

# Detoxified castor-bean meal replaces soybean meal in the diet of pasture-finished steers

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## ABSTRACT

The use of agroindustrial byproducts in cattle diets, such as castor-bean (*Ricinus communis* L.) meal, is a more sustainable practice because it does not compete with human food and reduces the volume of organic waste deposited in the environment. The aim of this study was to examine the effect of replacing soybean (*Glycine max* (L.) Merr.) meal with castor-bean meal on the intake, digestibility, feeding behavior and performance of crossbred steers supplemented while on *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Marandu' pasture. The experiment was laid out in a randomized complete design with 40 animals, which started the experiment weighing 227.1 kg, at 10 mo of age, and were divided into four treatment groups. Castor-bean meal was added to replace soybean meal at the levels of 0, 90, 180, and 280 g kg<sup>-1</sup> in the supplement, which was supplied at the rate of 0.4% of body weight. Total DM, pasture DM and neutral detergent fiber intakes did not change ( $P > 0.05$ ) with the castor-bean levels added to the supplement. Ether extract intake and digestibility decreased linearly ( $P < 0.05$ ). The animals showed no differences ( $P > 0.05$ ) in production performance (average daily gain), which averaged 0.65 kg d<sup>-1</sup>. Grazing, idle, and rumination times were not influenced ( $P > 0.05$ ) by the treatments. Castor-bean meal can be included up to 280 g kg<sup>-1</sup> in the total diet without changing the performance of crossbred steers finished on tropical pasture.

**Key words:** Beef cattle, biodiesel by-product, steers performance, *Ricinus communis*, *Urochloa brizantha*.

## INTRODUCTION

The intensification of animal production systems with the use of supplementation has a major impact on animal performance. Detmann et al. (2014) highlighted that protein is the most deficient nutrient in tropical forages. As such, it must be supplemented to increase forage intake and improve basal energy (Tedeschi et al., 2019).

The growing global concern with the environment and the search for renewable energy sources have put a spotlight on biodiesel. The biodiesel industry generates wastes such as oilseed by-products, which can be used in animal feeding as a source of protein (Carrera et al., 2012; Oliveira et al., 2012). In this scenario, castor-bean (*Ricinus communis* L.) meal is a by-product with potential for use in ruminant diets after detoxification (Antunes et al., 2019). The detoxified castor-bean meal (DCM) presents 903 ± 13 g kg<sup>-1</sup> DM; 320 ± 58 g kg<sup>-1</sup> crude protein; 20 ± 2 g kg<sup>-1</sup> ethereal extract; 383 ± 33 g kg<sup>-1</sup> neutral detergent fiber; 62 ± 37 g kg<sup>-1</sup> non-fibrous carbohydrates (Oliveira et al., 2019; Lima et al., 2020; Araújo et al., 2021). However, most research with DCM in ruminant feeding is conducted in feedlots (Diniz et al., 2011; Gionbelli et al., 2014; Novaes et al., 2020), and little is known about the effects of this ingredient on the production performance of grazing animals, especially beef cattle.

We have thus hypothesized that the replacement of soybean (*Glycine max* (L.) Merr.) meal with DCM in the diet of steers can improve their production performance. Thus, the aim of this study was to evaluate the influence of the substitution of soybean meal by DCM on the intake, digestibility, performance, and feeding behavior of grazing supplemented beef steers.

## MATERIALS AND METHODS

All experimental procedures complied with the Ethics Committee on Animal Use (license 084/2015, Ethics Committee on Animal Use/Southwestern Bahia State University, UESB, Bahia, Brazil).

### Experimental conditions and treatments

The study was conducted in the municipality of Ribeirao do Largo (15°27'32" S, 40°44'20" W), Bahia, Brazil, during the dry season of the year. The climate of the region is considered tropical (AW type), according to the Köppen-Geiger classification. In total, the experiment lasted 98 d, of which the first 14 d were used as a period for the animals to acclimate to the treatments, and the remaining days were divided into three experimental periods of 28 d each. The experimental area was 13 ha, which were divided into 12 paddocks of *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster 'Marandu'. The experiment was carried out during the dry season of the year.

Forty Holstein-Zebu crossbred steers with an initial weight of 227.1 kg and average age of 24-mo were distributed into four treatments in a completely randomized design into four lots with 10 animals each. The treatments consisted of increasing levels of castor-bean (*Ricinus communis* L.) meal (DCM) (0, 90, 190 or 280 g kg<sup>-1</sup> DM) replacing soybean (*Glycine max* (L.) Merr.) meal in the supplement. The animals received supplementation formulated according to the NRC (2016) for an intake of 0.4% of their body weight (BW). The supplement was based on ground sorghum bean, soybean, detoxified castor-bean, urea and mineral salt (Table 1). The castor-bean was previously detoxified using a solution of CaO, following the methodology of Oliveira et al. (2010).

The supplement was provided daily at 10:00 h in uncovered collective plastic troughs with double accesses. The feeder dimensions allowed 50 linear centimeters per animal. The paddocks were equipped with individual drinkers with an automatic float valve. Before the experiment began, the steers were treated against worm infections with a long-acting endectocide, and whenever necessary, sanitary care was performed on the animals.

### Forage evaluation

Forage production was monitored every 28 d at the time the animals entered and exited the paddocks. For sampling (six sampling/paddocks), the grass contained within a 0.25 m<sup>2</sup> (0.50 × 0.50 cm) thick-wire square frame was collected and cutting the plants near the soil surface (5 cm). The intermittent grazing system was adopted, with a continuous stocking rate. According to the McMeniman (1997) methods for the collection and determination of the forage biomass, availability of total DM (TDM), potential digestible DM (pdDM), green DM (DM<sub>green</sub> = DM<sub>leaf</sub> + DM<sub>stem</sub>), and forage allowance (FA, kg DM 450 kg<sup>-1</sup> BW d<sup>-1</sup>) were assessed.

Four paddocks were occupied each period, where each treatment group remained for 7 d. After this time, the animals were transferred randomly to another paddock in a way that every paddock remained occupied to reduce the influence of biomass.

**Table 1. Centesimal composition of the supplement (DM basis).**

|                              | Detoxified castor-bean meal level (g kg <sup>-1</sup> supplement DM) |     |     |     |
|------------------------------|--|-----|-----|-----|
|                              | 0  | 90  | 190 | 280 |
| Sorghum grain                | 620  | 620 | 620 | 620 |
| Soybean meal                 | 310  | 220 | 120 | 30  |
| Detoxified castor-bean meal  | 0  | 90  | 190 | 280 |
| Urea                         | 40   | 40  | 40  | 40  |
| Mineral mixture <sup>1</sup> | 30   | 30  | 30  | 30  |

<sup>1</sup>Composition: 140 g Ca, 65 g P, 148 g Na, 5 g Mg, 12 g S, 107 mg Co, 1550 mg Cu, 150 mg I, 1400 mg Mn, 30 mg Ni, 18 mg Se, 4500 mg Zn, 650 mg F (maximum).

Forage quality was evaluated by the “hand-plucking” (grazing simulation), whereby the type of material consumed is identified and a similar sample is collected. Sampling took place at the start and end of each experimental period.

### Chemical analysis

Samples of supplement, forage and feces were dried in a forced-air oven at a 55 °C for 72 h. After the drying cycle, the samples were weighed and then ground in a Wiley mill to 2 mm particles. A portion was reserved for in situ evaluation and the remaining material was ground to 1 mm particles and reserved for chemical composition analysis.

Mineral matter (MM), DM, crude protein (CP) and ether extract (EE) contents were determined by the methods described in AOAC (1990). Ash-and protein-free neutral detergent fiber (NDFap) was measured as described by Mertens (2002). Non-fibrous carbohydrates were determined also free of ash and protein (NFCap), by the following equation:  $NFCap = 100 - MM - CP - EE - NDFap$ . Because the supplement contained urea, its NFCap content was determined by the following equation:  $NFCap = 100 - MM - EE - NDFap - (CP - CPu + U)$ , where CPu is CP in urea; and U is urea content. Total digestible nutrients (TDN) were calculated using the equation  $TDN\% = DCP + DNDFap + DNFC + 2.25 DEE$ , where DCP is digestible CP; DNDFap is digestible NDFap; DNFC is digestible NFC; and DEE is digestible EE.

The potentially digestible DM (pdDM) of the pasture was measured as follows:  $pdDM = 0.98 (100 - \% NDF) + (\%NDF - \% iNDF)$ , where 0.98 is true digestibility coefficient of the cell content; NDF is neutral detergent fiber; and iNDF is indigestible NDF. The Table 2 describes the chemical composition of supplement, hand-plucked pasture (grazing simulation) and DCM samples.

The animals were weighed at the beginning and end of the experiment and every 28 d to adjust the supply of supplement. Production performance was evaluated based on average daily gain, which was calculated by subtracting the initial body weight from final body weight and dividing the result by the experimental period (84 d).

### Digestibility and intake determination

To estimate the fecal DM output (FO), chromic oxide ( $CrO_3$ ) was used as an external marker, in a single daily dose (10 g animal<sup>-1</sup>). The marker was given orally, inside a paper cartridge, to the steers, which were restrained in a collective chute in a pen. After 7 d of adaptation, feces samples were collected from the 8<sup>th</sup> to the 12<sup>th</sup> day of the experiment. The feces were collected at the very paddock after spontaneous defecation. Fecal output was calculated as the ratio between the amount of marker supplied and its concentration found in the feces, as shown below:  $FO = AMS/(MCFe) \times 100$ , where AMS is amount of marker supplied (g); and MCFe is marker concentration in the feces (%).

**Table 2. Chemical composition of *Urochloa brizantha* ‘Marandu’, detoxified castor-bean meal (DCM), concentrates and total diets.**

|                            | Forage | DCM   | Detoxified castor-bean meal level<br>(g kg <sup>-1</sup> supplement DM) |       |       |       |
|----------------------------|--------|-------|---|-------|-------|-------|
|                            |        |       | 0   | 90    | 190   | 280   |
| Dry matter <sup>1</sup>    | 327.9  | 897.2 | 810.1   | 810.8 | 811.6 | 812.3 |
| Ashes <sup>2</sup>         | 113.8  | 162.7 | 26.3  | 35.0  | 44.7  | 53.4  |
| Crude protein <sup>2</sup> | 76.5   | 305.0 | 302.8   | 290.4 | 276.5 | 264.0 |
| Ether extract <sup>2</sup> | 31.2   | 14.7  | 42.1  | 36.3  | 29.9  | 24.1  |
| NDFap <sup>2</sup>         | 631.7  | 468.0 | 486.8   | 504.6 | 524.5 | 542.3 |
| iNDF <sup>2</sup>          | 257.1  | 26.1  | 13.1  | 38.1  | 65.8  | 90.8  |
| pdDM <sup>2</sup>          | 736.9  | 707.4 | 910.3   | 885.7 | 855.3 | 833.7 |
| Total diet                 |        |       |   |       |       |       |
| Crude protein <sup>2</sup> |        |       | 113.2   | 114.6 | 110.6 | 110.6 |
| Ether extract <sup>2</sup> |        |       | 45.8  | 44.8  | 43.6  | 42.3  |
| NDFap <sup>2</sup>         |        |       | 582.4   | 582.7 | 589.0 | 591.4 |
| iNDF <sup>2</sup>          |        |       | 209.4   | 214.2 | 218.6 | 221.1 |
| TDN <sup>2</sup>           |        |       | 544.4   | 524.6 | 518.7 | 513.6 |

<sup>1</sup>g kg<sup>-1</sup> fresh matter.

<sup>2</sup>g kg<sup>-1</sup> DM.

NDFap: Neutral detergent fiber corrected for ash and protein; iNDF: indigestible neutral detergent fiber; pdDM: potentially digestible DM; TDN: total digestible nutrients.

To determine the individual supplement intake (ISI), titanium dioxide (TiO<sub>2</sub>) was used as a marker, at the rate of 15 g animal<sup>-1</sup> d<sup>-1</sup>. The marker was mixed with the supplement at the moment it was supplied in the trough and the same fecal collection procedures described for chromic dioxide were applied. Individual supplement intake was determined by the following equation: ISI = (FO × TDFe)/TDS, where TDFe and TDS are TiO<sub>2</sub> concentration in the feces (%) and supplement (%), respectively. The fecal samples were analyzed by atomic absorption spectrophotometry to determine the concentration of chromium in the feces, and by spectrophotometry to determine the TiO<sub>2</sub> concentration.

Voluntary forage intake was estimated using indigestible NDF as an internal marker. Approximately 0.6 g forage and feces and 1.0 g concentrate were placed in duplicate in non-woven fabric (“TNT”) bags (5 × 5 cm) with porosity of 100 g m<sup>-2</sup>. The TNT bags holding the samples were incubated in the rumen of an adult cattle for 288 h. Total DM intake (TDMI) was estimated by the following equation: TDMI (kg d<sup>-1</sup>) = ([FO × MCFe] – MCC) + CDMI/MCFo, where FO is fecal DM output (kg d<sup>-1</sup>), determined using TiO<sub>2</sub>; MCFe is marker concentration in the feces (kg kg<sup>-1</sup>); MCC is marker concentration in the concentrate (kg kg<sup>-1</sup>); CDMI is concentrate DM intake (%); and MCFo is marker concentration in the forage (%).

### Feeding behavior

The animals’ feeding behavior was observed over 24 h, on the 53<sup>rd</sup> and 56<sup>th</sup> days of the experimental period. The steers were evaluated visually at 5 min intervals, and the time they expended grazing (GT), ruminating (RT), feeding at the trough (TT), and idle were recorded (Almeida et al., 2014). The time the animals took to select and prehend the forage, including the short time spaces used in displacement to select the forage, were considered as grazing time. Rumination time corresponded to the processes of regurgitation, re-chewing, re-insalivation and re-swallowing. The time expended feeding at the trough was the time used to consume the supplement, whereas idle time was the time expended on activities other than those described previously (resting, water consumption, interactions and others).

Feeding and rumination times were calculated based on the intakes of DM and NDF (min kg<sup>-1</sup> DM or NDF). The total feeding (TFT, min) and chewing (TCT, min) times were determined by the following equations: TFT = GT + TT and TCT = GT + RT + TT. The results of the chewing and swallowing observations were recorded on three occasions throughout the day. Feeding and rumination efficiencies (kg h<sup>-1</sup>) in DM and NDF were calculated by dividing the intake of each chemical component by the total feeding or rumination time, respectively.

### Statistical analysis

Data were evaluated by ANOVA and regression, using SAS 9.2 computational software package (SAS institute, Cary, North Carolina, USA). The mathematical model used was  $Y_{ij} = \mu + H_j + e_{ij}$ , where  $Y_{ij}$  is value referring to the observation of the repetition “i” of the treatment “j”;  $\mu$  is overall average;  $H_j$  is effect of treatment “j” (0, 90, 190 and 280 g kg<sup>-1</sup> DM DCM) and  $e_{ij}$  is random error associated with observation. The data were evaluated using variance and regression analysis. The statistical models were chosen according to the significance of the regression coefficients, with t test used at 5% probability level, and determination coefficient (R<sup>2</sup>) as the studied biological phenomenon.

## RESULTS

The amounts of TDM and pdDM decreased after high seasonal production as the dry period progressed (Table 3).

The replacement of soybean meal with DCM did not influence ( $P > 0.05$ ) the intakes of supplement DM in kg d<sup>-1</sup> (1.0 kg d<sup>-1</sup>), pasture DM (4.7 kg d<sup>-1</sup>), or total DM (5.6 kg d<sup>-1</sup>) (Table 4). However, total DM intake in %BW showed a quadratic response ( $P < 0.05$ ) and EE intake increased linearly ( $P < 0.05$ ) with the increasing DCM levels in the diet. There were no differences ( $P > 0.05$ ) in the digestibility of DM (596.2 g kg<sup>-1</sup> DM), NDF (544.8 g kg<sup>-1</sup> DM) and other nutrients.

The inclusion of DCM in the diet did not influence ( $P > 0.05$ ) the grazing or rumination times, which averaged 8.2 and 7.2 h, respectively (Table 5). Trough time decreased ( $P < 0.05$ ) as DCM was included in the diet. Feed and rumination efficiencies (in kg DM and NDF) were not affected ( $P > 0.05$ ) by the dietary inclusion of DCM. The number of bites and the time expended per cud decreased ( $P < 0.05$ ) as the DCM level in the diet was increased.

Average daily gain (0.65 kg d<sup>-1</sup>) and feed conversion (9.6 kg kg<sup>-1</sup>) did not change ( $P > 0.05$ ) in response to the dietary inclusion of DCM (Table 6).

**Table 3. Forage allowance, total dry matter (TDM) availability, potential digestible dry matter (pdDM), green dry matter (DMgreen = DMleaf + DMstem) of *Urochloa brizantha* ‘Marandú’.**

|           | Forage allowance                               | TDM                 | pdDM    | DMgreen |
|-----------|--|---------------------|---------|---------|
|           | kg DM 450 kg <sup>-1</sup> BW ha <sup>-1</sup> | kg ha <sup>-1</sup> |         |         |
| August    | 1.55   | 6097.53             | 4208.09 | 3882.79 |
| September | 1.70   | 4300.92             | 3009.50 | 2847.71 |
| October   | 1.79   | 4854.99             | 2884.46 | 3213.78 |
| November  | 1.93   | 3153.10             | 2160.21 | 1822.88 |
| Average   | 1.74   | 4602.00             | 3065.00 | 2942.00 |

**Table 4. Nutrient intake and digestibility by steers finished on *Urochloa brizantha* ‘Marandú’ while receiving supplements with increasing levels of detoxified castor-bean meal.**

|  | Detoxified castor-bean meal level (g kg <sup>-1</sup> supplement DM) |       |       |       | SEM   | P-value             |                     |
|--|--|-------|-------|-------|-------|---------------------|---------------------|
|  | 0  | 90    | 190   | 280   |       | L                   | Q                   |
| <b>Intake</b>                                  |  |       |       |       |       |                     |                     |
| Supplement DM, kg d <sup>-1</sup>              | 1.0  | 1.0   | 1.0   | 1.0   | 0.28  | 0.8940              | 0.9032              |
| Supplement DM, %BW                             | 0.4  | 0.4   | 0.4   | 0.4   | 0.11  | 0.9646              | 0.7958              |
| Pasture DM, kg d <sup>-1</sup>                 | 4.8  | 4.9   | 4.8   | 4.3   | 0.86  | 0.2687              | 0.3293              |
| Pasture DM, %BW                                | 1.8  | 1.9   | 1.8   | 1.8   | 0.43  | 0.6419              | 0.8728              |
| Total DM, kg d <sup>-1</sup>                   | 5.8  | 5.9   | 5.8   | 5.3   | 0.95  | 0.3041              | 0.3641              |
| Total DM, %BW                                  | 2.2  | 2.3   | 2.2   | 2.2   | 0.49  | 0.6843              | 0.0070 <sup>a</sup> |
| Crude protein, kg d <sup>-1</sup>              | 0.7  | 0.7   | 0.7   | 0.6   | 0.11  | 0.1663              | 0.3045              |
| Ether extract, kg d <sup>-1</sup>              | 0.3  | 0.3   | 0.3   | 0.2   | 0.04  | 0.0437 <sup>b</sup> | 0.3510              |
| Neutral detergent fiber, kg d <sup>-1</sup>    | 3.4  | 3.4   | 3.4   | 3.2   | 0.57  | 0.4154              | 0.3569              |
| Neutral detergent fiber, % BW                  | 1.3  | 1.3   | 1.3   | 1.3   | 0.29  | 0.8127              | 0.9249              |
| Total digestible nutrients, kg d <sup>-1</sup> | 3.2  | 3.1   | 3.0   | 2.8   | 0.52  | 0.0979              | 0.5240              |
| <b>Digestibility</b>                           |  |       |       |       |       |                     |                     |
| Dry matter, g kg <sup>-1</sup>                 | 603.2  | 590.2 | 607.1 | 584.3 | 82.03 | 0.7398              | 0.8590              |
| Crude protein, g kg <sup>-1</sup>              | 595.4  | 609.5 | 597.2 | 572.1 | 51.69 | 0.2865              | 0.2381              |
| Ether extract, g kg <sup>-1</sup>              | 437.7  | 312.1 | 381.1 | 340.2 | 88.48 | 0.0867              | 0.1427              |
| Neutral detergent fiber, g kg <sup>-1</sup>    | 561.1  | 549.2 | 531.2 | 537.1 | 39.92 | 0.1142              | 0.5061              |

SEM: Standard error of the mean; L: linear effect; Q: quadratic effect.

<sup>a</sup> $\hat{y} = 2.2592 - 0.0001x + 0.00000007x^2, r^2 = 0.74.$

<sup>b</sup> $\hat{y} = 0.271916 - 0.0004x, r^2 = 0.82.$

**Table 5. Feeding behavior of steers finished on *Urochloa brizantha* ‘Marandú’ pastures while receiving supplements with increasing levels of detoxified castor-bean meal.**

|   | Detoxified castor-bean meal level (g kg <sup>-1</sup> supplement DM) |      |      |      | SEM   | P-value             |                     |
|---|--|------|------|------|-------|---------------------|---------------------|
|   | 0  | 90   | 190  | 280  |       | L                   | Q                   |
| Grazing time, h                               | 7.4  | 8.7  | 8.3  | 8.4  | 1.23  | 0.7976              | 0.0957              |
| Idle time, h                                  | 9.0  | 7.4  | 8.6  | 7.7  | 1.80  | 0.7874              | 0.3722              |
| Rumination time, h                            | 7.1  | 7.4  | 6.7  | 7.5  | 1.21  | 0.5785              | 1.0000              |
| Trough, min                                   | 29.5   | 24.9 | 22.5 | 20.6 | 11.41 | 0.2409              | 0.0463 <sup>a</sup> |
| Feeding efficiency, kg DM h <sup>-1</sup>     | 0.8  | 0.7  | 0.7  | 0.6  | 0.12  | 0.6360              | 0.5578              |
| Feeding efficiency, kg NDF h <sup>-1</sup>    | 0.5  | 0.4  | 0.5  | 0.4  | 0.05  | 0.2750              | 0.3196              |
| Rumination efficiency, kg DM h <sup>-1</sup>  | 0.9  | 0.8  | 0.9  | 0.7  | 0.15  | 0.1607              | 0.3897              |
| Rumination efficiency, kg NDF h <sup>-1</sup> | 0.6  | 0.5  | 0.6  | 0.5  | 0.07  | 0.1450              | 0.3831              |
| Number of bites per cud                       | 31.3   | 33.1 | 32.4 | 25.6 | 13.94 | 0.0000              | 0.0008 <sup>b</sup> |
| Time per cud, s                               | 41.7   | 43.1 | 39.5 | 30.1 | 17.57 | 0.0000              | 0.0051 <sup>c</sup> |
| Bite rate                                     | 46.8   | 47.2 | 48.9 | 51.4 | 7.39  | 0.0000 <sup>d</sup> | 0.0965              |
| Bite mass, g DM bite <sup>-1</sup>            | 0.3  | 0.3  | 0.3  | 0.3  | 0.08  | 0.0063              | 0.0761 <sup>e</sup> |

SEM: Standard error of the mean; L: linear effect; Q: quadratic effect.

<sup>a</sup> $\hat{y} = 29.4125 - 0.1654x + 0.00076x^2, r^2 = 0.94.$

<sup>b</sup> $\hat{y} = 31.1269 - 0.1156313x + 0.002399x^2, r^2 = 0.98.$

<sup>c</sup> $\hat{y} = 41.6477 + 0.142285x - 0.00300x^2, r^2 = 0.81.$

<sup>d</sup> $\hat{y} = 46.2669 + 0.051853x, r^2 = 0.99.$

<sup>e</sup> $\hat{y} = 0.284835 - 0.00116x + 0.000006x^2, r^2 = 0.65.$

**Table 6. Production performance of steers finished on *Urochloa brizantha* ‘Marandú’ pastures while receiving supplements with increasing levels of detoxified castor-bean meal.**

|  | Detoxified castor-bean meal level (g kg <sup>-1</sup> supplement DM) |       |       |       | SEM   | P-value |        |
|--|--|-------|-------|-------|-------|---------|--------|
|  | 0  | 90    | 190   | 280   |       | L       | Q      |
| Initial body weight, kg                | 229.7  | 225.6 | 231.6 | 221.5 | 30.88 | 0.6730  | 0.7609 |
| Final body weight, kg                  | 282.0  | 283.7 | 282.8 | 279.2 | 38.53 | 0.8657  | 0.8296 |
| Average daily gain, kg d <sup>-1</sup> | 0.6  | 0.7   | 0.6   | 0.7   | 0.16  | 0.6322  | 0.9338 |
| Feed conversion, kg kg <sup>-1</sup>   | 9.6  | 8.7   | 10.2  | 9.9   | 3.13  | 0.8753  | 0.8547 |

SEM: Standard error of the mean; L: linear effect; Q: quadratic effect.

## DISCUSSION

Despite increasing the iNDF content of the supplements, the inclusion of DCM did not influence DM intake from pasture, supplement and the total diet, or NDF intake. It is possible that the small particle size of DCM (about 3 mm) used in the supplements caused it to leave the cattle rumen by passage, contributing to less rumen distension and to the regulation of intake due to a physical limiting factor (White et al., 2017; Cunha et al., 2021). Moreover, according to Oliveira et al. (2010) the alkaline treatment can improve the rumen degradation rate of the potentially degradable fraction of NDF (NDFap) by up to 7%. The chemical treatment of DCM and its physical processing, associated with the good ruminal conditions as evidenced by CP intake, provided a better use of the feed, facilitating its rumen disappearance. In this study, NDFap intake was higher than the 1.2% reported by Mertens (2002) as the limit for the regulation of intake in cattle. This proves that this rule cannot be applied generally in tropical situations, especially in *U. brizantha* pastures and *Bos taurus indicus* animals (Tedeschi et al., 2019).

In addition to altering fiber digestibility, the treatment with CaOH<sub>2</sub> denatured part of the protein in DCM, which became part of the non-degradable protein fraction in the rumen (Oliveira et al., 2010). This fact can compromise the degradability of the fermentable organic matter of the forage in the rumen, as well as CP intake and digestibility. Nevertheless, as stated by Sampaio et al. (2009), when the CP content is greater than 10%, the NDF substrate is used with greater efficiency. It is also noteworthy that, due to rumen fill, the substrate did not compromise total DM intake (Delevatti et al., 2019), which was 18% higher than the 4.8 kg d<sup>-1</sup> estimated by the equation of BR-CORTE (2016). De Souza et al. (2017) also did not observe differences in CP intake or digestibility in cows that received supplement with DCM replacing soybean meal while on *U. brizantha* pasture.

The inclusion of DCM in the supplement resulted in decreased intake and digestibility of EE from the experimental diets, which was possibly due to the reduced EE content in the supplement. Diniz et al. (2011) showed that the alkaline treatment of DCM reduced EE digestibility in cattle. Despite reducing the digestible EE content of the supplement, DCM inclusion did not affect TDN intake or the TDN content of the experimental diets. The average TDN intake in this study (3.0 kg d<sup>-1</sup>) agreed with the value recommended by BR-CORTE (2016) for this animal category in grazing conditions, suggesting that DCM was able to meet the energy requirements of the animals. Thus, in spite of its higher NDF and lower CP levels compared with soybean meal, DCM does not seem to compromise the intake of energy from supplements and diets. Araújo et al. (2020) also reported no effects of replacing soybean meal with DCM treated with CaOH on the TDN intake of goats.

The time devoted to grazing by the animals in this study was considered normal for cattle (Boval and Sauvant, 2021). de Souza et al. (2017) also reported no effects of replacing soybean meal with DCM on the grazing or rumination times of dairy cows. The trough time probably decreased due to the neutral detergent fiber content in the diet. Feeding efficiencies in DM and NDFap were not changed by DCM inclusion in the diets. The feeding efficiency response was due to the lack of changes in the total DM and NDFap intakes. Ash-and protein-free NDF indicates the rhythm of rumination, as this is the dietary nutrient ingested in largest quantity and takes the longest to be ruminated (Tedeschi et al., 2019). This characteristic probably explains the lack of changes in NDFap intake and digestibility, since fibrous feeds should be chewed more slowly for their particle size to be reduced. This occurred without changes in rumination time, which suggests that the animals modified their digestive metabolism without altering their intake or digestibility patterns,

corroborating the descriptions of Sichonany et al. (2017).

Bite rate per minute was low when compared with the values reported by Boval and Sauvant (2021). The present results suggest that the number of bites performed rose as the level of DCM in the supplement was increased, but in a shorter time interval, i.e., because intake was similar, the animals that received the treatments with more DCM had a higher bite rate. However, the volume of DM per bite decreased. Decreases in forage mass translate into increased bite rates, since the size of a bite decreases as the difficulty toprehend the forage increases (da Silva et al., 2013). In a compensatory mechanism, the animal tends to increase its bite rate and extend grazing time (Zanine et al., 2016). Based on these results, we may infer that the animals developed a change in their physiology to avoid compromising their intake and nutritional requirements, but adjusted their behavior to the type of diet. The fact that forage allowance and availability were similar regardless of the treatment also corroborates this inference.

The replacement of soybean meal with DCM did not influence the cattle's performance, possibly due to the adequate intake of protein and energy provided by the diets including DCM. Freitas et al. (2017) and Araújo et al. (2021) also did not observe an effect of including DCM in the supplement on the performance of meat sheep and grazing beef cattle, respectively. In the present study, average daily gain was higher than the 0.50 kg d<sup>-1</sup> estimated in the formulation of the diets. This was only possible because of the adequate supply and availability of forage, especially regarding the more digestible materials (green leaves and stems), which compose the potentially digestible DM (Costa et al., 2021). The higher nutrient intake possibly provided greater performance than expected.

Supplementation has a great contribution to the rearing of steers on pasture (Cardoso et al., 2020). In traditional Brazilian livestock systems, production rates are below the potential of these animals, mainly during the dry season of the year (Strassburg et al., 2014). This is evidenced by the production result obtained in the experimental period, which was 27.45 kg carcass equivalent in 3 mo, whereas the average Brazilian yield for traditional livestock on pasture is 45 kg carcass equivalent ha<sup>-1</sup> in one entire year (Silva et al., 2017). This shows that efficient use of an available basal resource (forage) associated with a supplement that complements its nutritional deficiencies allows increasing production rates in a period characterized by limited forage availability and poor animal performance (Rocha et al., 2016).

## CONCLUSIONS

Detoxified castor-bean meal can be included at up to 280 g kg<sup>-1</sup> replacing soybean meal in the diet of grazing crossbred steers without having adverse effects on production performance or nutritional parameters.

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