Acta Scientiarum. Technology
ISSN: 1806-2563
ISSN: 1807-8664
actatech@uem.br
Universidade Estadual de Maringá
Brasil

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Acta Scientiarum. Technology, vol. 41, 2019

Universidade Estadual de Maringá, Brasil

Available in: https://www.redalyc.org/articulo.oa?id=303260200001

DOI: https://doi.org/10.4025/actascitechnol.v41i1.34988

Ciência, Tecnologia de Alimentos e Engenharia de Alimentos

Different doses of sodium monensin on feedlot performance, carcass characteristics and digestibility of Nellore cattle

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DOI: https://doi.org/10.4025/actascitechnol.v41i1.34988
Redalyc: https://www.redalyc.org/articulo.oa?id=303260200001

Received: 25 January 2017
Accepted: 11 May 2017

Abstract:

The objective of this study was to determine the effects of different doses of sodium monensin on feedlot performance, carcass characteristics and nutrient digestibility of Nellore cattle. The experiment was designed as a completely randomized block, replicated 12 times, in which 60 20-months old yearling Nellore bulls (402.52 ± 33.02 kg) were fed in individual pens for 84 days according to the different doses of monensin expressed in ppm (dry matter basis): 0, 9, 18, 27 and 36. As doses of monensin increased, final body weight, average daily gain, gain-to-feed ratio, and dressing percentage were affected cubically ($P < 0.03$), where animals fed 9 ppm of monensin presented greater average daily gain and better gain-to-feed ratio. Likewise, as dose of monensin increased, dry matter intake, hot carcass weight, and neutral detergent fiber and fecal starch digestibility in finishing period decreased linearly ($P < 0.05$). In addition, neutral detergent fiber digestibility in adaptation period in creased linearly ($P = 0.01$) as doses of monensin increased. Thus, based on the results of this study, if monens in is going to be included in finishing diets for feedlot Nellore cattle, the dose of 9 ppm should be considered as the most feasible option.

Keywords: additive, ionophore, starch, NDF, Zebu.

Introduction

Ionophores, such as sodium monensin (MON), are among the most studied feed additives for ruminant diets. Studies to evaluate the efficacy of MON on feedlot cattle on gain-to-feed ratio (G:F), average daily gain (ADG) and dry matter intake (DMI) have been conducted since the 70s (Ellis et al., 2012).

The feeding of MON increases propionic acid production and reduces molar percentages of butyric and acetic acids (Oliveira et al., 2007), reduce methane emissions (Hristov et al., 2013), and decreases ruminal

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deaminase activities (Wang et al., 2015). Although in some situations, carcass characteristics have been negatively affected (Goodrich et al., 1984). Currently, MON is the primary feed additive used in American and Brazilian feedlots (Millen, Pacheco, Arrigoni, Galyean, & Vasconcelos, 2009; Oliveira & Millen, 2014; Samuelson, Hubbert, Galyean, & Löest, 2016); however, the most part of the studies involving MON used the commercial product Rumensin ($C_{36}H_{62}O_{11}$-H_2O - Elanco Animal Health, Indianapolis, IN, USA).

Based on the facts just described, many animal nutrition companies have been trying to develop and sell their own MON. However, as the manufacturing process to produce MON is complex, and each company performs it in different ways, studies to test new products-containing MON are required in order to recommend the best dose for either grain-fed or grass-fed cattle. Thus, the objective of this study was to determine the best dose of a new product-containing MON ($C_{36}H_{61}O_{11}Na$ - Rumenpac, MCassab, São Paulo, state São Paulo, Brazil), on feedlot performance, carcass characteristics, and apparent nutrients digestibility of feedlot Nellore cattle.

Material and methods

Animals were cared for in accordance with the guidelines established by São Paulo State University Ethical Committee for Animal Use (CEUA), with protocol 40/2012.

The trial was conducted at the São Paulo State University feedlot, Dracena campus, Brazil, from January to April of 2013. Sixty 20-mo-old yearling Nellore bulls (402.52 ± 33.0 kg), housed in individual pens (1.0 x 7.0 m) were used in this study. The study was designed as a completely randomized block, in which animals were divided into five treatments (12 replications each) according to the dose of MON expressed in ppm, dry matter (DM) basis: 0, 9, 18, 27 and 36. The commercial product used in this study was the Rumenpac ($C_{36}H_{61}O_{11}Na$), which contained 20% of MON.

Yearling bulls were fed *ad libitum* twice daily throughout the study at 0800 (40% of total ration) and 1500h (60% of total ration), and ration was delivered to each pen in a feed bunk (1.00 m per yearling bull). The amount of feed offered was adjusted every day based on amount of feed refusals before morning delivery. Yearling bulls had free-choice access to a water trough (0.89 × 1.00 × 1.00 m).

The trial lasted 84 days: 14 days of adaptation and 70 days of finishing, the adaptation program consisted of *ad libitum* feeding of two adaptation diets over period of 14 days with concentrate level increasing from 68 to 84% of diet DM. The experimental diets were formulated according to LRNS (Large Ruminant Nutrition System, Fox et al., 2004), which are shown in Table 1.

The DMI was recorded by weighing offerings (0800h) and refusals (0700h in the morning after), and it was expressed both in kg and as percentage of body weight (BW). Cattle were weighed at the beginning and at the end of the study, when ultrasound measures were collected as well, according to Ribeiro, Tedeschi, Stouffer, and Carstens (2008). Cattle were withheld from feed for 16 hour before every BW assessment, which were performed at the beginning and at the end of the study.

The G:F was calculated by dividing the overall ADG by DMI. Final BW was obtained at feedlot before harvesting, and dressing percentage was calculated by dividing hot carcass weight (HCW) by final BW. At the packing plant, liver abscesses were classified according to the severity and incidence as described by Brown and Lawrence (2010).

In order to estimate the dietary net energy for gain (NEg) for each yearling bull in this study, it was used the methods described by Nuñez et al. (2013). The observed NEg to expected NEg ratio was obtained by dividing the estimated NEg by the expected NEg, which was given by the LRNS.

The apparent digestibility of DM, neutral detergent fiber (NDF) and starch was determined using chromium dioxide as an external marker according to Marino et al. (2011). Cattle received, 30 g of chromium oxide for 30 days, which was mixed into the experimental diets. Diet samples were collected from each pen on days 7 and 8 (adaptation period), and 19 and 20 (finishing period); and composite samples of feces and orts were collected on days 8 and 9 (adaptation period), and 20 and 21 (finishing period).

The concentration of chromium oxide was determined colorime trically by its reaction with s-diphenyl carbazide according Marino et al. (2011). The chemical analysis of NDF according to Schulze, Weisbjerg, Storm, and Nørgaard (2013). For NDF analysis, it was added α-amylase. The starch concentration was determined with previous extraction of soluble carbohydrates as proposed by Marino et al. (2011).

TABLE 1.
Feed ingredients and chemical composition of the experimental diets fed to yearling Nellore bulls consuming high-concentrate diets provided with different doses of sodium monensin during the adaptation and finishing periods (n = 60).

Item	Percentage of concentrate		
	68%	76%	84%
Days to feed	7	7	70
Ingredients (% of dry matter)			
Sugarcane bagasse	32.00	24.00	16.00
Corn grain cracked	48.10	58.00	71.50
Soybean meal	16.70	14.05	7.70
Supplement[1]	3.20	3.95	4.80
Nutritional content (% of dry matter)			
Dry matter	71.00	75.00	79.00
Total digestible nutrients	71.00	74.00	76.00
Net energy for gain (Mcal/kg of DM)	1.06	1.12	1.18
Starch			
Crude protein	15.50	15.50	14.20
Rumen-degradable intake protein	75.00	77.00	78.00
Neutral detergent fiber	33.00	27.90	22.80
Ca	0.49	0.55	0.62
P	0.34	0.35	0.34

[1]Supplement contained 26.66% of urea as a N source, as well as Ca, 11.31; P, 1.17; S, 2,24; Mg, 0.88; Na, 3.80; Co, 0.001; Cu, 0.02; I, 0.001; Mn, 0.07; Se, 0.0005; and Zn, 0.10%; Vitamin A, 56430 UI; Vitamin D, 7054 UI; Vitamin E, 257 UI; [5]Dry matter.

Initial BW was the criteria adopted for blocking, and all data collected in this study were analyzed using PROC MIXED of Statistical Analysis System (SAS, 2011), including the CONTRAST option. Orthogonal contrasts were used to assess linear, quadratic, cubic and quartic relationship between doses of MON and the dependent variable. However, quartic relationships are not shown in the tables because it was not significant for any of the variables analyzed. Results were considered significant at the P (< 0.10) level. Tests for normality and heterogeneity of treatment variances were performed before analyzing the data.

Results and discussion

Results of the feedlot performance are presented in Table 2. Significant (P < 0.10) MON effect was observed for all of the feedlot performance variables. As doses of MON increased, final BW (P = 0.01), ADG (P = 0.01), G:F (P = 0.01), NEg (P = 0.01) and observed/expected NEg (P = 0.01) were affected cubically, in which yearling bulls fed 9 ppm presented greater ADG, final BW and NEg, and improved G:F (Table 2). Moreover, DMI in kg and expressed as percentage of BW decreased linearly (P < 0.01) as dose of MON increased (Table 2).

However, no significant (P > 0.10) MON effect was observed for any of the carcass characteristics variables with the exception of HCW, dressing percentage, final 12th rib fat thickness and final P8 fat thickness (Table 2). As doses of MON increased, HCW decreased linearly (P = 0.01), dressing percentage was affected cubically (P = 0.03) and final 12th rib fat thickness (P = 0.07) and final P8 fat thickness (P = 0.10) were affected quadratically.

Regarding liver abscesses incidence, no abscesses were observed for any of the treatments, with the exception for yearling bulls fed 9 ppm of MON, in which two animals had one abscess each, both classified as A+. As a result, due to the presence of only two liver abscesses, it was not possible to run any statistical analysis this variable.

No significant (P > 0.10) MON effect was observed for any of the digestibility variables (Table 3) in adaptation period, with the exception of NDF digestibility, which increased linearly (P = 0.01) as doses of MON increased. In addition, in the adaptation period, DMI was affected quadratically (P = 0.02) as dose of MON increased. Moreover, in finishing period, DMI, NDF digestibility and fecal starch decreased linearly (P = 0.01) as dose of MON increased, and starch digestibility was affected cubically (P = 0.03).

It is well documented in the literature that feeding MON leads to a reduction in DMI (Duffield, Merrill, & Bagg, 2012). In this study, the DMI was not reduced when yearling bulls were fed 9 ppm of MON (Table 2), which may explain, in part, the greater ADG presented for those animals. In addition, G:F was improved in yearling bulls fed 9 ppm of MON, which is a consequence of the greater ADG just described. Likewise, Barducci et al. (2013) fed 30 ppm of MON to feedlot cattle, and did not observe any reduction in the DMI; however the authors reported an increase in ADG, and as a result, an improvement in G:F.

In one of the first studies that evaluated doses of MON, Raun, Cooley, Potter, Rathmacher, and Richardson (1976) observed greater ADG (1.01 kg) at the dose of 11 ppm, and best feed-to-gain ratio (8.66) when animals were fed 33 ppm. In this study, the dose of 9 ppm was the closest to the 11 ppm used by Raun et al. (1976), which may help to explain the greater ADG observed for yearling bulls fed 9 ppm of MON. Furthermore, the feeding of lower doses of MON to feedlot cattle may not negatively impact DMI, what may lead to increases in ADG.

Duffield et al. (2012) conducted a meta-analysis of the impact of MON (Rumensin product) on growing and finishing beef cattle bringing together 40 peer-reviewed articles and 24 additional trial reports. The average supply of MON was 28.1 ppm, and the authors reported that ADG increased by 2.5%, G:F was improved by 6.4%, and DMI was reduced by 3%. In this study, yearling bulls fed 9 ppm of MON (Rumenpac product) had greater ADG (8.28%) and improved G:F (6.47%) when compared to animals that did not receive MON (Table 2).

Also, yearling bulls fed 9 ppm of MON showed higher NEg (6.03%) when compared to animals that did not consume MON. This increase in NEg observed for those yearling bulls fed 9 ppm meets the value predicted by the LRNS when an ionophore is included into the diet. This is the reason by which yearling bulls fed 9 ppm of MON had observed NEg/expected NEg equal to 1.0 (Table 2).

Regarding carcass characteristics, the feeding of MON negatively affected the dressing percentage and HCW, despite the greater fat deposition observed. Goodrich et al. (1984) also observed negative effects of MON on dressing percentage; however, the authors also reported a decrease in 12^{th} rib fat thickness. According to the authors, standard deviations for percentage change in carcass characteristics indicate that these effects of MON are highly variable.

TABLE 2.
Effect of different doses of sodium monensin on feedlot performance and carcass characteristics of yearling Nellore bulls consuming high-concentrate diets.

Item	Sodium Monensin (ppm)					SEM	P-value		
	0	9	18	27	36		L[1]	Q[2]	C[3]
Feedlot performance									
Initial BW[4], kg	403.13	402.41	402.48	402.14	402.12	9.53	0.70	0.88	0.93
Final BW, kg	527.00	537.67	516.08	503.83	509.25	11.07	0.10	0.96	0.01
ADG[5], kg	1.44	1.57	1.32	1.18	1.25	0.07	0.11	0.92	0.01
DMI[6], kg	11.23	11.38	10.89	10.62	9.73	0.33	0.01	0.11	0.98
DMI, % of BW	2.42	2.43	2.37	2.34	2.14	0.06	0.01	0.07	0.60
Gain-to feed ratio	0.130	0.139	0.122	0.113	0.130	0.005	0.10	0.24	0.01
NEg[7], Mcal kg^{-1}	1.09	1.16	1.05	1.00	1.14	0.03	0.54	0.10	0.01
NEg/expected NEg	0.94	1.00	0.90	0.86	0.98	0.02	0.54	1.00	0.01
Carcass characteristics									
Dressing percentage	54.28	51.51	53.58	53.95	51.98	0.78	0.34	0.97	0.03
HCW[8], kg	286.08	276.58	276.42	271.42	264.42	6.58	0.01	0.97	0.48
Initial 12th rib FT[9], mm	2.42	2.49	2.33	2.45	2.40	0.08	0.75	0.95	0.79
Final 12th rib FT, mm	4.77	5.32	5.11	4.82	4.72	0.20	0.35	0.07	0.14
Initial P8[10] FT, mm	2.89	2.95	2.84	3.07	2.94	0.10	0.53	0.89	0.58
Final P8 FT, mm	5.73	6.17	6.17	5.84	5.63	0.26	0.54	0.10	0.50
KPF[11], kg	2.05	2.13	2.17	1.78	1.86	0.16	0.16	0.47	0.32
KPF , % of HCW	0.72	0.77	0.79	0.66	0.69	0.05	0.42	0.37	0.29

[1]Linear; [2]Quadratic; [3]Cubic; [4]Body weight; [5]Average daily gain; [6]Daily dry matter intake; [7]Dietary net energy for gain; [8]Hot carcass weight; [9]Fat thickness; [10]*Biceps femoris* muscle; [11]Kidney-pelvic fat.

Furthermore, in this study, two yearling bulls that were fed 9 ppm of MON presented liver abscesses, classified as A+, the most severe, which may have further contributed to decrease dressing percentage in these two animals (44.02 and 50.32% of dressing percentage respectively). Brown and Lawrence (2010) reported that the major economic effect of liver abscesses is the decrease in dressing percentage.

With respect to the apparent digestibility, in a companion paper Pereira et al. (2015) observed a linear reduction (P = 0.01) on time spent ruminating (0 ppm: 389.17 min; 9 ppm: 381.25 min; 18 ppm: 351.25 min; 27 ppm: 345.83 min; 36 ppm: 311.25 min and SEM: 17.64) and reported a linear increase (P = 0.04) on consumption rate of DM (0 ppm: 21.48 min kg^{-1}; 9 ppm: 18.96 min kg^{-1}; 18 ppm: 24.36 min kg^{-1}; 27 ppm: 25.25 min kg^{-1}; 36 ppm: 25.55 min kg^{-1} and SEM: 2.07) and consumption rate of NDF (P = 0.02; 0 ppm: 51.88 min kg^{-1}; 9 ppm: 47.57 min kg^{-1}; 18 ppm: 53.77 min kg^{-1}; 27 ppm: 61.16 min kg^{-1}; 36 ppm: 62.39 min kg^{-1} and SEM: 5.39), which may have resulted in lower passage rate and increased digestion rate, and consequently increased linearly the digestibility of NDF in the adaptation period (Table 3).

Furthermore, for the finishing period, it was observed a linear decrease for apparent digestibility of NDF (Table 3), which may be explained by the fact that gram-positive bacteria are more sensitive to MON than gram-negative bacteria. Monensin modifies the transport of ions across bacterial cell walls and inhibits gram-positive bacteria growth because of differences in bacterial cell wall structure (Duffield, Rabiee, & Lean, 2008).

Dong, Bae, McAllister, Mathison, and Cheng (1999) also observed decrease of cellulose (27%) and hemicellulose (17%) digestibility. Weimer, Stevenson, Mertens, and Thomas (2008) suggested that MON in high-starch diets does not suppress thegram-negative ruminal populations (*Succinivibrio dextrinisolvens, Ruminobacter amylophilus* and *Selenomonas ruminantium*), and based on this fact, the linear increase on apparent digestibility of starch on finishing period (Table 3) may be due to the linear decrease of DMI (Table 3). MON had no effect (Table 3) on apparent digestibility of DM (Benchaar, Duynisveld, & Charmley, 2006).

Therefore, the improved performance of animals fed 9 ppm of MON can be explained by the following facts: DMI was not affected; and as a result, G:F ratio was improved, maybe due to similar starch digestibility when compared to yearling bulls fed 27 and 36 ppm of MON in the finishing period (Table 3).

In addition, the reasons just described may be consequences of the reduction in methane production, which results in lower energy losses (Hristovet al., 2013), and contributes to greater NEg and NEg/expected

NEg ratio (Table 2), greater ruminal production of propionate (Oliveira et al., 2007), as well as larger absorptive surface area and greater mitotic index of ruminal papillae. Such effects were observed in a similar study (Pereira et al., 2014), resulting in greater carcass fat deposition.

TABLE 3.
Effect of different doses of sodium monensin on fecal starch and dry matter, starch, and neutral detergent fiber apparent digestibility in yearling Nellore bulls consuming high-concentrate diets.

Item	Sodium Monensin (ppm)					SEM	P-value		
	0	9	18	27	36		L[1]	Q[2]	C[3]
Adaptation period									
Dry matter intake, kg	10.91	12.52	11.68	11.56	10.57	0.51	0.29	0.02	0.32
Fecal starch, %	6.06	8.25	7.57	6.07	6.72	1.37	0.84	0.42	0.22
Starch digestibility, %	95.91	94.00	92.66	95.15	95.88	1.60	0.77	0.20	0.57
NDF[4] digestibility, %	56.77	59.39	65.75	63.22	70.74	3.65	0.01	0.95	0.59
DM[5] digestibility, %	80.88	78.20	82.10	80.75	81.59	1.31	0.33	0.71	0.27
Finishing period									
Dry matter intake, kg	12.12	11.65	11.20	9.73	9.11	0.62	0.01	0.58	0.67
Fecal starch, %	15.73	9.64	12.12	7.32	5.42	1.67	0.01	0.86	0.27
Starch digestibility, %	91.38	95.05	90.32	94.63	96.03	1.20	0.09	0.39	0.03
NDF digestibility, %	74.00	65.35	69.83	64.50	52.30	4.86	0.01	0.36	0.19
DM digestibility, %	80.49	81.23	76.08	80.03	78.23	1.94	0.33	0.58	0.98

[1]Linear; [2]Quadratic; [3]Cubic; [4]Neutral detergent fiber; [5]Dry matter.

Conclusion

Thus, based on the results of this study, increasing doses of MON affected feedlot performance, carcass characteristics and nutrients digestibility of Nellore cattle. The MON tested in this study (Rumenpac) should be included in finishing diets for feedlot Nellore cattle at dose of 9 ppm.

Acknowledgements

The authors thank the São Paulo State Foundation (FAPESP) process number 2012/13480-8 and MCassab Tecnologia Animal, São Paulo, Brazil, for financially support this study.

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