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Corn and sorghum ground or rehydrated and ensiled in feedlot cattle diets

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ABSTRACT - This study aimed to evaluate the effects of dried or rehydrated corn and sorghum grains on nutrient intake, performance, and economic analysis in high-grain diets (30:70) of Nellore bulls finished in a feedlot system. The experiment was completely randomized and replicated four times (two animals/pen), in which 32 Nellore bulls with an initial body weight (IBW) of 324.8±4.42 kg were fed in 16 pens according to the following treatments: rehydrated corn silage (RCS), rehydrated sorghum silage, dry corn grain, and dry sorghum grain. Dry matter intake, IBW, and final body weight did not differ among treatments, although diets with RCS and ground corn grain had better daily weight gain (1.60 and 1.52 kg/head/day, respectively). Rehydrated corn silage allowed lower daily costs (US$ 2.12/day) in relation to ground corn grain (US$ 2.14/day). Rehydrated sorghum grain silage is recommended instead of dry sorghum grain in beef cattle diets since it provides greater net margin, without affecting the average daily gain. Similarly, the rehydrated corn grain diet presents greater technical and economic efficiency than dry sorghum or rehydrated sorghum silage, indicating greater system profitability.

Keywords: economic analysis, Nellore, performance, processing

1. Introduction

Corn grain has great economic importance in Brazil because of its different forms of use in human and animal food. In the Brazilian feedlot industry, corn remains the most used energy source in beef cattle diets (Silvestre and Millen, 2021), directly affecting the final production costs because there is great variation in prices throughout the year. Thus, animal nutritionists have studied alternative feeds to replace this cereal, such as sorghum.

Sorghum grain is used in ruminant diets because of its similar energy value to corn grain and lower cost (Lopes and Carvalho, 2002). Despite these positive aspects, only 2.8% of the Brazilian nutritionists utilize this grain (Silvestre and Millen, 2021). The low digestibility of sorghum coupled with the low content of essential amino acids are the main obstacles to its use in cattle diets (Mudge et al., 2016).

In Brazil, flint corn is the predominant type; it contains higher content of vitreous endosperm, which has lower ruminal *in situ* degradability, as well as lower *in vitro* and *in vivo* digestibility (Correa et al., 2002; Allen et al., 2008). Thus, the rehydration and ensiling of grains have been used as a strategy to increase ruminal degradability of starch (Philippeau and Michalet-Doreau, 1998) and improve the starch digestibility of corn (Ferraretto et al., 2018).

The rehydration of grain to silage consists of adding water to the dry ground grains until they reach the right moisture content to be ensiled (Mombach et al., 2018). During the fermentation of rehydrated grains, the proteolysis of the protein matrix surrounding the starch granules occurs, which can increase starch digestibility (Hoffman et al., 2011). Furthermore, rehydration and ensiling of grains are an alternative for grain-storage deficiency in regions where weather conditions compromise optimal harvest and storage. Besides, rehydration grain silage allows livestock farmers to purchase a large quantity of grain at times of lower value and store it for long periods to reduce the risks of pest attacks, which occur in bagged grains.

Although it is well known that rehydration of cereal grains has positive effects on animal performance, few studies have evaluated sorghum rehydrated in beef cattle diets, and to the best of our knowledge, no studies have evaluated the economic effect of its inclusion in the diets in the final production cost. Thus, economic analysis becomes important to identify the main factors of production influencing the final costs of the activity, allowing animal nutritionists to plan nutritional strategies to reduce costs and ensure animal performance. As is known, most of the energy in grains is in the form of starch. Thus, many grain processing methods have been used to improve their use in ruminant feed.

We hypothesized that the rehydration and ensiling process of sorghum and/or corn grain could increase animal performance and allow a complete substitution of dry cracked grains. In addition, this technology could provide a reduction in feedlot costs. Thus, the objective of this study was to evaluate the performance of Nellore cattle fed finishing diets composed of rehydrated and ensiled corn grain, dry grain corn finely ground, rehydrated and ensiled sorghum grain, or dry sorghum grain finely ground. Additionally, an economic analysis of the feedlot diets was performed to indicate the best nutritional strategy for beef cattle producers.

2. Material and methods

Animal research was conducted according to the Institutional Committee on Animal Use (012/2018) in Curvelo, Minas Gerais State, Brazil (18°49' S and 44°24' W, 632 m altitude).

2.1. Animals, facilities, and experimental design

Thirty-two Nellore bulls [age = 24 months; initial body weight (IBW) = 324.8±4.42 kg] from a commercial herd were used. Initially, animals were identified, treated for internal and external parasites, and housed in 16 pens (n = two bulls/pen) equipped with water and feed troughs. The experiment was conducted using a completely randomized design with four treatments, with four repetitions per treatment (each pen was considered an experimental unit).

Four experimental diets were developed according to the requirements for a body weight gain of 1.5 kg/day, as outlined in BR-CORTE® (Valadares Filho et al., 2020). The inclusion of grains (rehydrated and ensiled or not) was set at 39.6%, and the roughage:concentrate ratio was 30:70. The ingredients used in the diets included rehydrated corn silage (RCS), rehydrated sorghum silage (RSS), dry corn grain (DCG), dry sorghum grain (DSG), soybean hulls, soybean meal, wheat meal, salt, mineral supplement, and sorghum silage as roughage (Table 1). Animals were fed twice daily (08:00 and 16:00 h) for *ad libitum* intake.

Table 1 - Ingredients and chemical composition of the experimental treatments

Item	Treatment[1]			
	DCG	DSG	RCS	RSS
Ingredients (% DM)				
Sorghum silage	30	30	30	30
Soybean meal	9.4	9.4	9.4	9.4
Ground corn	39.6	0	0	0
Reydrated corn silage	0	0	39.6	0
Ground sorghum	0	39.6	0	0
Reydrated sorghum silage	0	0	0	39.6
Wheat meal	9.9	9.9	9.9	9.9
Soybean hulls	9.1	9.1	9.1	9.1
Mineral supplement	2	2	2	2
Chemical composition (% DM)				
Dry matter (%)	58.46	55.58	52.69	52.66
Crude protein	12.66	10.48	13.25	11.40
Neutral detergent fiber	33.01	29.59	32.12	27.22
Acid detergent fiber	18.09	22.17	17.81	19.92
Ash	6.72	7.37	6.43	5.96
Organic matter	93.28	92.63	93.57	94.04
Ether extract	3.24	2.92	3.18	2.74

[1] DCG - dry corn grain; DSG - dry sorghum grain; RCS - rehydrated corn silage; RSS - rehydrated sorghum silage.

2.2. Grain processing

Corn and sorghum grains were first milled to a particle size of 2 mm and ensiled. Water was added until the dry matter (DM) decreased to ~70%, as described by Pereira and Pereira (2013), and stored for 42 days. During ensiling, a commercial inoculant containing *Lactobacillus plantarum*, *Pediococcus pentosaceous*, *Pediococcus acidilactici*, *Lactobacillus rhamnosus*, *Lactobacillus lactis*, and *Bacillus subtilis* was added according to the manufacturer's instructions.

An additional portion of each grain was ground and stored dry. Therefore, two grains (corn and sorghum) with two processing methods (dry ground or rehydrated and ensiled) were used in this study.

2.3. Performance

The total experimental period lasted 88 days, of which 14 days were spent on adaptation and 74 days on the experimental recording period. To determine the daily dry matter intake (DMI) of each animal, refusals of each pen were collected and weighed daily before feeding and divided by two animals per pen.

Animals were weighed upon arrival, at the end of the adaptation period, and every 21 days of the experimental period to monitor the evolution of weight gain. At the end of the experimental period, the average daily gain (ADG) and feed efficiency (FE) were calculated.

2.4. Chemical analysis

Feed, silage, total diet, refusal, and feces were collected weekly and frozen (−20 °C). The samples were homogenized to form composite samples, for each period of 28 days, and subsequently dried in a forced-ventilation oven at 55 °C for 72 h. The samples were ground in a Wiley-type mill™ (Thomas Scientific®) fitted with a 1-mm-sieve and stored in a plastic container for subsequent chemical analysis. Dry matter (DM), organic matter (OM), mineral matter (MM), and ether extract (EE) analysis was performed according to AOAC (1995); crude protein (CP) using the LECO® CHNS/O; and neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to Van Soest and Wine (1967).

2.5. Economic evaluation

Economic performance was evaluated using the methodology proposed by Matsunaga et al. (1976), which involves the total operating cost (TOC) that consists of effective operating cost (EOC) and depreciation.

From production costs and total revenue (TR), the following economic indicators were obtained: TOC, EOC, gross margin (GM), net margin (NM), and operating costs/@ produced. The effective operating cost was calculated by adding the costs of purchasing animals, feed, labor, health, administration, and mechanization. The total operating cost was calculated as the sum of EOC and depreciation, whereas GM was calculated as the difference between TR and EOC. Net margin was calculated as the difference between TR and TOC.

Feedlot costs per bull during the data collection period (88 days) were based on technical coefficients described by ANUALPEC (2017): mechanization (US$ 11.39), veterinary inputs (US$ 2.10), labor (US$ 2.08), depreciation (US$ 1.07), and administrative expenses (US$ 4.96). Expenses with concentrate were obtained based on regional prices (US$ 0.24/kg for DCG, US$ 0.22/kg for DSG, US$ 0.25 for RCS, and US$ 0.22 for RSS). The production cost and supply of sorghum silage was US$ 0.03/kg, estimated based on regional prices. For the purchase price of animals, the price of lean cattle (US$ 36.88/@) at the beginning of the experimental period (September 2018) was considered, considering 51.6% carcass yield (Couto et al., 2017). Total revenue was simulated considering the amount obtained from the sale of animals, which occurred in December 2018 (US$ 39.89/@). To obtain the value, animal weight was multiplied by the price of fat cattle @ at the time.

2.6. Statistical analysis

This was a completely randomized design with four treatments (RCS, RSS, DCG, and DSG) and four replications (each pen was considered an experimental unit).

Data were analyzed using R version 3.5.3 and subjected to Shapiro–Wilk, Bartlett, and Durbin–Watson tests to assess the normality, homoscedasticity, and independence of residuals, respectively. Analysis of variance was applied, followed by Tukey's test at 5% probability, when significant (P<0.05).

3. Results

There were no differences in DMI (P = 0.810), IBW (P = 0.790), and final body weight (P = 0.450) of cattle fed RCS, RSS, DCG, and DSG (Table 2).

Table 2 - Performance of Nellore bulls finished in feedlot fed corn and sorghum ground or rehydrated and ensiled

Item	Treatment[1]				CV (%)	P-value
	DCG	DSG	RCS	RSS		
IBW (kg)	332±23.90	343±35.20	348±17.20	347±26.30	6.99	0.790
FBW (kg)	444±24.00	435±20.20	466±19.50	443±32.50	5.61	0.450
ADG (kg/day)	1.52±0.10ab	1.24±0.08c	1.60±0.16a	1.30±0.13bc	8.36	0.004
DMI (kg/day)	9.57±0.85	9.23±0.52	9.19±0.40	9.19±0.68	7.01	0.810
FE	0.16±0.015ab	0.13±0.014b	0.17±0.012a	0.14±0.009b	8.37	0.007

IBW - initial body weight; FBW - final body weight; ADG - average daily gain; DMI - dry matter intake; FE - feed efficiency.
[1] DCG - dry corn grain; DSG - dry sorghum grain; RCS - rehydrated corn silage; RSS - rehydrated sorghum silage.
Mean values followed by different letters in the same line are significantly different (P<0.05).

Diets containing DCG or RCS resulted in higher ADG (P = 0.004) and FE (P = 0.007). Diets containing RCS exhibited better feed conversion, similar to treatment containing ground corn grain (P = 0.006).

No difference was detected in the nutrient intake of animals fed different experimental diets (Table 3).

The TR obtained in the experiment was US$ 609.78 for DCG treatment, US$ 596.49 for DSG treatment, US$ 639.80 for RCS treatment, and US$ 608.50 for RSS treatment (Table 4), with the sale of animals in December 2018 at the price of US$ 39.89/@ multiplied by the weight of the animals.

Total operating cost, which involves EOC (where expenses are made to support the activity) and depreciation cost, was US$ 582.19, 571.72, 588.89, and 578.61 for DCG, DSG, RCS, and RSS treatments, respectively. The EOC was higher for RCS, followed by DCG and RSS (US$ 587.82, 580,90, and 577.54, respectively). The DSG treatment presented the lowest EOC of US$ 570.65. Regarding efficiency indicators, confinement showed positive GM and NM, demonstrating that it was economically viable for all evaluated treatments.

Table 3 - Nutrient intake of Nellore bulls finished in feedlot fed corn and sorghum ground or rehydrated and ensiled

Item	Treatment[1]				CV (%)	P-value
	DCG	DSG	RCS	RSS		
Intake (kg/d)						
DM	9.57±0.85	9.23±0.52	9.19±0.40	9.19±0.68	7.01	0.81
OM	7.81±1.48	7.54±1.68	8.61±0.40	7.70±1.97	19.88	0.82
CP	1.42±0.56	1.29±0.46	1.19±0.16	1.30±0.40	33.25	0.90
NDF	3.17±0.41	2.75±0.37	3.03±0.26	2.52±0.19	11.35	0.07
Ash	1.15±0.14	1.09±0.09	1.13±0.05	1.13±0.10	9.06	0.88

DM - dry matter; OM - organic matter; CP - crude protein; NDF - neutral detergent fiber; CV - coefficient of variation.
[1] DCG - dry corn grain; DSG - dry sorghum grain; RCS - rehydrated corn silage; RSS - rehydrated sorghum silage.

Table 4 - Economic parameters of young feedlot Nellore bulls fed corn and sorghum ground or rehydrated and ensiled

Item (US$ per head)	Treatment[1]				CV (%)	P-value
	DCG	DSG	RCS	RSS		
Total revenue	609.78b	596.49d	639.80a	608.50c	0.001	<0.0001
TOC[2]	582.19b	571.72d	588.89a	578.61c	0.001	<0.0001
EOC[2]	580.90b	570.65d	587.82a	577.54c	0.001	<0.0001
Depreciation	1.07b	1.07d	1.07a	1.07c	0.066	0.3813
GM	28.88	25.84	51.99	30.96	0.017	<0.0001
NM	27.81c	27.77c	50.91a	29.88b	0.032	<0.0001
TOC/@ produced	40.56b	41.59a	36.15d	40.49c	0.002	<0.0001
Cattle daily cost[3]	2.13b	1.92c	2.30a	1.90c	0.34	<0.0001

TR- total revenue; TOC - total operating cost, EOC - effective operating cost; GM - gross margin; NM - net margin; CV - coefficient of variation.
[1] DCG - dry corn grain; DSG - dry sorghum grain; RCS - rehydrated corn silage; RSS - rehydrated sorghum silage.
[2] Includes the cost of purchasing the animals.
[3] Total operating cost per day without the cost of purchasing the animals.
Mean values followed by different letters in the same line are significantly different (P<0.05).

4. Discussion

Although DMI was not influenced by treatments (Table 2), the average DMI during the experimental period was 9.29 kg/day, close to the value recommended by BR-CORTE® for this animal category

(≈9.11 kg/day DM; Valadares Filho et al., 2020). A lower DMI was expected for diets containing ensiled rehydrated grains because of the greater energy supply provided by these diets through the greater availability of starch; however, this did not occur in this study.

The process of rehydrating and ensiling grains is considered a process of forage preservation and a strategy to increase the digestibility of DM and starch of grains (Ferraretto et al., 2015; Mombach et al., 2018), which can provide greater use of nutrients and, consequently, improve animal performance.

In this study, treatments containing RCS and ground corn grain showed similar ADG, although numerically, RCS treatment provided 5% more weight gain (1.60 kg/day). The opening of the rehydrated grain silo 42 days after ensiling probably did not guarantee complete proteolysis of the protein matrix that involves starch granules (Hale, 1973; Baron et al., 1986). According to Hoffman et al. (2011), a few months of storage are required to maximize starch availability and digestibility.

Nutrient intake was not influenced by treatments (Table 3), demonstrating that grain ensiling can be carried out on rural properties as a strategy for grain storage without changing the nutrient intake by animals. According to Mombach et al. (2019), rehydrating and ensiling grains have become an important practice in Brazil, mainly to avoid losses caused by climate changes that can negatively affect the quality of the grains for harvest. Delayed harvest and the corresponding decrease in DM content can impair silo fermentation and reduce starch digestibility (Goodrich et al., 1975; Ferraretto et al., 2014).

Considering the analysis and the economic efficiency indicators of the feedlot, the activity pays at least in the short term, as the GM, referring to TR less EOC, was positive, with values of US$ 28.88, 25.84, 51,99, and 30.96 for DCG, DSG, RCS, and RSS treatments, respectively. In the case of NM (TR − TOC), it was higher for RCS (US$ 50.91), followed by RSS (US$ 29.88), DCG (US$ 27.80), and DSG (US$ 24.77). This margin was positive for all treatments, demonstrating that the activity was profitable and could be guaranteed in the long term, providing financial stability and the possibility of expanding the business (Lopes and Carvalho, 2002).

Treatments with rehydrated silages showed higher NM despite higher costs. The higher cost of RCS treatment is due to grain processing that requires greater preparation steps, which increases the diet cost. However, even with the highest costs, including the daily feedlot cost of US$ 2.12, RCS treatment provided a greater economic return as the animals gained more weight (Table 2).

When the TOC per arroba produced was evaluated, the lowest cost per arroba produced was for RCS treatment, although TOC was the highest among those evaluated. These results indicated that when only the diet cost and the daily cost of feedlot are evaluated, the best economic result will not necessarily be observed. It is essential to analyze the performance together for better observation and conclusion on the reasons for the higher costs and revenues and on the efficiency system and the treatment used. Thus, the RCS diet showed greater technical and economic efficiency in relation to the others because it resulted in greater weight gain and presented greater NM (US$ 50.91), indicating greater system profitability.

It is necessary to measure and economically evaluate the impact of available technologies, such as grain rehydration, to increase zootechnical and economic indices in the feedlot. Technical planning combined with financial planning is essential for verifying the operational and economic viability of the strategies assumed within the system (Barbosa and Souza, 2007).

5. Conclusions

Rehydrated corn silage is recommended for beef cattle confinement because it provides numerically 5% more weight gain and greater net margin for beef cattle confined. Rehydrated sorghum grain silage is recommended instead of dry sorghum grain in beef cattle diets since it provides greater net margin, without affecting the average daily gain. The rehydrated corn grain diet is recommended since it presents greater technical and economic efficiency than dry sorghum or rehydrated sorghum silage, indicating greater system profitability.

Author contributions

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Conflict of interest

The authors declare no conflict of interest.

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