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Feedlot performance of Nellore bulls fed high-concentrate diets containing the association of tannins and saponins with sodium monensin

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ABSTRACT - The objective of this study was to evaluate the performance of Nellore bulls finished in the feedlot and fed high-energy diets containing sodium monensin associated or not with tannins and saponins. Ninety-six Nellore bulls were used with an average initial body weight of 350.6±17.9 kg. The bulls were weight-blocked and randomly allocated to 12 pens, which were considered the experimental units. The treatments were assigned to the pens according to the blocks, as follows: sodium monensin (25 ppm; SM) and sodium monensin (25 ppm) plus tannins (350 ppm) and saponins (3.92 ppm, SM+TS). The bulls received an adaptation diet for the first 19 days, a growing diet from day 20 to day 59, and a finishing diet from day 60 to 98 of the experimental period. The animals were slaughtered after 98 days of study. The addition of tannins and saponins to the diets of feedlot Nellore cattle did not change the dry matter intake, hot carcass weight, and dressing percentage; however, it increased body weight by 2.0% and average daily gain by 5.4% and improved feed conversion by 4.3%. The addition of tannins and saponins to high-concentrate diets containing sodium monensin improves the productive performance of Nellore cattle finished in a feedlot for 98 days.

Keywords: additives, cattle, efficiency, intake

1. Introduction

In general, the feed additives often used in ruminant nutrition aims at modifying ruminal microbiota composition to optimize dietary digestion and synthesis of ruminal end products, such as short-chain fatty acids, and reducing energy losses, resulting in improved feed efficiency, growth rate, and animal performance (Min et al., 2020).

Sodium monensin is by far the most used feed additive in feedlot diets in Brazil (Silvestre and Millen, 2021). Duffield et al. (2012) reported that the major effects of sodium monensin on beef cattle metabolism include a reduction in dry matter intake (DMI), a decrease in ruminal deamination, and improvements in feed efficiency. Other feed additives that have received attention of the scientists recently are tannins and saponins (Bele et al., 2010; Cieslak et al., 2014), which are secondary plant compounds that do not interfere with the vital metabolism of plants and are present in leaves, bark, fruit, seeds, and sap, but mainly in cell vacuoles. When used in animal feeding, tannins and saponins can reversibly bind to proteins and other larger molecules that break down depending on the pH where these complexes are formed (Min et al., 2020).

Therefore, plant extracts have the potential to be used in ruminant feeding as feed additives; however, since they are dose-dependent, the correct amount may prevent metabolic disorders without interfering with ingestion, reducing the production of ruminal ammonia and methane, and resulting in an increased flow of aminoacids into the duodenum and improved animal performance (Bele et al., 2010; Halvorson et al., 2017; Orzuna-Orzuna et al., 2021b). In addition, saponins may decrease the population of protozoa and methanogens, enhancing the production of volatile fatty acids, especially propionate (Darabighane et al., 2021). Furthermore, the concentration of condensed tannins and saponins in the diets of feedlot cattle may result in beneficial or adverse nutritional and physiological effects (Tedeschi et al., 2014; Lotfi, 2020). Another factor that may interact with the presence of tannins and saponins in feedlot cattle diets is the presence of sodium monensin, which can decrease ruminal deamination, DMI, and production of ruminal ammonia and methane, resulting in an increased flow of aminoacids into the duodenum and improved animal performance (Tseu et al., 2021; Yanza et al., 2021).

In Brazil, Nellore bulls are the most used animal type in feedlot operations for finishing purposes (Silvestre and Millen, 2021), and just recently they started to be slaughtered close to the mature weight (NASEM, 2016). Thus, the association of tannins and saponins with sodium monensin in feedlot diets may promote positive effects on the performance of feedlot cattle in Brazil, since Nellore bulls, even in the finishing period, may still benefit from the increased flux of dietary aminoacids into the small intestine. Very few studies that evaluated the effects of the association of tannins and saponins with sodium monensin in the diets of feedlot cattle have been carried out (Rivera-Méndez et al., 2017; Koenig et al., 2018).

We hypothesize that the combination of condensed tannins (in a lower dose) and saponins with sodium monensin may reveal a synergistic effect and then maximize the feedlot performance of Nellore cattle. In this context, the objective of this study was to evaluate the effects of the addition of condensed tannins and saponins associated with sodium monensin on animal performance and carcass characteristics of Nellore cattle finished in a feedlot.

2. Material and Methods

Research on animals was conducted according to the Institutional Ethics Committee on the Use of Experimental Animals (CEUA Protocol 21/2022). The experiment was carried out in Presidente Bernardes, SP, Brazil, in a circumscribed area defined by the coordinates 22°00'22" S latitude, 51°33'11" W longitude, and 429 m elevation.

Ninety-six Nellore bulls, with an initial body weight of 350.6±17.9 kg and age ranging from 24 to 26 months old, were used in this study. The animals were blocked according to the initial body weight (six blocks) and allocated randomly in 12 pens (n = 8 animals per pen), characterizing a completely randomized block design. Pens were considered the experimental unit, and each one of them had 2.5 m of linear bunk space and 213.75 m^2 (17.1 by 12.5 m). Thus, each animal had an average of 26.76 m^2 of available area in each pen, as well as 0.31 m of bunk space.

The treatments were randomly assigned to pens, according to blocks, as follows: sodium monensin (25 ppm or 0.0025% of the diet dry matter (DM); SM); sodium monensin (25 ppm or 0.0025% of the diet DM) plus tannins (350 ppm or 0.035% of the diet DM) and saponins (3.92 ppm or 0.000392% of the diet DM; SM+TS). From the beginning to the end of the study, cattle were fed three diets: adaptation, grower, and finisher, which differed only regarding the feed additives that represented the treatments. Experimental diets (Table 1) were formulated to contain the same content of both energy and protein (LRNS; Fox et al., 2004). Cattle received the adaptation diet for the first 19 days of the study, the grower diet was provided from day 20 to day 59, and the finisher diet from day 60 to 98 of the experimental period.

Table 1 - Feed ingredients and chemical composition of the experimental diets

Ingredient (% of dry matter)	Adaptation	Growing	Finishing
Corn silage	16.0	14.0	12.0
Sugarcane bagasse	13.0	10.0	7.0
Finely ground corn	35.0	45.0	55.0
Soybean hulls	11.3	8.2	5.1
Cottonseed meal	20.0	17.0	14.0
Rumen-protected fat	1.5	2.5	3.5
Urea	0.4	0.5	0.6
Mineral suplement[1]	2.8	2.8	2.8
Nutritional composition (% of dry matter)			
Dry matter (% of organic matter)	64.0	67.0	70.0
Total digestible nutrients	67.0	69.0	73.0
Neutral detergent fiber	38.6	33.2	27.9
Crude protein	14.4	13.8	13.3
Ether extract	3.40	4.50	5.70
Calcium	0.71	0.82	0.90
Phosphorus	0.29	0.31	0.32

[1] Composition per kg of dry matter: calcium, 160 g; phosphorus, 22 g; sodium, 70 g; potassium, 40 g; magnesium, 35 g; sulfur, 25 g; cobalt, 30 mg; copper, 450 mg; iodine, 25 mg; manganese, 850 mg; selenium, 5 mg; zinc, 1,350 mg; chrome, 15 mg; vitamin A, 60,000 IU; vitamin D, 8,000 IU; vitamin E, 480 IU; sodium monensin, 900 mg; condensed tannins BX, 12.6 g; saponins BX, 140 mg.

Cattle were fed twice a day (9:00 and 14:00 h), targeting 1 to 2% refusal with free-choice access to a water trough. The dry matter intake (DMI) was calculated daily by weighing the ration offered and refused before the next morning delivery and expressed in kilograms and as a percentage of body weight (BW). Samples of the feed ingredients offered were analyzed weekly for DM, dietary DM was adjusted on a weekly basis according to changes in feed ingredient DM, and water was added to the experimental diets to equalize the DM content in approximately 70%. Feed ingredient samples were dried in a forced-air oven for DM determination (AOAC, 1990; method 930.15). The DMI variation was calculated as the difference in intake between two consecutive days throughout the study (Bevans et al., 2005). Daily DMI variation was expressed as a percentage of variation.

The animals were weighed on days 0, 28, 56, 84, and 98 of the study. All Nellore bulls were withheld from feed for 16 h before the first and last BW assessment. On days 28, 56, and 84, cattle were weighed without fasting, and a 4% discount was adopted to obtain shrunk BW (Stock et al., 1983). Consequently, average daily gain (ADG) and feed efficiency (ADG/DMI) were calculated at the end of the experiment. Cattle were transported 40 km (~1 h) to a commercial abattoir. Hot carcass weight (HCW) was obtained after kidney, pelvic, and heart fat removal. The dressing percentage was calculated by dividing HCW by the final BW (Pereira et al., 2020).

The experimental design was a completely randomized block, and the initial BW was utilized as a criterion for block formation, with the block included as a random effect. Data were analyzed using the PROC MIXED of SAS (Statistical Analysis System, 2003), and all measured response variables were tested for normality (Shapiro-Wilk and Kolmogorov-Smirnov) and heterogeneity of variances (GROUP option of SAS). There was no need for data transformation, as all response variables presented residuals with normal distribution. Similarly, all response variables tested non-significant for heterogeneous variances. Differences between treatments were considered significant when P-values < 0.05.

The statistical analysis for each of the response variables in this study was according to the following statistical model:

$$Y_{ij} = \mu + A_i + B_j + E_{ij},$$

in which Y_{ij} = dependent variable; μ = overall mean of all observations; A_i = effect of additives of order i, in which 1 = SM, 2 = SM+TS; B_j = effect of a block of order j; and E_{ij} = random residual effect.

3. Results

A significant effect (P = 0.01) was observed for the final BW (day 98), in which cattle consuming diets SM+TS were 10.8 kg heavier than those fed SM (Table 2). Therefore, the addition of tannins and saponins increased the final BW by 2.0%.

A similar response was observed for ADG after 98 days on feed. Adding tannins and saponins to high-concentrate diets containing SM increased ADG (1.96 vs. 1.86 kg) by 5.4%. However, no effect of the addition of tannins and saponins was detected on DMI, expressed in kilograms or percentage of BW (P>0.17). As a result, the addition of tannins and saponins improved the feed conversion of Nellore cattle finished in the feedlot after 98 days on feed (P = 0.01) by 4.3%.

No effect of treatments was detected (P>0.08) on BW, DMI, ADG, and feed conversion on the first 84 days of the study.

Table 2 - Performance and carcass traits of feedlot Nellore cattle fed high-concentrate diets containing sodium monensin, with or without the addition of tannins and saponins

Day	Treatment[1]		SEM	P-value
	SM	SM+TS		
	Body weight (kg)			
0	350.72	350.51	7.34	0.80
28	409.46	413.90	6.97	0.32
56	465.10	466.00	7.17	0.67
84	505.97	513.70	6.78	0.09
98	533.00	543.80	6.30	0.01
	Average daily gain (kg)			
0-28	2.10	2.30	0.07	0.14
0-56	2.04	2.06	0.03	0.52
0-84	1.85	1.94	0.04	0.08
0-98	1.86	1.96	0.03	0.01
	Dry matter intake (kg)			
0-28	8.99	8.98	0.12	0.90
0-56	10.49	10.52	0.15	0.76
0-84	10.94	10.99	0.19	0.56
0-98	10.94	11.06	0.19	0.17
	Dry matter intake (% BW)			
0-28	2.37	2.35	0.03	0.46
0-56	2.56	2.57	0.04	0.87
0-84	2.54	2.54	0.04	0.65
0-98	2.47	2.47	0.04	0.99
	Feed conversion (kg/kg)			
0-28	4.28	3.90	0.16	0.12
0-56	5.14	5.11	0.11	0.71
0-84	5.91	5.66	0.15	0.08
0-98	5.88	5.64	0.15	0.01
	Fluctuation of dry matter intake (kg)			
0-28	0.34	0.29	0.02	0.03
0-56	0.45	0.44	0.02	0.68
0-84	0.60	0.56	0.02	0.16
0-98	0.62	0.57	0.02	0.17
Hot carcass weight (kg)	292.94	293.30	3.74	0.10
Dressing (%)	54.95	55.05	0.21	0.76

SEM - standard error of the mean.
[1] SM - sodium monensin; SM+TS - sodium monensin + tannins and saponins.

Concerning the fluctuation of DMI, cattle consuming SM+TS presented lower variation from 0 to 28 days on feed (P = 0.03); however, no further effects of adding tannins and saponins were detected for the rest of the study.

Finally, the addition of tannins and saponins to high-concentrate diets containing SM did not affect HCW and dressing percentage (P>0.10).

4. Discussion

Research work on the influence of the addition of tannin extracts to the diet of ruminants in recent decades has been quite extensive (Jayanegara et al., 2019). However, the results associated with the addition of tannins in ruminant diets have shown great variability (Yanza et al., 2021), either regarding beneficial or harmful effects on animal health and performance. Nevertheless, in this study, cattle consuming SM+TS showed improved feed conversion, which resulted in an increase of 2.0 and 5.3% in final BW and ADG, respectively.

In a meta-analysis of about 70 studies, Yanza et al. (2021) observed that the effect of adding condensed tannins to ruminant diets on animal performance is variable as well. A meta-analysis conducted by Orzuna-Orzuna et al. (2021a) reported that dietary supplementation with the addition of tannins at average doses of 14.61 g kg^{-1} DM did not affect ADG or feed efficiency in beef cattle. The ADG across treatments in this study was 1.91 kg. In general, the ADG of Nellore cattle finished in a feedlot with diets containing similar energy content to the experimental diets offered in this study ranges from 1.2 to 1.60 kg (Zawadzki et al., 2011; Françozo et al., 2013). On the other hand, crossbred cattle, involving Nellore and *Bos taurus* genotypes, may present ADG up to 2.0 kg (Dian et al., 2010; Fugita et al., 2012). Therefore, the performance results obtained in this study are consistent without large variations, which is shown by the SEM of ADG from 0 to 98 days (Table 2).

It is well documented in the literature that tannins possess anti-nutritional factors, causing a reduction in DMI, associated with the astringent taste; however, according to Makkar (2003), the DMI reduction occurs when diet inclusions are above 3%. Therefore, the negative effect of tannins on the DMI of feedlot cattle depends on its concentration in the diet (Jayanegara et al., 2012). Diets containing low (0.5-3.0%) tannin concentration do not affect feed intake (Piñeiro-Vázquez et al., 2018). It has been reported that doses of tannins higher than 0.5% of diet DM may decrease the rate of nutrient digestion in the rumen (Mueller-Harvey, 2006). In contrast, some studies have reported a non-harmful effect of tannin extract on ruminant intake (Al-Kindi et al., 2016; Santos et al., 2012). In this study, we decided to use a dose of condensed tannins that is approximately ten times lower than the usual doses reported in most studies in the literature to minimize further negative effects, mainly on DMI and ruminal deamination, which are also effects promoted by sodium monensin (Duffield et al., 2012). Tannins were included at 0.035% of the diet (DM basis), which did not negatively affect DMI (Table 2) and may explain the improved feed conversion that resulted in a positive effect on ADG, since negative effects on intake and on nutrient digestion may have been absent. Furthermore, in this study, DMI can be considered high for feedlot Nellore cattle (11.5 kg/day or 2.5% of BW across treatments), although feed intake was *ad libitum*. In general, DMI ranges from 2.0 and 2.3% of BW in diets containing similar energy content (Ornaghi et al., 2017; Souza et al., 2019; Carvalho et al., 2021).

The addition of condensed tannins and saponins positively affected the fluctuation of DMI in the first 28 days of the study, which is an indication that feedlot diets containing SM+TS may promote a more consistent protective effect against ruminal acidification. This phenomenon may partially explain the feed conversion improvement obtained in this study when SM was associated with tannins and saponins.

Moreover, the addition of tannins and saponins to the feedlot diets may have benefited the Nellore bulls used in this study; because of their mature weight about 560 kg (Fox et al., 1992), the aminoacids requirements are still high (NASEM, 2016), and tannins, by binding to dietary proteins in the rumen, may have increased the flow of aminoacids to the intestines (Huang et al., 2018). As a result, this may explain the lack of effect on HCW and dressing percentage by adding tannins and saponins to feedlot diets containing SM, since it would be more pronounced in a subsequent phase that greater carcass fat deposition is expected (Owens et al., 1995). Unfortunately, measures of rib-eye area and fat thickness were not taken in this study.

Saponins manage to inhibit the growth of gram-positive bacteria of the rumen flora, due to the similar action of ionophores, altering the surface tension of the extracellular matrix (Cheeke, 2000). Lila et al. (2003) observed that the addition of saponins stimulated fermentation, as the production of volatile fatty acids increased proportionally to the increase in saponin addition. Goel et al. (2008) concluded that the addition of saponins has the potential to increase the efficiency of rumen fermentation. The addition of saponins to the diet does not influence digestibility in the rest of the digestive system, being limited to effects in the rumen (Wina et al., 2005). Somehow, saponins may have positively interacted with tannins and monensin to improve ruminal fermentation; however, the magnitude of the effect of saponins in the rumen associated with monensin and tannins is still unknown and deserves further investigation.

The dose of condensed tannins used in this study is approximately ten times lower than the doses used in most studies in the literature, in addition to being associated with saponins. However, it is not possible to infer in this study that tannins alone, or their association with saponins, without sodium monensin, contributed to the positive responses observed. Therefore, further studies are needed to better understand the effects of a lower dose of condensed tannins associated with saponins.

5. Conclusions

The addition of tannins and saponins to high-concentrate diets interacts positively with sodium monensin by improving the feedlot performance of Nellore cattle. Thus, the use of saponins and condensed tannins, at a dose 10 times lower than usually practiced, associated with sodium monensin, may be an alternative to feedlot cattle operations, especially those that sell cattle on a body weight basis.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Data curation: Ferracini, J. G.; Prado, I. N. and Millen, D. D. **Formal analysis:** Ferracini, J. G. **Investigation:** Ferracini, J. G. **Methodology:** Millen, D. D. **Project administration:** Polli, D.; Gasparim, M. B. and Millen, D. D. **Resources:** Ferracini, J. G. **Software:** Millen, D. D. **Supervision:** Feba, L. T. and Millen, D. D. **Writing – original draft:** Lelis, A. L. J. **Writing – review & editing:** Millen, D. D.

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