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Animal performance and carcass characteristics of Nellore young bulls fed coated or uncoated urea slaughtered at different weights

Raul Dirceu Pazdiora[1], Flávio Dutra de Resende[1,2], Marcelo Henrique de Faria[2], Gustavo Rezende Siqueira[1,2], Geraldo Benedito de Souza Almeida[1], Ricardo Linhares Sampaio[1], Paulo Santana Pacheco[3], Murilo Sergio Rodrigues Prietto[4]

[1] Programa de Pós-Graduação em Zootecnia, UNESP/FCAV- Jaboticabal/SP, Brazil.
[2] APTA – Pólo Regional da Alta Mogiana (Colina/SP, Brazil).
[3] Departamento de Zootecnia – Universidade Federal de Santa Maria.
[4] Acadêmico de Zootecnia - UNIFEB – Barretos/SP, Brazil.

ABSTRACT - The objective of this study was to evaluate animal performance and carcass characteristics of 64 Nellore young bulls at 22 months of age finished in a feedlot and slaughtered at five body weights (350; 455; 485; 555 and 580 kg) fed diets containing coated or uncoated urea. The experimental design adopted was completely randomized, set in a 4 × 2 factorial arrangement, and for the variables assessed in the control animals, it was 5 × 2. No effect of interaction between slaughter weights and diets were observed, so the variables were analyzed separately, compared by polynomial contrasts and by the F test, respectively. The time animals remained in the feedlot to reach slaughter weights was 66, 88, 145 and 194 days. Average daily gain (ADG) showed quadratic behavior, with a maximum of 1.44 kg/day with animals of 491.7 kg. Dry matter intake (DMI) (kg/day) was similar in all the treatments, but it decreased linearly as body weight increased. The bionutritional efficiency worsened linearly as body weight rose. The elevation in slaughter weight resulted in linear decrease in the percentage of beef round and increase in forequarter. Backfat thickness and rib eye area of the *longissimus* increased linearly and the percentages of muscle and protein in the carcass reduced and those of fat and ether extract increased linearly as body weight increased. Average daily gain, DMI, feed efficiency and carcass characteristics were not affected by diets containing coated or uncoated urea. However, animals fed coated urea presenter better crude fiber and neutral detergent fiber intake.

Key Words: body composition, fat thickness, feed efficiency, feedlot, gain yield, high grain rations

Introduction

The feedlot is an alternative utilized by some farmers for finishing cattle. However, the period of confinement can vary according to factors like sex, breed group and the concentrate:roughage ratio. A longer period of confinement implicates higher production cost due to the worsening in feed conversion. In high grain diets ingested by ruminants, the evaluation of the nutritional value is a key point, and it has been a challenge for nutritionists. In the last few years, products that aim at the control of the release of non-protein nitrogen (NPN) in the rumen have been developed so as to improve the efficiency of transformation of nitrogen into microbial protein (Akay et al., 2004). According to Santos et al. (2011), the replacement of feeds that contain true protein by feeds with a higher content of non-protein nitrogen, such as urea, can improve the financial efficiency of feeding and reduce the need to purchase protein contents. Moreover, it allows for the formulation of diets with greater inclusion of energy feeds, fibrous by-products and forages.

The weight at slaughter is an important factor for cattle, once it has a direct effect on the animal response, affecting feed intake and animal performance, carcass characteristics and meat quality. Thus, determining the ideal slaughter weight for animals that meets the requirements of the commercialization and distribution systems is essential, once slaughterhouses prefer heavier animals and those with adequate fat degree, which is not interesting to the farmer, who needs more time for animals to stay in confinement, which may have a direct effect on productive and economic efficiency (Costa et al., 2002a; Restle et al., 2007). When slaughterhouses adopt bonus programs, the uniformity of the animals; sex; age; fat cover; and weight at slaughter are criteria utilized for a differentiated remuneration. Among these, one of the main factors is carcass weights, because this characteristic is correlated to boneless yield and standardization of the meat cuts.

The objective of this study was to evaluate the effect of slaughter weight on animal performance and the carcass

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Corresponding author: pazdiora@yahoo.com.br

characteristics of Nellore young bulls finished in a feedlot and fed high grain rations containing coated or uncoated urea.

Material and Methods

This experiment was carried out at Pólo Regional de Desenvolvimento Tecnológico dos Agronegócios da Alta Mogiana, located in the municipality of Colina, São Paulo State, Brazil, pertaining to Agência Paulista de Tecnologia dos Agronegócios (APTA).

Sixty-four Nellore young bulls at 22 months of age were used in this study. Animals were confined in individual semi-covered 10 m^2 pens provided with individual feeders and drinkers.

The treatments consisted of five slaughter weights: 350, 455, 485, 555 and 580 kg body weight and two diets with urea: coated or uncoated. The coated urea was from the commercial brand Optigen® (Alltech). For each treatment, the number of animals (replications) was different. For the group slaughtered at 455 and 485 kg, eight animals were utilized for the diet without coated urea (wCU) and seven for the diet with coated urea (WCU). For the animals slaughtered at 555 kg, seven animals were used for each diet; and for 580 kg, eight animals for wCU and six for WCU (Table 1).

Six animals from the group of slaughter weight at 350 kg (adopted as reference), representing the batch, were slaughtered at 348.5 kg body weight on the twenty-third day of adaptation. However, when the evaluation period started, the other animals weighed 363 kg.

Diets were formulated so as to meet the requirements for an average daily gain (ADG) of 1.5 kg (NRC, 1996), using diet-formulation software Ração de Lucro Máximo (RLM, version 3.0) (Table 2). Feed was supplied twice daily: 50% in the morning (08h00) and 50% in the afternoon (14h00), keeping orts at around 10% of the amount supplied.

Table 1 - Distribution of animals by slaughter weight (kg) and utilization of coated urea

Slaughter weight	Diet
350 (6 animals)	---
455 (15 animals)	With coated urea (7 animals) Without coated urea (8 animals)
485 (15 animals)	With coated urea (7 animals) Without coated urea (8 animals)
555 (14 animals)	With coated urea (7 animals) Without coated urea (7 animals)
580 (14 animals)	With coated urea (6 animals) Without coated urea (8 animals)

The adaptation of animals to the diet was restricted, gradually increasing the amount of feed, starting at 1% of the body weight on the first three days and increasing 0.2% at every three days, until the twenty-first day. Afterwards, feed was supplied *ad libitum* until the twenty-eighth day. Next, the evaluation period started at different days according to the slaughter weights desired. Animals were weighed after solid- and liquid-food deprivation of 16 hours.

Dry matter intake (DMI) per animal was determined by the amount of feed supplied minus orts, expressed in kg/day in relation to body weight (DMIBW), and feed conversion (FC), by the ratio between DMI and ADG.

To obtain the bionutritional efficiency values, variables ADG and DMI were considered together in a bivariate analysis, utilizing procedure MANOVA of software SAS (Statistical Analysis System, version 9.0). To complement the analysis, the first canonical discriminant function was used; according to Harris (1975), it results in higher value for the F test, considering any linear combination involving the variables analyzed. Bionutritional efficiency was determined from the coefficients generated by the analysis of the first canonical variable, forming the following equation: coefficient of bionutritional efficiency = 6.2172*(ADG) – 0.4836*(DMI). The least efficient animals were those which presented lowest bionutritional efficiency, because the canonical coefficient associated with gain was positive and the coefficient associated with intake was negative. Comparisons between the values obtained by the first canonical discriminant function were made via regression analysis.

Samples of ingredients of feeds and orts were collected three times a week and transformed in composite samples per animal at every 28-day period. These were pre-dried in a forced air circulation oven at 55±5 ºC for 72 hours, then ground in a mill with 1 mm diameter pore sieve and stored for subsequent analyses. Percentages of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), ether extract (EE), organic matter (OM) and ash were determined according to the analytical procedures described by the AOAC (1995). The total digestible nutrient (TDN) content was calculated according to Weiss et al. (1992).

Total weight gain was obtained by the difference between slaughter weight and the initial weight of evaluation. Average daily gain was the result of total body weight gain in relation to the total days the animal remained in confinement.

Hot carcass dressing (HCD) was the ratio between the body weight of the animal on the previous day and hot carcass weight. Total carcass gain was determined by the equation: (slaughter weight × CD) – (initial weight × iCD). For initial carcass dressing (iCD), 52.9 kg/100 kg body weight was used, determined by the slaughter of reference animals. The average daily gain in carcass was expressed considering the number of days the animal remained confined as well as its relation with ADG. The number of days animals remained in feedlot varied from 66 to 194 according to the slaughter weights intended.

The slaughter of animals was performed at slaughterhouse JBS Friboi, 20 km away from the feedlot, following the normal flow of the establishment (Brasil, 1971). During slaughter, the liver and the kidney-pelvic fat were collected for determination of weight. At the end of the slaughter line, carcasses were divided in two halves and weighed, resulting in hot carcass weight (HCW) and then taken to a cold chamber for 24 hours at a temperature of 0-4 ºC. After cooling down, carcasses were weighed, thus obtaining cold carcass weight (CCW). Shrinkage loss was determined by the difference between HCW and CCW. The right half-carcass was separated in prime cuts: forequarter, between the fifth and sixth ribs; short ribs or back ribs; and beef round or hindquarter.

A cut was made between the 12th and 13th ribs on the left half-carcass so as to expose the *longissimus* muscle to determine the *longissimus* muscle area (REA) and backfat thickness (BFT), as described by Müller (1987).

Carcass length, hindquarter length and cushion thickness were measured on the right half-carcass, according to Müller (1987). The carcass compactness index was determined by the ratio between CCW and carcass length. Fat cover degree was determined by a score ranging from 0 to 4, where 0 = absent; 1 = scarce; 2 = medium; 3 = uniform; and 4 = excess, according to Luchiari Filho (2000). The conformation, relating the muscle expression in the hindquarter, was determined by scoring from 1 to 5, as follows: 1 = convex; 2 = sub-convex; 3 = rectilinear; 4 = sub-rectilinear; and 5 = concave, according to Luchiari Filho (2000).

For determination of the carcass physical composition in muscle, fat and bone, a piece corresponding to the 9-10-11th ribs (HH section) of the cold left half-carcass was extracted, according to the methodology proposed by Hankins & Howe (1946), according to the equations: muscle = 15.56+0.81(MHH); fat = 3.06+0.82(FHH) and bone = 4.30+0.61(BHH); where MHH, FHH and BHH are the percentages of muscle, fat and bone, respectively, obtained from the HH equation. The HH section was analyzed for evaluation of chemical composition in relation to moisture, ash, crude protein and ether extract, according to the analytical procedures described by the AOAC (1995).

The experimental design adopted was completely randomized, set in a factorial arrangement, considering the effects of diet (with and without coated urea - 1 degree of freedom, DF), slaughter weights (455; 485; 555 and 580 kg - 3 DF) and the interaction between diets and slaughter weights (3 DF) and the residue as having 50 DF. However, for the variables assessed on the reference animals, the factorial arrangement was 2 × 4 + 1 (diets × slaughter weights + reference slaughter), because reference animals slaughtered at the beginning of the experiment did not undergo any treatment. Firstly, the data were subjected to normality test, by the Shapiro-Wilk test; on the variables which did not present normality (ADG and FC), logarithmic transformation was performed. The data were subjected to variance analysis of statistical software SAS (Statistical Analysis System, version 9.0; 2002), utilizing procedure MIXED. The interaction effects were tested and analyzed, but they were not significant in any variable, so the main effects were discussed. When significant by the F test, the effect of slaughter weights was decomposed in 3 orthogonal contrasts: linear, quadratic and cubic. Since the slaughter weights were not equidistant, procedure PROC IML of SAS (9.0) was used to determine the coefficients of the contrasts. The effect of diets was analyzed by the F test. Significance for slaughter weights and for diets was

Table 2 - Composition of the diet utilized for feeding experimental animals

Diets	Diet composition, g/kg dry matter						
	Raw sugarcane bagasse	Corn grain	Cottonseed	Soybean meal	Urea	Coated urea	Mineral mixture[1]
Diet without coated urea	130.0	674.2	99.4	50.0	12.5	0.00	33.9
Diet with coated urea	200.0	584.2	99.4	70.0	2.50	10.0	33.9
Diets	Bromatological composition, g/kg dry matter						
	Dry matter	Mineral matter	Crude protein	Ether extract	Neutral detergent fiber	Acid detergent fiber	Total digestible nutrients[2]
Diet without coated urea	814.7	75.4	140.7	55.4	242.6	143.4	682.4
Diet with coated urea	802.5	83.2	141.7	54.9	302.4	187.2	687.8

[1] Composition per kg of product: vitamin A - 78000 IU; vitamin D3 - 9750 IU; vitamin E - 325 IU; calcium - 160 g; phosphorus - 18.75 g; sodium - 62.5 g; potassium - 50 g; magnesium - 15 g; sulfur - 25 g; manganese - 780 mg; zinc - 1875 mg; copper - 390 mg; cobalt - 23.6 mg; iodine - 23.6 mg; selenium - 6.5 mg; sodium monensin - 780 mg.
[2] Estimated by the equation of Weiss et al. (1992).

declared P<0.05. Pearson's correlation was utilized to determine the correlation between DMI with nutrient intake and BFT with physical and chemical composition.

Results and Discussion

There was no effect of interaction between slaughter weights and diets. Therefore, slaughter weights and diets were analyzed, presented and discussed separately.

Dry matter intake (kg/day) was similar for the animals slaughtered at the different weights. However, when DMI was expressed as ratio of body weight (DMIBW), there was a linear decrease for the heavier animals (Table 3). The data found in the literature about DMI according to slaughter weight are contradictory. Bailey et al. (1985), Galvão et al. (1991), Jorge et al. (1997) and Mello (2007) observed increases in DMI, expressed in kg/day, of diets as the slaughter weight increased, whereas Van Koevering et al. (1995), Costa et al. (2002a), Arboitte et al. (2004a) and Cruz et al. (2004a) did not observe any alteration. This demonstrates that there is variation in ingestion and that other factors, such as genetics, weight at maturity and type of diet, can interfere with this parameter. Reduction in DMIBW between the slaughter weight from 400 to 480 for animals of different genetic groups was reported by Cruz et al. (2004a). However, Mello (2007) did not observe difference for DMIBW when slaughtering crossbred Red Angus or Blonde D'Aquitaine with Nellore at 480, 520 and 560 kg body weight.

As for the evaluation of diets with and without coated urea, no differences were observed for DMI and DMIBW, showing averages of 8.66 kg and 19.7 g/kg body weight, respectively. Evaluating coated urea (Optigen®) in diets for steers at the growth and finishing phases, Tedeschi et al. (2002) also did not find differences for DMI and DMIBW in relation to the diet containing urea.

The increase in slaughter weight did not affect nutrient intake. The similarity in the ingestion of nutrients is due to the similarity of DMI over the confinement period, since there were (P<0.0001) correlations between DMI and OM intake (r = 0.99), CP intake (r = 0.95), EE intake (r = 0.86), NDF intake (r = 0.84) and TDN intake (r = 0.99).

Feed conversion (FC) worsened as the slaughter weight increased, corroborating the literature (Costa et al., 2002a; Arboitte et al., 2004a; Cruz et al., 2004a). Costa et al. (2002a) reported that with increase in animal weight feed efficiency is lowered, and this is due to the differences in the composition of weight gain. With the increases in slaughter weight, there is an augmentation in the proportion of adipose tissue in gain in relation to the other tissues. Fat has a caloric value 2.25 times higher than protein and the fat deposition in the tissues is usually followed by reduction in the water content, which worsens even more the efficiency of weight gain (Cruz et al., 2004a). Feed conversion is the most important characteristic from the practical point of view, since it is characterized by the ratio between what is spent in the form of feed and what is returned in the form of weight gain.

The association of intake and gain, denominated bionutritional efficiency by Euclides Filho et al. (2001), results in a more efficient value to evaluate animal performance. Bionutritional efficiency (Table 3) decreased linearly with increase in body weight, confirming FC, wherein animals slaughtered at a higher weight are less efficient. However, many are the results found in the literature evaluating slaughter weight, breed group, feeding level and types of diet, in which no differences are found for FC; nevertheless, analyzing the bionutritional efficiency, some differences can be verified (Euclides Filho et al., 2001; Euclides Filho et al., 2003; Detmann et al., 2005; Mello, 2007). According to Detmann et al. (2005), bionutritional efficiency ensures maximum discrimination between

Table 3 - Feed intake and feed efficiency of Nellore young bulls fed diets with or without coated urea slaughtered at different weights

Variables	Slaughter weight (SW), kg				Diets (D)		CV (%)	P-value				
	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Cubic	D
DMI	8.76	8.80	8.68	8.40	8.77	8.55	9.69	0.688	0.234	0.450	0.775	0.339
DMIBW	21.3	20.8	18.8	17.7	19.9	19.5	7.88	0.530	0.000	0.349	0.826	0.348
OMI	8.27	8.29	8.14	7.84	8.19	8.09	9.71	0.732	0.147	0.442	0.750	0.655
CPI	1.23	1.24	1.19	1.16	1.25	1.16	10.5	0.713	0.064	0.534	0.801	0.007
EEI	0.74	0.77	0.75	0.75	0.75	0.76	11.7	0.858	0.934	0.431	0.662	0.715
NDFI	2.81	2.75	2.72	2.66	2.95	2.51	11.1	0.794	0.217	0.969	0.672	0.000
TDNI	6.04	5.99	5.89	5.70	5.98	5.84	9.91	0.741	0.123	0.660	0.711	0.438
FC	6.44	6.28	6.63	7.58	6.81	6.64	6.44	0.358	0.000	0.020	0.363	0.433
BNE	4.68	4.54	3.98	2.92	3.93	4.13	22.8	0.635	0.000	0.063	0.224	0.424

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea.
DMI - dry matter intake (kg/day/animal); DMIBW - dry matter intake in relation to body weight (g/kg body weight); OMI - organic matter intake (kg/day); CPI - crude protein intake (kg/day); EEI - ether extract intake (kg/day); NDFI - neutral detergent fiber intake (kg/day); TDNI - total digestible nutrient intake (kg/day); FC - feed conversion; BNE - bionutritional efficiency.
Equations: DMIBW = 34.55741-0.02867SW (r^2 = 0.48); FC = 2.37771+0.00833SW (r^2 = 0.18); BNE = 10.55297-0.01256SW (r^2 = 0.32).

experimental groups and allows for the identification of non-perceivable differences of intensity and production characteristics, associated with the application of bionutritional efficiency.

As for the evaluation of efficiency and ingestion of nutrients in relation to the diets with urea, coated or not, no differences were observed (P>0.05) for FC, bionutritional efficiency and daily intakes of OM, EE and TDN. Tedeschi et al. (2002), evaluating coated urea (Optigen®) in diets for Aberdeen Angus steers in the growth and finishing phase, also did not find differences for FC in relation to the diet containing urea. However, animals receiving a diet containing coated urea obtained greater (P<0.05) intakes of CP and NDF than animals not receiving coated urea, presenting an average intake of 1.25 vs. 1.16 kg and 2.95 *vs.* 2.51 kg, respectively. This higher NDF intake was because the composition of the diet presented more raw sugarcane bagasse, which contains a high percentage of this component.

The time animals remained confined, in days, varied according to the pre-determined slaughter weight (Table 4). The values were 66, 88, 145 and 194 days, respectively. Total body weight gain increased linearly as slaughter weight rose.

Average daily gain showed quadratic behavior, in which the peak was obtained when animals reached 491.7 kg body weight, presenting 1.44 kg/day (Table 3). With this slaughter weight, the estimated FC was 6.5 kg DM ingested/kg of gain. Arboitte et al. (2004a) verified that ADG decreased linearly as slaughter weight increased. This deceleration in weight gain in the final stage of confinement can be suggested mainly as being a result of the greater energy requirement for maintenance and composition of gain (NRC, 1996), wherein the proportion of fat tissue in gain increases along with the body weight and proportional reduction in DMI, and consequently, the higher the body weight, the lower the DMIBW. The ratio of dry matter intake by body weight limited animal performance, mainly at the heavier slaughter weights (555 and 580 kg). The lower DMIBW was insufficient to keep ADG, which rose until 491.7 kg and subsequently reduced until the highest slaughter weight (580 kg).

Final weight and total body weight gain were not affected by the type of diet, presenting averages of 519.5 and 156 kg, respectively, which reflected the similar ADG, with an average of 1.31 kg. Tedeschi et al. (2002), evaluating coated urea (Optigen®) in diets for finishing Aberdeen Angus steers also did not find differences for the ADG in the diet containing urea.

The gain in carcass per day, expressed in kg, decreased linearly. However, when expressed as a ratio of body weight gain it presented quadratic behavior with increase in the slaughter weight of animals, in which the minimum was obtained when animals presented 506.7 kg (Table 4). This demonstrates that there is a tendency to increase in the percentage of body weight gain, which is converted in carcass with increase in animal weight. Mello (2007) found 95, 79 and 79% in the carcass gain:weight gain ratio of animals slaughtered at 480, 520 and 560 kg, but without significant differences. The similarity in the carcass gain: weight gain ratio and the high value found can be a result of the underestimation, by these authors, of the initial carcass dressing (CD) of 50% for confined animals.

Similarity for the animals fed the diets was also verified (P>0.05) for daily carcass gain and gain yield, with averages of 0.81 and 61.9 g carcass gain/100 g body weight gain, respectively.

Hot and cold carcass weights (Table 5) increased linearly (P<0.05) along with increase in the body weight of animals, as a consequence of the weight gain associated with increase in CD. Heavier carcasses are more and more requested by slaughterhouses, because they reduce operational costs, in addition to providing heavier meat cuts.

Table 4 - Days in feedlot, body weight, body weight gain, carcass gain and carcass dressing gain of Nellore young bulls fed diets with or without coated urea slaughtered at different weights

Variables	Slaughter weight (SW), kg				Diets (D)		CV (%)	P-value				
	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Cubic	D
Days	66	88	145	194	-	-	-	-	-	-	-	-
IW	365	360	364	365	364	363	4.46	0.881	0.746	0.470	0.642	0.673
FW	457	485	555	583	520	519	5.02	0.820	0.000	0.702	0.931	0.834
TBWG	92	124	191	218	156	156	13.3	0.651	0.000	0.930	0.634	0.945
ADG	1.35	1.41	1.31	1.22	1.31	1.31	55.4	0.289	0.000	0.015	0.340	0.987
ADCG	0.88	0.83	0.80	0.72	0.80	0.82	14.1	0.072	0.000	0.554	0.176	0.483
DRESS	64.0	58.7	61.2	63.7	61.0	62.8	9.39	0.394	0.709	0.010	0.410	0.254

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea.
IW - initial weight (kg); FW - final weight (kg); TBWG - body weight gain (kg); ADG - average daily gain (kg/day); ADCG - average daily carcass gain (kg/day); DRESS - carcass dressing gain (g gain in carcass/100 g gain in body weight).
Equations: $FW = -3.36804+1.00841SW$ ($r^2 = 0.81$); $TBWG = -358.53810+0.99250SW$ ($r^2 = 0.87$); $ADG = -8.03611+0.03856SW-0.00003921SW^2$ ($R^2 = 0.28$); $ADCG = -232.695+0.635SW$ ($r^2 = 0.18$); $DRESS = 309.85144-0.99147SW+0.0009784SW^2$ ($R^2 = 0.12$).

The increase in body weight of animals at slaughter rose CD linearly. These results are similar to those obtained by Galvão et al. (1991), Mello (2007) and Restle et al. (1997), who stated that the lower CD obtained in lighter animals is due to the greater relative weight of hides, paws and head, and also as a consequence of the more advanced fat cover of heavier animals, resulting in greater deposition of fat in the carcass. Even in a short period of confinement (66 days) animals already produced carcasses that meet the minimum required by slaughterhouses (225 kg).

Hot and cold carcass weights and carcass dressing did not differ between the animals which received diets with or without coated urea. This similarity in the carcass can be attributed to the similar initial weight and ADG among the animals that received the diets (Table 4), promoting same slaughter weight. Working with Aberdeen Angus steers in the finishing phase, Tedeschi et al. (2002) did not find differences in relation to the carcass containing urea.

The increase in slaughter weight (Table 5) resulted in linear decrease in the percentage of beef round in relation to the carcass, wherein each additional kilogram resulted in a reduction of 0.022 kg/100 kg hindquarter carcass. For the forequarter, the result observed was the opposite, in which the increase in animal body weight at slaughter elevated the percentage of forequarter in the carcass. Costa et al. (2002b) found decrease in the percentage of hindquarter in relation to carcass weight, with increase in slaughter weight from 340 to 370, 400 or 430 kg, also in accordance with the results found by Galvão et al. (1991), who also observed reduction in the percentage of hindquarter with increased slaughter weight. However, Jorge et al. (1999) did not find differences in the percentages of beef round with increase in slaughter weight from 500 to 550 kg for crossbred animals and from 450 to 500 kg for Nellore animals.

The differences in percentage of hind- and forequarter might also have occurred by the sexual dimorphism of uncastrated animals, in which there is a more accelerated muscle development of the forequarter. This fact might not be advantageous for the slaughterhouse, once the meat cuts of highest commercial value (sirloin, tenderloin and full rump) are located in the hindquarter. However, the percentage of these cuts in relation to the cold carcass weight remained similar with increase in body weight, presenting an average value of 11.2%. This fact demonstrates that the slaughterhouse can benefit from having heavier carcasses.

At the evaluation of carcass weight, it is desirable that the proportion of beef round be superior to 48 kg/100 kg carcass, forequarter up to 39 kg/100 kg carcass and short ribs up to 13 kg/100 kg carcass (Luchiari Filho, 2000), given the location of the noble cuts of highest commercial value. In this study, the percentage of beef round was inferior to 48 kg/100 kg carcass in the animals with body weight higher than 517 kg. However, the percentage of forequarter in the animals slaughtered between 350 and 580 kg was always above 39 kg/100 kg carcass, probably because animals presented sexual dimorphism with greater development of the forequarter, especially of the hump, for being Nellore (*Bos taurus indicus*) animals; brisket and short ribs remained lower than 13 kg/100 kg carcass.

As to the prime cuts yield, animals presented similarity (P>0.05) in the cuts among the diets, which was expected, since the diet has little direct effect on these cuts and there are other factors that present greater importance for the alteration in the proportion of commercial cuts, such as slaughter weight, age, sex and breed group.

Backfat thickness (BFT) and fat cover degree increased linearly along with the body weight of animals (Table 6), which is in line with the reports found in the literature (Galvão et al., 1991; Restle et al., 1997; Leme et al., 2000; Kuss et al., 2005), wherein we observe an increase of 0.028 mm BFT for each increase in body weight. The fat cover in the carcass is important, because it reduces the losses by dehydration during cooling. Besides, it also avoids external darkening of the muscles that cover the carcass, providing better visual aspect and preventing the quick cooling of the carcass and shortening of the muscle fibers due to the cold. The bonus programs for carcasses implanted in most exporting slaughterhouses require a minimum of 6.0 mm BFT, e.g., the program of reward for carcasses of Angus animals (Group Marfrig, 2012). With the results obtained (Table 6), this value would be reached with a body weight at slaughter of 537.5 kg, which is equivalent to 300.9 kg hot carcass, with an estimated beef round and forequarter yields of 47.3 and 41.9 kg/100 kg carcass, respectively.

The loss by cooling (shrinkage loss) decreased linearly as slaughter weight increased, due to the smaller loss of liquid during cooling caused by the greater fat content in the carcass. In general, carcasses with better fat cover degree present lower loss during cooling, resulting in negative correlation between the two variables, according to the results published by Restle et al. (1997) and Arboitte et al. (2004b) and the present study, presenting significant correlation (r= -0.45). According to Restle et al. (1997), the variation in shrinkage loss is also associated with the oscillations that occur in the cold chamber (temperature, wind speed, number of carcasses). In the present study, although all slaughters were performed in the same slaughterhouse, they took place at different dates, so there might have been variations in the environment of the cold chamber.

Backfat thickness (Table 6), expressed in 100 kg cold carcass, increased linearly with elevation in body weight. According to Arboitte et al. (2004b), this result reflects the intensification of the fat deposition process as the animals reach adult weight. However, Restle et al. (1997) reported that in order to reach the desired fat cover degree, animals must be fed for a longer period, since fat cover is a tissue of late deposition and increases proportionally with the age and weight of cattle.

Kidney-pelvic fat, in kg and in percentage of CCW and body weight, rose linearly along with increased body weight (Table 6). The internal fats are important indicators of body fat deposition. Leme et al. (2000) evaluated different breed groups slaughtered at three weights, and verified increase in the sum of kidney, pelvic and inguinal fats, both in kg and percentage of carcass, with increased slaughter weight (448, 493 and 515 kg), finding 6.1, 8.4 and 10.4 kg; and 2.6, 3.2 and 3.7%, respectively.

The results obtained for absolute liver weight and in relation to CCW and slaughter weight (Table 6) were similar to those published by Kuss et al. (2007), who slaughtered cows at 465, 507 and 566 kg and observed that the weight of the liver was superior for animals slaughtered at 507 and 566 kg in relation to those at 465 kg. When the authors analyzed it in percentage of empty body, they verified reduction for the animals slaughtered at a heavier weight. These authors suggested that the greater rate of body mass deposition may require more synthesis of nutrients from the liver for the formation of tissues. According to Owens et al. (1993) and Ferrel & Jenkins (1998), of the vital organs, the liver has the highest metabolic rates, because of its important participation in the nutrient metabolism; it is also directly related to nutrient intake. These authors verified in their study that DMI and weight of the liver, expressed as percentage of body weight, decreased linearly with increased slaughter weight.

Table 5 - Carcass characteristics of Nellore young bulls fed diets with or without coated urea slaughtered at different weights

Variables	Slaughter weight (SW), kg					Diets (D)		CV (%)	P-value				
	350	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Lack of fit	D
HCW, kg	184	251	264	309	331	267	269	5.5	0.513	0.000	0.492	0.683	0.598
CCW, kg	179	248	260	305	327	263	265	5.5	0.602	0.000	0.647	0.116	0.521
CD	52.8	54.9	54.4	55.7	56.8	54.7	55.2	2.3	0.209	0.000	0.594	0.354	0.092
HIND	51.6	49.1	48.4	46.7	46.4	48.5	48.5	2.5	0.630	0.000	0.748	0.737	0.908
FORE	40.4	40.2	41.0	42.1	42.9	41.4	41.3	2.8	0.811	0.000	0.004	0.584	0.785
SRIB	8.0	10.6	10.6	11.0	10.7	10.1	10.2	6.0	0.626	0.000	0.000	0.700	0.462

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea.
HCW - hot carcass weight; CCW - cold carcass weight; CD - carcass dressing (kg carcass/100 kg body weight); HIND - hindquarter or beef round (kg/100 kg carcass); FORE - forequarter (kg/100 kg carcass); SRIB - short-ribs or back ribs (kg/100 kg carcass).
Equations: HCW = -38.62727+0.63173SW (r^2 = 0.90); CCW = -42.73877+0.63196SW (r^2 = 0.90); CD = 47.36287+0.01570SW (r^2 = 0.40); HIND =59.37885-0.02253*SW (r^2 = 0.64); FORE = 34.64091+0.01358*SW (r^2 = 0.38); SRIB =5.98141+0.00894*SW (r^2 = 0.38).

Table 6 - Backfat thickness (BFT), backfat in relation to cold carcass weight (BFT_CCW), carcass dressing (DRES), shrinkage loss (SL) and weights of kidney-pelvic fat and liver of Nellore young bulls fed diets with or without coated urea slaughtered at different weights

Variables	Slaughter weight (SW), kg					Diets (D)		CV (%)	P-value				
	350	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Lack of fit	D
BFT, mm	0.58	3.91	4.30	5.75	7.83	4.46	4.48	26.3	0.787	0.000	0.667	0.431	0.939
BFT_CCW[1]	0.32	1.58	1.68	1.89	2.39	1.56	1.58	26.9	0.533	0.000	0.093	0.188	0.926
DRES[2]	0.33	1.60	1.85	2.28	2.62	1.68	1.80	31.5	0.755	0.000	0.240	0.444	0.455
SL[3]	2.75	1.40	1.35	1.40	1.25	1.72	1.55	28.3	0.431	0.000	0.000	0.121	0.219
KPF	1.73	4.75	5.66	7.97	9.58	5.82	6.05	22.9	0.639	0.000	0.203	0.358	0.561
KPF _HCW	0.93	1.89	2.14	2.58	2.88	2.05	2.11	20.5	0.643	0.000	0.612	0.534	0.606
KPF _BW	0.49	1.04	1.16	1.43	1.64	1.13	1.18	20.6	0.568	0.000	0.847	0.376	0.507
LIV	3.93	5.31	5.51	5.44	5.52	5.15	5.13	10.3	0.626	0.000	0.000	0.511	0.897
LIV_CCW	2.12	2.11	2.08	1.76	1.66	1.95	1.94	8.0	0.607	0.000	0.000	0.785	0.716
LIV_BW	1.12	1.16	1.14	0.98	0.94	1.07	1.07	7.5	0.408	0.000	0.000	0.345	0.941

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea.
KPF - kidney-pelvic fat (kg); KPF_HCW - kidney-pelvic fat in relation to hot carcass weight (kg/100 kg hot carcass); KPF_BW- kidney-pelvic fat in relation to body weight (kg/100 kg body weight); LIV - liver weight (kg); LIV_CCW - liver in relation to cold carcass weight (kg/100 kg hot carcass weight); LIV_BW - liver in relation to body weight (kg/100 kg body weight).
Equations: BFT = -9.42533+0.0287SW (r^2 = 0.70); BFT_CCW = -2.02779+0.00750SW (r^2 = 0.55); DRES = -2.66063+0.00914SW (r^2 = 0.54); SL = 3.74800-0.00452SW (r^2 = 0.25); KPF = -10.76351+0.03435SW (r^2 = 0.73); KPF_CAR= -1.84539+0.00813SW (r^2 = 0.62); KPF_BW = -1.16404+0.00479SW (r^2 = 0.64); LIV = 2.78273+0.00503SW (r^2 = 0.25); LIV_HCW = 3.22255-0.00257SW (r^2 = 0.51); LIV_BW= -0.48303+0.00790SW-0.00000942SW^2 (R^2 = 0.59).
[1] mm/100 kg cold carcass.
[2] Score: 0 = absent, 1= scarce, 2 = medium, 3 = uniform, 4 = excess.
[3] kg/100 kg carcass.

Animals receiving diets with or without coated urea showed similarity in the amount of kidney-pelvic fat and liver in absolute weight and also in relation to HCW and body weight. Tedeschi et al. (2002) evaluated coated urea (Optigen®) in diets for steers in the finishing phase and did not find differences in relation to the diet containing urea for BFT and kidney-pelvic-heart fat, either.

Carcass length and depth increased linearly along with slaughter weight (Table 7), which demonstrates that animals were still under body growth. The regression equation indicates that for every additional kilogram at slaughter there was an increase of 0.075 and 0.037 cm in carcass length and depth, respectively. This behavior was reported by Costa et al. (2002b) and Restle et al. (1997), working with growing animals.

Other measures related to the muscle development of the carcass are cushion thickness and hindquarter length, which increased linearly along with slaughter weight. The estimates by the equation show that the increases were of 0.082 and 0.018 cm, respectively, for each additional kilogram in the weight at slaughter. Cushion thickness was positively and significantly correlated ($P<0.0001$) with slaughter weights, hot and cold carcasses, beef round weight and carcass compactness index, presenting respective values of 0.87, 0.90, 0.90, 0.93 and 0.89.

Concerning compactness index (Table 7), it increased linearly with elevation in slaughter weights. Through the estimate of the regression equation we can verify that the increase was of 0.003 kg/cm for every additional kilogram in the slaughter weights of animals, i.e., more kilograms of carcass are deposited per centimeter.

The conformation, which measures the carcass muscle expression subjectively, rose linearly with increase in body weight. According to Müller (1987), carcasses with better conformation tend to present a lower percentage of bone and greater edible portion. Slaughtering animals at 425, 467 and 510 kg, Arboitte et al. (2004a) did not verify differences in conformation with increase in weight. Costa et al. (2002b) verified significant correlations between conformation and the measures that evaluated the muscle development of the carcass, according to increase in body weight.

Rib eye area increased linearly as slaughter weight increased, which was similar to the results reported in the literature, in which increase in body weight at slaughter resulted in greater REA, both in late breeds, like Charolais (Restle et al., 1997); early breeds, like Aberdeen Angus (Costa et al., 2002b); crossings between various breeds (Cruz et al., 2004b); and Zebu breeds, like Gyr, Guzerat, Tabapuã and Nellore (Jorge et al., 1999). The rib eye area expressed in 100 kg cold carcass decreased with increase in body weight, agreeing with the results observed in the literature, demonstrating linear decrease from 27 to 24 and from 26.2 to 23.2 cm^2/100 kg carcass, with increase in slaughter weight from 550 to 700, in crossbred Blonde D'Aquitaine × Charolais (Patterson et al., 1994) and from 440 to 507 kg in crossbred Aberdeen Angus × Brahman (Huffman et al., 1990). According to Restle et al. (1997), the decrease is a consequence of the reduction in the level of muscle development as the weight of animals increases.

Carcass length and depth, cushion thickness, beef round length, carcass compactness index, conformation, REA and REA in relation to CCW did not differ ($P>0.05$) between the animals fed diets with or without coated urea.

The percentage of muscle in the carcass decreased linearly with increase in body weight at slaughter (Table 8). Of the carcass tissues, the muscle was predominant, but its participation decreased from 63.7 to 55.9 kg/100 kg of carcass when slaughter weight was elevated from 350 to 580 kg.

Table 7 - Metric measures and carcass conformation of Nellore young bulls fed diets with or without coated urea slaughtered at different weights

Variables	Slaughter weight (SW), kg					Diets (D)		CV (%)	P-value				
	350	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Lack of fit	D
CARL	128	136	139	144	146	139	138	2.3	0.966	0.000	0.770	0.383	0.164
CARD	37.9	38.7	40.6	41.6	43.9	40.5	40.6	5.2	0.930	0.000	0.011	0.432	0.585
CUSTH	97	108	109	115	117	109	110	2.4	0.352	0.000	0.415	0.110	0.216
HINDL	86.8	86.3	85.4	88.1	90.2	87.9	86.8	2.9	0.797	0.012	0.001	0.159	0.130
CCI	1.40	1.82	1.86	2.11	2.25	1.87	1.90	5.6	0.640	0.000	0.883	0.061	0.240
CONF[1]	1.83	2.72	3.15	3.57	3.81	3.08	2.95	22.3	0.354	0.000	0.729	0.844	0.477
REA	52.8	64.9	65.5	72.0	76.7	65.5	67.2	12.0	0.182	0.000	0.968	0.300	0.444
REACCW	29.5	26.1	25.2	23.6	23.4	25.5	25.7	9.9	0.253	0.000	0.368	0.787	0.749

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea.
CARL - carcass length; CARD - carcass depth; CUSTH - cushion thickness; HINDL - hindquarter length; CCI - carcass compactness index; CONF - conformation; REA - rib eye area; REACCW - rib eye area in relation to cold carcass weight (cm^2/100 kg cold carcass).
Equations: CARL = 101.87631+0.07599SW (r^2 = 0.74); CARD = 26.64790+0.02808SW (r^2 = 0.51); CUSTH = 69.27326+0.08247SW (r^2 = 0.82); HINDL = 78.46491+0.01777SW (r^2 = 0.16); CCI = 0.17671+0.00354SW (r^2 = 0.84); CONF = -1.02407+0.00834SW (r^2 = 0.41); REA =18.68137+0.09858SW (r^2 = 0.41); REACCW = 37.76202-0.02526SW (r^2 = 0.33).
[1] Score: 1 = convex, 2 = sub-convex, 3 = rectilinear, 4 = sub-rectilinear and 5 = concave.

Among the tissues that compose the carcass, the muscle is of highest commercial importance, for being the most desired by the consumer, in addition to presenting relevant nutritional importance, due to its adequate proportion of essential amino acids, lipids, vitamins and mineral salts for human nutrition (Arboitte et al., 2004c). Although the absolute weight of the bone tissue increased along with slaughter weight, its percentage participation decreased, as a consequence of increase in the weight of muscle and (especially) fat tissues, similarly to the results obtained by Galvão et al. (1991) and Restle et al. (1997).

The percentage of fat in the carcass was contrary to the muscle (Table 8), since this component increased along with elevation in the body weight of animals. Linear increase in the percentage of fat in the carcass with increased slaughter weight was reported by Galvão et al. (1991), Restle et al. (1997), Costa et al. (2002b) and Arboitte et al. (2004c). According to Berg & Butterfield (1976), fat has its highest deposition increase at the most advanced developmental stage of the animal; Boggs & Merkel (1979) ratified that during the growth phase, fat is the tissue that presents the latest development, but it is deposited at all ages provided the energy intake exceeds the requirement of maintenance and growth of the animal. The percentage of fat in the carcass followed the behavior of the variation in BFT, and the correlation between these two variables was highly elevated (r = 0.73; P<0.05).

During the confinement period, the physical components of the carcass, in absolute weight, increased by 39.0% for bone, 60.3% for muscles and 219.5% for fat, indicating that in the finishing phase, under the same nutritional conditions, the fat tissue is the most intensely deposited in the carcass. Evaluating the increase in the three tissues that compose the carcass, Costa et al. (2002b) verified that elevating the slaughter weight of Red Angus steers from 340 to 430 resulted in an increase of 24.1 and 23.8 kg/100 kg carcass, respectively, in the muscle and bone weights, and 60.2 kg/100 kg carcass in the fat weight.

The ratio between the amount of muscle and fat decreased as the body weight at slaughter increased, and this is due to the superiority of fat gain compared with the muscle, as previously reported. Reduction in muscle:fat ratio with increase in slaughter weight is reported in the studies of Galvão et al. (1991), Restle et al. (1997), Jorge et al. (1999), Costa et al. (2002b) and Arboitte et al. (2004c). However, the muscle + fat:bone ratio, representing the edible part, increased with elevation in body weight. Evaluating the influence of slaughter weight on the carcass characteristics of Red Angus steers, Costa et al. (2002b) verified similarity in the muscle:bone ratio (4.40) and quadratic effect in the muscle portion + fat:bone ratio, presenting maximum value of 6.47 in animals slaughtered at 395 kg.

Regarding the diets, animals fed both coated and uncoated urea did not show similarity (P>0.05) in physical composition of the carcass. The similarity in these traits is related to the similarity in the other previously mentioned characteristics, such as slaughter weight, ADG and BFT.

The chemical composition of the HH section was modified as the body weight of animals increased (Table 9). The percentage of dry matter increased linearly with increase in body weight, as a consequence of the elevation in the percentage of EE, presenting a correlation (P<0.05) of 0.96. Ether extract in the carcass rose from 8.84 to 28.9 kg/100 kg carcass as body weight at slaughter rose from 350 to 580 kg, following the same tendency of fat composition in the carcass (r = 0.92; P<0.05). The percentages of mineral matter and crude protein reduced with increased slaughter weight, showing negative correlation (P<0.05) with the percentage of EE (r = 0.84 and r = 0.46, respectively), but in line with the decrease in percentage of muscle and bone in the carcass with increase in body weight. The chemical composition of the HH section has a high correlation with the body and carcass chemical compositions (Peron et al., 1993; Jorge et al., 2000), so further studies on nutrition should be conducted to evaluate feeds and animal growth.

Table 8 - Physical composition of the carcass of Nellore young bulls fed diets with or without coated urea and slaughtered at different weights

Variables	Slaughter weight (SW), kg					Diets (D)		CV (%)	P-value				
	350	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Lack of fit	D
MUS	63.7	59.9	56.6	54.8	55.9	58.6	57.8	4.9	0.870	0.000	0.137	0.072	0.256
FAT	17.2	24.4	27.8	30.2	29.6	25.3	26.4	11.7	0.824	0.000	0.016	0.092	0.182
BONE	19.0	15.7	15.6	14.9	14.2	15.8	15.8	6.0	0.508	0.000	0.000	0.296	0.947
M:F	3.72	2.53	2.06	1.84	1.92	2.51	2.32	16.0	0.594	0.000	0.000	0.102	0.064
M+F:B	4.25	5.57	5.42	5.75	6.07	5.42	5.40	6.9	0.500	0.000	0.035	0.202	0.858

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea.
MUS - muscle (kg/100 kg carcass); FAT - fat (kg/100 kg carcass); BONE - bone (kg/100 kg carcass); M:F - ratio between the amount of muscle and fat; M+F:B - ratio between the amount of muscle + fat and bone.
Equations: MUS = 75.46674-0.03582SW (R^2 = 0.42); FAT = 0.73504+0.05231SW (R^2 = 0.54); BONE = 23.79435-0.01676SW (R^2 = 0.54); M:F = 5.82615-0.00714SW (R^2 = 0.58); M+F:B = 2.41037+0.00618SW (R^2 = 0.52).

Table 9 - Chemical composition of the Hankins & Howe section (HH section) of Nellore young bulls fed diets with or without coated urea slaughtered at different weights

Variables	Slaughter weight (SW), kg					Diets (D)		CV (%)	P-value				
	350	455	485	555	580	WCU	wCU		SW×D	Linear	Quadratic	Lack of fit	D
DM	37.4	44.5	47.6	49.4	52.2	45.6	46.8	5.3	0.930	0.000	0.168	0.454	0.065
MM	7.48	6.46	6.85	6.22	5.78	6.46	6.60	12.7	0.611	0.000	0.439	0.181	0.849
CP	21.3	18.0	18.4	16.6	17.4	18.3	18.4	6.2	0.338	0.000	0.003	0.551	0.844
EE	8.84	19.9	22.4	26.6	28.9	20.7	21.9	14.4	0.933	0.000	0.063	0.485	0.197

CV - coefficient of variation; WCU - diet with coated urea; wCU - diet without coated urea; HH section: collected according to Hankins & Howe (1946).
DM - dry matter (kg/100 kg carcass); MM - mineral matter (kg/100 kg carcass); CP - crude protein (kg/100 kg carcass); EE - ether extract (kg/100 kg carcass).
Equations: DM = 17.76004+0.05903SW (r^2 = 0.72); EE = -17.72671+0.08108SW (r^2 = 0.74); CP = 25.99336-0.01606SW (r^2 = 0.44); MM = 9.49231-0.00598SW (r^2 = 0.20).

Conclusions

Nellore animals starting confinement at 360 kg body weight present their best performance when slaughtered at 491 kg. Increasing slaughter weight worsens efficiency to transform feed into carcass; however, it improves the carcass fat cover. To obtain carcasses of uncastrated Nellore animals with a minimum of 6.0 mm backfat, the body weight at slaughter must be 537.5 kg. The use of coated urea in high grain diets with 7% more sugarcane bagasse and 9% less corn grain promotes similar productive performance in uncastrated feedlot-finished Nellore animals.

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