Combined use of ionophore and virginiamycin for finishing Nellore steers fed high concentrate diets

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ABSTRACT: Zebu cattle fed high concentrate diets may present inconsistent performance due to the occurrence of metabolic disorders, like acidosis. The isolated use of ionophores and virginiamycin in high grain diets can improve animal performance and reduce the incidence of such disorders, but recent studies suggested that their combination may have an additive effect. Thus, 72 Nellore steers, 389 ± 15 kg initial body weight (BW), were confined and fed for 79 days to evaluate the combination of virginiamycin and salinomycin on performance and carcass traits. Animals were allocated to a randomized complete block design by BW, in a 2 × 2 factorial arrangement of treatments, with two concentrate levels (73 and 91 %) and two virginiamycin levels (0 and 15 mg kg^{-1}), and salinomycin (13 mg kg^{-1}) included in all diets. The interaction was not significant ($p > 0.05$). Dry matter intake (DMI), average daily gain (ADG), gain-to-feed ratio (G:F), starch consumed, and fecal starch content were higher ($p \leq 0.05$) for the 91 % concentrate treatment. These animals also had higher ($p \leq 0.05$) hot carcass weight and dressing percentage. Virginiamycin-treated animals showed lower DMI, but ADG and G:F did not differ ($p > 0.05$) between treatments. Starch consumed and estimated dietary net energy for maintenance (NE$_m$) and gain (NE$_g$) were higher ($p \leq 0.05$) for virginiamycin-treated animals, with no substantial effects on carcass traits. The inclusion of virginiamycin in finishing diets containing salinomycin reduced DMI while maintaining ADG and improving NE$_m$ and NE$_g$, suggesting an additive effect of virginiamycin and ionophores, but without affecting carcass quality.

Introduction

Diets with high concentrate levels are widely used for feedlot cattle because they can improve animal performance, carcass characteristics and, consequently, increase profitability (Woody et al., 1983). However, feeding high grain diets to ruminant animals increases the risk of metabolic disorders, such as ruminal acidosis (Krause and Oetzel, 2006). This disturbance, which reflects an imbalance between microbial production, utilization, and ruminal absorption of organic acids, is associated with many other feedlot problems (such as rumenitis, liver abscesses, and laminitis) and can significantly impact animal performance (Nagaraja and Titgemeyer, 2007).

There are breed differences concerning the development of metabolic disorders. *Bos indicus* breeds, which represent the majority of the Brazilian feedlot herd, are observed to develop acidosis more frequently than *Bos taurus* (Brawner et al., 1969; Elam, 1976). Thus, it is important to develop nutritional strategies that allow the safe utilization of high concentrate diets for Zebu cattle.

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Antimicrobial feed additives can stabilize ruminal fermentation by promoting changes in microbial populations and their activity in the rumen, reducing the incidence of metabolic disorders, and improving rate and efficiency of growth (Nagaraja, 1995). The isolated utilization of ionophore, like monensin or salinomycin, or non-ionophore antibiotics, such as virginiamycin, as growth promoter feed additives has been thoroughly investigated. The results are consistent in demonstrating improvements on animal performance (Rogers et al., 1995; Zinn, 1986). Moreover, Silva et al. (2004) suggested that virginiamycin and ionophore may have an additive effect on growth performance when used in combination, but with no substantial effects on carcass characteristics.

Thus, this study aimed to evaluate the combined use of virginiamycin and ionophore (salinomycin) on growth performance and carcass traits of Nellore cattle fed high concentrate diets.

Materials and Methods

All animals were managed under approved animal care and use guidelines. The experiment was carried out in Andradina, state of São Paulo, Brazil (20°50′ S; 51°20′ W; and 381 m a.s.l.), between Sep and Dec 2006. Seventy-two Nellore steers, with approximately 36 months of age and 389 ± 15 kg of initial body weight (BW), were housed in individual pens with covered troughs for 79 days. Animals were blocked by initial BW and allocated

to a randomized complete block design, in a 2×2 factorial arrangement of treatments, with two concentrate levels (73 and 91 %) and two virginiamycin levels (0 and 15 mg kg^{-1}) in the diet dry matter (DM), resulting in a total of four treatments, with 18 animals per treatment. All diets had the ionophore salinomycin at the concentration of 13 mg kg^{-1}.

The 79-d experiment consisted of an adaptation period of 19 days, when all animals received a 55 % concentrate diet for the first nine days and a 73 % concentrate diet for the last ten days, followed by four 15-d periods, when steers received their respective final treatments. Steers from the virginiamycin treatment received the antibiotic since the first day of adaptation. Also, animals were fed *ad libitum* and data were already collected in the adaptation period. The compositions of the experimental diets are shown in Table 1.

Total mixed rations were fed once daily at 8h00 and steers were allowed *ad libitum* access to feed and water. The amount of feed offered was adjusted daily (10 % orts), and dry matter intake (DMI) was determined

Table 1 – Ingredient proportions and chemical composition of the experimental diets.

Item	Experimental diets[a,b]		
	55 % C	73 % C	91 % C
Ingredient proportions, % DM			
Corn silage	45.00	27.00	9.00
Dry ground corn	32.50	52.00	70.25
Whole cottonseed	15.00	12.75	10.10
Soybean meal	5.00	5.50	7.60
Limestone	1.30	1.30	1.65
Urea	0.55	0.80	0.50
Potassium chloride	0.00	0.00	0.25
Mineral-vitamin premix[c]	0.65	0.65	0.65
Chemical composition [d]			
TDN, % DM	62.58	69.09	79.12
DE, MJ kg^{-1}	11.56	12.77	14.61
ME, MJ kg^{-1}	9.46	10.47	11.97
NE$_m$,[e] MJ kg^{-1}	5.83	6.72	8.01
NE$_g$,[e] MJ kg^{-1}	3.39	4.20	5.33
EE, % DM	4.81	3.83	4.79
CP, % DM	15.24	16.05	16.00
NDF, % DM	41.78	30.50	19.14
NDF$_{forage}$, % DM	30.79	18.48	6.16
NDF$_{forage}$, % total NDF	73.70	60.59	32.18
ADF, % DM	29.41	20.59	11.73

[a]55 % C = diet containing 55 % concentrate in DM (animals were fed this diet only for the first nine days of the adaptation period); 73 % C = diet containing 73 % concentrate in DM; 91 % C = diet containing 91 % concentrate in DM. [b]Diets were the same for both virginiamycin groups, except for virginiamycin levels, which were 0 and 15 mg kg^{-1}. [c]Composition: 7.9 % Ca; 5.9 % P; 2.6 % Mg; 6.2 % S; 18 % Na; 27 % Cl; 3100 mg kg^{-1} Mn; 4700 mg kg^{-1} Zn; 1000 mg kg^{-1} Fe; 1580 mg kg^{-1} Cu; 70 mg kg^{-1} Co; 110 mg kg^{-1} I; 22 mg kg^{-1} Se; 250000 IU vitamin A; 40000 IU vitamin D; 1500 IU vitamin E. [d]TDN = total digestible nutrients; DE = digestible energy; ME = metabolizable energy; EE = ether extract; CP = crude protein; NDF = neutral detergent fiber; NDF$_{forage}$ = neutral detergent fiber from forage; ADF = acid detergent fiber. [e]Calculated based on feed analyses (NRC, 1996).

as the difference between feed offered and orts, which were weighed every morning. Corn silage samples were collected weekly and analyzed for DM to ensure constant forage-to-concentrate ratio of the diet.

Feed offered and orts samples were collected every three days, frozen at -18 °C, composited for each animal at the end of the trial, and analyzed for their chemical composition to estimate total digestible nutrients according to Weiss et al. (1992). Samples were analyzed for DM, ash, ether extract, crude protein (AOAC, 2005), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (Van Soest et al., 1991), neutral detergent insoluble crude protein, and acid detergent insoluble crude protein (Licitra et al., 1996). The NDF concentrations were determined utilizing α-amylase and sodium sulfite.

Animals were weighed without fasting at the onset of the trial and at the end of each experimental period. Average daily gain (ADG) was determined by linear regression of BW on time. Gain-to-feed ratio (G:F) was calculated by dividing ADG by DMI. Total digestible nutrients were converted to metabolizable energy (ME) according to NRC (1996) so that metabolizable energy intake (MEI) could be estimated. Dietary net energy for maintenance (NE$_m$) and gain (NE$_g$) based on feed analyses were calculated according to NRC (1996).

In order to estimate NE$_m$ and NE$_g$ of the diets, energy gain (EG, Mcal d^{-1}) was determined by the equation: EG = (0.0493 BW$^{0.75}$) ADG$^{1.097}$ (NRC, 1984). Maintenance energy expended (EM, Mcal d^{-1}) was calculated by the equation: EM = 0.077 BW$^{0.75}$ (Lofgreen and Garrett, 1968), multiplied by a correction factor of 0.9 for *Bos indicus* breeds (NRC, 1996), so that: EM = 0.069 BW$^{0.75}$. Estimated dietary NE$_m$ and NE$_g$ (Mcal kg^{-1}) were calculated according to Zinn and Shen (1998) with the following equations: NE$_m$ = (-b -(b^2-4ac)^{0,5}) / 2c, where a = -0.41EM, b = 0.877EM + 0.41DMI + EG, and c = -0.877DMI; NE$_g$ = 0.877NE$_m$ - 0.41. Units were converted to MJ kg^{-1} by multiplying the results obtained in Mcal kg^{-1} by 4.184.

Fecal samples were collected by rectal palpation on days 19, 49, and 79 (weighing days), frozen at -18 °C, composited for each animal at the end of the experiment, and analyzed for DM. Immediately after collection, 4-g samples of fresh feces were mixed in 4 mL of deionised water and pH was determined with a portable pH meter. Feed offered, orts, and feces samples were analyzed for their starch contents as described by Knudsen (1997). Dietary and orts starch contents (DSC and OSC, respectively), in kg d^{-1}, were determined as the amount of feed offered and orts multiplied by their respective starch contents, in percentage. Starch consumed (SC), in percentage, was calculated as the difference between DSC and OSC divided by DMI.

At the end of the experimental period, animals were weighed and transported to a commercial packing plant, and slaughtered according to humanitarian approved methods. Empty BW was calculated by multiplying the

final BW by 0.96 (NRC, 1996), and hot carcass weights (HCW) were recorded so that dressing percentage could be determined by the equation: dressing percentage (%) = (HCW / empty BW) 100. Kidney, pelvic, and heart fat weights (KPH) were also recorded during the slaughter process. Measurements of longissimus muscle (LM) area and backfat thickness were obtained between the 12th and 13th ribs after carcasses were chilled for 24 h.

Statistical analyses were performed using the MIXED procedure of SAS (2009). The random effects of blocks, and the fixed effects of concentrate level, virginiamycin level, and the two-factor interaction (concentrate × virginiamycin) were included in the model. The least square means statement was used to calculate the adjusted means for the dietary treatments, and comparisons were made using the PDIFF option based on Student's t-test. Pearson correlation coefficients (PCC) between fecal starch content (FSC) and performance variables were determined with the CORR procedure of SAS (2009). All *p*-values were shown in the tables for better interpretation, but significant effects were considered when $p \leq 0.05$.

Results and Discussion

Because the two-factor interaction was not significant for any of the analyzed variables, the main effects of concentrate and virginiamycin levels will be discussed. It was hypothesized that virginiamycin may have a different effect in very high concentrate diets when compared with diets containing less grains, thus an interaction between concentrate and virginiamycin levels was expected but not demonstrated.

Dry matter intake was higher ($p \leq 0.05$) for animals receiving the diet containing 91 % concentrate (Table 2). Means were 13 and 11 % higher for the 91 % concentrate treatment in comparison with the 73 % concentrate level, when expressed as kg d^{-1} and % BW, respectively. The differences in feed consumption between concentrate levels suggest that a physical limitation of intake resulting from higher NDF content may have occurred for the 73 % concentrate group. However, such results were not expected for the range of dietary TDN observed in this experiment (69 and 79 % TDN for the 73 and 91 % concentrate diets, respectively). According to Van Soest (1994), higher intakes are observed when dietary TDN is around 67 %, and DMI is decreased when TDN is below or above this optimal value, which can be even lower for Nellore cattle (Véras et al., 2000; Almeida and Lanna, 2003). Thus, the increased TDN of the 91 % concentrate treatment should have decreased DMI.

Metabolizable energy intake was higher ($p \leq 0.05$) for the 91 % concentrate group (Table 2), which can be explained by higher DMI and higher energy concentration in the diet (10.47 vs. 11.97 MJ kg^{-1} ME for the 73 and 91 % concentrate diets, respectively). Average daily gain differed ($p \leq 0.05$) between treatments, with means 22 % higher for animals receiving the 91 % concentrate

ration, which is also due to higher DMI and higher energy concentration in the diet.

Woody et al. (1983) evaluated the effect of grain level on performance of growing and finishing steers and also observed that animals fed 90 % concentrate gained 7 % faster than those fed 70 % grain. Bartle et al. (1994) observed linear decreases in ADG as roughage level increased. These authors reported that there was only a small difference between 10 and 20 % dietary roughage (0.01 kg d^{-1}), and a larger decrease in gain between 20 and 30 % forage in the diet (0.07 kg d^{-1}). In the same way, Resende et al. (2001) evaluated the effects of five concentrate levels (25 to 75 %) on performance of crossbred steers and observed positive linear effect on ADG as grain level increased. On the other hand, Bulle et al. (2002) observed higher ADG and DMI for crossbred bulls fed 85 % concentrate in comparison with those receiving a 91 % grain diet. Feedlot steers fed high energy finishing diets containing less than 6 % NDF from roughage may present marked depressions in energy intake and ADG (Alvarez et al., 2004), which did not occur in this experiment, because the 73 and 91 % concentrate diets contained 18.48 and 6.16 % NDF supplied by forage, respectively.

Gain-to-feed ratio increased ($p \leq 0.05$) as dietary concentrate level increased (Table 2), which agrees with the data found in the literature (Stock et al., 1987; Stock et al., 1990, Resende et al., 2001). Because ADF is not digested well in the rumen of cattle fed high concentrate finishing diets, the addition of roughage should reduce feed efficiency when acidosis is not a problem (Stock et al., 1990). Even though G:F was higher for the 91 % concentrate treated animals, estimated dietary NE_m and NE_g did not differ between treatments ($p > 0.05$). As MEI was higher for the 91 % concentrate group, this lack of difference in estimated NE_m and NE_g of the diets indicates that these animals had lower efficiencies of dietary energy utilization.

Dietary and orts starch contents were higher ($p \leq 0.05$) for animals receiving the 91 % concentrate ration (Table 2), which was expected due to the higher proportion of corn in that diet (52 and 70 % for the 73 and 91 % concentrate diets, respectively). Starch consumed was also higher ($p \leq 0.05$) for the 91 % concentrate treated animals, which can be explained by higher DSC and DMI.

Animals receiving the 91 % concentrate diet also showed higher FSC ($p \leq 0.05$) (Table 2), indicating lower efficiencies of dietary starch and energy utilization. This is in agreement with estimated dietary net energy values and may be due to the use of Nellore steers in this experiment. Zebu cattle are known to present reduced digestibility of high grain diets when compared with *Bos taurus* breeds (Moore et al., 1975; Putrino et al., 2007). Direct determination of FSC could explain 68 % of the variation in ruminal starch digestion, and 91 % of the variability in total tract starch digestion (Zinn et al., 2002). Thus, the higher FSC indicates that animals

Table 2 – Effect of concentrate and virginiamycin levels on performance of finishing Nellore steers.

Item[1]	Concentrate level		Virginiamycin level		SEM[2]	p-value		
	73	91	0	15		Concentrate	Virginiamycin	Interaction[3]
	——— % ———		——— mg kg^{-1} ———					
Initial BW, kg	389.08	389.03	389.69	388.42	1.80	0.98	0.48	0.27
Final BW, kg	468.86[b]	487.42[a]	484.33[c]	471.94[d]	3.80	< 0.01	0.05	0.92
DMI, kg d^{-1}	6.81[b]	7.69[a]	7.65[c]	6.85[d]	0.16	< 0.01	< 0.01	0.44
DMI, % BW	1.58[b]	1.75[a]	1.75[c]	1.59[d]	0.03	< 0.01	< 0.01	0.42
MEI, MJ d^{-1}	73.96[b]	93.61[a]	88.25[c]	79.31[d]	1.99	< 0.01	< 0.01	0.30
ADG, kg d^{-1}	1.149[b]	1.408[a]	1.317	1.240	0.040	< 0.01	0.30	0.97
G:F	0.167[b]	0.183[a]	0.172	0.179	0.003	0.01	0.26	0.35
NE$_m$,[4] MJ kg^{-1}	8.98	9.12	8.82[c]	9.27[d]	0.11	0.50	0.04	0.24
NE$_g$,[4] MJ kg^{-1}	6.16	6.28	6.02[c]	6.42[d]	0.09	0.48	0.04	0.23
DSC, %	29.70[b]	45.30[a]	37.50	37.50	0.93	< 0.01	-	-
OSC, %	13.68[b]	23.34[a]	19.99	17.03	1.53	< 0.01	0.31	0.83
SC, %	32.48[b]	49.32[a]	40.26[c]	41.54[d]	1.04	< 0.01	0.03	0.52
FSC, %	13.96[b]	19.27[a]	17.29	15.94	0.86	< 0.01	0.40	0.06
Fecal pH	6.02	5.97	5.96	6.03	0.04	0.59	0.39	0.48

[1]BW = body weight; DMI = dry matter intake; MEI = metabolizable energy intake; ADG = average daily gain; G:F = gain-to-feed ratio; NE$_m$ = dietary net energy for maintenance; NE$_g$ = dietary net energy for gain; DSC = dietary starch content; OSC = orts starch content; SC = starch consumed; FSC = fecal starch content. [2]SEM = standard error of the mean. [3]Interaction = two-factor interaction (concentrate × virginiamycin). [4]Estimated based on performance (Zinn and Shen, 1998). [a,b]Means for concentrate levels within rows with different superscripts differ ($p \leq 0.05$). [c,d]Means for virginiamycin levels within rows with different superscripts differ ($p \leq 0.05$).

fed the higher concentrate diet may have presented reduced starch digestibility, suggesting that the amounts of this carbohydrate in the 91 % concentrate treatment may have been greater than what Nellore cattle is able to efficiently utilize.

Fecal pH may be the simplest indicator of the amount of starch fermented in the large intestine (Channon et al., 2004), with lower pH reflecting higher levels of acids resulting from fermentation (DeGregorio et al., 1982). In this experiment, fecal pH did not differ ($p > 0.05$) between treatments (Table 2), indicating that the site of starch digestion may have been the same for both 73 and 91 % concentrate treated animals.

Animals supplemented with virginiamycin in combination with salinomycin had lower ($p \leq 0.05$) DMI, in kg d^{-1} and % BW, and MEI in comparison with steers receiving only salinomycin (Table 2). Despite the lower feed intake for virginiamycin-treated animals, ADG was not different ($p > 0.05$) between treatments. These results suggest that animals receiving both additives probably had higher efficiencies of dietary energy utilization, which may have occurred due to alterations in ruminal fermentation patterns promoted by the supplementation with virginiamycin. In this way, intake may have been reduced because physiological energy demands of virginiamycin-treated animals were supplied.

Virginiamycin has the potential to improve ruminal fermentation due to its selective effects on rumen microorganisms. In general, virginiamycin is primarily effective against Gram-positive bacteria, which are responsible for the production of undesirable compounds, such as hydrogen (methane precursor), and lactate (Nagaraja and Taylor, 1987; Nagaraja et al., 1987). The lactate accumulation in the rumen may account for increased

acidosis incidence in ruminant animals, reducing the efficiency of energy utilization. Coe et al. (1999) observed that virginiamycin is more efficient in controlling lactate production than ionophores. These authors also observed that mean counts of *Lactobacillus* and *Streptococcus bovis*, the major lactic acid producing bacteria, were lower for steers receiving virginiamycin than for those supplemented with ionophores.

Some authors also observed that virginiamycin can increase *in vitro* concentrations of propionate (Hedde et al., 1980; Nagaraja et al., 1987). Propionic fermentation is energetically more efficient than acetic or butyric fermentations because of differences in the incorporation of metabolic hydrogen (Chalupa, 1977). Thus, enhancing the production of propionate can increase the energy recovered in fermentation end products. Additionally, increasing propionic acid and reducing acetic acid proportions tend to decrease methane production (Wolin, 1960). It is clear that virginiamycin changes ruminal fermentation patterns, enhancing the efficiency of dietary energy utilization, which may explain the reduction in DMI and MEI with no alterations in ADG observed in this experiment.

In contrast to our results, Silva et al. (2004) observed no differences on ADG for Nellore steers fed a 77 % concentrate diet and supplemented with salinomycin, virginiamycin, or their combination. However, steers receiving both salinomycin and virginiamycin showed higher DMI in comparison with those supplemented with the isolated additives. Salinas-Chavira et al. (2009) reported no differences on ADG or DMI for confined Holstein steer calves supplemented with three virginiamycin levels (0, 16, or 22.5 mg kg^{-1}), which also differs from our results.

Even though animals receiving virginiamycin in combination with salinomycin had lower DMI with no substantial effects on ADG, G:F did not differ ($p >$ 0.05) between treatments (Table 2). Similar results were observed by Silva et al. (2004), in which G:F of finishing Nellore steers did not differ among groups (control, salinomycin, virginiamycin, or both additives). On the other hand, some authors reported linear improvements in feed efficiency when cattle were fed increasing levels of virginiamycin (Rogers et al., 1995; Salinas-Chavira et al., 2009).

Despite the lack of difference in G:F, estimated dietary NE_m and NE_g were higher ($p \leq 0.05$) for steers supplemented with both additives in comparison with those receiving only salinomycin (Table 2), which also indicates improved efficiencies of dietary energy utilization. As previously mentioned, this may have occurred due to changes in ruminal fermentation promoted by virginiamycin supplementation. These results are similar to others reported in the literature, in which estimated NE_m and NE_g of the diets were higher for feedlot beef cattle supplemented with virginiamycin when compared with control animals (Rogers et al., 1995; Salinas-Chavira et al., 2009).

In addition to the effects of virginiamycin on ruminal metabolism, another possible explanation for the improved efficiency of dietary energy utilization is upon alterations in the digestive physiology in the gut, as it happens in non-ruminants. Virginiamycin acts in monogastric animals by increasing nutrient availability due to selective inhibition of enteric bacteria (Dierick et al., 1986). Vervaeke et al. (1979) observed decreased *in vitro* organic acid production in ileal contents of pigs promoted by virginiamycin, which results in a substantial sparing of carbohydrates, increasing their availability for intestinal absorption. This antibiotic can reduce the breakdown of carbohydrates to lactate by 94 % in the small intestine of chicken (Davis, 1998). Virginiamycin can also inhibit decarboxylation of amino acids in the gut, mainly in the small intestine, sparing essential amino acids by reduced formation of ammonia or amines. These amino acids could be available to the animal, resulting in increased quantities of metabolizable protein (Dierick et al., 1986).

Dietary and orts starch contents did not differ ($p >$ 0.05) between steers receiving 0 or 15 mg kg^{-1} virginiamycin (Table 2). However, animals receiving 15 mg kg^{-1} virginiamycin showed higher ($p \leq 0.05$) SC. These results indicate that steers from this treatment selected more dietary starch, possibly due to an enhanced ruminal environment promoted by virginiamycin supplementation, which allowed animals to safely consume higher quantities of rapidly fermentable carbohydrates. No differences were observed ($p > 0.05$) for FSC or fecal pH between treatments, suggesting that the antibiotic did not alter the extent or site of starch digestion.

There was a negative correlation ($p \leq 0.05$; PCC = -0.57) between FSC and pH of feces (data not shown), which is in agreement with the reports of Zinn et al. (2002), who stated that, generally, fecal pH is inversely correlated with FSC, because the starch that reaches the large intestine considerably reduces pH in this site. Depenbusch et al. (2008) also found that fecal pH is negatively correlated with FSC, even though the correlation coefficient was lower (-0.34). Dry matter intake was positively correlated ($p \leq 0.05$; PCC = 0.23) with FSC, agreeing with the results reported by Galyean et al. (1979). These authors observed that FSC increased considerably as DMI increased from one to two times maintenance levels of intake. Apparently, larger amounts of starch reaching the intestine did not seem to be as efficiently digested as intake increased. No correlations were observed ($p > 0.05$) between FSC and ADG or G:F, agreeing with the reports of Turgeon et al. (1983), in which FSC was not correlated with ADG or feed conversion. These results indicate that the relationships between FSC and animal performance are inconsistent, especially for Nellore cattle.

Animals receiving the 91 % concentrate diet showed higher HCW ($p \leq 0.05$) as a consequence of higher ($p \leq 0.05$) empty BW and dressing percentage (Table 3). The variations observed in dressing percentage for animals fed different concentrate levels may result from changes in gastrointestinal tract weight (Duarte et al., 2011). Steers receiving lower concentrate diets may present higher viscera weights due to increased gastrointestinal fill associated with greater NDF intake, which

Table 3 – Effect of concentrate and virginiamycin levels on carcass traits of finishing Nellore steers.

Item [1]	Concentrate level		Virginiamycin level		SEM [2]	*p*-value		
	73	91	0	15		Concentrate	Virginiamycin	Interaction [3]
	——— % ———		——— mg kg^{-1} ———					
Empty BW, kg	450.11[b]	467.91[a]	464.96[c]	453.06[d]	3.65	< 0.01	0.05	0.92
HCW, kg	245.35[b]	259.81[a]	256.39[c]	248.76[d]	2.22	< 0.01	0.04	0.55
Dressing percentage, %	54.52[b]	55.53[a]	55.15	54.90	0.22	0.02	0.55	0.34
LM area, cm^2	59.38	60.84	60.33	59.90	0.78	0.36	0.79	0.99
Backfat thickness, mm	3.75	4.00	4.28	3.48	0.26	0.63	0.13	0.20
KPH, kg	7.19[b]	8.13[a]	8.08[c]	7.24[d]	0.21	0.03	0.04	0.33

[1]Empty BW = empty body weight; HCW = hot carcass weight; LM area = longissimus muscle area; KPH = kidney, pelvic, and heart fat weight. [2]SEM = standard error of the mean. [3]Interaction = two-factor interaction (concentrate × virginiamycin). [a,b]Means for concentrate levels within rows with different superscripts differ ($p \leq 0.05$). [c,d]Means for virginiamycin levels within rows with different superscripts differ ($p \leq 0.05$).

leads to reductions in dressing percentage. These results are similar to others reported in the literature, in which dressing percentage increased linearly as forage level decreased (Duarte et al., 2011; Leme et al., 2003; Pereira et al., 2006).

Despite the higher ADG observed for the 91 % concentrate treatment, LM area and backfat thickness did not differ ($p > 0.05$) between concentrate levels (Table 3). These results indicate that steers from both treatments had similar carcasses regarding their physical composition. However, KPH was higher ($p \leq 0.05$) for the 91 % concentrate group. The developmental order for fat deposition is abdominal, intermuscular, subcutaneous, and finally intramuscular (Pethick et al., 2004). Thus, the increased KPH indicates an alteration in the composition of gain towards fat deposition for steers receiving the 91 % concentrate diet. Ribeiro et al. (2002) also observed increases in KPH of crossbred bulls as forage level decreased, but in contrast to our results, they observed a trend for increased backfat thickness as concentrate levels increased.

Steers receiving 15 mg kg^{-1} virginiamycin had lower ($p \leq 0.05$) empty BW and HCW, but no differences were observed ($p > 0.05$) for dressing percentage (Table 3). Despite the higher DMI for steers fed only salinomycin, variations in gastrointestinal tract weight may not have occurred between virginiamycin levels. Thus, a decreased HCW for steers receiving both additives is more likely a result of the non-significant decrease in ADG and decreased empty BW observed for this treatment. Even though KPH was higher ($p \leq 0.05$) for steers receiving only salinomycin, LM area and backfat thickness did not differ ($p > 0.05$) between treatments, suggesting that the physical composition of the carcasses were similar for animals receiving only the ionophore or both additives. The supplementation with virginiamycin usually has no adverse effects on carcass quality (Rogers et al., 1995).

Silva et al. (2004) also did not observe differences in carcass traits, except for backfat thickness, which was greater for Nellore steers fed salinomycin in comparison with those receiving the combination of salinomycin and virginiamycin. Similarly, Salinas-Chavira et al. (2009) did not detect differences in carcass characteristics of feedlot steers supplemented with increasing levels of virginiamycin, except for a trend for increased LM area. Thus, despite the beneficial effects on animal performance, the inclusion of virginiamycin on diets containing ionophore does not seem to affect carcass traits.

Conclusion

The efficient use of high concentrate diets for finishing Nellore steers was highlighted, even though Zebu cattle is known to have lower ability to cope with high quantities of rapidly fermented carbohydrates. The inclusion of virginiamycin in finishing diets containing

salinomycin can reduce intake and maintain daily gain, improving estimated net energy content of feeds, which suggests a possible additive effect of virginiamycin and ionophores. Additionally, the positive effects of using both additives in combination on animal performance were achieved without affecting carcass quality.

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