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REGULAR ARTICLES

Monensin associated or not with virginiamycin or functional oil for feedlot beef cattle

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Abstract

The objective of this study was to evaluate diets containing monensin (MON) associated or not with virginiamycin (VM) or functional oil based on cashew nut shell and castor beans (FO_{cc}) for beef cattle in feedlots on nutritional (intake and digestibility) and productive parameters. A total of 1410 non-castrated Nellore cattle were selected, with an average age of 18 months and with an initial mean body weight (BW) of 305 ± 41.52 kg. The diet showed a roughage to concentrate ratio of 23:77, with the supply of corn silage as a source of roughage. The following additive inclusions in the diet were evaluated: (1) MON: 27 mg MON/kg dry matter (DM); (2) MON + VM: 22 mg MON/kg DM + 19 mg VM/kg DM; and (3) MON + FO_{cc}: 22 mg MON/kg DM + 500 mg FO_{cc}/kg DM. Statistical analyses were obtained through a linear model using initial BW and days of feedlot as covariables and comparisons between treatments using mutually orthogonal linear contrasts with a 5% significance level. The association or not of MON with VM or FO_{cc} does not affect any of the nutritional and productive parameters evaluated. Animals that receive diets with MON + VM have higher average daily gain and feed efficiency (FE) than those that receive MON + FO_{cc} without showing differences in nutritional parameters. The supply of MON associated with VM or FO_{cc} does not increase intake and productive performance and, consequently, efficiency of feedlot beef cattle. However, in the case of use associated with MON, the VM provides greater performance than FO_{cc} without changing food intake.

Keywords Cashew nut shell · Castor bean · Carcass · Intake · Performance

Introduction

Feedlot diets are characterized by a high proportion of concentrate, which can favor the occurrence of metabolic disorders. In this sense, food additives have been widely used in these diets to reduce these disorders and improve animal performance and profits and decrease production costs (Silva et al. 2019).

Monensin (MON) and virginiamycin (VM) additives are widely used as growth promoters, due to positive effects on average daily gain (ADG) and feed efficiency (FE) (Duffield et al., 2012; Tedeschi and Gorocica-Buenfil 2018). In this context, functional oils have been used with food additives to replace additives, since they improve the performance of the animals due to their antimicrobial, anti-inflammatory, antioxidant, and digestive modulator effects in ruminants (Benchaar et al., 2006).

Regarding functional oils, the cashew and castor-based blend (FO_{cc}) has been considered potential ruminal modulators (Ferreira de Jesus et al., 2016). Some studies have included FO_{cc} in the diet of cattle and observed improvement (Valero et al. 2014, 2016) or no effect (Jedlicka et al. 2009; Cruz et al. 2014; Silva et al., 2019) on the animal performance compared to those received MON or without additives.

The most common form of inclusion of these additives in diets is as the only additive, that is, not associated with each other. However, Calsamiglia et al. (2005) indicated that the combination of additives with different mechanisms of action can result in synergistic effects that can improve the ADG and FE of animals in feedlot.

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The MON and VM association has been studied with satisfactory results on animal performance, as it acts differently by optimizing rumen fermentation (Benatti et al., 2017). On the other hand, only one study (Heker Junior et al., 2018) was found that evaluated diets containing FO_{cc} associated with MON offered to beef cattle. Thus, further studies are needed to better assess the effects of using FO_{cc} associated with monensin on the nutritional and productive parameters of feedlot beef cattle.

It turns out that the potential synergistic effect of the combination of additives can be optimized, as there are differences in the susceptibility of bacteria to different antimicrobial agents. It is hypothesized that MON associated with VM or FO_{cc} promotes improvements in the nutritional and productive performance of feedlot beef cattle in relation to MON not associated. In addition, use of the FO_{cc} can be an alternative to VM when associated with MON. Thus, the objective was to evaluate the nutritional and productive performance of feedlot beef cattle receiving diets containing MON associated or not with VM and FO_{cc}.

Table 1 Ingredients and chemical composition (g/kg DM) of the diet based on the presence of monensin associated or not with virginiamycin and functional oil

Item	Diet		
	MON	MON + VM	MON + FO_{cc}
Ingredient			
Corn silage	230	230	230
Mineral supplement	27	27	27
Rehydrated corn	493	493	493
Cottonseed meal	150	150	150
Rice bran	100	100	100
Monensin (ppm)	27	22	22
Virginiamycin (ppm)	.	19	.
Functional oil (ppm)	.	.	500
Chemical composition (g/kg DM)			
Dry matter	707		
Organic matter	940		
Crude protein	133		
Ether extract	67		
NFC_{ap}	531		
NDF_{ap}	226		
NDF_i	79		

MON, monensin; *VM*, virginiamycin; FO_{cc}, functional oil based on cashew nut shell and castor beans; NFC_{ap}, non-fibrous carbohydrates corrected for ash and protein; NDF_{ap}, neutral detergent fiber corrected for ash and protein; NDF_i, neutral detergent insoluble fiber

Materials and methods

Experimental design, animals, and diets

The experiment was conducted in the confinement of the Recreio Feedlot, located in the city of Cláudia (geographic coordinates: 11°20′64.14″ S and 55°36′94.89″ W) in the state of Mato Grosso, Brazil, from July to November 2017.

A total of 1410 Nellore bulls were used, with an average age of 18 months and an initial mean BW of 305 ± 41.52 kg. The animals were randomly allocated to 15 pens (experimental unit) of 1600 m^2 each, provided with a feeder and drinking fountain, weighed, dewormed (Cydectin®), and identified with individual and pen numbers. Then, 94 animals/pen were distributed in a completely randomized design, composed of three treatments (Table 1).

The diet (13.3% crude protein (CP)) presented roughage to concentrate ratio at 23:77, with corn silage as a source of roughage (Table 1). Available as the following additives in the diet: (1) MON: 27 mg MON/kg DM; (2) MON + VM: 22 mg MON/kg DM + 19 mg VM/kg DM; and (3) MON + FO_{cc}: 22 mg MON + 500 mg FO_{cc}/kg DM.

The experiment lasted 143 days, with 14 days of adaptation to food and facilities. On the last day of the experimental period, the animals were weighed and then taken to a commercial abattoir (JBS-Friboi, Colíder, MT, Brazil).

Experimental procedures and sampling

Daily, the feed was prepared and supplied as total mixed ration with the help of a mixer equipped with an electronic scale (CASALE—RotorMix). The feed was supplied four times a day, at 6:00 am (30% of the offer), 10:00 am (20% of the offer), and at 13:00 (15% of the offer) and 6:00 pm (35% of the offer). The amount of food provided was adjusted daily from the intake observed the previous day, allowing 5 to 10% of orts.

The orts from each pen were collected and weighed daily, obtaining a sample composed of pen/week. A sample of the mixed diet was collected every day and at the end of the week a composite sample/pen was performed.

Fecal collection was carried out for 3 days, the first at 16:00 (day 1), the second at 13:00 (day 2), and the third at 9:00 (day 3). Considering that the collection of feces from 1410 animals would be unfeasible, on each collection day, fecal samples from 50 animals per pen were taken, after defecation, and any dirt was removed to avoid contamination according to Benedeti et al. (2016). Fecal production (FP) was estimated using indigestible neutral detergent fiber (iNDF) as an internal marker for calculating apparent digestibility (AD). The FP was performed using the formula: FP (kg/DM/day) = (intake of iNDF/% iNDF in feces) × 100. The calculation of AD of nutrients was performed using the formula: DA (%) = [(nutrient intake—nutrient excreted)/nutrient intake] × 100. Net energies for maintenance (NE_m) and for gain (NE_g) were based on animal performance and calculated according to Zinn and Shen (1998).

Laboratory analysis

The samples were taken to the NEPI Laboratory at UFMT, Campus Sinop, where they were pre-dried in an oven with forced ventilation (55 °C for 72 h) and processed in knife mills with 1-mm porosity sieves for chemical analysis and 2 mm for ruminal in situ incubation (indigestible neutral detergent insoluble fiber—iNDF determination).

The samples were analyzed according to AOAC (2005) regarding the concentrations of DM (method no. 934.01), organic matter (OM, obtained from the ash content; method no. 924.05), CP (method no. 920.87), and ether extract (EE, method no. 920.85). For analysis of the neutral detergent fiber corrected for ash and protein (NDF_{ap}) concentration, the samples were treated with thermostable α-amylase without the use of sodium sulfite, corrected for ashes (Mertens, 2002), and residual proteins (Licitra et al. 1996). The non-fibrous carbohydrates corrected for ash and protein (NFC_{ap}) were calculated according to Detmann and Valadares Filho (2010). The iNDF was quantified by in situ incubation procedures with Ankom F57 bags for 288 h (Valente et al. 2011).

Statistical analysis

The comparisons between the treatment averages were performed using two mutually orthogonal linear contrasts, in which the first tested differences between MON versus MON + VM and MON + FO_{cc}. In the second contrast, the combinations MON + VM versus MON + FO_{cc} were tested. The data were analyzed by analysis of variance, using the MIXED procedure of the statistical package SAS (version 9.4), and the level of significance adopted was 0.05.

Results

Intake and digestibility

Intake (Table 2) and digestibility (Table 3) of dietary constituents were not affected ($P > 0.05$) by the association or not of MON with VM or FO_{cc}. Consequently, the same dietary concentration of digestible organic matter (DOM) was observed for all treatments.

Animal performance, carcass traits, and feed efficiency

The association or not of MON with VM or FO_{cc} did not affect ($P > 0.05$) the ADG, final BW, final carcass weight (FCW), carcass yield (CY), FE, NE_m, and NE_g regarding diets containing only MON (Table 4).

No effects of association of VM or FO_{cc} with MON were observed ($P > 0.05$) for the CY. However, animals that received MON + FO_{cc} presented lower ADG, FCW, FE, NE_m, and NE_g ($P < 0.05$) than animals fed diets containing MON + VM.

Discussion

Absence of effects on the intake and digestibility of dietary constituents in cattle fed individual MON or associated with VM (Lemos et al., 2016; Benatti et al., 2017; Neto, 2018) or with FO_{cc} (Heker Junior et al., 2018) has been reported.

On the other hand, other authors reported higher DM intake in animals that received diets containing FO_{cc} in relation to those that received MON (Meyer et al., 2009; Silva et al., 2019). In general, this higher intake has been attributed to the attractive properties and greater acceptability of these organic compounds by animals. Duffield et al. (2015) in a meta-analytical study found that DM intake was reduced on feeding MON in the diet. This fact occurs due to the animal aversion to this additive due to its low palatability (Baile et al., 1979).

Research has reported that functional oils have attractive and palatable properties that positively influence the intake of animals (Wallace, 2004; Cardozo et al., 2006). In fact, Silva et al. (2019) observed that animals fed with FO_{cc} had higher DM intake than those fed with VM.

The absence of observed effects on intake in the present study may be due to the fact that all diets contain MON in their formulation. In this way, acceptability may have decreased and consequently prevented greater intake by animals receiving MON + FO_{cc}.

Regarding digestibility, similar results were observed by Heker Junior et al. (2018) when verifying the absence of effects on apparent digestibility when associating MON with VM or FO_{cc}. Coneglian et al. (2020) found that the use of FO_{cc} in high-grain diets for growing cattle gave similar effects to MON in terms of the total apparent digestibility of nutrients.

Generally, antibiotics and functional oils act in the rumen environment, reducing the abundance of Gram-positive bacteria, preventing greater lactate production from starch fermentation and resulting in fewer episodes of acidosis (Nagaraja and Lechtenberg, 2007). Ionophore (MON) and non-ionophore (VM) additives have different modes of action on the growth of Gram-positive bacteria. While the MON acts at the membrane level, changing the permeability and the normal flow of ions (Bergen & Bates 1984), the VM blocks protein synthesis by binding to the 50S subunit of the ribosome (Cocito 1979).

Table 2 Effect of the presence of monensin associated or not with virginiamycin and functional oil on the intake of feedlot beef cattle

Item	Diets[a]			s.e.m	Contrast	
	MON	MON				
		VM	FO_{cc}		A	B
	kg/day					
Dry matter	8.23	8.07	8.69	0.29	0.812	0.253
Organic matter	7.71	7.66	8.08	0.27	0.680	0.322
Crude protein	1.07	1.05	1.09	0.05	0.955	0.463
Ether extract	0.45	0.43	0.43	0.04	0.457	0.920
NDF_{ap}	1.72	1.64	1.70	0.05	0.612	0.482
NDFi	0.88	0.84	0.91	0.03	0.948	0.183
NFC_{ap}	4.51	4.56	4.88	0.16	0.381	0.225
DOM	5.48	5.49	5.56	0.22	0.441	0.189
	g/kg body weight					
Dry matter	21.31	21.80	22.09	0.12	0.616	0.996
NDF_{ap}	4.48	4.46	4.49	0.10	0.823	0.789

MON, monensin; *VM*, virginiamycin; FO_{cc}, functional oil based on cashew nut shell and castor beans; *s.e.m*, standard error of the mean; *A*, MON versus (MON + VM and MON + FO_{cc}); *B*, MON + VM versus MON + FO_{cc}; NDF_{ap}, neutral detergent fiber corrected for ash and protein; NDF_i, neutral detergent insoluble fiber; NFC_{ap}, non-fibrous carbohydrates corrected for ash and protein; *DOM*, digestible organic matter

Table 3 Effect of the presence of monensin associated or not with virginiamycin and functional oil on the digestibility and dietary concentration of digestible organic matter in feedlot beef cattle

Item	Diets			s.e.m	Contrast	
	MON	MON				
		VM	FO_{cc}		A	B
Dry matter	0.69	0.70	0.71	0.006	0.203	0.450
Organic matter	0.72	0.72	0.73	0.007	0.421	0.382
Crude protein	0.71	0.73	0.70	0.005	0.534	0.147
NDF_{ap}	0.51	0.52	0.53	0.008	0.454	0.688
Ether extract	0.72	0.65	0.70	0.006	0.189	0.147
NFC_{ap}	0.85	0.85	0.86	0.011	0.588	0.322
	Dietary concentration (g/g)					
DOM	0.67	0.68	0.69	0.015	0.344	0.666

MON, monensin; *VM*, virginiamycin; FO_{cc}, functional oil based on cashew nut shell and castor beans; *s.e.m*, standard error of the mean; *A*, MON versus (MON + VM and MON + FO_{cc}); *B*, MON + VM versus MON + FO_{cc}; NDF_{ap}, neutral detergent fiber corrected for ash and protein; NFC_{ap}, non-fibrous carbohydrates corrected for ash and protein; *DOM*, digestible organic matter

Table 4 Effect of the presence of monensin associated or not with virginiamycin and functional oil on the performance, carcass traits, feed efficiency, and dietary net energy of feedlot beef cattle

Item	Diets			s.e.m	Contrast	
	MON	MON				
		VM	FO_{cc}		A	B
ADG (kg/day)	1.52	1.54	1.48	0.01	0.528	< 0.001
Final body weight (kg)	451.81	454	444.69	1.25	0.271	< 0.001
Carcass						
FCW (kg)	248.36	250.29	243.87	1.29	0.478	< 0.001
CY (%)	54.97	55.13	54.84	1.11	0.939	0.116
Efficiency						
FE (kg gain/kg DMI)	0.19	0.22	0.18	0.89	0.142	0.034
Net energy (MJ/kg DM)						
Maintenance	7.66	7.95	6.95	1.01	0.201	0.041
Gain	4.98	5.23	4.35	0.88	0.444	0.034

MON, monensin; *VM*, virginiamycin; FO_{cc}, functional oil based on cashew nut shell and castor beans; *s.e.m*, standard error of the mean; *A*, MON versus (MON + VM and MON + FO_{cc}); *B*, MON + VM versus MON + FO_{cc}; *ADG*, average daily gain; *FW*, final weight; *CY*, carcass yield; *FE*, feed efficiency

The liquid in the cashew nut shell contains phenolic compounds (anacardic acid, cardanol, and cardol) that also inhibit the growth of Gram-positive bacteria and allow the proliferation of Gram-negative bacteria, and thus increasing the production of ruminal propionate (Castañeda- Serran et al., 2020). Castor oil is rich in ricinoleic acid that has antimicrobial properties (Ferreira et al., 2002) and according to Ramos Morales et al. (2012) reduce and increase, respectively, the concentrations of acetate and propionate.

According to Neto (2018), additives used alone or in association have similar behavior in stabilizing ruminal pH and controlling possible metabolic disorders associated with the high-grain diet provided to animals. Thus, it can be inferred that in all treatments evaluated there was a maintenance of ruminal pH since no deleterious effects were observed on the digestibility of nutrients.

Although the associated use of additives has provided positive effects on ADG (Jedlicka et al., 2009; Nuñez et al., 2013; Fonseca et al., 2016), FE (Jedlicka et al., 2009; Benatti et al., 2017), and NE_m and NE_g from diets (Navarrete et al., 2017), these effects were not observed in the present study for the diet containing only MON.

The highest FE observed in the animals that received MON + VM (versus MON + FO_{cc}) was due to the higher ADG and the absence of effects on the DM intake. In addition, even though the experimental diets were formulated to be isocaloric, the NE_m and NE_g estimates of the diet were higher for the MON + VM. Thus, it could be an indicator that MON + VM provides greater efficiency in the use of energy from the diet than MON + FO_{cc} and, consequently, reflected in the higher AGD in animals.

The increase in the dietary energy content without increasing net energy intake indicates an increase in the efficiency of metabolizable energy utilization, reducing dietary requirements or DMI. This context suggests a better efficiency in the use of dietetic energy, probably due to changes in the rumen fermentation pattern caused by the associated use of MON with VM. Fonseca et al. (2016) found lower methane production in animals fed with MON + VM compared to those that present these additives alone. Castañeda-Serran et al. (2020) observed that the use of FO_{cc} can also modulate methane production and energy efficiency, improving rumen fermentation.

However, it is not clear how the FO_{cc} associated with MON could alter rumen fermentation patterns that may have reduced the efficiency of energy use in the diet and explain the lower ADG without changes in the consumption of DM and DOM. In this context, the possible effects of the MON + FO_{cc} still remain unclear and deserve further investigation, since no information was found to support the possible effects of this association on the pattern of ruminal fermentation.

Conclusions

The supply of monensin associated with virginiamycin or functional oil based on cashew nut shell and castor beans does not increase intake and productive performance and, consequently, efficiency of feedlot beef cattle.

However, in the case of use associated with monensin, virginiamycin provides greater performance than functional oil based on cashew nut and castor beans without changing food intake.

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Author contribution The study was designed by EHBKM and KAKM. AL conducted the experiment. AL, HAS, JNS, APF, KRS, and LOC conducted the laboratory analysis. CVA contributed with statistical analyses. AL wrote the first version of the manuscript. EHBKM, KAKM, and LFM revised and edited the final version of the manuscript. All the authors read and approved the manuscript.

Data availability The data that support the results of this study are available from the corresponding author upon reasonable request.

Declarations

Statement of animal rights The experiment was conducted according to the standards of the Brazilian Ethics Committee on Animal Use.

Conflict of interest The authors declare no competing interests.

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