), since the use of glycogen in *post-mortem* biochemical processes reduces carcass pH by anaerobic irreversible glycolysis, and the consequent production of lactic acid, converting the muscle into meat (MENDES et al., 2012).

The carcasses of young bulls that received 0.71, 0.97 and 1.24% BW in DM day^{-1} of concentrate presented the minimum pH values after 14, 11 and 20 hours of cooling, respectively. Despite the differences in the pH curves between concentrate contents, these did not influence (P> 0.05) the carcass pH after cooling (23 hours), which presented a mean value of 5.57. Kuss et al. (2010) observed similar results for young ½ Purunã x ½ Canchim bulls slaughtered at 16 months of age, reporting a value of 5.59. The pH of the carcasses after cooling was within the reference range for obtaining meat with normal characteristics, ranging from 5.50 to 6.00 after 12 to 24 hours *post-mortem*, while values above 6.00 result in meat that is dark, firm and dry - DFD (ADZITEY; NURUL, 2011).

Table 3. Means and standard error of the mean (SEM) for pH and temperature during the cooling period in the carcasses of young ½ Purunã x ½ Canchim bulls fed rations with three concentrate contents during the finishing phase.

Variable	CT[I] (hours)	Concentrate[I] (% BW in DM day^{-1})			Mean[II]	SEM
		0.71	0.97	1.24		
pH[III] (1 to 14)	0	6.69 a	6.82 a	6.72 a	6.74	0.03
	2	6.07 b	5.80 b	5.89 b	5.92	
	4	5.94 b	5.73 b	5.71 c	5.80	
	6	5.71 cd	5.62 cd	5.69 c	5.67	
	8	5.70 cd	5.68 bc	5.68 cd	5.68	
	11	5.72 c	5.59 cd	5.66 cd	5.66	
	14	5.63 de	5.55 d	5.62 cde	5.60	
	17	5.59 e	5.59 cd	5.66 cd	5.61	
	20	5.58 e	5.58 cd	5.58 de	5.58	
	23 (PC)	5.59 e	5.57 d	5.57 e	5.57	
Temperature[III] (ºC)	0	38.6	38.9	38.4	38.6 a	0.7
	2	30.4	30.5	29.9	30.2 b	
	4	23.1	23.5	22.4	23.0 c	
	6	18.9	20.3	19.8	19.6 d	
	8	17.3	18.5	18.4	18.1 e	
	11	13.5	14.0	13.9	13.8 f	
	14	10.8	11.8	12.0	11.5 g	
	17	8.1	9.1	9.5	8.9 h	
	20	7.1	6.9	7.2	7.1 i	
	23 (PC)	8.1	8.4	9.0	8.5 h	

[I]BW: body weight; DM: dry matter; CT: cooling times; PC: post-cooling
[II]Means followed by different lowercase letters in the same column differ by F test (P<0.05)
[III]Regression equation: $pH_{CT4} = 6.218 - 0.435*C$ ($R^2 = 0.82$)
$T_{PC} = 6.896 + 1.637*C$ ($R^2 = 0.99$)
C: addition of concentrate to the ration (% BW in DM day^{-1}).

There was no interaction (P> 0.05) between concentrate content and cooling times for the carcass temperature; however, there was an isolated effect (P <0.05) of cooling times on this trait (Table 3). The lowest temperature of the carcasses (7.1 ºC) was recorded at 20 hours of cooling. Between 20 and 23 hours of cooling, the time at which the post-cooling temperature was recorded, the temperature of the carcass rose to 8.5 °C. There was an effect (P <0.05) of the concentrate content on the post-cooling temperature, which increased linearly with the inclusion of concentrate in the ration. The temperature increased from 8.1 to 9.0 °C between 0.71 and 1.24% BW in DM day^{-1} of concentrate, which corresponded to an increase of 0.16 °C with an increase of 0.10% BW in DM day^{-1} of concentrate in the ration. Neumann et al. (2014) observed a similar response in young Canchim bulls slaughtered at 15 months of age and 467 to 490 kg BW, with an increase of 12.5 to 14.9 ºC in post-cooling temperature of the carcasses between 0.38 and 0.97% BW in DM day^{-1} of concentrate in the ration.

Given the probable increase in the level of glycogen in the muscle tissue with the inclusion of concentrate in the ration, the degradation of glycogen associated with the high temperature of the carcass shortly after slaughter could increase the temperature of the muscle, catalyzing metabolic reactions such as ATP hydrolysis and glycolysis (OLIVEIRA et al., 2011). This could explain the linear increase in the carcass temperature after cooling in relation to the concentrate contents tested in the present study.

There was no effect (P> 0.05) of concentrate content on the weights of flank steak, tongue, tail, heart, liver, kidneys, perirenal fat or internal fat (Table 4), which presented mean values of 1.66, 0.80, 0.96, 1.28, 4.32, 0.67, 3.07 and 7.30 kg, respectively. Except for flank steak weight, perirenal fat and internal fat, these results corroborate those found by Neumann et al. (2014) in young Canchim bulls.

Table 4. Means and standard error of the mean (SEM) for weight of flank steak and non-carcass components of young ½ Purunã x ½ Canchim bulls fed rations with three concentrate contents during the finishing phase.

Variable	Concentrate[I] (% BW in DM day^{-1})			SEM	*P*-value[II]	
	0.71	0.97	1.24		L	Q
Flank steak (kg)	1.57	1.52	1.86	0.10	0.2320	0.4116
Tongue (kg)	0.76	0.79	0.85	0.04	0.2923	0.8823
Tail (kg)	0.87	0.96	1.03	0.05	0.1885	0.9097
Heart (kg)	1.31	1.21	1.31	0.06	0.9917	0.4574
Liver (kg)	4.12	4.26	4.53	0.09	0.0663	0.7745
Kidneys (kg)	0.69	0.64	0.68	0.04	0.9627	0.6285
Perirenal fat (kg)	2.69	3.12	3.34	0.25	0.3041	0.8383
Internal fat (kg)	6.28	7.48	8.01	0.45	0.1155	0.7142

[I]BW: body weight; DM: dry matter
[II]Probability for linear (L) and quadratic (Q) regression.

To date, few studies have evaluated the relationship between flank steak weight and concentrate in the ration. Studies on the weight of this cut are associated with the selection of Nellore cattle based on post weaning weight (LUCILA SOBRINHO et al., 2013) and the evaluation of commercial cuts in dairy cattle carcasses (ALMEIDA et al., 2017). However, an increase in flank steak weight was expected with the increase of SW between 0.71 and 1.24% BW in DM day^{-1} of concentrate, since the correlation between these traits was high and positive (r = 0.76, P <0.05).

According to Peron et al. (1993), heart and lung weights are not affected by the characteristics of the ration or feed intake, indicating that these organs maintain their integrity and have priority in the use of nutrients. When evaluating the non-carcass components in young Charolais x Nellore bulls fed rations containing four concentrate levels ranging from 22 to 79%, Missio et al. (2009) found no influence of concentrate content on heart weight. Also, Menezes et al. (2011) evaluated the non-carcass components of Devon steers finished on feedlot or exclusively on tropical or temperate pastures, and did not observe any effect of finishing systems on heart weight. These results corroborate those obtained in the present study, in which the concentrate content did not affect the heart weight of the young bulls.

The lack of effect of concentrate content on liver and kidney weights was not expected, as there was an increase in energy and protein intake between 0.71 and 1.24% BW in DM day^{-1} of concentrate, which could lead to greater development of these organs due to the higher intensity of metabolism of energy and nutrients (FERRELL et al., 1976; FERREIRA et al., 2000; MENEZES et al., 2011). The liver is the vital organ most affected by variations in food intake, energy requirements and metabolic rates, being responsible for the metabolism of nutrients (OWENS et al., 1993). When evaluating F1 Simmental x Nellore bulls fed rations with five levels of concentrate varying from 25 to 75%, Ferreira et al. (2000) reported an increasing linear effect of concentrate content on liver and kidney weights, which was attributed to the linear increase in energy and protein intake. In the present study, between 0.71 and 1.24% BW in DM day^{-1} of concentrate, there was an increase from 32 to 46% in the proportion of concentrate in the diet consumed by the young bulls, which was not enough to raise the liver and kidney weights of these animals.

The results obtained for perirenal and internal fat weights were also unexpected, since the increase in energy intake between 0.71 and 1.24% BW in DM day^{-1} of concentrate could have led to higher deposition of cavity and visceral fat. Ferreira et al. (2000) reported an increasing linear effect of concentrate content on internal fat weight in F1 Simmental x Nellore bulls. When evaluating the internal fat deposition in Charolais steers fed diets containing 35, 50 and 65% concentrate, Silveira et al. (2013) observed higher internal fat weights in steers that received 50 and 65% of concentrate. In both studies, the increase in internal fat deposition was related to the increase in energy intake from the concentrate. In this way, the perirenal and internal fat weights could have been higher if the bulls had received more than 1.24% BW in DM day^{-1} of concentrate in the ration.

Conclusions

The inclusion of 1.24% body weight per day of concentrate in the ration, on dry matter basis, is indicated for young bulls in the growth and finishing phases, when the intention is to obtain a higher slaughter weight and, consequently, a higher carcass weight. Nevertheless, up to this level of concentrate, the tissue composition of the carcass, the weight of the flank steak and the non-carcass components are not changed. Furthermore, the inclusion of more than 0.71% body weight per day of concentrate in the ration, on dry matter basis, modifies the pH curve during cooling and increases the post-cooling temperature of the young bulls' carcass, which may interfere with the process of converting muscle into meat after slaughter.

References

ADZITEY, F.; NURUL, H. Pale soft exudative (PSE) and dark firm dry (DFD) meats: Causes and measures to reduce these incidences - a mini review. *International Food Research Journal*, Serdang, v. 18, n. 1, p. 11-20, 2011.

ALMEIDA, M. P.; SOUZA, E. J. O.; VÉRAS, A. S. C.; MORAIS, I. M. V.; VÍTOR, D. R.; SILVA, J. R. C. Cuts of dairy-origin cattle fed mesquite pod meal in replacement of corn. *Acta Scientiarum Animal Sciences*, Maringá, v. 39, n. 4, p. 401-407, 2017.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. Official methods of analysis. 15th ed. Arlington: AOAC International, 1990. 1117 p.

BREN, L.; MOLETTA, J. L.; ROSSI JUNIOR, P.; SANTANA, M. H. A. Desempenho de novilhos Purunã x Canchim terminados com diferentes níveis de concentrado. *Revista Acadêmica: Ciências Agrárias e Ambientais*, Curitiba, v. 12, n. 1, p. 71-77, 2014.

CREWS JÚNIOR, D. H. Alternative ultrasound predictors of beef carcass longissimus muscle area. *Professional Animal Scientist*, Champaign, v. 17, n. 4, p. 303-308, 2001.

EIRAS, C. E.; ORNAGHI, M. G.; VALERO, M. V.; RIVAROLI, D. C.; GUERRERO, A.; PRADO, I. N. How does the dietary cottonseed hull affect the carcass characteristics and meat quality of young bulls finished in a high concentrate diet? *Acta Scientiarum Animal Sciences,* Maringá, v. 38, n. 3, p. 301-310, 2016.

FAVARO, V. R.; EZEQUIEL, J. M. B.; ALMEIDA, M. T. C.; D'AUREA, A. P.; PASCHOALOTO, J. R.; VAN CLEEF, E. H. C. B.; CARVALHO, V. B.; JUNQUEIRA, N. B. Carcass traits and meat quality of Nellore cattle fed different non-fiber carbohydrates sources associated with crude glycerin. *Animal*, London, v. 10, n. 8, p. 1402-1408, 2016.

FERRAZ, J. B. S.; FELÍCIO, P. E. Production systems - an example from Brazil. *Meat Science*, Amsterdam, v. 84, n. 2, p. 238-243, 2010.

FERREIRA, M. A.; VALADARES FILHO, S. C.; MUNIZ, E. B.; VERAS, A. S. C. Características das carcaças, biometria do trato gastrintestinal, tamanho dos órgãos internos e conteúdo gastrintestinal de bovinos F1 Simental x Nelore alimentados com dietas contendo vários níveis de concentrado. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 29, n. 4, p. 1174-1182, 2000.

FERRELL, C. L.; GARRET, W. N.; HINMAN, N. Estimation of body composition in pregnant and non-pregnant heifers. *Journal of Animal Science*, Champaign, v. 42, n. 5, p. 1158-1166, 1976.

HANKINS, O. G.; HOWE, P. E. *Estimation of the composition of beef carcasses and cuts*. [S.l]: US Department of Agriculture - Technical Bulletin n. 926, Washington: US Government Printing Office, 1946. 19 p.

KUSS, F.; LÓPEZ, J.; RESTLE, J.; BARCELLOS, J. O. J.; MOLETTA, J. L.; LEITE, M. C. P. Qualidade da carne de novilhos terminados em confinamento e abatidos aos 16 ou aos 26 meses de idade. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 39, n. 4, p. 924-931, 2010.

LUCILA SOBRINHO, T.; BONILHA, S. F. M.; GONÇALVES, H. C.; CASTILHOS, A. M.; MAGNANI, E.; RAZOOK, A. G.; BRANCO, R. H. Feedlot performance, feed efficiency and carcass traits in Nellore cattle selected for postweaning weight. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 42, n. 2, p. 125-129, 2013.

MAGGIONI, D.; PRADO, I. N.; ZAWADZKI, F.; VALERO, M. V.; MARQUES, J. A.; BRIDI, A. M.; MOLETTA, J. L.; ABRAHÃO, J. J. S. Grupos genéticos e graus de acabamento sobre qualidade da carne de bovinos. *Semina: Ciências Agrárias*, Londrina, v. 33, n. 1, p. 391-402, 2012.

MENDES, G. A.; ROCHA JÚNIOR, V. R.; RUAS, J. R. M.; SILVA, F. V.; CALDEIRA, L. A.; PEREIRA, M. E. G.; SOARES, F. D. S.; PIRES, D. A. A. Características de carcaça e qualidade da carne de novilhas alimentadas com silagem de capim-marandu. *Pesquisa Agropecuária Brasileira*, Brasília, v. 47, n. 12, p. 1774-1781, 2012.

MENEZES, L. F. G.; BRONDANI, I. L.; RESTLE, J.; ALVES FILHO, D. C.; CALLEGARO, A. M.; WEISE, M. Características dos componentes não integrantes da carcaça de novilhos superjovens da raça Devon, terminados em diferentes sistemas de alimentação. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, Belo Horizonte, v. 63, n. 2, p. 372-381, 2011.

MISSIO, R. L.; BRONDANI, I. L.; ALVES FILHO, D. C.; RESTLE, J.; ARBOITTE, M. Z.; SEGABINAZZI, L. R. Características da carcaça e da carne de tourinhos terminados em confinamento, recebendo diferentes níveis de concentrado na dieta. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 39, n. 7, p. 1610-1617, 2010.

MISSIO, R. L.; BRONDANI, I. L.; RESTLE, J.; SILVA, J. H. S.; SILVEIRA, M. F.; SILVA, V. S. Partes não-integrantes da carcaça de tourinhos alimentados com diferentes níveis de concentrado na dieta. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 38, n. 5, p. 906-915, 2009.

MÜLLER, L. *Normas para avaliação de carcaças e concurso de carcaças de novilhos*. 2. ed. Santa Maria: UFMS, 1987. 31 p.

NATIONAL RESEARCH COUNCIL - NRC. Nutrient requirements of beef cattle. 7^{th} rev. ed. Washington: National Academy Press, 2000. 248 p.

NEUMANN, M.; SILVA, M. R. H.; MARAFON, F.; WROBEL, F. L.; CARLETTO, R. Características da carcaça e carne de novilhos terminados em confinamento com níveis fixos de concentrado. *Revista Brasileira de Ciências Agrárias*, Recife, v. 9, n. 2, p. 277-283, 2014.

OLIVEIRA, I. M.; PAULINO, P. V. R.; MARCONDES, M. I.; VALADARES FILHO, S. C.; CAVALI, J.; PRADOS, L. F.; DUARTE, M. S.; DETMANN, E. Beef quality traits of Nellore, F1 Simmental × Nellore and F1 Angus × Nellore steers fed at the maintenance level or ad libitum with two concentrate levels in the diet. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 40, n. 12, p. 2894-2902, 2011.

OWENS, F. N.; DUBESKI, P.; HANSON, C. F. Factors that alter the growth and development of ruminants. *Journal of Animal Science*, Champaign, v. 71, n. 11, p. 3138-3150, 1993.

PERON, A. J.; FONTES, C. A. A.; LANA, R. P.; SILVA, D. J.; QUEIROZ, A. C.; PAULINO, M. F. Tamanho de órgãos internos e distribuição da gordura corporal, em novilhos de cinco grupos genéticos, submetidos à alimentação restrita e ad libitum. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 22, n. 5, p. 813-819, 1993.

PINTO, A.; PASSETTI, R. A. C.; GUERRERO, A.; RIVAROLI, D. C.; PEROTTO, D.; PRADO, I. N. Concentrate levels of crossbred bulls slaughtered at 16 or 22 months: performance and carcass characteristics.

Acta Scientiarum Animal Sciences, Maringá, v. 37, n. 2, p. 149-157, 2015.

PRADO, I. N.; EIRAS, C. E.; FUGITA, C. A.; PASSETTI, R. A. C.; ORNAGHI, M. G.; RIVAROLI, D. C.; PINTO, A. A.; MOLETTA, J. L. Animal performance and carcass characteristics of bulls (1/2 Purunã vs 1/2 Canchim) slaughtered at 16 and 22 months old, and three different weights. *Asian-Australasian Journal of Animal Science*, Seoul, v. 28, n. 5, p. 612-619, 2015a.

PRADO, I. N.; PASSETTI, R. A. C.; RIVAROLI, D. C.; ORNAGHI, M. G.; SOUZA, K. A.; CARVALHO, C. B.; PEROTTO, D.; MOLETTA, J. L. Carcass composition and cuts of bulls and steers fed with three concentrate levels in the diets. *Asian-Australasian Journal of Animal Science*, Seoul, v. 28, n. 9, p. 1309-1316, 2015b.

RODRIGUES, K. K. N. L.; ROSSI JUNIOR, P.; MOLETTA, J. L. Avaliação das características de carcaça de bovinos mestiços Purunã, alimentados com diferentes níveis de energia na dieta. *Archives of Veterinary Science*, Curitiba, v. 13, n. 4, p. 265-273, 2008.

ROTTA, P. P.; PRADO, R. M.; PRADO, I. N.; VALERO, M. V.; VISENTAINER, J. V.; SILVA, R. R. The effects of genetic groups, nutrition, finishing systems and gender of Brazilian cattle on carcass characteristics and beef composition and appearance: A review. *Asian-Australasian Journal of Animal Science*, Seoul, v. 22, n. 12, p. 1718-1734, 2009.

SILVA, F. F.; VALADARES FILHO, S. C.; ÍTAVO, L. C. V.; VELOSO, C. M.; PAULINO, M. F.; VALADARES, R. F. D.; CECON, P. C.; SILVA, P. A.; GALVÃO, R. M. Consumo, desempenho, características de carcaça e biometria do trato gastrintestinal e dos órgãos internos de novilhos Nelore recebendo dietas com diferentes níveis de concentrado e proteína. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 31, n. 4, p. 1849-1864, 2002.

SILVA, R. M.; RESTLE, J.; MISSIO, R. L.; BILEGO, U. O.; PACHECO, P. S.; REZENDE, P. L. P.; FERNANDES, J. J. R.; SILVA, A. H. G.; PÁDUA, J. T. Características de carcaça e carne de novilhos de diferentes predominâncias genéticas alimentados com dietas contendo níveis de substituição do grão de milho pelo grão de milheto. *Semina: Ciências Agrárias*, Londrina, v. 36, n. 2, p. 943-960, 2015.

SILVEIRA, M. F.; ALVES FILHO, D. C.; MISSIO, R. L.; METZ, P. A. M.; RESTLE, J.; SEGABINAZZI, L. R.; CALLEGARO, A. M.; JONER, G. Componentes externos e gordura interna de novilhos Charolês ou Nelore alimentados com diferentes proporções de concentrado. *Semina: Ciências Agrárias*, Londrina, v. 34, n. 2, p. 863-874, 2013.

STATISTICAL ANALYSIS SYSTEM INSTITUTE - SAS. SAS user´s guide: statistics. Version 9.0. Cary: SAS Institute, 2002.

VAN SOEST, P. J.; ROBERTSON, J. B.; LEWIS, B. A. Methods for dietary fiber, neutral detergent fiber, and no starch polysaccharides in relation to animal nutrition. *Journal Dairy Science*, Champaign, v. 74, n. 10, p. 3583-3597, 1991.

WEISS, W. P.; CONRAD, H. R.; St. PIERRE, N. R. A theoretically-based model for predicting total digestible nutrient values of forages and concentrates. *Animal Feed Science and Technology*, Philadelphia, v. 39, n. 1-2, p. 95-110, 1992.