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RESEARCH PAPER

Performance of confined and grazing lambs fed diets with different mineral-concentrate supplements

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Abstract

A.M.A. Silva, L.R. Bezerra, S.R.M. Rufino, J.M. Pereira Filho, J.M. Freire, D.S. Silva, R.L. Oliveira and G.F.V. Bayão. 2014. Performance of confined and grazing lambs fed diets with different mineral-concentrate supplements. Cien. Inv. Agr. 41(3):285-295. For confined animals, performance is improved when their diet is supplemented with a mineral mixture and protein energy. This study evaluated the effect of dietary supplementation on feedlot sheep on native pasture. Two experiments were conducted in sequence, with the animals constrained in one and animals confined to pasture in the other. The experiments were conducted with 32 Santa Ines lambs, with average initial weights of 16.8 and 19.9 kg for the constrained and pasture studies, respectively. In both experiments, the animals were offered the following supplements: Supplement 1 = 200 g of the concentrate without mineral mixture; Supplement 2 = 200 g of the concentrate with mineral mixture + Mn + Zn; Supplement 3 = 300 g of the concentrate with mineral mixture + Mn + Zn; and Supplement 4: 300 g of the concentrate with mineral mixture + Zn without Mn. The intake of the mineral mixture resulted in a higher average intake of crude protein in feedlot lambs and neutral detergent fiber in pasture lambs than the other diets, regardless of the presence of manganese and thus provided more consistent weight gain among the animals. The mineral mixture supplementation increased the average daily intake of Zn and Mn. The animals on the diets containing 300 g day^{-1} supplementation with the concentrated mineral mixture also had more weight gain and better feed conversion than those on the other diets, most likely because of the greater responsiveness to supplementation in these animals.

Key words: Dry matter, feed conversion, manganese, ovine, zinc.

Introduction

During the rainy season, the native grasslands of arid and semiarid regions have high rates of growth and high nutritional values compared with grasses in the dry period. Although the difficulties in the management of the Caatinga for the production of goats and sheep are acknowledged, studies have demonstrated its forage potential and that there is the possibility of storing excess forage produced

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during the rainy season as hay or silage (Pereira Filho *et al.*, 2013; Souza *et al.*, 2013).

The feeding of lambs on native pasture with a protein content of less than 7% makes it impossible to maintain the minimum level of 8 mg dL^{-1} of ammonia nitrogen (NH_3-N) required to maintaining the growth of cellulolytic bacteria, thus reducing the digestive activity and consumption. However, small amounts of readily soluble N increase the digestion of low-quality forage, and in some cases, increase consumption (Van Soest, 1994). One of the limitations of the use of urea is its high solubility in the rumen, where the urea is quickly converted into ammonia through the action of urease enzymes produced by rumen microorganisms. Excess ammonia can reduce the retention of N and consequently reduce productivity or even poison the animal due to the rate of accumulation of NH_3 in the rumen being greater than the rate of use.

Therefore, supplements that contain high levels of urea as a source of NPN release high concentrations of NH_3-N in the rumen, which cannot be converted into microbial protein due to an insufficient amount of readily soluble carbohydrates (Kozloski, 2009) because of the low availability of energy from pastures. The fodder structural carbohydrates are a major source of energy for animals on pasture, but these compounds are less susceptible to hydrolysis than the polymers of starch; therefore, it is necessary in such cases to administer small concentrations of readily available carbohydrates to meet the needs of the microorganisms (Bezerra *et al.*, 2013; Ramdani *et al.*, 2013).

According to Berchielli (2006), forage plants alone are not able to meet the mineral requirements of animals, so there is a need for the development of appropriate supplements for each situation. Although the trace mineral nutritional needs and the effects of supplementation on animal production are not well understood, it is essential to provide sufficient quantities for intake. Additionally, excess trace minerals may modulate the degradation of urea in the rumen and the slow release of ammonia, which inhibits the accumulation of ammonia formed from urea, as occurs with copper (Cu), zinc (Zn), manganese (Mn), and magnesium (Mg).

The mineral requirements are typically not clearly defined in the diets of ruminants, and neither are several factors that cause interference with mineral absorption, such as for the presence and absorption of Zn and Mn, which can be affected by other nutrients such as Ca, Fe, P, Cd, Cr, and Zn as additional levels of antagonism (Mendes *et al.*, 2010). Thus, increased understanding of the effects of the supplementation with different levels of these minerals and the relationships with mineralization is fundamental to the performance of sheep and directly reflects on the final quality of the carcass to be sold.

Another important factor is that lambs may have a Zn or Mn deficiency when their diet contains less Mn and Zn than required or when other mineral antagonists inhibit the absorption and use of dietary Mn and Zn. Therefore, an adequate supply of minerals should be provided with complete mineral supplements that supply the quantities required in each category without excess or deficiency because both situations affect animal performance. Thus, the aim of this study was to evaluate the performance of confined and grazing lambs fed diets with different mineral-concentrate supplements, with the additional effect of the presence of the minerals Zn and Mn.

Materials and methods

Two experiments were conducted sequentially. The first trial (experiment I) was performed with lambs confined in the Sheep Sector Health Center and Rural Technology facility. For experiment II, the animals were allowed to freely graze on the pasture of the Research Center for the Development of Semi-Arid Tropics. Both experiments were conducted on the Federal University of Campina Grande, located in Patos City, Paraiba State, Brazil.

In experiment I, thirty-two Santa Inês lambs were used with an average weight of 16.8 ± 3.12 kg and an average initial age of 75 days. The animals were confined for 66 days and then were placed for 21 days in individual pens for adaptation (0.6 m × 1.00 m), which were located in a shed covered with asbestos tiles. The experimental design was a randomized complete block with four treatments and six replications, with the blocks defined by the weight and initial age of the animals.

The ingredients used for the preparation of the supplements for each experimental treatment were as follows: corn and soybean meal, urea, bicalcium phosphate, limestone, sulfur, manganese sulfate, zinc sulfate, copper sulfate, cobalt sulfate, sodium selenite, and potassium iodate. The levels were calculated by following the recommendations of the AFRC (1995) to avoid any danger of toxicity to the animal. From these ingredients, the treatments were created as follows: Supplement 1 = 200 g animal^{-1} day^{-1} of corn mixture + soybean + sodium chloride + urea; Supplement 2 = 200 g animal^{-1} day^{-1} of corn mixture + soybean + sodium chloride + urea + mineral mixture; Supplement 3 = 300 g animal^{-1} day^{-1} of corn mixture + soybean + sodium chloride + urea + mineral mixture; and Supplement 4 = 300 g animal^{-1} day^{-1} of corn mixture + soybean + sodium chloride + urea + mineral mixture without manganese sulfate. The diets were developed for the requirement of average daily weight gain of 100 g (AFRC, 1995).

In experiment I, because forage was used, a mixture (1:1) of grass hay Andrequicé (*Leersia hexandra* cv. S.W.) and Brachiaria (*Brachiaria radicans* cv. Nappier) was offered at will to ensure a surplus of 10%. Food was offered twice daily (0700 and 1500). The weight of the animals was recorded every 14 days, after fasting for 14 h, and daily intake was determined according to the difference between the total diet offered and the remains, which were harvested and weighed. Samples of feed and remains were stored in plastic bags at –10°C. At the end of the harvest period, the samples were thawed, and the feed and remains were dried in a forced-air oven at 60 ± 5°C for 72 h (Silva and Queiroz, 2002) and then ground in a knife mill with a 1 mm sieve. Based on the dry weight of the animals in each experimental period, composite samples were then made and stored for chemical analyses.

Experiment II began five days after completion of experiment I with the same animals. For this study, the animals began with an average weight of 19.9 ± 3.12 kg and an average initial age of 120 days. The animals received no more hay as forage and began to graze on native pasture with natural dicots until they reached the weight of 30 kg or 200 days of age; the criteria preestablished for slaughter. This allowed for an adaptation period of 11 days and an experimental period of 60 days.

The animals had access to a water reservoir and collective troughs. The animals remained in each paddock until herbaceous pasture was reduced to 60% of initial cover, after which they were transferred to another paddock. This allowed for a rest period of the grazed area, which typically depended on the length of stay of the animals in the following paddock. The lambs had access to pasture for 6 h and were returned at 1600, when they were separated according to treatment and housed in collective cages with food and water. In the bays, the animals received their treatment supplements, which were same combinations as in experiment I.

The biomass of the grazing area was estimated with eight samples per paddock. The samples were collected using an iron rectangular frame, 0.25 m × 1.0 m (Araújo Filho *et al*., 1991), and the biomass within the rectangle was cut and separated. For each sample, the biomass was separated into grasses and forbs and weighed. Each paddock was sampled before the entry of the animals and after they left. The samples were dried at the Animal Nutrition Laboratory of the University Federal of Campina Grande. Then, the samples were ground to pass through a 1 mm sieve with a Wiley-type mill, placed in glass-stoppered polyethylene vials, and properly identified for further analyses. The chemical composition of the ingredients and the energy-mineral-protein components in experiments I and II are shown in Tables 1 and 2, respectively. The analyses of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), ash, and crude energy (CE) in the food and remains were performed according to procedures described by Silva and Queiroz (2002). The analyses of calcium (Ca), phosphorus (P), manganese (Mn), and zinc (Zn) were performed with an atomic absorption spectrophotometer (Model. X), and a mineral solution prepared according to procedures described by Silva and Queiroz (2002).

The treatments were evaluated for average daily intake of nutrients, weight gain, and feed conversion in experiments I and II. The experimental design was completely randomized with four treatments and six replications. The results were evaluated with analysis of variance using the SAS statistical software package (Statistical Analysis System, 2005), and the contrasts between means were tested with Tukey's test, assuming a 5% probability for significance.

Table 1. Chemical composition of ingredients in the diets of Experiments I (containment) and II (grazing).

Ingredients	DM[1]	C[P1]	CE[2]	NDF[1]	Ash[1]	Mn[3]	Zn[3]
Soybean meal	91.64	45.96	4976	14.57	6.00	46	110
Corn meal	90.00	12.63	4395	41.93	2.41	38	34
Andrequicé hay	92.08	3.67	3994	66.31	9.72	296	19
Brachiaria hay	94.39	2.89	4332	69.90	8.09	415	12
Native pasture	43.26	6.84	4517	66.53	7.68	89	185
Dicot forbs	47.35	14.42	4179	51.36	6.96	100	108

[1]%, DM = Dry matter, CP = Crude protein, NDF = Neutral detergent fiber; [2]Mcal kg^{-1}, CE = Crude energy, and [3]mg L^{-1}, Mn = Manganese and Zn = Zinc.

Table 2. Percentage composition of the different constituents and supplements used in Experiments I (containment) and II (grazing).

Ingredients	Supplement 1	Supplement 2	Supplement 3	Supplement 4
Soybean meal	37.37	33.30	33.85	33.85
Corn meal	37.37	33.30	33.85	33.85
Mineral mixture[1]	0.00	15.27	16.68	16.68
Urea (%)	6.58	3.36	3.67	3.67
Salt	18.68	14.77	11.95	11.95
Total	100	100	100	100
Crude Protein (%)	30.09	27.05	28.17	28.17
Metabolizable energy (Mcal kg^{-1})	2.43	2.17	2.22	2.22
Ca (%)	0.16	3.45	3.25	3.25
P (%)	0.33	2.12	2.02	2.02
Manganese (ppm)	0.00	600.00	600.00	0.00
Zinc (ppm)	0.00	600.00	600.00	600.00

[1]Mineral mixture: 123.8 g Ca kg^{-1}; 68 g P kg^{-1}; 12 g S kg^{-1}; Cu 600 ppm, Co 100 ppm, Fe 368 ppm, I 120 ppm, and Se 12 ppm.

Table 3. Means and probability (P) for the daily intakes of dry matter (IDM), crude protein (ICP), neutral detergent fiber (INDF), ash, manganese (IMn), zinc (IZn), average daily weight gain (ADWG), total weight gain (TWG), and feed conversion (FC; kg DM kg^{-1} body weight) of confined lambs (Experiment I) subjected to different supplementation strategies with concentrate and minerals.

Variables	Supplement 1	Supplement 2	Supplement 3	Supplement 4	P-value
IDM (g)	712.85 a	721.13 a	787.08 a	801.22 a	0.5522
IDM (g $kg^{0.75\ -1}$)	83.70 a	85.170 a	88.49 a	90.38 a	0.8510
ICP (g)	68.55 b	69.07 b	88.68 a	93.11 a	0.0007*
ICP (g $kg^{0.75\ -1}$)	8.07 b	8.16 b	9.86 ab	10.51 a	0.0005*
INDF (g)	414.12 a	418.88 a	439.02 a	446.06 a	0.8742
INDF (g $kg^{0.75\ -1}$)	48.61 a	49.47 a	49.53 a	50.31 a	0.9898
IAsh (g)	79.06 a	83.13 a	83.39 a	85.69 a	0.8947
IAsh (g $kg^{0.75\ -1}$)	9.32 a	9.33 a	9.38 a	10.07 a	0.8450
IMn	178.43 b	290.68 a	333.53 a	181.45 b	<.0001*
IMn $kg^{0.75\ -1}$	20.90 b	34.35 a	37.45 a	20.20 b	<.0001*
IZn	9.517 b	70.16 a	56.80 a	57.13 a	<.0001*
IZn $kg^{0.75\ -1}$	1.11 c	8.31 a	6.28 b	6.46 b	<.0001*
ADWG (g)	73.00 ab	63.00 b	86.00 ab	114.00 a	<.0001*
TWG (kg)	2.499 ab	2.159 b	2.935 ab	3.876 a	0.0165*
FC (kg DM kg BW^{-1})	9.75 ab	11.44 b	9.15 ab	7.02 a	<.0001*

*Means followed by different letters in the same row are significantly different ($P \leq 0.05$) based on Tukey's test. Supplement 1: Concentrate energy protein containing 0.16% Ca, 0.33% P, and without Mineral Mixture and Mn and Zn; Supplement 2: Concentrate energy protein, Mineral Mixture and 600 ppm each of Mn and Zn were offered at 200 g $animal^{-1}$ day^{-1}; Supplement 3: Concentrate energy protein, Mineral Mixture and 600 ppm each of Mn and Zn were offered at 300 g $animal^{-1}$ day^{-1}; Supplement 4: Concentrate energy protein, Mineral Mixture and 600 ppm of Zn, without Mn were offered at 300 g $animal^{-1}$ day^{-1}.

Results and discussion

In experiment I (confinement), no effects of the diets on average daily intake of dry matter, neutral detergent fiber, or mineral matter, both in grams and in metabolic live weight ($P > 0.05$; Table 3), were found.

The daily average dry matter intake was 756 g in relation to body weight between the initial and final periods of confinement, and the consumption per unit of metabolic size ($kg^{0,75}$) and % of body weight (% BW) were 85.55 g $kg^{0,75\ -1}$ and 4.14% of BW, respectively. It was expected that the largest amount of concentrate combined with the mineral mixture would be equal to the dry matter intake of the animals, but this was not statistically ($P > 0.05$) different.

A significant effect ($P = 0.0007$) was found for crude protein intake. The group that received 300 g of concentrate and mineral supplementation (88.68 g, Supplement 3) and the group supplemented with the same amount without Mn (93.11 g, Supplement 4) had higher intakes based on body weight ($P = 0.0007$) and intake per unit of metabolic size ($kg^{0,75}$; $P = 0.0005$) than the group without the mineral mixture (Supplement 1). However, among the treatments with the same levels of the mineral mixture, there was no significant difference ($P > 0.05$), which indicated no effects of Mn and Zn in the diet on dry matter intake, crude protein availability, or consequent production level.

Regarding the use of Mn and Zn, concentrate and mineral supplementation resulted in a greater consumption ($P \leq 0.0001$) of these trace elements. For Zn, a lack of mineral supplementation reduced ($P \leq 0.0001$) the intake of the mineral Zn by 86.5% compared with the group receiving 200 g of mineral supplementation (Supplement

2). In treatments supplemented with 200 g daily, the intake of Zn ($P \leq 0.0001$) was higher than the other treatments, which did not differ between the other treatments ($P > 0.05$).

The diets containing 200 and 300 g of supplemental feed (Supplements 2 and 3, respectively) increased the Mn intake by 62.9 and 89.4% compared with the treatments without mineral mixture (Supplement 1) and with 300 g of concentrate with mineral supplementation without Mn (Supplement 4), respectively ($P \leq 0.0001$). Nevertheless, this increased consumption of Mn interfered with animal performance.

The removal of Mn mineral supplementation (Supplement 4) did not affect the consumption of the mineral Zn ($P > 0.05$). For Mn, the diets without mineral mixture (Supplement 1) and without Mn supplementation (Supplement 4) had lower consumption, which was expected because the sources of this element were only the hay and the concentrate supplement.

The increase in crude protein intake might be directly linked to the minerals Zn and Mn acting as activators of enzymes and directly influencing the metabolism of nucleic acids and carbohydrates, which affects protein synthesis and increases the effects of hormones and the transport and use of vitamins (Laguna *et al.*, 2013; Laubach *et al.*, 2013).

There was no influence ($P > 0.05$) of Mn (Supplement 3) on the weight gain of the animals, but the amount of supplementation received was significant ($P \leq 0.0001$). The average daily weight gain and total weight gain presented a similar result to that observed for crude protein. The amount of supplement had a significant effect on average daily weight gain ($P \leq 0.0001$) and total weight gain ($P \leq 0.0165$). The treatments with 300 g of daily supplementation showed higher average daily weight gain (0.086 and 0.114 g for Supplement 3 and 4, respectively) and total weight gain (2.93 and 3.87 kg for Supplement 3 and 4, respectively) regardless of the presence of trace Mn.

The effects of the treatment with 200 g of supplementation (Supplement 2) and the treatment with 300 g of concentrate and mineral salts including Mn (Supplement 3) were similar ($P > 0.05$) and showed lower total weight gain ($P \leq 0.0165$) than the treatment with 300 g of concentrate and the presence of mineral salts without Mn (Supplement 4). Silva *et al.* (2003) reported that the crude protein requirement was 7.2 g $kg^{0.75-1}$ for the maintenance of Santa Inês lambs with 20 kg of body weight. The average consumption in the treatments with 200 g of concentrate supplementation, with and without mineral mixture (Supplements 1 and 2, respectively), in this research was only 10% higher than these requirements for maintenance.

The AFRC (1995) suggested that for animals with 20 kg live weight and an average daily weight gain of 100 g the nutritional requirement for metabolizable protein was 64 g day^{-1}. If the conversion efficiency of crude protein into metabolizable protein is 0.6, meaning a requirement of 107 g of crude protein per day, then the crude protein intake in the treatments with 200 g of concentrate supplementation, with and without mineral supplementation (Supplements 1 and 2, respectively), met 65% of the requirement, whereas the treatments with 300 g of supplementation with more concentrate and mineral supplementation with and without Mn (Supplements 3 and 4, respectively) supplied approximately 90% of the amount recommended by the AFRC (1995).

The animals on diets with 200 g of concentrate supplementation with and without mineral mixture (Supplements 1 and 2, respectively) had a mean weight gain of 68.5 g day^{-1}, which represented 68% of the estimated gain of 100 g day^{-1} recommended by AFRC (1995), which meant the animals achieved the expected gain based on the crude protein intake (65% of the requirements).

No effect of including mineral supplementation in the diet with 200 g of concentrate (Supplements 1 and 2, respectively; $P > 0.05$) was found. However, the animals on the diets with 300 g of concentrate supplement plus mineral supplementation with and without Mn (Supplements 3 and 4, respectively) had an average daily weight gain of 105 g day^{-1}, which represented a gain of 5% more than expected, whereas the CP intake represented only 90% of the amount recommended by the AFRC (1995). The animal diet with 300 g of concentrate supplementation and additional mineral supplementation without Mn (Supplement 4) produced an average daily weight gain of 14% more for consumption of approximately 90% of the recommended amount, which meant higher efficiency due to supplementation with Zn in the absence of high levels of Mn.

The animals that received 300 g of concentrate plus mineral supplement without Mn (Supplement 4) had a higher rate of feed conversion (7.02 kg DM kg BW^{-1}; $P \leq 0.0001$), which was similar in the other groups ($P > 0.05$). There was no significant difference ($P > 0.05$) between the group receiving 300 g of concentrate plus the mineral mix containing Mn (Supplement 3) and the groups receiving 200 g of concentrate with and without mineral supplementation (11.44 and 9.75 kg DM kg BW^{-1} for Supplements 1 and 2, respectively).

The animals had a higher intake of dry matter in experiment I, with the base of the forage Andrequicé (*Leersia hexandra* cv. S.W.) and Brachiaria (*Brachiaria radicans* cv. Nappier; Table 4), than in experiment II, conducted during grazing. This was due to the quality of the dicotyledonous native forbs, which contained 14% crude protein during the experiment. Diets with higher protein levels, especially with young animals that show good response to that type of supplementation, have been used to intensify the production system. This resulted in higher dry matter intake, increased slaughter weight, and produced a category of animal fat with a suitable finish without damaging the meat quality (Cirne *et al*., 2013; Silva *et al*., 2013).

Table 4. Means and probability (P) for the daily intakes of dry matter (IDM), crude protein (ICP), neutral detergent fiber (INDF), ash, manganese (IMn), zinc (IZn), average daily weight gain (ADWG), total weight gain (TWG), and feed conversion (kg DM kg^{-1} body weight) of lambs in pasture (Experiment II) subjected to different supplementation strategies of concentrate and minerals.

Variables	Supplement 1	Supplement 2	Supplement 3	Supplement 4	P-value
IDM (g)	853.10 a	859.53 a	933.72 a	980.04 a	0.4558
IDM (g kg$^{0.75\ -1}$)	81.50 a	83.00 a	85.67 a	87.33 a	0.9406
ICP (g)	534.55 a	538.58 a	585.07 a	614.09 a	0.4558
ICP (g kg$^{0.75\ -1}$)	51.06 a	51.91 a	53.65 a	54.57 a	0.9459
INDF (g)	154.00 b	154.00 b	175.66 a	180.00 a	<.0001*
INDF (g kg$^{0.75\ -1}$)	14.68 a	14.78 a	15.91 a	15.98 a	0.2042
IAsh (g)	87.96 b	93.88 a	94.73 a	96.33 a	<.0001*
IAsh (g kg$^{0.75\ -1}$)	8.47 a	8.50 a	8.61 a	8.97 a	0.6402
IMn	56.70 c	165.70 b	211.11 a	56.70 c	<.0001*
IMn kg$^{0.75\ -1}$	5.40 c	15.95 b	19.15 a	4.98 c	<.0001*
IZn	175.90 c	216.31 b	253.06 a	258.80 a	<.0001*
IZn kg$^{0.75\ -1}$	16.80 b	20.733 a	23.01 a	22.83 a	<.0001*
ADWG (g)	162.00 b	165.00 b	203.00 a	194.00 ab	<.0001*
TWG (kg)	8.64 ab	7.25 b	7.96 b	9.16 a	<.0001*
FC (kg DM kg BW^{-1})	5.26 b	5.20 b	4.59 a	5.14 b	0.0245

*Means followed by different letters in the same row are significantly different ($P \leq 0.05$) based on Tukey's test. Supplement 1: Concentrate energy protein containing 0.16% Ca, 0.33% P, and without Mineral Mixture and Mn and Zn; Supplement 2: Concentrate energy protein, Mineral Mixture and 600 ppm each of Mn and Zn were offered at 200 g animal^{-1} day^{-1}; Supplement 3: Concentrate energy protein, Mineral Mixture and 600 ppm each of Mn and Zn were offered at 300 g animal^{-1} day^{-1}; Supplement 4: Concentrate energy protein, Mineral Mixture and 600 ppm of Zn, without Mn were offered at 300 g animal^{-1} day^{-1}.

No difference between the treatments for the average daily intake of dry matter and crude protein as a function of the metabolic weight ($P > 0.05$) was found. There was no difference in the crude protein intake between the groups supplemented with 200 g with and without the mineral mixture (Supplements 1 and 2, respectively) and 300 g with or without the mineral Mn (Supplements 3 and 4, respectively; $P > 0.05$).

The groups that received 300 g of concentrate supplementation and minerals with or without Mn (Supplements 3 and 4, respectively) consumed more neutral detergent fiber than ($P < 0.0001$) the animals that received only 200 g of concentrate supplementation with and without minerals (Supplements 1 and 2, respectively). Thus, for the use of Mn and Zn with the pasture animals, the concentrate and mineral supplementation resulted in an increased intake ($P \leq 0.0001$) relative to the amount of supplemental trace elements offered.

The supplementation with 300 g of concentrate and mineral supplements with or without Mn (Supplements 3 and 4, respectively) produced a proportionally larger intake ($P < 0.0001$) of the trace element Zn (253.06 and 258.80 g, respectively). For Mn, the result was similar, but the treatment in which the mineral was excluded from the formulation presented a consumption that was similar ($P > 0.05$) for only the animals supplemented with concentrate. The trend for consumption as a function of body weight was similar to that measured in grams.

The mineral supplementation influenced the performance of the animals ($P \leq 0.0001$). Lambs fed the treatment with 300 g of concentrate supplementation and more minerals with and without Mn (Supplements 3 and 4, respectively) performed better ($P \leq 0.0001$) than the other treatments, which were not significantly different from each other ($P > 0.05$).

The average daily weight gain (203 g) and total weight gain (8.56 kg) of the animals receiving the largest supplementations were approximately 27% higher than the average for lambs fed treatments without mineral supplementation and supplementation with 200 g and minerals (Supplements 1 and 2, respectively). There was no significant difference ($P \leq 0.0001$) in the average daily weight gain of the animals receiving concentrate supplementation without mineral mixture for the 200 g group (Supplement 1) and the group receiving 300 g of concentrate supplementation and more minerals without the presence of Mn (Supplement 3). However, the Mn produced a higher total weight gain ($P \leq 0.05$).

This superior performance was due to the greater responsiveness of these animals to the supplement when they had forage available with better nutritional value. The increased availability of protein and lower fiber concentration promoted greater efficiency in the use of protein and energy, and the levels of Mn and Zn produced an increase in the average daily weight gain between groups of treatments without mineral supplementation; 200 g of concentrate and mineral supplementation (Supplement 2) yielded 45 g for an increase of only 100 g of supplement, which pointed to different responses to high concentrations of Mn and Zn as a function of diet quality (Walk *et al.*, 2013).

The aim of this research was to study the supplementation of the diet of lambs during food shortages to limit possible weight loss in the animals during this period. To accomplish this, a mix of energy-protein-mineral was offered that would meet their requirements for maintenance. However, the protein consumption also yielded different weight gains.

Thus, the response to supplementation of the minerals could also be due to the interrelationships between nutrients such as between protein and energy (Anderson *et al.*, 2013; McGrath *et al.*, 2013). Furthermore, the concentrations of the minerals in the diet are regulated in the body of the animal by homeostatic mechanisms and remain within small ranges to achieve a well-balanced steady state.

The mobilization of minerals occurs if there is a deficit in the body, and with this mobilization, increased absorption from the gastrointestinal tract occurs to maintain homeostasis during periods of low or high-energy needs. The reverse also occurs if there is an excess supply or energy needs are low (Hugejiletu *et al.*, 2013; Liesegang *et al.*, 2013). During experiments I and II, the consumption of mineral salts by the animals was within the recommended range, and thus no decrease in weight gain occurred. Therefore, supplementation provided a concentrated mineral intake sufficient to meet the needs of the animals. For the animals raised on pasture, the consumption of Mn and Zn was further increased by the higher concentration of minerals in the fodder than the green hay.

No antagonism was observed between the minerals because Mn did not change the average daily weight gain of the group that received 300 g of concentrate and mineral supplementation (Supplement 3), but the presence and the quantity of minerals that were provided did have an effect. Furthermore, the increasing availability of protein and lower fiber concentration provided higher efficiency of protein and energy use, pointing to the different responses. The efficiency of use of high concentrations of Mn and Zn depended on the quality of the diet. The results found by Arelovich *et al.* (2000) were in agreement with those of this study.

In conclusion, the supplementation with 300 g of protein-energy concentrate and a mineral mixture (Supplements 3 and 4, respectively) increased average daily weight gain in the animals subjected to confinement, regardless of the presence of the mineral Mn in the mix. With grazing, supplementing the energy mix with protein and Mn yielded a better performance and better feed for the grazing animals because of the higher nutrient availability and the amount of protein in the pasture grasses than in the hay supplied in confinement.

Resumen

A.M.A. Silva, L.R. Bezerra, S.R.M. Rufino, J.M. Pereira Filho, J.M. Freire, D.S. Silva, R.L. Oliveira y G.F.V. Bayão. 2014. Rendimiento de corderos estabulados y en pastoreo, sometidos a diferentes estrategias de suplementación de concentrado mineral. Cien. Inv. Agr. 41(3):285-295. La suplementación con una mezcla de minerales y energía de proteína proporciona un mejor rendimiento en los animales confinados. El objetivo fue evaluar el efecto de estrategias suplementarias de corderos. Se realizaron dos experimentos en secuencia, utilizando 32 animales de Santa Inés, con un peso inicial promedio de 16.8 kg en estabulación y 19.9 kg régimen de pastoreo. En ambos experimentos se ofrecieron: Suplemento 1 = 200 g de concentrado sin mezcla mineral; Suplemento 2 = 200 g de concentrado + mezcla mineral + Mn + Zn; Suplemento 3 = 300 g de concentrado + mezcla mineral + Mn + Zn; Suplemento 4: 300 g de concentrado + mezcla mineral + Zn sin Mn. La mezcla de minerales tuvo una mayor ingesta media de proteína bruta en comparación con otras dietas, en la estabulación y fibra en pastoreo, independientemente de la presencia de manganeso, proporcionando de este modo la ganancia de peso más consistente entre los animales. La administración de suplementos de mezcla mineral aumentó la ingesta diaria de Zn y Mn. Los animales sometidos a dietas que contienen la suplementación con 300 g día^{-1} con la mezcla de mineral concentrado también tuvieron aumento de peso y mejor conversión del alimento que los de las otras dietas, muy probablemente, debido a la mayor capacidad de respuesta a la suplementación de estos animales.

Palabras clave: Conversión alimenticia, materia seca, manganeso, ovino, zinc.

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