Carcass characteristics of immunocastrated steers finished on diets with different energy patterns

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Abstract

The aim of this study was to evaluate the effects of various dietary energy levels on the carcass and meat characteristics of feedlot-finished steers. A total of 27 purebred and crossbred Charolais and Nellore steers were used, with a mean initial age of 22 months and weight of 253 kg. The animals were allotted to a completely randomized design with three treatments and nine replicates each. Dietary treatments were arranged so that the average forage to concentrate ratio (FCR) was equivalent to that of a constant FCR treatment. The treatments consisted of CT (constant FCR at 60 to 40), CT5 (starting with 70: 30 FCR and finishing with 50: 50 FCR, that is, a mean overall FCR of 60: 40), and CT10 (starting with 80: 20 FCR and finishing with 40: 60, that is, a mean overall FCR of 60: 40). The dietary treatments did not affect slaughter weight, carcass weight, carcass conformation, physiological maturity, subcutaneous fat thickness, ribeye area, marbling score, and carcass measurements or the yield of commercial cuts. Chilling loss was higher in CT10 steers (2.41%) than in CT (2.26%) and CT5 (2.15%).

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Introduction

Adequate feed management is fundamental to successful animal production in which a balance is sought between nutritional intake and the animal's energy requirements (Ribeiro *et al*., 2011). Current trends towards increasing grain prices and decreasing beef prices motivate a search for alternative feeding programmes for use by farmers that contribute to the economic efficiency of feedlot systems (Peel, 2011).

Cattle feedlot finishing is an essential tool in maximizing animal performance in a short period and in allowing sales at strategic moments (e.g., shortage of animals on the market) to provide a higher remuneration to farmers. However, feedlot economics depends on feeding costs, the purchase price of stocker animals, and the selling price of fattened cattle multiplied by their slaughter weights. In turn, all of these parameters depend on diet quality (Signoretti *et al*., 2008). But feeding costs are generally high for feedlot-fed animals owing to the prices of grain and by-productS. These high costs affect this technology negatively as about 65% is usually spent on concentrate feeds (Missio *et al*., 2009).

Knowledge of the composition of weight gain is as crucial as that associated with the mean daily weight gain. The closer an animal is to the maturity weight, the higher the fat deposition in proportion to protein composition, which will increase demands for weight gain (Marcondes *et al*., 2016). Thus, an understanding of the requirements and growth curve of cattle allows the diet to be modified and increases the energy supply throughout finishing, since animals demand more energy as they approach adult weight, despite maintaining the same feed input volumes.

This study aimed to compare a pre-slaughter feeding programme with a FCR of 60: 40 with a pre-slaughter feeding programme in which the FCR was reduced from 70: 30 to 50: 50 over five 21-day periods, and a pre-slaughter feeding programme in which the FCR was likewise changed from 80: 20 to 40: 60. Dependent variables of interest were the carcass and meat characteristics of feedlot-finished steers.

Materials and Methods

The experiment was carried out at the Beef Cattle Laboratory, Animal Science Department of the Federal University of Santa Maria (UFSM), Santa Maria, located in the Central Valley of the State of Rio Grande do Sul, Brazil (95 m above sea level; 29 ° 43′ S, 53 ° 42 ′ W). According to Köppen, the climate of the region is classified as 'Cfa' (warm temperate–fully humid–hot summer) (Alvares *et al.*, 2013). All procedures were performed according to the standards and protocols set by the Ethics Committee on Animal Use of UFSM (Protocol No. 5813030715).

A total of 27 purebred and crossbred Charolais and Nellore immunocastrated steers from the experimental herd of the Beef Cattle Laboratory were used in the study. The animals had been immunocastrated with an anti-GnRH vaccine. The animals had a mean initial age of 22 months and a mean bodyweight of 252.8 kg. The steers were distributed so that each treatment contained two purebred Nellore, one purebred Charolais, one 21/32 Nellore, one 21/32 Charolais, one 43/64 Nellore, and three 43/64 Charolais individuals.

The constant FCR diet was formulated to meet NRC requirements (NRC, 1996) of steers and had 13% crude protein (CP) and an estimated dry matter (DM) intake of 2.5 kg per 100 kg of live weight. The two growth rate-related diets were formulated by manipulating the CT diet. Corn silage was used as the sole forage, and the concentrate was composed of ground corn, soybean meal, limestone, and salt (Table 1).

Each animal was considered an experimental unit, and a completely randomized design was used with three treatments and nine replicates. Two treatments were based on the growth rate of the steers (variable forage to concentrate ratio (FCR)), whereas the FCR was kept constant in the third treatment. The growth rate-related treatment diets were arranged so that the average FCR was equivalent to that used in the constant FCR treatment. The CT treatment had a constant FCR (60: 40). The CT5 treatment started with a FCR of 70: 30 with five units of forage removed and five units of concentrate added every 21 days. Thus, at the end of the finishing period the CT5 treatment had a 50: 50 FCR. The CT10 treatment started with an 80:20 FCR with 10 units of forage removed and 10 units of concentrate added every 21 days. Thus, at the end of the finishing period the CT10 treatment had a 40: 60 FCR.

Steers were finished individually in 9.5m² covered pens with concrete floors and equipped with feeders and waterers regulated with float valves. Food and water were provided ad libitum. The animals were randomly assigned to treatments and had already been adapted to facilities and diets for 14 days. The control of endoparasites and ectoparasites was performed by subcutaneous application of an ivermectin-based product at 1%, as recommended by the manufacturer. The experiment lasted for 105 days, divided into five periods of 21 days each.

The animals were fed twice a day, at 08h00 and 14h00. During the experimental period, samples of dietary ingredients and leftovers of each animal were collected, weighed, and pre-dried in a forced-air oven at 55 °C for 72 hours, then the samples were weighed again to obtain the pre-dry mass. Subsequently, the samples were ground to pass a 1-mm Willey mill sieve and packed into air- and humidity-free plastic bags for further chemical analysis. Samples of leftovers were taken homogeneously three times a week. The DM content was determined by oven drying the samples at 105 °C until constant weight. The ash content was determined by calcination in a muffle furnace at 550 °C for 4 hours until constant weight. The organic matter (OM) content was calculated by dividing the DM value by the ash content value. The DM, OM, ash, CP, and EE contents were determined according to the AOAC methodology (1996). The neutral detergent fibre content was determined according to the method described by Van Soest *et al.* (1991). The total digestible nutrient content was obtained by the in-situ digestibility technique which measured the disappearance of feed from porous bags incubated in the rumen of cannulated cattle for 24 hours and resulted a measure of digestibility of the OM which is equivalent to the TDN (Van Soest, 1994). Digestible energy was calculated according to the NRC method (NRC, 1996) (1 kg TDN = 4.4 Mcal DE).

At the end of the experimental period, the animals were weighed and slaughtered at an average age of 25 months in a commercial slaughterhouse after solid and liquid fasting. After slaughter, the hot carcasses were weighed and then cooled in a cold room, where they were weighed again after 24 hours. The hot and cold carcass yields were obtained as a percentage of the live weight, that is, by dividing the cold or hot carcass weight (kg) by the live slaughter weight and multiplying by 100. Each cooled carcass was sectioned longitudinally, and the two half-carcasses were evaluated and scored subjectively for conformation and physiological maturity by two trained evaluators (Müller, 1987). The left half carcass was divided into three regions, namely forequarter, hindquarter, and ribs. The individual weights of each region were recorded, and

the proportion of each region from the left half carcass was calculated in relation to the original carcass weight. The right half carcass was used to determine carcass length, leg length, leg thickness, forearm circumference and length.

Table 1 Forage to concentrate ratio per treatment and period, and nutritional composition of diets fed to feedlot steers with different energy patterns.

Treatment	Nutrient	21-day period 1	2	3	4	5	Mean
CT	Forage to concentrate	60:40	60:40	60:40	60:40	60:40	60:40
	DM, g/kg	915.71	915.78	915.81	923.3	918.6	917.83
	CP, g/kg of DM	128.93	127.53	128.02	134.1	136.2	130.95
	EE, g/kg of DM	25.69	25.77	25.80	26.46	27.26	26.20
	Ash, g/kg of DM	34.80	34.63	34.57	35.17	35.82	35.00
	NDF, g/kg of DM	368.51	368.40	368.37	364.32	368.65	367.65
	TDN, g/kg of DM	711.40	711.64	711.82	923.26	918.57	710.33
	DE, Mcal/kg of DM	3.13	3.13	3.13	3.12	3.11	3.13
CT5	Forage to concentrate	70:30	65:35	60:40	55:45	50:50	60:40
	DM, g/kg	914.74	915.34	915.81	922.59	916.62	917.01
	CP, g/kg of DM	128.42	128.39	128.02	134.32	137.71	131.37
	EE, g/kg of DM	23.16	24.44	25.80	27.72	30.13	26.25
	Ash, g/kg of DM	37.36	36.04	34.57	33.84	33.46	35.05
	NDF, g/kg of DM	415.34	391.89	368.37	340.99	323.93	368.10
	TDN, g/kg of DM	682.25	696.83	711.82	723.34	735.36	709.92
	DE, Mcal/kg of DM	3.00	3.07	3.13	3.18	3.24	3.12
CT10	Forage to concentrate	80:20	70:30	60:40	50:50	40:60	60:40
	DM, g/kg	912.76	914.85	915.81	922.04	915.25	916.14
	CP, g/kg of DM	127.81	127.79	128.02	134.67	139.13	131.49
	EE, g/kg of DM	20.63	23.17	25.80	28.98	33.02	26.32
	Ash, g/kg of DM	39.92	37.31	34.57	32.51	31.09	35.08
	NDF, g/kg of DM	462.18	415.29	368.37	317.66	279.26	368.55
	TDN, g/kg of DM	652.92	682.01	711.82	738.12	764.51	709.88
	DE, Mcal/kg of DM	2.87	3.00	3.13	3.25	3.36	3.12

CT: constant 60: 40 FCR, CT5: starting with 70: 30 FCR, and finishing with 50: 50 FCR, CT10: starting with 80: 20 FCR and finishing with 40: 60, DM: dry matter, CP: crude protein, EE: ether extract, NDF: neutral detergent fibre, TDN: total digestible nutrients, DE: digestible energy

The carcass compactness index was calculated from the relationship between the cold carcass weight and length. The HH section at the 10th and 12th rib height was taken (Müller (1987). Then, the *Longissimus dorsi* area (ribeye area) was outlined on acetate paper (cm^2), the subcutaneous fat thickness (mm) was measured, and the degree of beef marbling was determined.

Data were tested for normality using the Shapiro–Wilk test. Analysis of variance was done with the GLM procedure of SAS. Significant means were compared with Tukey's test at 5% significance level. Physiological maturity was analysed using the Kruskal–Wallis test. The analyses were performed with SAS version 3.5 (SAS Institute Inc., Cary, North Carolina, USA). The mathematical model was:

$$Y_{ijk} = \mu + T_j + \varepsilon_{ijk}$$

where: Y_{ijk} = a dependent variable, µ = the overall mean, T_j = the effect of the jth treatment, and
ε_{ijk} = random error.

Results and Discussion

The dietary treatments did not influence the slaughter, hot and cold carcass weights or their yields and commercial cuts (Table 2). The authors had expected animals in the CT5 and CT10 groups to be heavier than those in the CT group because they had been fed diets with higher energy content by the end of the finishing period, which coincided with the phase of higher energy requirement. The hot (57.82%) and cold (56.50%) carcass yields were both relatively satisfactory, since many slaughterhouses consider that 50% of the live steer is retained as carcass when buying animals based on live weight (Lopes *et al.*, 2012).

The absolute and relative weights of commercial cuts did not differ between treatments (Table 2), which is explained by the similarity of the slaughter weights of animals. There is a close relationship between the slaughter weight and commercial cuts of steers with different genetic predominance (Silva *et al.,* 2015). The proportion of the hindquarter to the total carcass is essential in beef cattle systems, especially for the slaughterhouses, since the prime cuts, and consequently better-priced cuts, are found in this portion of the carcass (Missio *et al.*, 2010). The average yields of the hindquarter, forequarter, and ribs in this study were 50.91%, 38.08%, and 11.74%, respectively. These values were within the desirable range (Luchiari Filho, 2000), which stated that the yields of the hindquarter, forequarter, and ribs should be >48%, ≤39%, and ≤13% in steer carcasses, respectively.

Table 2 Slaughter, hot and cold carcass weights, hot and cold carcass yields, and absolute weights and yields from commercial cuts of carcasses of feedlot-finished steers fed diets with different energy patterns

Variable	Treatment			SE	P-value
	CT	CT5	CT10		
Slaughter weight, kg	415.72	416.17	402.94	12.46	0.539
Hot carcass weight, kg	240.87	242.27	232.23	9.20	0.529
Cold carcass weight, kg	235.43	237.08	226.63	9.02	0.497
Hot carcass yield, kg-1 100 kg live weight	57.90	58.01	57.54	0.69	0.882
Cold carcass yield, kg-1 100 kg live weight	56.60	56.76	56.15	0.68	0.807
Forequarter, kg	90.24	89.82	86.40	3.83	0.711
Forequarter, kg 100 kg-1 of cold carcass	38.27	37.90	38.07	0.44	0.835
Rib, kg	27.80	28.44	25.73	1.16	0.246
Rib, kg 100 kg-1 of cold carcass	11.83	11.97	11.41	0.28	0.337
Hindquarter, kg	118.84	121.13	116.22	4.68	0.526
Hindquarter, kg 100 kg-1 of cold carcass	50.47	51.10	51.27	0.46	0.451

CT: constant 60: 40 FCR, CT5: starting with 70: 30 FCR, and finishing with 50: 50 FCR, CT10: starting with 80: 20 FCR and finishing with 40: 60

No differences were observed between treatments for subcutaneous fat thickness, and the conformation values were similar (Table 3). This may have been caused by the similarity in hot carcass weight, which also reflects carcass muscularity (Rodrigues *et al.*, 2015).

Chilling loss, which corresponds to the loss in carcass weight during the first 24 hours of chilling after slaughter (Menezes *et al.*, 2010), was higher in CT10 steers than in the CT and CT5 groups. Chilling is critical to meat hygiene, safety, shelf life, appearance, and eating quality (Ockerman & Basu, 2014). Chilling loss is influenced primarily by carcass fat thickness, which is also considered an important parameter when evaluating the final product (Lage *et al.*, 2012). Carcass shrinks of 2.41% are considered high (Vaz *et al.*, 2013). However, studies that evaluated various animal categories and diets reported similar means of 2.36% (Silva *et al.*, 2015), 2.70% (Olmedo *et al.*, 2011), 2.46% (Menezes *et al.*, 2010), and 2.19% (Missio *et al.*, 2010). Based on these values in the literature, the higher carcass shrink did not compromise the cold carcass weight and yield in CT10 steers.

Table 3 Conformation, physiological maturity, chilling loss, subcutaneous fat thickness, ribeye area, marbling, and carcass traits of feedlot-finished steers fed diets with various energy patterns

Variable	Treatment			SE	P-value
	CT	CT5	CT10		
Conformation, points[1]	9.67	9.89	8.67	0.59	0.312
Physiological maturity, points[2]	13.56	13.67	13.44	0.17	0.648
Chilling loss, kg 100-1 kg of cold carcass	2.26[b]	2.15[b]	2.41[a]	0.04	<0.01
Subcutaneous fat thickness, mm	3.86	4.78	3.40	0.53	0.168
Longissimus dorsi area, cm[2]	71.59	71.28	62.97	3.39	0.146
Marbling, points[3]	6.44	6.11	6.33	0.94	0.968
Carcass length, cm	122.44	121.50	122.28	1.40	0.921
Leg length, cm	70.67	71.16	71.56	0.99	0.819
Forearm length, cm	36.39	37.00	36.56	0.84	0.867
Forearm circumference, cm	37.50	36.63	36.50	0.88	0.689
Leg thickness, cm	26.69	26.13	26.13	0.59	0.711
Compactness, kg cm^{-1}	1.92	1.94	1.85	0.06	0.537

[a,b] Within a row, values with a common superscript were not different at probability *P* =0.05
CT: constant 60: 40 FCR, CT5: starting with 70: 30 FCR, and finishing with 50: 50 FCR, CT10: starting with 80: 20 FCR and finishing with 40: 60
[1] 1 - 3: poor; 4 - 6: inferior; 7 - 9: regular; 10 - 12: good; 13 - 15: very good; 16 - 18: superior
[2] 1 - 3: >8 years old; 4 - 6: 5.5–8 years old; 7 - 9: 4–5.5 years old; 10 - 12: 2.5 - 4 years old; 12 - 15: <2.5 years old
[3] 1 - 3: traces; 4 - 6: slight; 7 - 9: small; 10 - 12: modest; 13 - 15: moderate; 16 - 18: abundant

Fat deposition follows the order in which internal fat is deposited first, followed by intermuscular, subcutaneous, and finally by intramuscular or marbling fat (Paulino *et al.*, 2009). Therefore, higher levels of fat, primarily subcutaneous and intramuscular, were expected in CT10 steers. These animals had higher energy intake during the phase in which fat was deposited in greater amounts as they approached slaughter weight. Thus, more time would be needed to ensure higher energy input and late fat deposition.

The subcutaneous fat thickness did not differ between treatments and was higher than 3 mm, which is the minimum recommended by Brazilian slaughterhouses (Freitas *et al.*, 2008). Differences were expected in CT5 and CT10 animals because of the higher energy intake in the late finishing period. The current results corroborate those of Missio *et al.* (2010), who did not find differences in subcutaneous fat thickness in feedlot steers with the same slaughter weight and fed diets containing 22%, 40%, 59%, and 79% concentrate. On the other hand, Diniz *et al.* (2016) observed a mean chilling loss of 3.13% in a study that evaluated the carcass and meat characteristics of crossbred Guzerá steers, which was associated with the low subcutaneous fat thickness (mean 2.13 mm).

There was no difference between treatments for the ribeye area owing to its high correlation with slaughter and hot and cold carcass weights (Table 2). The ribeye area is an indicator of carcass composition as it reflects carcass muscularity (Freitas *et al.*, 2008). In a study with steers with ages and genetic compositions that were similar to those in the current study, but with a lower slaughter weight, Cattelam *et al.* (2013) reported a mean *Longissimus dorsi* area of 58.27 cm². On the other hand, Signoretti *et al.* (2008) reported a mean ribeye area of 66.59 cm² for Nellore steers fed corn silage-based diets, which is similar to the value reported in the present study (68.61 cm²).

A small degree of marbling or intramuscular fat was found in all treatment groups (Table 3). Marbling is one of the most critical factors that determine meat quality (Peña *et al.*, 2013). Both the Charolais and Nellore cattle have a small degree of marbling in the meat (Mayer, 2017), with reduced marbling until 24 months old (Chambaz *et al.*, 2002; Chardulo *et al.*, 2013).

Significant differences were not found for carcass measurement traits. This corroborates a previous study (Hirai *et al.*, 2014), which found no differences in carcass measurement traits between animals with the same genetic patterns and similar ages at slaughtering. When standardized for weight, carcass measurements are a straightforward indicator of carcass conformation (Campion *et al.*, 2009), which may

explain the similarity in carcass conformation characteristics between treatments. Moreover, Olmedo *et al.* (2011) stated that these characteristics are related mainly to breed and age.

The carcass compactness index averaged 1.90 kg cm^{-1} and did not differ between treatments. These results are similar to those obtained by Cattelam *et al.* (2013), who evaluated animals of similar age, breed, and weight. Overall, the current results are in line with the pattern of the animals since the carcass compactness index and measurement traits are associated mainly with the animal's weight and age (Olmedo *et al.*, 2011).

Conclusions

Feeding various energy levels during the finishing phase resulted in higher carcass shrink, but did not compromise the weights, yields, and commercial cuts of carcasses. These dietary energy levels did not influence the qualitative characteristics of the carcasses and meat from feedlot-finished steers.

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Authors' Contributions
AFM, DCAF, RFP and ARM contributed to the project idea, design and execution of the study. LBP, GJ, APMM, MBS and DB participated in the acquisition of data. MBS and DB contributed to laboratory analyses. AFM and RFP analysed the data. AFM drafted and wrote the manuscript. Critical reviews were made by DCAF and ILB. All authors have read and approved the finalized manuscript.

Conflict of Interest Declaration
The authors declare that there was no conflict of interest regarding the material in this manuscript.

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