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Bionutritional efficiency and carcass characteristics of confined steers receiving different nitrogen sources with whole or milled corn

Eficiência bionutricional e características da carcaça de novilhos confinados recebendo distintas fontes nitrogenadas com milho moído ou inteiro

John Lenon Klein[1]*; Diego Soares Machado[2]; Renata Volpatto Porsch[3]; Ivan Luiz Brondani[4]; Dari Celestino Alves Filho[4]; Amanda Farias de Moura[2]; Gilmar dos Santos Cardoso[2]; Adrieli Linhat da Silva[5]; Camille Carijo Domingues[1]; Marcelo Ascoli da Silva[3]

Abstract

The objective of this study is to evaluate the bionutritional efficiency and carcass characteristics of confined steers receiving different nitrogen sources associated or not with corn grain processing in the diet. The study used a completely randomized design with a 3 × 2 factorial arrangement. Fifty-three Charolais and Nellore crossbred steers were used, with a mean age of 22 ± 0.23 months and initial weight 250 ± 15.80 kg. The animals were randomly divided into the following treatments: soybean meal + whole corn, soybean meal + milled corn, conventional urea + whole corn, conventional urea + milled corn, slow-release urea + whole corn, and slow-release urea + milled corn. A roughage: concentrate ratio of 50: 50 was used. The steers were confined until reaching a weight of 420 kg. The slaughtering occurred according to the schedule of the commercial slaughterhouse. Feed efficiency was lower in animals receiving slow-release urea than those fed true protein. The steers fed soybean meal presented a higher Kleiber ratio and higher nutritional index compared to those receiving conventional or slow-release urea. The provision of soybean meal promoted higher production of rib meat and meat with a higher L* compared to those receiving urea, and better carcass finish compared to those receiving slow-release urea. Diets with milled corn increased warm and cold carcass yields and decreased weight loss during carcass chilling. Total replacement of soybean meal with conventional or slow-release urea reduced the biological efficiency of steers. The supply of milled corn in the concentrated fraction increased carcass yield.

Key words: Feed efficiency. Multivariate biological nutritional index. Slow-release urea. Soybean meal. Subcutaneous fat thickness.

[1] Discentes, Curso de Mestrado, Programa de Pós-Graduação em Zootecnia, Universidade Federal de Santa Maria, UFSM, Santa Maria, RS, Brasil. Bolsista CAPES. E-mail: johnlenonklein@yahoo.com.br; camidomingues1@gmail.com

[2] Discentes, Curso de Doutorado, Programa de Pós-Graduação em Zootecnia, UFSM, Santa Maria, RS, Brasil. Bolsista CAPES. E-mail: dsm_zootecnista@hotmail.com; af.moura@hotmail.com; cardoso-gilmar@bol.com.br

[3] Mestres em Zootecnia, UFSM, Santa Maria, RS, Brasil. Bolsista CAPES. E-mail: renatavp.zoot@gmail.com; maszootec@live.com

[4] Profs. Drs., UFSM, Santa Maria, RS, Brasil. E-mail: brondani@pq.cnpq.br; darialvesfilho@hotmail.com

[5] Zootecnista, UFSM, Santa Maria, RS, Brasil. E-mail: alszootecnia@gmail.com

* Author for correspondence

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Resumo

Objetivou-se avaliar a eficiência bionutricional e as características da carcaça de novilhos confinados, recebendo diferentes fontes nitrogenadas, associadas ao processamento ou não do grão de milho nas dietas. O delineamento experimental foi o inteiramente casualizado, em arranjo fatorial 3 x 2. Foram utilizados 53 novilhos mestiços Charolês e Nelore, com idade e peso médio inicial de 22 ± 0,23 meses e 250 ± 15,80 kg, respectivamente, os quais foram divididos aleatoriamente nos seguintes tratamentos: farelo de soja + milho grão; farelo de soja + milho moído; ureia comum + milho grão; ureia comum + milho moído; ureia de liberação lenta + milho grão e ureia de liberação lenta + milho moído. Utilizou-se relação volumoso:concentrado de 50:50. Os novilhos permaneceram confinados até atingir peso pré-estipulado de 420 kg. O abate transcorreu conforme fluxograma do frigorífico comercial. A eficiência alimentar foi menor nos animais que receberam ureia protegida, em relação aos alimentados com proteína verdadeira. Novilhos alimentados com farelo de soja apresentaram maior Relação de Kleiber e índice nutricional multivariado biológico, que alimentados com ureia protegida ou não. O fornecimento de farelo de soja, promoveu maior participação de costilhar e carne com maior valor de L*, em relação às ureias, além de melhor acabamento de carcaça, em relação à ureia protegida. Dietas com milho moído proporcionaram aumentos nos rendimentos de carcaça quente e fria, com menores perdas de líquidos no resfriamento. A substituição total do farelo de soja por ureia, protegida ou não, reduz a eficiência biológica de novilhos. Maiores rendimentos de carcaça são obtidos quando se fornece milho moído na fração concentrado.

Palavras-chave: Eficiência alimentar. Espessura de gordura subcutânea. Farelo de soja. Índice nutricional multivariado biológico. Ureia de liberação lenta.

Introduction

The cost of diets in the finishing system of confined cattle is approximately 70% of the total cost, excluding the cost of animal acquisition (PACHECO et al., 2014). This factor is one of the obstacles to the adoption of this finishing system by Brazilian producers. In this context, the nitrogen source is usually the most costly fraction of cattle feed. However, true protein from grains can be replaced with non-protein nitrogen (NPN) sources to reduce feed costs without decreasing animal production (MACITTELLI et al., 2007). The main NPN source for cattle is urea, which is used to provide ammonia for bacteria that ferment structural carbohydrates, allowing the synthesis of microbial proteins (MEDEIROS; MARINO, 2015).

The rate of solubility of conventional urea in the rumen is high, and 30% to 40% of ammoniacal nitrogen can be lost when nitrogen supply is not synchronized with energy supply in the rumen (GONSALVES NETO, 2011) and the absorption of excess ammonia in the rumen increases the risk of intoxication. Slow-release urea is used to reduce this risk and increase the rate of replacement of true protein with NPN. Benedeti et al. (2014) found a correlation between the release of ammonia from slow-release urea and fiber degradability in the rumen.

In the finishing diets of beef cattle, the primary source of carbohydrates is grains, and starch degradability and energy availability in the rumen depend on the degree of grain processing. Gonsalves Neto (2011) reported that the exposure of food substrates to microorganisms significantly improved starch degradability, and the mean degradability was 62.6% for whole grains, 76.4% for milled grains, and 65% for broken grains.

The choice of ingredients that constitute the diet and the animal response define the economic viability of this beef finishing system. Achieving the highest bioeconomic efficiency is primarily associated with the conversion of ingested food into the production of animal protein. In this respect, some studies determined the biological efficiency of confined cattle using different parameters and different statistical analytical methods to identify the best discrimination between different groups (MELLO et al., 2010; NICHELE et al., 2015; PAZDIORA et al., 2013).

The diet provided to cattle during the finishing stage directly determines carcass characteristics and meat quality, and affect the relationship between producers, industry, retail market, and consumers. Vaz et al. (2013) found that characteristics such as slaughter and carcass weight of finishing steers affected marketing conditions and meat quality. With respect to the effects of grain processing on carcass characteristics, Restle et al. (2009) observed that milling oat grains increased fat deposition in the carcass of discard cows.

The objective of this study is to evaluate the effect of complete replacement of soybean meal with NPN sources (conventional or slow-release urea) combined with corn grain processing on the bionutritional efficiency in the finishing stage and the characteristics of carcass and beef of steers.

Material and Methods

The study was conducted from August to December 2015 at the of Beef Cattle Laboratory in the Department of Animal Science of the Federal University of Santa Maria (UFSM), in Santa Maria (longitude, 53° 42' W; latitude 29° 43' S; altitude, 95 meters), Rio Grande do Sul, Brazil. The climate of the region is subtropical with humid and hot summers according to the classification of Köppen (ALVARES et al., 2013).

Fifty-three immunocastrated calves of advanced generations of the rotational crossbreeding between Charolais and Nellore (65% Charolais and 35% Nellore, and 65% Nellore and 35% Charolais) were used, with a mean age of 22 ± 0.23 months and initial mean body weight of 250 ± 15.80 kg. The animals were weighed and randomly divided into treatments according to the administered diet, maintaining a roughage: concentrate ratio of 50: 50. The roughage used was whole corn silage obtained from hybrid AS 1596.

The concentrated fraction varied according to treatment, and different combinations of nitrogen sources and physical forms of corn grains were used. The treatments were SMWC (soybean meal + whole corn), SMMC (soybean meal + milled corn), CUWC (conventional urea + whole corn), CUMC (conventional urea + milled corn), SRUWC (slow-release urea + whole corn), and SRUMC (slow-release urea + milled corn). The procedure used to obtain milled corn was grinding in a hammer mill and sieving on a 2-mm sieve.

Before the start of the experiment, feed samples were pre-dried in a forced-air oven at 55 °C for 72 h, milling in a Willey-type mill, and sieving on a 1-mm mesh sieve for bromatological analysis and dietary formulation (Table 1). The bromatological analyses were carried out at the Laboratory of Bromatology and Nutrition of Ruminants of the UFSM.

The cattle were housed in individual pens with reinforced concrete floors with a slope of 3%, feeders for supplying food, and buoy-regulated drinkers with water *ad libitum*. The diets were calculated according to the NRC (2000) seeking to maintain them isonitrogenated and isoenergetic and meet the nutritional requirements of the animals to achieve a daily mean weight gain of 1.25 kg animal^{-1} and an estimated daily dry matter intake (DMI) of 2.53 kg dry matter per 100 kg live weight^{-1}.

The animals were adapted to the diets and facilities for 21 days to avoid metabolic problems, including intoxication from excessive urea consumption. Every two days, 15% of the recommended amount was added. Similarly, soybean meal was gradually added (15% every two days) to ensure that protein intake was equivalent between treatments during the adaptation period. In the study period, the diet was provided *ad libitum* and divided into two meals, one at 8:00 a.m. and the other at 2:00 p.m. DMI was recorded daily by weighing the amount of food provided and the leftovers from the previous day. The pre-established amount of food leftovers was 5% to 8% of the total amount provided the previous day.

The steers were weighed at the beginning and end of the adaptation period. During the experimental period, weighing was performed at 28-day intervals until the end of the study period preceded by a 14-hour fast of solids and liquids to monitor animal growth. The mean DMI, average daily weight gain (ADG), and confinement period are shown in Table 1.

Table 1. Ingredients, bromatological composition of the diets, and production parameters of steers in confinement in the study period.

	Diets		
Ingredients	Soybean meal	Conventional urea	Slow-release urea
[1]Corn silage, %	50	50	50
[2]Corn, %	67.90	94.40	94.30
[2]Calcitic limestone, %	1.10	1.20	1.00
[2]Sodium chloride, %	1.00	1.00	1.00
[2]Sulfur, %	--	0.12	0.12
[2]Kaolin, %	3.00	--	--
[2]Slow-release urea, %	--	--	3.60
[2]Conventional urea, %	--	3.30	--
[2]Soybean meal, %	27.00	--	--
	Bromatological composition		
[1]Dry matter, %	57.59	57.22	57.17
[1]Mineral matter, %	5.63	4.73	4.53
[1]Crude protein, %	12.4	12.4	12.4
[1]Ether extract, %	3.23	3.43	3.42
[1]Neutral detergent fiber, %	31.52	29.97	30.93
[1]Acid detergent fiber, %	13.54	12.26	12.91
[1]Non-fibrous carbohydrates, %	47.22	49.47	48.72
[1]Total digestible nutrients, %	65.83	65.44	65.38
	Production parameters[4]		
Dry matter intake, kg day^{-1}	9.24 ± 1.31	7.46 ± 1.25	7.61 ± 1.62
Average weight gain, kg day^{-1}	1.60 ± 0.29	1.22 ± 0.20	1.24 ± 0.19
Confinement period, days	105.0 ± 0.00	136.0 ± 3.60	136.0 ± 3.60

[1]Percentage in the total diet; [2]Percentage in the concentrated fraction; [3]Estimated according to Barber et al. (1984); [4]Adapted from Porsch (2017).

The biological efficiency was assessed using four parameters: feed efficiency (FE), Kleiber ratio (KR), residual feed intake (RFI), and multivariate biological nutritional index (MBNI). The FE was obtained by the nonlinear combination between normal and correlated continuous random variables, as follows: $FE = \frac{Y_{ijk}}{X_{ijk}}$; $<FE<1$, where Y_{ijk} and X_{ijk} are the average daily weight gain (kg day^{-1}) and DMI (kg day^{-1}), respectively, of the k-th repetition in the i-th nitrogenous source and j-th physical form of corn grains. The KR (KLEIBER, 1936) was calculated using the formula: $KR = \frac{Y_{ijk}}{\text{Mean } MLW_{ijk}}$, where $MMLW_{ijk}$ is the mean metabolic live weight ($MLW^{0.75}$) of the k-th repetition in the i-th nitrogenous source and j-th physical form of corn grains; and Y_{ijk} as defined above.

The RFI (KOCH et al., 1963) was obtained by multiple linear regression according to the following statistical model:

$$Y_{ijk}=\beta_0+\beta_1 X_{1ij}+\beta_2 X_{2ij}+\varepsilon_{ijk}$$

Where Yijk is the DMI (kg day^{-1}) of the k-th repetition in the i-th nitrogenous source and j-th physical form of corn grains; β_0 is the intercept or constant of the regression; β_1 and β_2 are regression coefficients; X_{1ij} is the mean ADG (kg day^{-1}) in the i-th nitrogenous source and j-th physical form of corn grains; X_{2ij} is the mean metabolic live weight (MMLW, $kg^{0.75}$), and ε_{ijk} is the residual random error, representing the RFI of observation *ijk*, assumption (0, σ^2). These parameters were estimated using PROC REG. DMI was estimated using the following equation: $DMI_{PREDICTED}$: -1.773 + (2.697 x ADG) + (0.078 x MMLW) (R^2 = 0.82; P<0.0001). Residual feed intake was obtained by the difference between the observed and predicted DMI.

The MBNI was calculated using multivariate analysis of variance (MANOVA) complemented by Fischer's canonical discriminant function (MARDIA et al., 1997). For this purpose, the ADG and DMI (kg day^{-1}) were subjected to MANOVA using a completely randomized design, disregarding the factorial arrangement according to the following model:

$$Y_{ijk}=\mu_k+T_{ik}+\varepsilon_{ijk}$$

Where Y_{ijk} is the observed value of the k-th variable under the effect of the i-th treatment in j-th repetition, μ_k is the overall mean of the k-th variable, T_{ik} is the effect of the i-th treatment on the k-th variable, and ε_{ijk} is the random effect associated with observation Y_{ijk}, assumed to be normal, independent, and identically distributed - NIID (0, σ^2). After that, the eigenvalues were calculated by determining the characteristic roots of the equation (HARRIS, 1975):

$$\left|E^{-1}H-\lambda I\right|=0$$

Where E^{-1} is the inverse of the matrix of the sums of squares and residual products, H is the matrix of the sums of squares and treatment products, λ_1 and λ_2 are eigenvalues of the matrix $E^{-1}H$, and I is the identity matrix of order p = 2.

After that, the non-normalized eigenvectors associated with λ_1 (higher eigenvalue) were estimated by solving the equations: $\left(E^{-1}H-\lambda I\right)\underset{\sim}{v}=\begin{bmatrix}0\\0\end{bmatrix}$ $\left(E^{-1}H-\lambda I\right)\begin{bmatrix}a\\b\end{bmatrix}=\begin{bmatrix}0\\0\end{bmatrix}$, where λ_1 is the higher eigenvalue, $\underset{\sim}{v}$ is the non-normalized eigenvector, *a* and *b* are canonical coefficients, and E^{-1}, H, and *I* are defined above.

The eigenvectors were normalized by solving the linear system according to the constraint $\underset{\sim}{\ell}\frac{E}{n_e}\underset{\sim}{\ell}$ $[a' \quad b']\frac{E}{n_e}\begin{bmatrix}a'\\b'\end{bmatrix}=1$, where $\underset{\sim}{\ell}$ is the normalized eigenvector associated with λ_1, $\underset{\sim}{\ell'}$ is the transpose of the normalized eigenvector, E is the matrix of the sums of squares and residual products, is the number of degrees of freedom of the residue, a' and and b' are canonical coefficients.

The calculation of a' and b' allowed obtaining the first canonical variable defined by: $CV_1=a'Y+b'X$, where VC_1 is the first canonical variable, Y is animal transformation (ADG, kg day^{-1}), X is the DMI (kg day^{-1}), and a' and b' are defined above. The values of this function were denominated multivariate biological nutritional index - MBNI (GUIDONI, 1994; MELLO et al., 2010). The analysis of variance was performed using PROC GLM. The canonical variables were analyzed using PROC CANDISC because they were significant using the Wilks Lambda test.

The animals were slaughtered when they reached a body weight of 420 kg and an adequate finishing condition, and the latter criterion was evaluated by the body condition score. Three slaughters were performed in a commercial slaughterhouse with state inspection, and the transportation of the animals to the slaughterhouse took approximately one hour at a distance of 20 km.

Each animal was previously weighed before being shipped to the slaughterhouse after a 14-hour fast of solids and liquids to obtain the slaughter weight. After slaughter, the two half-carcasses were identified and weighed to obtain the hot carcass weight. The carcasses were cooled for 24 hours to a temperature of 0 - 1ºC, and weight was measured again to obtain the cold carcass weight. These parameters allowed determining the hot and cold carcass yields and weight loss during carcass chilling. The left half-carcass was separated into prime cuts: forequarter, sidecut and hindquarter. Each piece was weighed for determining its percentage in the cold carcass.

The *Longissimus dorsi* area (cm^2) was measured by making a horizontal cut between the 12th and 13th ribs of the right half-carcass and exposing the *Longissimus dorsi* muscle, and this area was drawn on vegetable paper and later measured on a tablet. In this area, the subcutaneous fat thickness (mm) and degree of meat marbling were determined according to Müller (1987). After 30 min of exposure of the meat cut to oxygen, meat color was assessed in three different areas using a portable Minolta® CR10 colorimeter to evaluate the variables L* (luminosity), a* (red-green component), and b* (yellow-blue component) using the CIELAB system. A cut was made between the 10th and 12th ribs (section HH) of the right half carcass to determine the percentage of muscle, adipose, and bone tissues according to the methodology of Hankins and Howe (1946).

The study used a completely randomized design with nine replicates per treatment, and each animal constituted an experimental unit with a 3 × 2 factorial arrangement. The collected data were subjected to the analysis of outliers using the Studentized residual and tested for normality of residues using the Kolmogorov-Smirnov test. The variables a*, b*, and *Longissimus dorsi* area were transformed using a logarithmic function because the distribution was non-normal.

These variables were subjected to analysis of variance by the F test using PROC GLM. The means were compared using Tukey's test at a level of significance of 5%. The dependent variables were subjected to Pearson correlation analysis using PROC CORR. All statistical analyses were performed using the statistical package SAS (*Statistical Analysis System* version 3.5, SAS University Edition). The mathematical model used in ANOVA was:

$$Y_{ijk} = \mu + NS_i + PFCG_j + NS_i{*}PFCG_j + \varepsilon_{ijk}$$

Where Y_{ijk} are dependent variables; μ is the mean of all observations; NS_i is the effect of the i-th nitrogen source; $PFCG_j$ is the effect of the j-th physical form of corn grains; $NS_i{*}PFCG_j$ is the effect of the interaction between the i-th nitrogen source and the j-th physical form of corn grains; ε_{ijk} is the random error associated with observation Y_{ijk}.

Results and Discussion

Biological efficiency

There was no significant effect of the nitrogen sources and the physical forms of corn grains on the studied variables. For this reason, the factors were presented and discussed separately.

The biological efficiency indicators are presented in Table 2. The nitrogen source used in the diet changed the FE, and the FE of steers fed soybean meal was higher than that of animals fed slow-release urea ($P<0.05$), and the ADG of the former was 18 g per kg of dry matter consumed. This response is due to the higher growth provided by soybean meal and was further evidenced by the correlation analysis, in which the FE was more strongly associated with weight gain ($r = 0.42$; $P = 0.0024$) than with DMI ($r = -0.29$; $P = 0.0438$). The FE of the animals fed conventional urea was intermediate.

Table 2. Biological efficiency of confined steers fed with different nitrogen sources and physical forms of corn grains.

Characteristics	Nitrogen source			Physical form		CV (%)	p-value		
	SM	CU	SRU	Whole	Milled		NS	PF	NS*PF
FE	0.176a	0.164ab	0.158b	0.165	0.168	11.93	0.0250	0.4966	0.0858
MBNI	5.86a	4.48b	4.46b	4.81	5.02	13.91	<0.0001	0.4953	0.2865
KR	20.82a	16.08b	16.14b	17.43	17.78	12.37	<0.0001	0.8987	0.3760
RFI	0.32	-0.08	-0.08	0.09	0.01	-	0.0846	0.7240	0.9972

The means followed by lower case letters on the same line were significantly different by Tukey's test (P<0.05) using PROC GLM. SM: soybean meal; CU: conventional urea; SRU: slow-release urea; CV (%): coefficient of variation; NS: nitrogen source; PF: physical form; KR: Kleiber ratio (g UTM^{-1}); FE: feed efficiency (kg of weight gain kg dry matter ingested^{-1}); MBNI: multivariate biological nutritional index; RFI: residual feed intake (dimensionless).

However, the higher FE in the univariate analysis does not guarantee a higher FE in the multivariate analysis, and this hypothesis may be rejected (MELLO et al., 2010). In this respect, the MBNI was used because it met the assumptions of the standard normal Gauss-Markov model, taking advantage of the collective information on variables and their discriminatory character (GUIDONI, 1994). In our study, considering that the MANOVA was significant using the Wilks Lambda test (P = 0.0346), canonical variables were analyzed to identify the coefficients associated with ADG and DMI.

In addition, the MBNI, also known as nutritional efficiency (EUCLIDES FILHO et al., 2001; NICHELE et al., 2015; PAZDIORA et al., 2013), was defined by the equation MBNI = (3.97 x ADG) + (-0.06 x DMI). Higher MBNI values indicate more efficient animals because the canonical coefficient associated with ADG was positive and the canonical coefficient associated with DMI was negative. However, it should be noted that the solution also accepts the opposite sign.

The results for MBNI followed a trend similar to that of FE, but not identical because the steers that consumed soybean meal were more efficient than those receiving NPN in the diet. The univariate analysis indicated that there was no significant difference in the FE of animals fed soybean meal and conventional urea (Table 2).

The investigation of the biological efficiency using the KR and RFI, in contrast to FE and MBNI, does not imply changes in the animal body size at maturity because these variables are not correlated with weight (MELLO et al., 2010), and this fact was also observed in the correlation analysis in our study. The KR was higher in steers fed soybean meal than in animals that consumed urea as the nitrogen source (P<0.05). The ADG per unit of metabolic size was 22.76% and 22.48% higher in animals that consumed soybean meal relative to those fed urea and slow-release urea, respectively. The factors that contributed to higher growth rate with the same $MLW^{0.75}$ were the association between MWG and DMI and the nutritional profile of the feeds (true protein vs. NPN).

The animals with the highest ADG also presented higher DMI, and this result agrees with that of Paixão et al. (2006), whereby animal performance was affected by several factors but primarily by DMI, which determined the level of nutrient intake. Porsch (2017) evaluated the levels of blood metabolites and found that steers fed diets containing soybean meal had a better protein nutritional *status* than those consuming NPN. With respect to the profile of the diets, NPN yielded 100% of rumen degradable protein (RDP) where as in plant-based diets such as soybean meal produced a balance between RDP and rumen non-degradable protein (RNDP). Therefore, the more balanced availability of both RDP and RNDP may justify the better performance of the animals that consumed soybean meal and the improved KR. Fernandes et al. (2009) performed total or partial substitution of soybean meal in diets with 2%, 1%, and 0% of urea in beef cattle and observed that weight gain was higher in steers fed true protein than those receiving 2% urea because the diets with urea showed excess RDP. RDP is necessary for the synthesis of microbial protein in the rumen whereas RNDP escapes ruminal fermentation and reaches the abomasum, where it is digested (VASCONCELOS et al., 2007).

In contrast to the results found for the other efficiency characteristics (FE, MBNI, and KR), the RFI was similar between the nitrogen sources studied ($P>0.05$). Although there were no significant differences in RFI, steers consuming conventional or slow-release urea presented negative RFI values whereas those consuming soybean meal presented positive values. This result was affected by the lower DMI of steers treated with NPN because DMI was the only parameter correlated with RFI ($r = 0.50$; $P = 0.0003$).

The physical forms of corn grains (milled or whole) did not affect the variables related to biological efficiency ($P>0.05$). The main hypothesis in studying these two physical forms was that grain processing might favor the attack by microorganisms, leading to greater synchronism in the rate of degradation of nitrogenous sources (mainly urea) and carbohydrates. However, the analysis of the nutritional efficiency indicated that grain milling did not improve nutrient utilization and animal production. This result agrees with that of Corona et al. (2005), who observed that weight gain, DMI, and FE were similar between finishing steers in confinement receiving whole or milled corn. However, it should be noted that the responses of the animals to the degree of grain processing may change when the percentage of grains exceeds 50% of the diet.

Carcass characteristics

The quantitative characteristics of the carcass did not differ significantly between the protein sources used (Table 3). There was variability in the ADG. However, slaughter weight was similar because this variable was predetermined as a criterion for sending the animals to the slaughterhouse, with consequent differences in the period of confinement (Table 1). Animals receiving soybean meal had higher efficiency in the conversion of feed to body weight and thus reached slaughter weight (420 kg) approximately 31 days earlier than animals receiving urea (105.00 ± 0.00 vs. 136.00 ± 3.60 days). The confinement period affects the cost-effectiveness of the investment. This result agrees with that of Corona et al. (2005), wherein slaughter weight, carcass weight, and carcass yield were similar between confined steers fed whole or milled corn.

The similar slaughter weights were reflected in the absence of differences in hot and cold carcass weights. This result corroborates that of Mc Curdy et al. (2010), whereby the increase in slaughter weight was proportional to the increase in the carcass weight of the steers. The hot carcass weights obtained in our study was satisfactory considering the low slaughter weight of the steers, and the mean hot carcass weights were 238.72 kg for the nitrogen sources and 237.68 for corn. Obtaining similar values for slaughter weight and carcass weight eliminates the need to process corn grains before including them in the diets in this finishing system and does not affect the variables related to the profit of producers and slaughterhouses.

Table 3. Quantitative characteristics of the carcass of confined steers fed different nitrogen sources and physical forms of corn grains.

Characteristics	Nitrogen source			Physical form		CV (%)	p-value		
	SM	CU	SRU	Whole	Milled		NS	PF	NS*PF
Slaughter Weight, kg	421.50	413.72	412.41	410.19	421.48	14.57	0.8890	0.5024	0.9434
Hot carcass weight, kg	242.97	235.82	234.37	232.34	243.03	16.48	0.7749	0.3209	0.9713
Hot carcass yield, %	57.60	56.75	56.72	56.47b	57.57a	3.46	0.3039	0.0434	0.3445
Cold carcass weight, kg	237.72	229.96	229.18	226.62	237.85	16.60	0.7589	0.2905	0.9824
Cold carcass yield,%	56.35	55.33	55.46	55.07b	56.34a	3.47	0.2218	0.0193	0.4658
Chilling loss, %	2.17	2.26	2.23	2.31a	2.14b	9.10	0.3803	0.0040	0.5290
Forequarter, kg	86.80	86.11	85.33	82.27	87.86	17.76	0.9546	0.3942	0.9540
Forequarter, %	36.50	37.31	37.26	37.12	36.93	3.66	0.1482	0.5904	0.9897
Sidecut, kg	29.96	27.27	26.97	27.42	28.73	17.51	0.1485	0.3307	0.7736
Sidecut, %	12.59a	11.86b	11.76b	12.09	12.06	6.17	0.0033	0.8932	0.2205
Hindquarter, kg	120.89	116.59	116.83	114.92	121.22	16.23	0.7442	0.2325	0.9864
Hindquarter,%	50.87	50.83	50.95	50.78	50.98	2.25	0.9690	0.4964	0.4624

The means followed by lower case letters on the same line were significantly different by Tukey's test ($P<0.05$) using PROC GLM. SM: soybean meal; CU: conventional urea; SRU: slow-release urea; CV (%): coefficient of variation; NS: nitrogen source; PF: physical form.

The hot and cold carcass yields were similar between the nitrogen sources. However, steers fed milled corn presented higher hot and cold carcass yields than those receiving whole grains ($P<0.05$). This response may be associated with the higher volume of the gastrointestinal tract of steers that consumed whole grains. This hypothesis is corroborated by Owens et al. (1986), wherein the total digestibility of starch was higher in finely milled corn grains than whole grains (93.5% vs. 91.7%) and the former promoted better ruminal digestion (77.70% vs. 58.90%). This result suggests that diets containing milled corn grains allow a higher rate of passage of digestible material than whole grains. In our study, this result was evidenced by analyzing the carcass yields between milled and whole corn, with an increase in hot carcass weight of approximately 5 kg in the animals fed milled grains, when the carcass yield was increased to 57.57% (Table 3).

The weight loss during carcass chilling was significantly different in animals fed milled and whole corn (Table 3). The weight loss in steers fed milled corn was comparatively lower. This result is related to slaughter weight, in which the increase of 11.29 kg in steers consuming milled corn resulted in lower weight loss, confirmed by the correlation between these variables ($r = -0.54$; $P<0.0001$). A lower liquid loss provides higher cold carcass yields, and values close to 2% are considered desirable by slaughterhouses (VAZ et al., 2013).

The absolute weight of prime cuts was not significantly different between the protein sources (Table 3) whereas the relative weight of these cuts was significantly different between these sources. However, the physical form of the grains did not significantly affect the relative weight. Steers fed soybean meal had a higher percentage of sidecut than those fed NPN ($P<0.05$). This response is related to the higher degree of carcass finishing, which is evidenced by the increased subcutaneous fat thickness in the soybean meal treatment (Table 4). A similar result was observed by Vaz and Restle (2001), who attributed the higher percentage of sidecut to greater deposition of adipose tissue in this region of the carcass.

Table 4. Qualitative characteristics of the carcass and meat of confined steers fed different nitrogen sources and physical forms of corn grains.

Characteristics	Nitrogen source			Physical form		CV (%)	p-value		
	SM	CU	SRU	Whole	Milled		NS	PF	NS*PF
LDA, cm^2	69.65	63.03	67.53	65.93	67.42	16.65	0.1912	0.7774	0.3514
SFT, mm	4.10a	3.50ab	2.74b	3.70	3.24	34.14	0.0240	0.2616	0.8596
[1]Marbling	5.83	5.61	4.53	5.69	5.00	31.96	0.0671	0.1709	0.4849
Muscle, %	63.07	63.07	65.19	63.75	63.78	5.28	0.1196	0.9839	0.6892
Fat, %	23.09	22.76	20.69	22.06	22.33	15.30	0.0926	0.7673	0.7224
Bone, %	14.56	14.82	14.85	14.86	14.63	9.37	0.8065	0.5949	0.0594
Muscle: bone ratio	4.37	4.30	4.43	4.31	4.42	11.67	0.7809	0.4705	0.0523
M+F: bone ratio	5.98	5.86	5.84	5.81	5.97	11.19	0.8211	0.3974	0.0502
Color L*	40.15a	37.31b	37.39b	37.46	39.12	8.13	0.0119	0.0538	0.7912
Color a*	15.63	14.66	15.25	15.07	15.29	15.16	0.4807	0.7650	0.8551
Color b*	8.35	7.03	7.42	7.24	7.95	28.01	0.1671	0.0791	0.3088

The means followed by lowercase letters on the same line were significantly different by Tukey's test ($P<0.05$) using PROC GLM. SM: soybean meal; CU: conventional urea; SRU: slow-release urea; CV (%): coefficient of variation; NS: nitrogen source; PF: physical form; LDA: *Longissimus dorsi* area; SFT: subcutaneous fat thickness; [1]Marbling (scores): 1 - 3 (trace); 4 - 6 (mild); 7 - 9 (small); 10 - 12 (medium); 13 - 15 (moderate); 16 - 18 (abundant), as described by Müller (1987); M+F: muscle + fat.

There was no significant difference in the *Longissimus dorsi* area between the animal groups (Table 4). Cattelam et al. (2013) found that this variable was one of the indicators of carcass muscularity and was strongly correlated with slaughter weight (r = 0.71). In the present study, the correlation between these characteristics was 0.69 ($P<0.0001$), which justifies the similarity in the *Longissimus dorsi* area and absence of statistical difference because the slaughter weights of the animals were predetermined.

The subcutaneous fat thickness was higher in steers fed soybean meal than those fed slow-release urea (Table 4). This characteristic is related to the rate of ADG, and the animals who consumed soybean meal gained 23.12% more weight per day than those fed NPN, and this result may be related to higher DMI (Table 1). This result suggests that steers fed soybean meal ingested relatively higher amounts of digestible energy and, consequently, fat deposition was relatively higher.

The similar weight gain between the NPN sources also resulted in similar fat thickness. However, despite similar weight gains in the animal groups receiving urea, the longer confinement period in these groups relative to the group receiving soybean meal allowed the fat deposition in the carcass of the former to a level similar to that of the latter. However, the effect of the longer finishing stage was not observed in animals fed slow-release urea. Among the analyzed diets and experimental conditions, only steers receiving slow-release urea did not reach the fat thickness desired by the Brazilian slaughterhouses (3 to 6 mm).

The physical form of the grains did not affect the amount of subcutaneous fat. Restle et al. (2009) studied the effect of oat grain processing on the amount of subcutaneous fat in cows and observed a linear increase in this variable when whole grains were replaced with milled grains (0%, 50%, and 100%). This result was attributed to the better use of milled grains, which promoted higher energy intake by the animals. However, this effect was not observed in the present study and may be due to differences in the structural composition of corn and oat grains.

Despite the differences in fat thickness, marbling was similar between the animal groups. In the present study, the mean values were 5.32 (mild) in animals receiving nitrogen sources and 5.34 (mild) in animals fed corn. These values are considered low in confinement finishing systems, in which the energy density of the diet is usually higher than that of grazing systems. These results may also be related to the genetic potential of the evaluated breeds for deposition of this type of fat in the carcass.

The carcass tissue composition did not differ between the nitrogen sources and the physical forms of corn grains (Table 4). Differences in the percentage of bone tissue are not expected using different diets, and this characteristic is more strongly related to the animal category and racial grouping. In this study, the mean percentage of bone was 14.74%. Variability in the percentage of adipose and muscular tissue is relatively higher. The percentage of adipose tissue in the carcass was similar between the protein sources. This variable is positively correlated with subcutaneous fat thickness. However, in this study, the improved finishing for the animals fed soybean meal relative to those fed slow-release urea did not increase the percentage of adipose tissue in the carcass, although these groups followed the same trend ($P = 0.0926$). The observed correlation between these variables was 0.68 ($P<0.0001$), demonstrating a positive association between these characteristics.

The absence of significant differences in the percentage of fat was reflected in the similar percentage of muscle in the carcass. The muscle: bone and (muscle + fat): bone ratios were not significantly different between treatments. Alves Filho et al. (2016) reported that the muscle: bone ratio was probably the most critical characteristic because it indicated the amount of tissue most desirable in the carcass relative to parts not used by consumers.

Meat color is an important characteristic in product selection by consumers. In the present study, meat color was affected by the protein source but did not significantly differ between the physical forms of grains. A higher L* (luminosity) was observed in steers fed soybean meal compared to those receiving conventional or slow-release urea. This result may be attributed to the higher energy intake, which was reflected in higher weight gain for these animals. Higher L* indicates a brighter color. Therefore, steers fed soybean meal have brighter meat, which may help improve the attractiveness of the product.

The variables a* (intensity of red) and b* (intensity of yellow) were similar between the nitrogen sources. This similarity was expected because the factors that more strongly affect these characteristics are animal age and the food system used in the finishing stage. Nassu et al. (2016) reported that b* values were higher in older animals and animals finished with forage or silage in the diet. The obtained values of L*, a*, and b* were within the range recommended by Muchenje et al. (2009) for beef (33.2 - 41.0 for L*, 11.1 - 23.6 for a*, and 6.1 - 11.3 for b*).

Conclusions

The complete substitution of soybean meal with conventional or slow-release urea reduced the bionutritional efficiency of confined steers and the percentage of rib and produced meats with a darker color.

The use of slow-release urea decreased the amount of fat during the finishing stage compared to the use of true protein in the diet of steers.

The supply of milled corn increased hot and cold carcass yields and reduced weight loss during carcass chilling.

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