

Effect of previous narasin exposure on performance and gastrointestinal morphometrics of finishing bulls supplemented with either sodium monensin or narasin

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ABSTRACT - The objective of this study was to investigate the potential carryover effect of narasin (NAR) supplementation during the backgrounding phase on subsequent feedlot performance and gastrointestinal morphometrics of finishing Nelore bulls. Ninety-six bulls were used in a 2 × 2 factorial design, evaluating conditional NAR supplementation on the backgrounding phase (control [CON] or NAR) and finishing supplementation (sodium monensin [MON] or NAR), resulting in four treatments as follows: 1) CON+MON, 2) CON+NAR, 3) NAR+MON, and 4) NAR+NAR. During the backgrounding phase, NAR-fed cattle showed reduced dry matter intake (DMI) expressed in kilograms and as a percentage ($P \leq 0.03$), however, it did not significantly affect final body weight (BW), average daily gain (ADG), or feed efficiency compared with the CON-fed cattle ($P \geq 0.14$). In the finishing phase, neither backgrounding nor finishing supplementation, nor their interaction, had significant effects on BW, ADG, DMI, feed efficiency, hot carcass weight, dressing percentage, or gastrointestinal morphometrics ($P \geq 0.11$). Relative to CON+NAR and NAR+MON, cattle fed NAR+NAR showed reduced fluctuation in DMI throughout the entire experiment (%; $P \leq 0.02$); however, fluctuations, even above 10% in some treatments, did not lead to reduced ADG or increased rumenitis incidence. We conclude that dietary supplementation with NAR did not enhance performance or gastrointestinal development in Nelore cattle during backgrounding or finishing, nor was a carryover effect observed between phases. Although NAR-fed cattle in the finishing phase performed similarly to those receiving monensin, the absence of a negative control limits interpretation, warranting further research on its role in stabilizing dry matter intake.

Keywords: beef cattle, feed additive, ionophores, Nelore

1. Introduction

Feed additives, particularly ionophores, are widely used in feedlot systems in both North America (Samuelson et al., 2016) and Brazil (Silvestre and Millen, 2021). Ionophores exert several beneficial

effects on ruminal fermentation, including increasing the proportion of propionate, inhibiting lactate production (Nagaraja et al., 1987), and reducing methane emissions, thereby decreasing energy losses by up to 30%. They also inhibit the growth of proteolytic bacteria, which reduces deamination, thus promoting a “protein-sparing” effect (Russell and Strobel, 1989).

Among ionophores, sodium monensin (MON) has been the most extensively studied over the past decades (Goodrich et al., 1984). Since its approval in the mid-1970s, its effects in feedlot cattle have shown some variability; however, a meta-analysis demonstrated consistent overall benefits, including a 6.4% improvement in feed efficiency, a 3.0% reduction in dry matter intake (DMI), and a 2.5% increase in average daily gain (ADG; Duffield et al., 2012).

Due to the recognized efficacy of MON in growing and finishing cattle, alternative ionophores such as lasalocid (Golder and Lean, 2016), salinomycin (Bagley et al., 1988), and narasin (NAR; Assis et al., 2020) have also been evaluated. In an in vitro study, Nagaraja et al. (1987) compared several ionophores, including MON, and reported that NAR and salinomycin were the most effective at enhancing propionate production and inhibiting lactate accumulation. Notably, NAR exerted these effects at the lowest effective dose among the ionophores tested.

Narasin, a polyester ionophore produced by *Streptomyces aureofaciens*, is commonly used in livestock as a coccidiostat (Mantovani, 2012). The use of NAR as a dietary additive has been widely investigated in grazing cattle and in forage-based diets (Gobato et al., 2020; Soares et al., 2021; Miszura et al., 2023). Unlike MON, NAR does not appear to reduce DMI or increase nutrient digestibility in *Bos indicus* cattle (Polizel et al., 2020; Limede et al., 2021). Moreover, NAR has shown a stronger effect on ruminal fermentation by increasing the molar proportion of propionate while reducing acetate, compared with MON (Limede et al., 2021; Miszura et al., 2023). These changes are associated with improved feed efficiency in grazing cattle (Gobato et al., 2020) and reduced ruminal ammonia concentrations (Polizel et al., 2020; Soares et al., 2021). In finishing diets with a forage-to-concentrate ratio of 8:92, NAR increased DMI during the adaptation period compared with MON or a non-supplemented control. However, this effect did not persist throughout the entire feeding period, resulting in no differences in ADG or feed efficiency (Baggio et al., 2023).

As the forage-to-concentrate ratio shifts substantially between the backgrounding phase on pasture and finishing phase in a feedlot, nutritional strategies that optimize performance during backgrounding are critical for achieving a shorter and more efficient finishing period (McCurdy et al., 2010). In Brazil, cattle are typically weaned at the onset of the dry season, entering the backgrounding phase on pastures of low nutritional value (Reis et al., 2009; Detmann et al., 2014). Thus, effective supplementation strategies during backgrounding may generate carryover benefits into the finishing phase, enhancing overall cattle performance (Moretti et al., 2013). Nevertheless, studies investigating the long-term effects of strategic additive supplementation during backgrounding on subsequent feedlot performance remain scarce.

Based on this gap, we hypothesized that dietary inclusion of NAR during the backgrounding phase could enhance feedlot performance and gastrointestinal health during the finishing phase by stimulating ruminal epithelium development in advance and reducing the incidence of rumenitis in Nellore cattle. Therefore, the objective of this study was to evaluate the carryover effects of NAR supplementation during backgrounding on finishing performance, as well as to compare these outcomes with MON and NAR supplementation during the finishing phase, focusing on feedlot performance and ruminal epithelium morphometrics in Nellore cattle.

2. Material and methods

This study was conducted at the Ruminant Research Center of Gasparim Sementes e Nutrição Animal (Presidente Bernardes, SP, Brazil; 22°00'22" S, 51°33'11" W; at an altitude of 429 meters). All procedures involving the use of animals in this study were in accordance with the guidelines established by Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agrárias e Tecnológicas (FCAT/UNESP), Committee on the Use of Animals (02/2022 – CEUA).

2.1. Experimental design and treatments

Ninety-six Nellore bulls with an initial body weight of 334.1 ± 27.0 kg (mean \pm SD) were used in a randomized complete block design in a 2×2 factorial. Cattle were blocked by initial body weight (BW) to remove their potential effect on the variables analyzed and to avoid bunk competition and submission within the pen. Cattle were separated into six blocks and then allocated to 24 pens ($n = 4$ cattle/pen; pen dimension = 16×6 m, with 5 m of bunk space), which were considered the experimental unit. Treatments were randomly assigned to each pen to ensure that initial BW was the same for each of the four treatments. The main effects of the factorial arrangement were considered the conditional dietary inclusion of NAR (containing 12% NAR; Zimprova™, Elanco, USA) during the backgrounding phase (control [CON] or narasin [NAR]) and the dietary inclusion of MON (containing 20% MON; Rumensin™, Elanco, USA) or NAR during the finishing phase; thus, within blocks, pens were assigned to 1 of 4 treatments as follows: 1) CON+MON (ionophore addition in the backgrounding phase + ionophore addition in the finishing phase), 2) CON+NAR, 3) NAR+MON, and 4) NAR+NAR. For both backgrounding and finishing phases, MON and NAR were fed at 27 mg/kg of dry matter (DM) and 13 mg/kg of DM, respectively, as recommended by the manufacturers.

2.2. Diets, supplements, and feeding management

At arrival, cattle were vaccinated and dewormed (Tetanus, Bovine Viral Diarrhea Virus, Clostridium sp.; Cattlemaster and Bovishield, Pfizer Animal Health, New York, NY). During the experimental period, cattle were fed twice daily at 09h00 (45% of the offered feed) and 14h00 (55% of the offered feed), aiming to reach 2% of daily refusals. Before every morning feeding, refusals were collected and weighed, and the feed offered was adjusted based on the amount of refusal recorded for each pen.

During the backgrounding phase, considered from d-28 to d0 of the experimental period, cattle were also allocated to the feedlot pens and fed a forage-based diet (60% corn silage and 40% sugarcane bagasse) to mimic cattle on grazing. An additional bunk was added to the pens during this period to provide the mineral supplement (containing: total digestible nutrients = 8.10% crude protein = 20.00%, non-protein nitrogen = 19.04%, Ca = 19.54%, P = 4.00%, Na = 7.40%, K = 0.05%, Cl = 11.06%, Mg = 0.80%, S = 1.20%, Mn = 800.00 mg/kg, F = 3410.15 mg/kg, Zn = 2100.00 mg/kg, Cu = 800.00 mg/kg, Co = 60.00 mg/kg, Se = 18.00 mg/kg, I = 60.00 mg/kg, Cr = 25.00 mg/kg, and conditional addition of Zimprova™ = 2500.00 mg/kg) at 0.05% of the BW (reaching an average intake of 0.232 kg/cattle/day). Thus, the inclusion of 2,500 mg/kg of Zimprova™ in the supplement provided 300 mg/kg of NAR, resulting in an average intake of 69.6 mg/head/day of NAR. Considering the average DMI during the backgrounding period (5.36 kg/head/day), this corresponded to approximately 13 mg/kg of the total mixed ration.

At d1, cattle were assigned then submitted to the finishing period, and they were fed three different diets denominated: adaptation, growing, and finishing. Diets were composed of corn silage, sugarcane bagasse, ground corn, soybean husk, cottonseed meal, protected fat, urea, and mineral and vitamin premix, and formulated to meet cattle requirements using the Cornell Net Carbohydrate and Protein System (CNCPS) proposed by Fox et al. (2004), as shown in Table 1. The adaptation (containing 75% concentrate), growing (containing 79.5% concentrate), and finishing diet (containing 84% concentrate) were fed for 14 days (from day 1 to day 14), 42 days (from day 15 to day 56) and 61 days (from day 57 to day 117), respectively, resulting in a total of 145 days of the experimental period, considering the 28 days of the backgrounding phase. During this period, additives were incorporated into the mineral supplement and included in the total mixed ration at concentrations of 108.3 mg/kg of Zimprova™ or 135 mg/kg of Rumensin™. This resulted in an average daily intake of 274.05 mg/head of MON for the CON+MON treatment, 130.13 mg/head of NAR for the CON+NAR treatment, 265.14 mg/head of MON for the NAR+MON treatment, and 133.51 mg/head of NAR for the NAR+NAR treatment.

Table 1 - Experimental diets containing narasin or sodium monensin fed to feedlot Nellore bulls during the adaptation, growing, and finishing periods

Diet	Adaptation	Growing	Finishing
Ingredient (%)			
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 supplement ¹	2.8	2.8	2.8
Chemical composition (% of dry matter)			
Dry matter (% of OM)	64.0	67.0	70.0
Crude protein	14.4	13.8	13.3
Rumen-degradable protein	11.44	10.41	9.64
Ether extract	3.4	4.5	5.7
Total digestible nutrients	67.0	69.0	73.0
NEg (Mcal/kg)	1.02	1.09	1.19
Neutral detergent fiber	38.6	33.2	27.9
peNDF	23.52	20.00	16.59
Calcium	0.71	0.82	0.90
Phosphorus	0.29	0.31	0.32

OM - organic matter; NEg - net energy for gain.

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, 1350 mg; chromium, 15 mg; vitamin A, 60,000 IU; vitamin D, 8,000 IU; vitamin E, 480 IU. The additives were added to the premix to make a total of 13 ppm of narasin (Zimprova™, Elanco, USA) or 27 ppm of monensin sodium (Rumensin™, Elanco, USA); the inclusion in the total mixed ration was 108.3 mg/kg of Zimprova™ or 135 mg/kg of Rumensin™.

2.3. Performance and carcass characteristics

Dry matter intake (DMI) was calculated from the amount of feed offered and refused, collected on the following day, and then expressed in both kilograms and percentage of BW. Body weight was assessed on days -28, 0, 28, 56, 84, and 117 of the experimental period, and ADG was calculated for the backgrounding period (from day -28 to day 0), and for the intervals between day 0 and 28, 29 and 56, 57 and 84, and 85 and 117 of the finishing phase. Body weight assessments were conducted after 16 hours of fasting to obtain the shrunk BW. These intervals were also used to calculate the feed efficiency and DMI fluctuation (expressed in both kilograms and percentages), as described by Bevans et al. (2005). At d117, cattle were slaughtered at a commercial abattoir to obtain the hot carcass weight (HCW) used to calculate the dressing percentage ($HCW / \text{Final BW} \times 100$).

2.4. Sample collection and measurements

After slaughter and evisceration, the reticulo-rumen compartment was separated and cleaned with running water and scored according to the incidence of lesions (rumenitis and parakeratosis), following the methodology described by Bigham and McManus (1975), based on a scale from 0 (no lesions) to 10 (ulcerative lesions throughout the entire rumen wall). Similarly to the reticulo-rumen compartment, the cecum was also assessed, and the lesion incidence was scored using the same methodology applied to the ruminal epithelium, on a scale from 0 to 10. The classification of rumen and cecum lesions was performed by two trained individuals, with the final score being the average of both.

Morphometric analysis of the ruminal epithelium was performed on all animals ($n = 96$) according to the methodology proposed by Daniel et al. (2006) and Resende-Junior et al. (2006). A 1 cm^2 sample was collected from the cranial sac of the rumen and immediately placed in a container with phosphate-buffered solution (PBS = 0.79 g NaCl, 0.223 g Na_2HPO_4 , 0.0524 g NaH_2PO_4 , H_2O up to 100 mL) at 0.1 M and pH 7.4, and kept refrigerated for one day until measurements were made. The number of papillae per square centimeter of the rumen wall (NOP) was determined manually, with 12 papillae were randomly collected from each fragment (1 cm^2) and scanned. Four trained individuals manually determined the NOP per square centimeter of each sample, and the final data represented the average of the four readings. The mean papillae area (MPA) was determined using an image analysis system (Image Tool, version 2.01-4; UTHSCSA Dental Diagnostic Science, San Antonio, TX, USA). The rumen wall absorptive surface area (ASA) in cm^2 was calculated as follows: $1 + (\text{NOP} \times \text{MPA}) - (\text{NOP} \times 0.002)$, where 1 is the 1 cm^2 sample scanned and 0.002 is the estimated basal area of papillae, expressed in square centimeters. Additionally, the papillae area was also expressed as a percentage of ASA: $(\text{NOP} \times \text{MPA}) / \text{ASA} \times 100$.

2.5. Statistical analysis

Data was analyzed with the pen as the experimental unit ($n = 24$; containing four cattle per pen). All measured variables were analyzed using the MIXED procedure of SAS 9.3 (SAS Institute Inc., Cary, NC), and Tukey test was used for mean comparison. The main effects of the dietary addition of ionophores in backgrounding and finishing phase, along with their interaction, were treated as fixed variables in the experimental model. At the same time, the block was regarded as a random variable. The original data and residuals were assessed for normality using the Shapiro-Wilk test, and no data transformation was necessary once all variables showed a normal distribution, since P values were greater than 0.05 for the normality test. Original data was also evaluated for heterogeneity of variances using the GROUP command in SAS, which was similarly not significant according to the chi-square test, based on the $-2 \log$ likelihood parameter for all variables assessed. In all instances, significance was determined when $P \leq 0.05$.

The statistical model used for all the variables tested consisted of:

$$y_{ijk} = \mu + \tau_i + \rho_j + \tau\rho_{ij} + B_k + \varepsilon_{ijk} \quad (1)$$

in which y_{ijk} represents the relative observation of the experimental unit receiving the i -th dietary addition of ionophores in the backgrounding phase, the j -th dietary addition of ionophores in the finishing phase, within the k -th block; μ denotes the overall mean, τ_i indicates the fixed effect of the i -th dietary addition of ionophores in the backgrounding phase; ρ_j signifies the fixed effect of the j -th dietary addition of ionophores in the finishing phase; $\tau\rho_{ij}$ reflects the fixed effect of the interaction between the main effects of the dietary addition of ionophores in the backgrounding and finishing phase; B_k denotes the random effect of the k -th block; and ε_{ijk} represents the random effect associated with the y_{ijk} observation.

Correlations among all variables evaluated in the experiment were calculated using the CORR procedure in SAS, and statistical significance was considered at $P \leq 0.05$.

3. Results

3.1. Backgrounding phase

During the backgrounding phase, dietary inclusion of NAR did not affect final BW ($P = 0.20$), ADG ($P = 0.14$), feed efficiency ($P = 0.15$), and DMI fluctuation (both in kilograms and as a percentage; $P \geq 0.45$) compared to CON. However, NAR-fed cattle showed reduced DMI both in kilograms ($P = 0.03$) and as a percentage of the BW ($P = 0.02$) relative to CON-fed cattle, as shown in Table 2.

Table 2 - Growth performance, dry matter intake, and dry matter intake fluctuation of Nellore bulls during the backgrounding phase with conditional dietary addition of narasin

Item	Treatment ¹		SEM	P-value
	Control	Narasin		
Initial body weight (kg)	334.1	334.0	10.77	0.90
Final body weight (kg)	336.3	333.7	10.78	0.20
Average daily gain (g)	80	-11	40.0	0.14
Feed efficiency (kg/kg)	0.014	-0.001	0.0071	0.15
Dry matter intake (kg)	5.71	5.36	0.167	0.03
Dry matter intake (% of the BW)	1.71	1.61	0.029	0.02
Dry matter intake fluctuation (kg)	0.63	0.58	0.047	0.45
Dry matter intake fluctuation (%)	10.74	10.81	0.968	0.96

SEM - standard error of the mean.

¹ Control - dietary addition of narasin at 0 mg/kg of dry matter; Narasin - dietary addition of narasin at 13 mg/kg of dry matter.

3.2. Finishing phase

During the finishing phase, BW (on d0, d28, d56, d84, and d117), HCW, and dressing percentage were not affected by the main effects of dietary addition of ionophores during either the backgrounding or finishing phase, nor by their interaction ($P \geq 0.13$; Table 3).

When data were analyzed for the intervals from d29 to d56, from d57 to d84, and from d85 to d117, ADG ($P \geq 0.15$), feed efficiency ($P \geq 0.18$), DMI in kilograms ($P \geq 0.08$), DMI as a percentage of the BW ($P \geq 0.13$), DMI fluctuation in kilograms ($P \geq 0.08$), and DMI fluctuation as a percentage ($P \geq 0.07$) were not affected by the main effects of dietary addition of ionophores during either the backgrounding or finishing phase, nor by their interaction (Table 3).

In addition, when data were analyzed as cumulative intervals from d0 to d28, from d0 to d56, from d0 to d84, and from d0 to d117, ADG ($P \geq 0.34$), feed efficiency ($P \geq 0.16$), DMI as a kilograms ($P \geq 0.44$), and DMI in percentage of the BW ($P \geq 0.19$) were also not affected by the main effects of dietary addition of ionophores during either the backgrounding or finishing phase, nor by their interaction (Table 3).

However, when we analyzed DMI fluctuation in kilograms across the cumulative intervals, we observed an interaction between the main effects for the intervals between d0 - d56 ($P = 0.03$), d0 - d84 ($P = 0.02$), and d0 - d117 ($P = 0.01$). During the first 56 days of the experimental period, NAR+NAR-fed cattle presented the lowest DMI fluctuation compared to all the treatments, while CON+NAR-fed cattle presented the highest compared to all the treatments; moreover, CON+MON and NAR+MON showed intermediate values and did not differ from each other. On the other hand, during the first 84 days and in the entire experimental period (d0 - d117), CON+MON- and NAR+NAR-fed cattle presented the lowest DMI fluctuation in kilograms (and did not differ between them), compared to CON+NAR- and NAR+MON-fed cattle (which also did not differ between them; Table 3).

In addition, when DMI fluctuation was analyzed as a percentage of daily fluctuation, an interaction between the main effects was observed ($P \leq 0.02$) for all the cumulative intervals evaluated. During the first 28 days of the experimental period, NAR+MON-fed cattle showed the highest DMI fluctuation compared to all the treatments, while NAR+NAR-fed cattle showed the lowest DMI fluctuation compared to all the treatments; likewise, CON+MON- and CON+NAR-fed cattle showed intermediate values and did not differ between them. During the first 56 days of the experimental period, CON+NAR-fed cattle showed the highest DMI fluctuation and NAR+NAR-fed cattle showed the lowest DMI fluctuation compared to all the other treatments, while CON+MON- and NAR+MON-fed cattle showed intermediate values for DMI fluctuation and did not differ between them. During the first 84 days of the experimental period, CON+NAR- and NAR+MON-fed cattle presented higher DMI fluctuation than CON+MON- and NAR+NAR-fed cattle. Finally, over the entire experimental period (d0 - d117)

NAR+MON-fed cattle presented the highest DMI fluctuation among all the other treatments, and CON+MON- and NAR+NAR-fed cattle presented the lowest DMI fluctuation compared to the remaining treatments and did not differ between them.

Table 3 - Growth performance, dry matter intake, dry matter intake fluctuation, and carcass characteristics of Nellore bulls (during the finishing phase) fed either monensin (MON) or narasin (NAR) with previous conditional exposure to narasin during the backgrounding phase

Backgrounding ¹	Control		Narasin		SEM	P-value ³		
	MON	NAR	MON	NAR		BACK	FIN	INT
Finishing ²								
Body weight (kg)								
Day 0	335.3	337.2	333.3	334.1	1.63	0.13	0.42	0.74
Day 28	386.9	389.7	386.6	384.5	2.83	0.33	0.91	0.40
Day 56	441.5	441.9	436.4	434.8	4.04	0.14	0.89	0.81
Day 84	485.1	484.7	479.2	474.4	5.56	0.16	0.64	0.69
Day 117	539.3	537.7	532.0	529.0	5.94	0.17	0.66	0.87
Average daily gain (kg)								
Day 0 – day 28	1.84	1.87	1.90	1.80	0.112	0.93	0.74	0.54
Day 0 – day 56	1.90	1.87	1.84	1.80	0.080	0.43	0.67	0.92
Day 0 – day 84	1.78	1.76	1.74	1.67	0.069	0.34	0.50	0.77
Day 0 – day 117	1.74	1.71	1.70	1.66	0.053	0.37	0.53	0.95
Day 29 – day 56	1.95	1.87	1.78	1.80	0.080	0.15	0.69	0.52
Day 57 – day 84	1.56	1.53	1.53	1.41	0.096	0.47	0.45	0.66
Day 85 – day 117	1.64	1.61	1.60	1.64	0.087	0.94	1.00	0.67
Feed efficiency (kg/kg)								
Day 0 – day 28	0.191	0.189	0.203	0.187	0.0110	0.66	0.38	0.49
Day 0 – day 56	0.179	0.176	0.181	0.168	0.0066	0.68	0.29	0.53
Day 0 – day 84	0.170	0.170	0.173	0.158	0.0058	0.45	0.16	0.22
Day 0 – day 117	0.172	0.172	0.174	0.162	0.0053	0.47	0.29	0.28
Day 29 – day 56	0.176	0.169	0.169	0.163	0.0068	0.33	0.34	0.97
Day 57 – day 84	0.152	0.152	0.157	0.135	0.0080	0.45	0.18	0.19
Day 85 – day 117	0.176	0.181	0.175	0.162	0.0179	0.42	0.79	0.48
Dry matter intake (kg)								
Day 0 – day 28	9.65	9.91	9.40	9.57	0.178	0.11	0.23	0.80
Day 0 – day 56	10.59	10.63	10.21	10.56	0.325	0.50	0.55	0.63
Day 0 – day 84	10.47	10.41	10.09	10.55	0.391	0.76	0.61	0.51
Day 0 – day 117	10.15	10.01	9.82	10.27	0.356	0.92	0.67	0.42
Day 29 – day 56	11.08	11.06	10.54	11.05	0.610	0.55	0.59	0.57
Day 57 – day 84	10.23	10.11	9.87	10.54	0.502	0.94	0.60	0.44
Day 85 – day 117	9.38	9.40	9.25	10.05	0.235	0.26	0.08	0.09
Dry matter intake (%/BW)								
Day 0 – day 28	2.69	2.73	2.62	2.67	0.050	0.19	0.37	0.95
Day 0 – day 56	2.74	2.73	2.66	2.74	0.080	0.66	0.63	0.55
Day 0 – day 84	2.57	2.54	2.49	2.60	0.090	0.96	0.64	0.43
Day 0 – day 117	2.33	2.29	2.27	2.38	0.076	0.86	0.68	0.36
Day 29 – day 56	2.69	2.66	2.57	2.69	0.104	0.66	0.64	0.48
Day 57 – day 84	2.22	2.18	2.16	2.31	0.100	0.72	0.58	0.37
Day 85 – day 117	1.82	1.83	1.83	1.96	0.045	0.13	0.14	0.13
Dry matter intake fluctuation (kg)								
Day 0 – day 28	0.77	0.78	0.82	0.51	0.105	0.27	0.12	0.11
Day 0 – day 56	0.81b	0.96a	0.79b	0.65c	0.072	0.01	0.89	0.03
Day 0 – day 84	0.84b	1.02a	0.98a	0.83b	0.066	0.64	0.81	0.02
Day 0 – day 117	0.87b	1.01a	1.03a	0.83b	0.061	0.93	0.59	0.01
Day 29 – day 56	0.93	1.03	0.86	0.87	0.098	0.15	0.48	0.52
Day 57 – day 84	1.07	1.28	1.47	1.43	0.203	0.08	0.56	0.37
Day 85 – day 117	0.97	1.02	1.09	1.00	0.107	0.62	0.88	0.50

Continues...

Table 3 (Continued)

Backgrounding ¹	Control		Narasin		SEM	P-value ³		
	MON	NAR	MON	NAR		BACK	FIN	INT
Finishing ²								
Dry matter intake fluctuation (%)								
Day 0 – day 28	7.89b	8.36b	9.29a	5.57c	0.981	0.39	0.05	0.02
Day 0 – day 56	7.82b	9.78a	8.27b	6.31c	0.756	0.03	0.99	0.01
Day 0 – day 84	8.46b	10.51a	10.66a	8.22b	0.922	0.96	0.83	0.02
Day 0 – day 117	9.13c	10.84b	12.17a	8.53c	0.974	0.70	0.33	0.01
Day 29 – day 56	8.83	10.10	8.73	8.35	0.009	0.29	0.62	0.35
Day 57 – day 84	10.83	14.50	20.40	20.05	0.044	0.07	0.68	0.62
Day 85 – day 117	10.93	12.61	14.12	11.00	0.017	0.65	0.68	0.18
HCW (kg)	300.2	300.8	296.0	294.1	4.03	0.19	0.88	0.76
Dressing percentage (%)	55.8	55.7	55.6	55.6	0.32	0.55	0.66	0.71

HCW - hot carcass weight; SEM - standard error of the mean.

¹ Main effect of dietary addition of ionophores in the backgrounding phase, containing 0 mg/kg of narasin (Control) or 13 mg/kg of narasin (Narasin).

² Main effect of dietary addition of ionophores in the finishing phase, containing 27 mg/kg of monensin (MON) or 13 mg/kg of narasin (NAR).

³ BACK - main effect of the dietary addition of ionophores in the backgrounding phase; FIN - main effect of the dietary addition of ionophores in the finishing phase; INT - interaction between the main effects of the dietary addition of ionophores in the backgrounding and finishing phases. a,b,c - Different letters within a row differ at $P \leq 0.05$.

3.3. Rumen and cecum morphometry

After the entire experimental period, data regarding to rumen health and morphometrics, including rumenitis score ($P \geq 0.28$), mean papillae area ($P \geq 0.31$), number of papillae ($P \geq 0.23$) ruminal absorptive surface area ($P \geq 0.10$), and papillae area ($P \geq 0.19$) were not affected by the main effects of dietary addition of ionophores during backgrounding or finishing phases, nor by the interaction between them. The same was observed ($P \geq 0.26$) for cecum lesion score, as shown in Table 4.

Table 4 - Rumen morphometrics and lesion scores of rumen and cecum wall of feedlot Nellore bulls fed either monensin (MON) or narasin (NAR) with previous conditional exposure to narasin during the backgrounding phase

Backgrounding ¹	Control		Narasin		SEM	P-value ³		
	MON	NAR	MON	NAR		BACK	FIN	INT
Finishing ²								
Rumen measurements								
Rumenitis score ⁴	2.54	2.92	2.58	3.19	0.444	0.72	0.28	0.79
Mean papillae area (cm ²)	0.32	0.36	0.35	0.35	0.026	0.78	0.49	0.31
Number of papillae (n)	79.43	82.67	73.41	70.04	7.633	0.23	0.99	0.67
ASA (cm ² /cm ² of rumen wall)	24.42	27.58	23.55	23.34	1.534	0.10	0.33	0.27
Papillae area (% of ASA)	96.08	96.09	95.83	95.52	0.321	0.19	0.61	0.59
Cecum measurement								
Lesion score ⁴	1.40	1.62	0.90	1.50	0.330	0.31	0.26	0.52

ASA - absorptive surface area; SEM - standard error of the mean.

¹ Main effect of dietary addition of ionophores in the backgrounding phase, containing 0 mg/kg of narasin (Control) or 13 mg/kg of narasin (Narasin).

² Main effect of dietary addition of ionophores in the finishing phase, containing 27 mg/kg of monensin (MON) or 13 mg/kg of narasin (NAR).

³ BACK - main effect of the dietary addition of ionophores in the backgrounding phase; FIN - main effect of the dietary addition of ionophores in the finishing phase; INT - interaction between the main effects of the dietary addition of ionophores in the backgrounding and finishing phases.

⁴ Scores for rumen and cecum wall were given according to the incidence of lesions following the methodology described by Bigham and McManus (1975), based on a scale from 0 (no lesions) to 10 (ulcerative lesions throughout the entire organ wall).

4. Discussion

Usually, in the Brazilian beef cattle system, animals are kept on pasture, consuming a forage-based diet and receiving a low-intake supplement (Sartori et al., 2017). Although the supplementation in the backgrounding phase is part of the factorial arrangement, which is primarily valid for the finishing phase, we analyzed the cattle performance at this phase to validate two secondary hypotheses about dietary addition of NAR in the backgrounding phase: 1) dietary addition of NAR would increase cattle performance during the backgrounding phase, and 2) dietary addition of NAR in the backgrounding phase would have a carryover effect, altering the performance in the finishing phase.

Feed additives have been used in feedlots as an important tool to increase productivity and make the activity more profitable. Most research related to ionophores focuses on finishing diets, primarily aiming to improve feed efficiency and animal performance through modifications in fermentation pathways, as well as improving nutrient utilization from the diet (Tedeschi et al., 2003). Narasin is an ionophore produced by *Streptomyces aureofaciens* (Dorman et al., 1976) that shows positive effects on ruminal fermentation by decreasing acetate proportion and increasing propionate proportion (Limede et al., 2021; Miszura et al., 2023; Polizel et al., 2020), increasing total short-chain fatty acid production (Miszura et al., 2023; Polizel et al., 2021), and increasing ruminal ammonia concentration (Polizel et al., 2021).

Data published regarding dietary inclusion of NAR on cattle fed with forage-based diets did not show a reduction in DMI (Limede et al., 2021; Miszura et al., 2023). However, in the present study, NAR-fed cattle showed a reduction in DMI compared to CON-fed cattle during the backgrounding phase. It is noteworthy that all the studies published had a longer feeding period compared to the 28 days proposed in this study, and none of them fed the animals sugarcane bagasse, which has a greater indigestible fraction compared to the forage ingredients used in the other cited studies. The reduction in DMI for NAR-fed cattle compared to CON-fed cattle was not followed by an improvement in feed efficiency, which is common among feed additives (i.e., MON [Goodrich et al., 1984]), therefore this reduction was not sufficient to decrease either ADG or final BW; thus, we can refute our first hypothesis, since there was no difference between CON- and NAR-fed cattle during the backgrounding phase.

The second part of the hypothesis can also be refuted, since the main effect of backgrounding supplementation did not present any significant effect on feedlot performance, carcass characteristics, and rumen and cecum morphometrics during the finishing period.

Although the finishing period did not have a negative control (a treatment without additive supplementation), as occurred in the backgrounding phase, we proposed a positive control with the CON+MON treatment, since the effects of monensin are very well known and reported (Duffield et al., 2012; Goodrich et al., 1984). As previously discussed, feed additives usually modulate ruminal fermentation, altering feeding behavior and the digestibility of the nutrients, resulting in changes in DMI and feed efficiency. During the finishing phase, none of these variables were affected by the main effects of dietary addition of ionophores during either backgrounding or finishing phases, nor by the interaction between them. Thus, ADG and final BW were not affected by any treatment as well, after 117 days of feeding. Accordingly, hot carcass weight, dressing percentage, and rumen/cecum morphometric measurements were not influenced by the treatments.

In addition, we evaluated the correlations between performance and intake data with gastrointestinal development and health variables, and no significant associations were detected for any of these variables (data not shown).

On the other hand, a between interaction of the main effects of dietary addition of ionophores during the backgrounding and finishing phases was observed for dry matter intake fluctuation in absolute values (kilograms) and as a percentage (except for the fluctuation between day 0 and day 28 when expressed in absolute values). Data show that NAR+NAR-fed cattle presented reduced DMI fluctuation compared to CON+NAR- and NAR+MON-fed cattle throughout the entire experimental period, and from day 0 to day 56 relative to CON-MON treatment. Soto-Navarro et al. (2000) observed that DMI

fluctuations above 10% can decrease ADG and impair feed efficiency. In addition, a meta-analysis conducted by (Pereira et al., 2021) showed that reduced DMI fluctuations are also related to greater ADG, heavier carcasses, and lower rumenitis incidence. However, although CON+NAR- and NAR+MON-fed cattle had DMI fluctuation greater than 10%, this was not sufficient to reduce ADG or increase rumenitis incidence compared to treatments with fluctuations below 10%.

The mechanisms of action and effects of MON and NAR are well established in the literature, as both are highly lipophilic molecules that act on the cell membrane of bacteria, reducing the population and activity of Gram-positive bacteria and protozoa (McGuffey et al., 2001). In this context, it was expected that in the current study the inclusion of NAR in feedlot diets would influence ruminal fermentation, leading to positive outcomes, as was previously observed with dietary inclusion of MON. However, it appears that the combined protocols between MON and NAR during the backgrounding and finishing phases require further investigation to confirm the residual effects of the ionophores and their impact on ruminal fermentation, ultimately affecting cattle performance.

5. Conclusions

The dietary addition of NAR did not improve performance during the backgrounding or finishing phases in Nellore cattle. Moreover, there was no carryover effect of NAR from backgrounding to the finishing phase. Similarly, dietary addition of NAR during the backgrounding phase did not have a positive effect on variables related to ruminal and cecal epithelium by the end of the finishing phase. Nellore cattle fed NAR during the finishing phase in the feedlot showed performance similar to those receiving MON; however, this result should be interpreted with caution, because there was no negative control included in this study for the finishing phase. Further research is needed to understand how dietary NAR addition reduces DMI fluctuations, as this additive helps achieve more consistent intake throughout the feeding period.

Data availability

Data will be available upon request to the corresponding author.

Author contributions

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

Conflict of interest

The authors declare no conflict of interest.

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Declaration of generative AI in scientific writing

The authors declare that no generative artificial intelligence (AI) tools were used in the writing and editing of this manuscript except for grammar correction, which was conducted under the authors' supervision. The author is responsible for all intellectual contributions, data analysis, and interpretations this manuscript presents.

References

- Assis, R. G.; Biava, J. S.; Polizel, D. M.; Souza, T. T.; Sturion, T. U.; Pires, A. V.; Relling, A. E. and Ferreira, E. M. 2020. Use of narasin in diets for lactating ewes. *Small Ruminant Research* 187:106108. <https://doi.org/10.1016/j.smallrumres.2020.106108>
- Baggio, M.; Gouvêa, V. N.; Barroso, J. P. R.; Miszura, A. A.; Limede, A. C.; Soares, L. C. B.; Ferraz Jr, M. V. C.; Vicente, A. C. S.; Ferreira, E. M.; Marques, R. S. and Pires, A. V. 2023. Different combinations of monensin and narasin on growth performance, carcass traits, and ruminal fermentation characteristics of finishing beef cattle. *Frontiers in Veterinary Science* 10:1117639. <https://doi.org/10.3389/fvets.2023.1117639>
- Bagley, C. P.; Feazel, J. I.; Morrison, D. G. and Lucas, D. M. 1988. Effects of *Salinomycin* on ruminal characteristics and performance of grazing beef steers. *Journal of Animal Science* 66:792-797. <https://doi.org/10.2527/jas1988.663792X>
- Bevans, D. W.; Beauchemin, K. A.; Schwartzkopf-Genswein, K. S.; McKinnon, J. J. and McAllister, T. A. 2005. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. *Journal of Animal Science* 83:1116-1132. <https://doi.org/10.2527/2005.8351116X>
- Bigham, M. L. and McManus, W. R. 1975. Whole wheat grain feeding of lambs. V.* Effects of roughage and wheat grain mixtures. *Australian Journal of Agricultural Research* 26:1053-1062. <https://doi.org/10.1071/AR9751053>
- Daniel, J. L. P.; Resende Júnior, J. C. and Cruz, F. J. 2006. Participação do ruminoretículo e omaso na superfície absorvível total do proventrículo de bovinos. *Brazilian Journal of Veterinary Research and Animal Science* 43:688-694.
- Detmann, E.; Valente, E. E. L.; Batista, E. D. and Huhtanen, P. 2014. An evaluation of the performance and efficiency of nitrogen utilization in cattle fed tropical grass pastures with supplementation. *Livestock Science* 162:141-153. <https://doi.org/10.1016/j.livsci.2014.01.029>
- Dorman, D. E.; Paschal, J. W.; Nakatsukasa, W. M.; Huckstep, L. L. and Neuss, N. 1976. The use of ¹³C-NMR. Spectroscopy in biosynthetic studies. II[1]. Biosynthesis of narasin, a new polyether ionophore from fermentation of *Streptomyces aureofaciens* [2]. *Helvetica Chimica Acta* 59:2625-2634. <https://doi.org/10.1002/hlca.19760590802>
- Duffield, T. F.; Merrill, J. K. and Bagg, R. N. 2012. Meta-analysis of the effects of monensin in beef cattle on feed efficiency, body weight gain, and dry matter intake. *Journal of Animal Science* 90:4583-4592. <https://doi.org/10.2527/jas.2011-5018>
- Fox, D. G.; Tedeschi, L. O.; Tylutki, T. P.; Russell, J. B.; Van Amburgh, M. E.; Chase, L. E.; Pell, A. N. and Overton, T. R. 2004. The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion. *Animal Feed Science and Technology* 112:29-78. <https://doi.org/10.1016/j.anifeedsci.2003.10.006>
- Gobato, L. G. M.; Polizel, D. M.; Ferraz Júnior, M. V. C.; Miszura, A. A.; Barroso, J. P. R.; Martins, A. S.; Gonçalves, J. R. S.; Ferreira, E. M. and Pires, A. V. 2020. Supplementation of grazing beef cattle with narasin. *Pesquisa Agropecuária Brasileira* 55:e01270. <https://doi.org/10.1590/S1678-3921.pab2020.v55.01270>
- Golder, H. M. and Lean, I. J. 2016. A meta-analysis of lasalocid effects on rumen measures, beef and dairy performance, and carcass traits in cattle. *Journal of Animal Science* 94:306-326. <https://doi.org/10.2527/jas.2015-9694>
- Goodrich, R. D.; Garrett, J. E.; Gast, D. R.; Kirick, M. A.; Larson, D. A. and Meiske, J. C. 1984. Influence of monensin on the performance of cattle. *Journal of Animal Science* 58:1484-1498. <https://doi.org/10.2527/jas1984.5861484x>
- Limede, A. C.; Marques, R. S.; Polizel, D. M.; Cappellozza, B. I.; Miszura, A. A.; Barroso, J. P. R.; Martins, A. S.; Sardinha, L. A.; Baggio, M. and Pires, A. V. 2021. Effects of supplementation with narasin, salinomycin, or flavomycin on performance and ruminal fermentation characteristics of *Bos indicus* Nellore cattle fed with forage-based diets. *Journal of Animal Science* 99:skab005. <https://doi.org/10.1093/jas/skab005>
- Mantovani, A. 2012. Chemical risk assessment of animal feed. p.449-464. In: *Animal feed contamination: Effects on livestock and food safety*. Fink-Gremmels, J., ed. Woodhead Publishing Limited, Cambridge. <https://doi.org/10.1533/9780857093615.4.449>
- McCurdy, M. P.; Horn, G. W.; Wagner, J. J.; Lancaster, P. A. and Krehbiel, C. R. 2010. Effects of winter growing programs on subsequent feedlot performance, carcass characteristics, body composition, and energy requirements of beef steers. *Journal of Animal Science* 88:1564-1576. <https://doi.org/10.2527/jas.2009-2289>
- McGuffey, R. K.; Richardson, L. F. and Wilkinson, J. I. D. 2001. Ionophores for dairy cattle: current status and future outlook. *Journal of Dairy Science* 84:E194-E203. [https://doi.org/10.3168/jds.s0022-0302\(01\)70218-4](https://doi.org/10.3168/jds.s0022-0302(01)70218-4)

- Miszura, A. A.; Marques, R. S.; Polizel, D. M.; Cappellozza, B. I.; Cruz, V. A.; Ogg, M. A.; Barroso, J. P. R.; Oliveira, G. B.; Martins, A. S.; Limede, A. C.; Ferreira, E. M.; Gouvêa, V. N. and Pires, A. V. 2023. Effects of lasalocid, narasin, or virginiamycin supplementation on rumen parameters and performance of beef cattle fed forage-based diet. *Journal of Animal Science* 101:skad108. <https://doi.org/10.1093/jas/skad108>
- Moretti, M. H.; Resende, F. D.; Siqueira, G. R.; Roth, A. P. T. P.; Custódio, L.; Roth, M. T. P.; Campos, W. C. and Ferreira, L. H. 2013. Performance of Nellore young bulls on Marandu grass pasture with protein supplementation. *Revista Brasileira de Zootecnia* 42:438-446. <https://doi.org/10.1590/S1516-35982013000600008>
- Nagaraja, T. G.; Taylor, M. B.; Harmon, D. L. and Boyer, J. E. 1987. *In vitro* lactic acid inhibition and alterations in volatile fatty acid production by antimicrobial feed additives. *Journal of Animal Science* 65:1064-1076. <https://doi.org/10.2527/jas1987.6541064x>
- Pereira, I. C.; Costa, C. F.; Martins, C. L.; Pereira, M. C. S.; Squizatti, M. M.; Owens, F. N.; Cruz, G. D.; Millen, D. D. and Arrigoni, M. D. B. 2021. Voluntary daily fluctuation in dry matter intake is associated to feedlot performance, feeding behavior and rumen morphometrics in beef cattle. *Livestock Science* 250:104565. <https://doi.org/10.1016/j.livsci.2021.104565>
- Polizel, D. M.; Cappellozza, B. I.; Hoe, F.; Lopes, C. N.; Barroso, J. P.; Miszura, A.; Oliveira, G. B.; Gobato, L. and Pires, A. V. 2020. Effects of narasin supplementation on dry matter intake and rumen fermentation characteristics of *Bos indicus* steers fed a high-forage diet. *Translational Animal Science* 4:118-128. <https://doi.org/10.1093/tas/txz164>
- Polizel, D. M.; Marques, S. S.; Westphalen, M. F.; Gouvea, V. N.; Ferraz Júnior, M. V. C.; Miszura, A. A.; Barroso, J. P. R.; Limede, A. C.; Ferreira, E. M. and Pires, A. V. 2021. Narasin inclusion for feedlot lambs fed a diet containing high amounts of ground flint corn. *Scientia Agricola* 78:e20200010. <https://doi.org/10.1590/1678-992X-2020-0010>
- Reis, R. A.; Ruggieri, A. C.; Casagrande, D. R. and Páscoa, A. G. 2009. Suplementação da dieta de bovinos de corte como estratégia do manejo das pastagens. *Revista Brasileira de Zootecnia* 38(suppl. 1):147-159. <https://doi.org/10.1590/S1516-35982009001300016>
- Resende-Junior, J. C.; Alonso, L. S.; Pereira, M. N.; Roca Magallanes, M. G.; Duboc, M. V.; Oliveira, E. C. and Melo, L. Q. 2006. Effect of the feeding pattern on rumen wall morphology of cows and sheep. *Brazilian Journal of Veterinary Research and Animal Science* 43:526-536.
- Russell, J. B. and Strobel, H. J. 1989. Effect of ionophores on ruminal fermentation. *Applied and Environmental Microbiology* 55:1-6. <https://doi.org/10.1128/aem.55.1.1-6.1989>
- Samuelson, K. L.; Hubbert, M. E.; Galyean, M. L. and Löest, C. A. 2016. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey. *Journal of Animal Science* 94:2648-2663. <https://doi.org/10.2527/jas.2016-0282>
- Sartori, E. D.; Canellas, L. C.; Pereira, G. R.; Moojen, F. G.; Carvalho, H. R. and Barcellos, J. O. J. 2017. Performance of beef heifers supplemented with sodium lasalocid. *Tropical Animal Health and Production* 49:273-279. <https://doi.org/10.1007/s11250-016-1188-1>
- Silvestre, A. M. and Millen, D. D. 2021. The 2019 Brazilian survey on nutritional practices provided by feedlot cattle consulting nutritionists. *Revista Brasileira de Zootecnia* 50:e20200189. <https://doi.org/10.37496/rbz5020200189>
- Soares, L. C. B.; Marques, R. S.; Pires, A. V.; Cruz, V. A.; Limede, A. C.; Maia, K. S.; Baggio, M.; Barroso, J. P. R.; Biava, J. S.; Ferreira, E. M.; Castro Ferraz Jr, M. V. and Polizel, D. M. 2021. Effects of narasin supplementation frequency on intake, ruminal fermentation parameters, and nutrient digestibility of *Bos indicus* Nellore steers fed with forage-based diets. *Translational Animal Science* 5:txab125. <https://doi.org/10.1093/tas/txab125>
- Soto-Navarro, S. A.; Krehbiel, C. R.; Duff, G. C.; Galyean, M. L.; Brown, M. S. and Steiner, R. L. 2000. Influence of feed intake fluctuation and frequency of feeding on nutrient digestion, digesta kinetics, and ruminal fermentation profiles in limit-fed steers. *Journal of Animal Science* 78:2215-2222. <https://doi.org/10.2527/2000.7882215X>
- Tedeschi, L. O.; Fox, D. G. and Tylutki, T. P. 2003. Potential environmental benefits of ionophores in ruminant diets. *Journal of Environmental Quality* 32:1591-1602. <https://doi.org/10.2134/jeq2003.1591>