Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v35i2.16731

Micromineral nutritional requirements for weight gain in Canindé goats under grazing in the brazilian semiarid

Cicília Maria Silva de Souza[1*], Ariosvaldo Nunes de Medeiros[2], Roberto Germano Costa[2], Elzânia Pereira Sales[3], Aderbal Marcos de Azevêdo Silva[4] and Valdi de Lima Júnior[5]

*[1]Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Norte, Sítio Lagoa do Clemente, 999, 59700-971, Apodi, Rio Grande do Norte, Brazil. [2]Universidade Federal da Paraíba, Areia, Paraíba, Brazil. [3]Universidade Federal do Ceará, Fortaleza, Ceará, Brazil. [4]Universidade Federal de Campina Grande, Patos, Paraíba, Brazil. [5]Universidade Federal do Rio Grande do Norte, Natal, Rio Grande do Norte, Brazil. *Author for correspondence. Email: ciciliazoot@hotmail.com*

ABSTRACT. The purpose was to estimate the liquid requirements of Zn, Fe, Mn and Cu for weight gain in 46 castrated Canindé goats in grazing system in the Caatinga supplemented with 0, 0.5, 1 and 1.5% levels in relation to live weight. The animals had an initial average body weight of 15.76 ± 0.96 kg. Six animals were slaughtered at the onset of the experiment (16.1 ± 1.15 kg BW) and the rest (n = 40) were randomly distributed into one of the four levels of supplementation. The body composition (mg kg^{-1} EBW) varied from 8.47 to 9.09 mg Zn, 13.54 to 13.77 mg Fe, 6.34 to 6.36 mg Mn and 3.78 to 5.10 mg Cu, for Canindé goats with 15 and 25 kg BW, respectively, and the liquid requirements for gain (mg kg^{-1} BW gain) were estimated by the comparative slaughter method, and varied from 6.98 to 7.77 mg Zn; 10.20 to 10.72 mg Fe; 4.64 to 4.82 mg Mn and 4.28 to 5.96 mg Cu for the animals with BW varying from 15 to 25 kg, respectively. The liquid requirements of microminerals estimated in this research were inferior to the recommendations made by international committees.

Keywords: body composition, indigenous goats, mineral, supplementation.

Exigências nutricionais de microminerais para ganho em peso de caprinos Canindé em pastejo no semiárido brasileiro

RESUMO. Objetivou-se estimar as exigências líquidas de Zn, Fe, Mn e Cu para ganho em peso de 46 caprinos castrados da raça Canindé suplementados com níveis de 0; 0,5; 1; e 1,5% em relação ao peso vivo em sistema de pastejo na Caatinga. Os animais apresentaram peso corporal inicial médio de 15,76 ± 0,96 kg. Seis animais foram abatidos no início do experimento (16,1 ± 1,15 kg PV) e o restante (n = 40) foi distribuído aleatoriamente para um dos quatro níveis de suplementação. A composição corporal (mg kg^{-1} PCV) variou de 8,47 a 9,09 mg de Zn (não seria mg de Zn); 13,54 a 13,77 mg de Fe; 6,34 a 6,36 mg de Mn e 3,78 a 5,10 mg de Cu, para caprinos Canindé de 15 e 25 kg PV, respectivamente e as exigências líquidas para ganho (mg kg^{-1} PV ganho) foram estimadas pelo método do abate comparativo as quais variam de 6,98 a 7,77 mg de Zn; 10,20 a 10,72 mg de Fe; 4,64 a 4,82 mg de Mn; e 4,28 a 5,96 mg de Cu para os animais com PV variando de 15 a25 kg, respectivamente. As exigências líquidas em microminerais estimadas nesta pesquisa foram inferiores às recomendações feitas pelos comitês internacionais.

Palavras-chave: composição corporal, animais nativos, elementos traços, suplementação.

Introduction

Microminerals, or trace elements, are distributed throughout the body of animals in small quantities, representing less than 0.3% of total minerals stored in the body and 0.02% in diet (MAHAN; SHIELDS JR., 1998). They play an important role in maintaining normal cell metabolism in animals (LEE et al., 2002).

In order for these mineral elements to be absorbed by the body, they must be adequately supplied in the diet, as any excess or deficiency in one element interferes in the utilization of another (GERASSEV et al., 2000), impairing health, productivity and even animal survival. Copper deficiency reduces feed intake, growth and immunity, making animals more susceptible to disease, while also leading to loss of metabolic enzymes (DORTON et al., 2006). Reduced zinc levels in the blood result in lower lymphocyte count, possibly leading to atrophy of the spleen and thymus; resistance to infections is influenced by copper, iron, selenium and zinc; manganese deficiency leads to bone abnormalities, interrupted reproductive activity, ataxia in newborns and defective lipid and carbohydrate metabolism (UNDERWOOD; SUTTLE, 1999).

Despite the importance of microminerals, studies on the metabolism of these elements in goats are considered scarce, particularly with regard to determining body composition and nutritional requirement estimates.

U.S. norms, published in bulletins of the National Research Council (NRC, 2007), show the requirements for certain microminerals based on results from feeding trials and/or adapted from values obtained in other animal species (NRC, 2001); these are of limited value given that the ratios become invalid for different species, feeding and environmental conditions.

Most studies on mineral nutritional requirements are conducted in confined animals, under the argument that grazing already meets the needs of animals, as forage plants have sufficient concentrations along with soil and water sources (NRC, 2007).

In the Caatinga ecosystem, however, micromineral concentration is not sufficient in either the rainy or drought seasons, making micromineral supplementation necessary, especially during periods of feed shortage or when plants are dormant (RAMÍREZ et al., 2004), as well as due to variations in these concentrations resulting from climate changes, time of year and soil types.

Additionally, animal raising systems in the Brazilian Northeast are predominantly extensive, with high dependence on native vegetation (Caatinga) and use of native goats, which are rustic and adaptable to the most varied environmental and management conditions. Therefore, it is essential to estimate the micronutrient requirements of goats – in particular the Canindé breed - in order to devise nutrient tables adapted to local conditions. Thus, the present study was carried out to estimate the net requirements of Zn, Fe, Mn and Cu for weight gain in growing goats under supplementation in the semiarid of Paraíba State, Brazil.

Material and methods

The study was carried out at the Small Ruminant Experimental Station, belonging to the Federal University of Paraíba - CCA/UFPB, located in the municipality of São João do Cariri (Paraíba State, Brazil), 7º29’ 34” S, 36º 41’ 53” W. The climate in the region is classified as Bsh - hot semiarid according to the Köppen classification, and Caatinga vegetation (Bacia Escola - CTRN/UFCG). During the experimental period, mean values for precipitation were 7.71 mm, 31.9ºC for maximum temperature, 17.83ºC for minimum temperature, and 74.9% for relative air humidity.

A total of 46 Canindé castrated goats were used, with initial body weight (BW) and age equal to 15.7 ± 0.96 kg and 1 ± 0.2 years, respectively. Six of these animals were sacrificed at the start of the experimental stage, and represent the initial body composition (reference animals) averaging 16.1 ± 1.15 kg BW. The remaining animals (n = 40) were randomly allotted into one of four supplementation levels (0, 0.5, 1.0 and 1.5% BW), comprising 10 animals per supplementation level.

Animals had daily access to native pasture from 6 a.m. to 4 p.m., after which they were herded to receive supplementation in an uncovered pen featuring individual 2.0 x 1.0 m stalls, with hard-pack floor and a feeding trough. Water was provided *ad libitum* from collective drinking troughs located at the management center during the grazing. To control weight gain development and adjust concentrate supply, animals were weighed weekly prior to feeding on an empty stomach, in a 0.1-kg precision scale.

Feeding supplementation consisted of concentrate ration and mineral (Table 1), balanced according to NRC (1981) recommendations for daily gains of up to 150 g for animals in the higher levels of supplementation.

Table 1. Chemical composition and proportion of the experimental concentrate and extrusa.

					Chemical composition ($g\ kg^{-1}$ DM)			
Item	Corn meal[a]	Soybean meal	Wheat meal	Cotton meal	Mineral Supplement[b]	Limestone	Extrusa[c]	Concentrate
Dry matter	863.0	853.3	833.2	854.0	970.4	999.5	155.1	864.1
Mineral matter	41.7	59.8	60.1	53.4	98.04	994.3	151.1	121.6
Crude protein	111.5	467.4	157.8	325.0	-	-	89.3	215.5
ME[d]	2.25	2.58	2.36	2.38	-	-	1.30	2.41
Zinc[e]	71.71	76.77	88.26	70.52	121.78	60.00	88.59	75.09
Iron[e]	33.79	74.00	65.48	28.63	5246.62	3480.67	67.37	286.21
Manganese[e]	19.43	32.69	70.07	11.23	807.93	36.24	116.71	52.49
Copper[e]	9.81	1.22	4.08	1.77	61.64	36.68	4.08	4.88
					Ingredient proportion ($g\ kg^{-1}$ DM)			
	580	270	50	50	40	10	-	-

[a]By-product from corn flakes manufacture; [b]Mineral suplement: Zn1.600 mg, Cu 600 mg, Mn 1.500 mg, Fe 1.100 mg, Co 10 mg, I 27 mg e Se 22 mg. q.s.p. 1000 g. [c]The matter collected direct in rumen after access pasture; [d]Metabolizable energy - estimated considering 82% of digestible energy (Mcal kg^{-1}) (NRC, 1989); [e]mg kg^{-1} DM.

The experimental area consisted of two paddocks, approximately 8 ha each, with an average stocking rate of six animals per hectare, where there rotation experimental period (60 days). The rate of occurrence and availability of the botanical components analyzed in the study area during the experimental period were demonstrated by the predominance of Panasco grass (*Aristida setifolia*. H. B. K.) with 78.20%, followed by Pereiro (*Aspidosperma piryfolium*) with 10.62%, and Catingueira (*Caesalpinia pyramidalis*) with 12.23%. The average availability was estimated at 1674.5 kg of natural matter ha^{-1}.

The ruminal extrusa selected in pasture according to methodology described by Santos et al. (2008), by the animal was collected and stored in a freezer to comprise samples by composed of animal and period, to estimate dry matter intake (DMI) in pasture from the estimate of fecal production and dry matter digestibility of the extrusa from four castrated male Canindé goats fitted with permanent rumen cannulas, weighing 22 ± 2.23 kg and approximately 12 months old. Fecal production was estimated from 200 g samples using the indigestible neutral detergent fiber (iNDF) internal indicator, and then homogenized. Samples were formed per animal and period from ruminal extrusa and fecal samplings.

DMI from pasture was estimated by sampling feces excretion and dry matter digestibility of diet. After the experimental period, the samples were thawed, weighed and dried in a forced air oven at 55°C for 72h, and then ground in a knife mill with 1-mm sieves. Samples were then incubated in nylon bags inside the rumen (*in situ)* of goats via ruminal cannula during 240 hours (CASALI et al., 2008). After incubation, the residue was subjected to neutral detergent fiber (NDF) analysis to determine INDF. Estimated pasture DMI was determined from the fecal production estimate and extrusa DM. Extrusa digestibility was assessed using the *in vitro* dry matter digestibility (IVDMD) method as proposed by Tilley and Terry (1963). An intake regression equation was formulated from the DMI (BW, kg$^{0.75}$) of cannulated animals, considering supplementation level, resulting in the equation $y = 0.045 + 0.020x$, in which y = pasture DMI kg kg$^{-0.75}$ of BW and x = supplementation level. After applying the supplementation level into the equation, the following was obtained: 0.045, 0.055, 0.065, 0.075 kg kg$^{-0.75}$ of BW per day for 0.0, 0.5, 1.0 and 1.5%, respectively. These values were then used to estimate the DMI of animals in the nutritional requirements experiment. Total DMI was determined by combining pasture intake and concentrate intake, and mineral intake was estimated by determining its concentration in extrusa and concentrate (Table 1), multiplied by DMI.

The slaughter time of each animal group occurred as the animals in the 1.5% supplementation group based on BW reached 25 kg; with an average of 120 days of experiment. The animals were subjected to a 16-hour liquid and solid fast, and then weighed to obtain shrunk BW (SBW). Slaughter took place by stunning using the non-penetrating percussive concussion method, followed by bleeding through cutting of the carotid and jugular, in accordance with current legislation (BRASIL, 2010). After skinning and bleeding, the warm carcass was separated from individual components, which were weighed separately, including blood, internal organs (spleen, bladder, heart, esophagus, liver, kidneys and pancreas), respiratory tract, reproductive organs, total fats, digestive tract empty (DTE), tongue, tail, skin, head and legs.

Empty BW (EBW) was determined as the sum of warm carcass weight (WCW), skin, head, legs, tail, blood, DTE and internal organs (EBW = WCW + blood + internal organs + DTE + tail + skin + heads + legs).

The animal's entire body was individually conditioned in plastic bags, frozen, then cut with a band saw and ground to create a representative sample (800 g), which was pre-dried in a forced air oven at 55°C and later triturated in an industrial blender.

The samples carcass were defatted by ethyl ether extraction (Fat - method number 920.39) in a Soxhlet-type device (AOAC, 1990), triturated in a ball mill and stored in closed plastic containers. Levels of DM (with fat) were determined in an oven at 105°C until reaching constant weight; the levels of mineral matter (MM) and crude protein (CP) were determined as mentioned for the ingredients of the experimental concentrate, in fat-free samples.

DM (method number 930.15), MM (method number 924.05) and CP (method number 984.13) were calculated according to the method described by AOAC (1990). Gross energy (GE) was determined using a Parr adiabatic calorimetric bomb and metabolizable energy (ME) was estimated as 82% of digestible energy (DE - 2.94 Mcal kg^{-1}) (NRC, 1989).

The analyses to determine the microminerals under study in the ingredient samples of the concentrate, extrusa and defatted animal body were carried out by acid digestion as recommended by Tedesco et al. (1995). A mixture of nitric acid

(HNO_3), perchloric acid ($HClO_4$) and hydrogen peroxide (H_2O_2) was used to decompose the samples, resulting in a mineral extract, from which dilutions were made to determine the concentration of Zn, Fe, Mn and Cu; the readings were made using an atomic absorption spectrophotometer.

Initial empty body weight (EBWi) of the animals slaughtered at the end of the experiment was estimated from the regression equation developed from the "reference animals" (Eq. (1)), by subtracting the final empty body weight (EBWf) from EBWi to obtain empty body weight gain (EBWG).

$$\text{EBWi (kg)} = 0.05070 \pm 3.94 + 0.77460 \pm 0.26 \text{ BWi (kg)} \tag{1}$$

Estimated body composition was obtained from a logarithmized allometric equation (Eq. (2)), using the amount of nutrient present in the empty body as the dependent variable and EBW as the independent variable, according to the method described by ARC (1980).

$$\text{Log}_{10} \text{ (component amount, g)} = a + [\, b \times \log_{10} \text{ (EBW, kg)}] \tag{2}$$

For weight gain composition, the comparative slaughter technique was used as described by ARC (1980). All animals were used for the estimate of weight gain composition.

For the estimate of net micromineral requirements for EBWG (Eq. (3)), the logarithm regression equation of the amount of nutrient present in the empty body (Eq. (2)) was derived from the logarithm of EBW, in which [Component] = amount of micromineral per unit of EBWG (g kg^{-1} gain); EBW = empty BW (kg); a = intercept; b = regression coefficient of the logarithmized allometric equation for body composition.

$$[\text{Component}] = b \times 10^{a} \times \text{EBW}^{(b-1)} \tag{3}$$

Net micromineral requirements for BW gain (BWG) were obtained by converting EBW into BW. The weight gain composition values were divided by the correction factor generated from the ratio between BW and EBW. Moreover, the requirements were calculated, not only by the factorial method, but by the regression of mineral intake as a function of weight gain.

The statistical design was entirely randomized, with four treatments and ten replications, according to the mathematical model *Yij*= *ì* + *ti* + *eij*, where: *Yij* = value observed in the fragment that received treatment *i* for *j* times; *ì*= overall average of the population; *ti* = effect of treatment *i*; *eij* = random error. Statistical analyses were carried out using SAS software (SAS, 1999). The data were tested for homogeneity of variances using Bartlett's test (PROC GLM) and error normality was assessed by the Shapiro-Wilk test (PROC UNIVARIATE), which were prerequisites for the analysis of variance. PROC MEANS was used to obtain the means and standard error. PROC REG was used for linear regression analyses, using model y = a + bx, which demonstrates the behavior of dependent variable *y* as a function of independent variable *x*. PROC GLM was used for performance analysis, and Tukey's test was applied to evaluate the effect of treatments, at 5% significance.

Results and discussion

The performance expressed as body weight gain (g day^{-1}) of Canindé goats was influenced ($p < 0.0001$) positively by the supplementation levels, which in turn led to increased nutrient supply (Table 2). However, these gains were lower than those obtained by the NRC committee in 1981 and 2007 for animals with weight range and similar production. So, it is likely that this reduction has occurred because of differences in the genotype, rearing system and environment, as these factors were not taken into account in drawing up the recommendations of the committees concerned.

Table 2. Performance and body composition of Canindé goats grazing in the semiarid region of Brazil submitted to supplementation levels.

Item	BL	Supplementations level (%BW)				SEM	P-Value	
		0%	0.5%	1%	1.5%		L	Q
Initial BW (kg)	16.16	15.42	15.93	15.8	15.84	0.18	-	-
Final BW (kg)	16.16	15.22	18.66	21.60	23.34	0.56	<0.0001	0.13
SBW (kg)	14.89	13.66	17.16	19.86	21.25	0.54	<0.0001	0.07
EBW (kg)	11.59	11.02	11.96	14.82	16.33	0.46	<0.0001	0.31
BWG (g day^{-1})	-	-2.59	22.45	47.26	64.41	4.60	<0.0001	0.35
EBWG (g day^{-1})	-	-12.87	4.17	27.86	43.33	3.89	<0.0001	0.81
% EBW								
Fat	8.82	4.60	9.18	11.60	12.53	0.56	<0.0001	0.005
Crud protein	14.82	13.40	16.32	16.60	17.31	0.27	<0.0001	0.0002
Water	71.69	75.92	68.18	66.44	64.85	0.74	<0.0001	<0.0001
Mineral matter	4.06	4.77	4.64	5.52	4.98	0.14	0.25	0.47
% EBW x 10^{-4}								
Zinc	8.71	8.73	9.64	9.53	9.00	3.17	0.88	0.49
Iron	16.53	13.08	12.47	12.18	16.17	4.20	0.16	0.10
Manganese	8.67	5.63	6.04	4.01	8.83	1.12	<0.0001	<0.0001
Coppe	3.38	3.47	4.93	4.44	4.99	1.19	0.02	0.25

BL = baseline; BW = body weight; SBW = shrunk BW; EBW = empty BW; BWG = gain BW; EBWG = gain EBW; SEM = standart error of the mean; L = linear; Q = quadratic.

Body composition, expressed as empty body weight percentage (%EBW), was influenced by supplementation levels, in which the levels of fat, protein and Mn showed a linear and quadratic effect, whereas Cu showed only a linear effect. The amount of water stored in the body of animals decreased linearly as supplementation levels increased (Table 2). Empty body Zn and Fe levels were not influenced by supplementation levels.

The concentrations of Mn and Cu (%EBW x 10^{-4}; Table 2) in the empty body of Canindé goats in this study were higher than those obtained by Araújo et al. (2008) supplementing native Moxotó goats on pasture in the semiarid of Paraíba (Mn: 1.11, 1.05, 1.21 and 1.02; Cu: 1.47, 1.88, 1.77 and 1.71, for 0, 0.5, 1 and 1.5 %BW levels, respectively). The opposite was observed for Fe and Zn concentrations - levels of Fe and Zn rose and were higher (Fe: 46.85, 39.57, 44.82 and 49.00; Zn: 24.48, 25.09, 26.05 and 27.32 %EBW) for the same supplementation levels.

Fat is an element that features a positive relationship with animal age and weight - as empty body weight increases and physiological maturity is reached, muscle tissue is reduced and fat levels rise (SANZ SAMPELAYO et al., 2003), while body water levels are reduced. Thus, as animals experienced an increase in body fat, their water levels were reduced (Table 2), confirming the existence of an inversely proportional relationship.

In the present study, age in particular was not a decisive factor for the reduction in water stored in the body as supplementation levels rose, as the animals averaged nine months of age at the time of slaughter, with differences only in live slaughter weight.

The highest concentrations of trace elements were found in soft tissues such as the pancreas, liver, spleen, kidneys, accessory glands and digestive tract secretions (McDOWELL, 1992), as well as in the blood. Thus, studies on these elements and their metabolism are conducted predominantly to determine the chemical composition in individual tissues and organs, as these structures play important roles in storage and distribution.

Although the protein level (%EBW; Table 2) increased along with fat due to increased levels of supplementation, it is possible that, due to age (1 ± 0.2 years), the animals had not reached physiological maturity weight (average of 30 kg live weight), with considerable remaining muscle growth left.

From the equations listed in Table 3, micromineral body composition was estimated for the empty body of Canindé goats as a function of EBW (mg kg^{-1}; Table 3), showing increased concentrations of Zn (6.82%), Fe (1.67%), Mn (0.31%) and Cu (25.88%) when animal body weight increased from 15 to 25 kg BW.

Due to the low concentration of microminerals in animal bodies (Table 3), it may have led to data dispersion; although significant, equation adjustments for certain microminerals were reduced.

Body composition (g kg^{-1} EBW) of microminerals evaluated in this study were lower than those obtained by Araújo et al. (2008) except Mn and Cu. Both surveys were conducted in conditions of rearing system and similar environments, despite the native genotypes goats evaluated are different.

A behavior similar to that found in this study was observed by Bellof and Pallauf (2007), except for Fe and Cu, for which concentrations in the empty body of goats decreased from 32.9 to 28.0 and from 2.1 to 1.6 (g kg^{-1} EBW), respectively, when EBW rose from 15 to 50 kg. For Zn and Mn, increases were observed from 25.3 to 28.8 and 0.51 to 0.79 (g kg^{-1} EBW), respectively, in the same weight range.

By deriving regression equations of the body content logarithm for microminerals as a function of the EBW logarithm, we obtained the prediction equations of these nutrients per kg of empty body weight gain (EBWG) and the amount of nutrients stored in g kg^{-1} EBWE, in the different weight ranges (Table 4).

Micromineral deposition in weight gain (g kg^{-1} EBWG; Table 4) followed the same concentration trend in the empty body (g kg^{-1} EBW; Table 3), showing slight increases of 6.82% for Zn, 1.69% for Fe, 0.15% for Mn and 25.82% for Cu when body weight increased from 15 to 25 kg. Mn prediction was practically constant for the different weight ranges.

Table 3. Alometric regression of logarithm of body composition (mg kg^{-1} EBW) of Canindé goats grazing in the semiarid region of Brazil.

Variable	Intercept	Slop	R^2	RMSE[a]	S	BW[c] (kg)		
						15	20	25
EBW (kg)[b]	0.95435±0.67	0.79358±0.03	0.91	0.80	<0,0001	10.95	14.92	18.89
						mg kg^{-1} EBW		
Zinc	0.79415±0.29	1.12881±0.26	0.30	0.16	0.0001	8.,47	8.82	9.09
Iron	1.09079±0.29	1.03074±0.26	0.27	0.16	0.0003	13.54	13.67	13.77
Manganese	0.79774±0.13	1.00423±0.28	0.22	0.17	0.001	6.34	6.35	6.36
Copper	0.00739±0.24	1.54872±0.22	0.53	0.13	<0.0001	3.78	4.48	5.10

[a]RMSE = root mean square error; [b]EBW = empty BW; [c]Values were calculated from the equations.

Table 4. Estimates of mineral concentrations in the equation to predict net requirements for gain of the empty BW gain (EBWG) of Canindé goats grazing in the semiarid region of Brazil.

Variable	Equation	R^2	RMSE[a]	BW[b] (kg)		
				15	20	25
EBW (kg)				10.95	14.92	18.89
				mg kg^{-1} EBWG		
Zinc	$Zn = 7.0270 \times EBW^{0.1288}$	0.30	0.16	9.56	9.95	10.26
Iron	$Fe = 12.9699 \times EBW^{0.030}$	0.27	0.16	13.96	14.09	14.20
Manganese	$Mn = 5.6402 \times EBW^{0.0042}$	0.22	0.17	6.37	6.38	6.38
Copper	$Cu = 1.5752 \times EBW^{0.1288}$	0.53	0.13	5.86	6.94	7.60

Component concentration = $b \times 10^a \times EBW^{(b-1)}$, where the component is the mineral concentration per unit of EBWG, EBW is in kilograms, and α and b are coefficients determined from equations of table 3; [a]RMSE = root mean square error; [b]EBW = empty BW.

Micromineral contents from EBWG meet the net requirements for a 1-kg EBWG. These ranged between 13.96 and 14.20 mg for Fe, 9.56 and 10.26 mg for Zn, 6.37 and 6.38 mg for Mn, and 5.86 and 7.90 mg kg^{-1} for Cu EBWG, respectively, for animals with 15 and 25 kg BW (Table 4), in which Fe and Zn contents were lower than those obtained in the study by Araújo et al. (2008) with Moxotó goats in the same weight range; 53.48 to 70.84 mg for Fe, 30.43 to 35.74 mg kg^{-1} for Zn EBWG. For the concentrations of Mn and Cu, higher values were observed for Canindé goats compared with Moxotó goats, which ranged from 1.22 to 1.54 mg of Mn, and 1.93 to 2.32 mg kg^{-1} of Cu EBW. These differences may have occurred of changes that occur in body composition of gain in all genotypes compared with earlier conditions, low rainfall during the experimental period and gain weight later.

Data on weight gain composition (Table 4) were divided according to the correction factors generated from the BW-EBW ratio to obtain the net requirements per kg of BW gain, in order to isolate the influence of the difference in digestive tract content weight in animals at different weights - 1.37, 1.34 and 1.32, respectively for 5, 15 and 25 kg BW (Table 5).

Table 5. Net mineral requeriments for live weight gain (mg day^{-1}) of Canindé goats grazing in the semiarid region of Brazil.

BW[a] (kg)	ADG[b] (g day^{-1})	Net mineral requeriments (mg dia^{-1})			
		Zinc	Iron	Manganese	Copper
15	50	0.349	0.510	0.232	0.214
	100	0.698	1.020	0.464	0.428
20	50	0.371	0.526	0.238	0.259
	100	0.742	1.052	0.476	0.518
25	50	0.388	0.536	0.241	0.298
	100	0.776	1.072	0.482	0.596

[a]BW = body weighty; [b]Average daily gain.

The net requirements for weight gain of Canindé goats ranged from 6.98 to 7.77 mg Zn, 10.20 to 10.72 mg Fe, 4.64 to 4.82 mg Mn, and 4.28 to 5.96 mg kg^{-1} Cu BW gain (Table 5), values which were lower than the requirements found by Araújo et al. (2008) while evaluating Moxotó goats in conditions similar to those of this study, and the NRC (2007) to evaluate local goats. Because although both studies were carried out using native goats supplemented under grazing in Caatinga with comparable experimental period durations, the breeds, pasture availability and mean precipitation during the studies varied, justifying the different results found for micromineral requirements for gain. The Canindé goats in this study were subjected to an extended period of low rainfall (average 7.7 mm), which in turn led to a considerably longer period of feed shortage. In the study carried out by Araújo et al. (2008) with Moxotó goats, average rainfall during the experimental phase was 44.5 mm, a period in which feed availability was greater, enabling improved performance and nutrient deposition in the empty body.

This was only the second research study to involve data on micromineral nutritional requirements for native goats raised under grazing systems in semiarid conditions of Northeastern Brazil, making any comparison with other results more difficult. Thus, more studies should be carried out with animals raised in extensive or semi-extensive systems in order to generate data that better represent the environment conditions, and also perfect the methods for determining the chemical composition of animal bodies for these elements, given that current data vary considerably and focus more on protein and energy levels.

Conclusion

Net requirements (mg kg^{-1} BW gain) ranged from 6.98 to 7.77 for Zn, 10.20 to 10.72 for Fe, 4.64 to 4.82 for Mn, and 4.28 to 5.96 for Cu; dietary requirements (mg day^{-1}) were 230.82 (Zn), 113.89 (Fe), 233.33 (Mn) and 196.93 (Cu) for Canindé goats between 15 and 25 kg body weight, raised under grazing in the Paraíba semiarid.

References

ARAÚJO, M. J.; MEDEIROS, A. N.; GONZAGA NETO, S.; COSTA, R. G.; TEIXEIRA, I. A. M. A.; RESENDE, K. T.; MARQUES, C. A. T.; MELO, G. M. P.; SOMUZA, S. F. Mineral requirements for growth of Moxoto goats grazing in the semi-arid region of Brazil. **Journal of Animal Science**, v. 86, n. 1, p. 94, 2008. (E-suppl 2/J).

ARC-Agricultural Research Council. **The nutrient requirement of ruminant livestock**. Slough: Commonwealth Agricultural Bureaux, 1980.

AOAC-Association of Official Analytical Chemists. **Official methods of analysis**. 15th ed. Virginia: AOAC, 1990. v. 1.

BELLOF, G.; PALLAUF, J. Deposition of copper, iron, manganese and zinc in empty body growing of lambs of the breed German Merino Landsheep. **Animal**, v. 1, n. 6, p. 827-834, 2007.

BRASIL. Ministério da Agricultura. Instrução normativa n. 3 de 7 de Janeiro de 2000. Regulamento técnico de métodos de insensibilização para o abate humanitário de animais de açougue. S.D.A./M.A.A. **Diário Oficial da União**, Brasília, p. 14-16, 24 de Janeiro de 2000. Available from: <http://www.agricultura.gov.br/das/dipoa/Anexo%20Abate.htm>. Access on: Oct. 3, 2010.

CASALI, A. O.; DETMAN, E.; VALADARES FILHO, S. C.; PEREIA, J. C.; HENRIQUES, L. T.; FREITAS, S. G.; PAULINO, M. F. Influência do tempo de incubação e do tamanho de partículas sobre os teores de compostos indigestíveis em alimentos e fezes bovinas obtidos por procedimentos *in situ*. **Revista Brasileira de Zootecnia**, v. 37, n. 2, p. 335-342, 2008.

DORTON, K. L.; ENGLE, T. E.; HAMARB, D. W.; SICILIANO, P. D.; YEMM, R. S. Effects of copper source and concentration on copper status and immune function in growing and finishing steers. **Animal Feed Science and Technology**, v. 110, n. 1/4, p. 31-44, 2006.

GERASSEV, L. C.; OLALQUIAGA, J. R.; RESENDE, K. T.; SILVA FILHO, J. C.; BANAGURIU, S. Composição corporal e exigências nutricionais do cálcio e fósforo para ganho e mantença de cordeiros Santa Inês dos 15 aos 25 kg de peso vivo. **Revista Brasileira de Zootecnia**, v. 29, n. 1, p. 261-268, 2000.

LEE, J.; KNOWLES, S. O.; JUDSON, G. J. Trace-element and vitamin nutrition of grazing sheep. In: FREER, M.; DOVE, H. (Ed.). **Sheep Nutrition**. Wallingford: CAB International, 2002. p. 285-311.

MAHAN, D. C.; SHIELDS JR., R. G. Macro - and micromineral composition of pigs from birth to 145 kilograms of body weight. **Journal of the Animal Science**, v. 76, n. 2, p. 506-512, 1998.

McDOWELL, L. R. **Minerals in animal and human Nutrition**. San Diego: Academic Press, 1992.

NRC-National Research Council. **Nutrient requirement of goats**: angora, dairy, and meat goats in temperature and tropical countries. nacional academy of sciences. Washington, D.C.: National Academy Press, 1981.

NRC-National Research Council. **Nutrient Requirements of Dairy Cattle**. 6th Revised Edition. Washington, D.C.: National Academy Press, 1989.

NRC-National Research Council. **Nutrient Requirements of Dairy Cattle**. 7th ed. Washington, D.C.: National Academy Press, 2001.

NRC-National Research Council. **Nutrient requirements of small ruminants**: sheep, goats, cervids and new words camelids. Washington, D.C.: National Academy Press, 2007.

UNDERWOOD, E. J.; SUTTLE, N. F. **The Mineral Nutrition of Livestock**. 3rd ed. New York: Cabi International, 1999.

RAMÍREZ, R. G.; HAENLEIN, G. F. W.; GARCIA-CASTILHO, C. G.; NÚNEZ-GONZÁLEZ, M. A. Protein, lignin and mineral contents and in situ dry matter digestibility of native Mexican grasses consumed by range goats. **Small Ruminants Research**, v. 52, n. 3, p. 261-269, 2004.

SAS-Statistical Analysis System. **User's guide**: statistics. Cary: SAS Institute, 1999.

SANZ SAMPELAYO, M. R.; ALLEGRETTI, L.; GIL EXTREMERA, F.; BOZA, J. Growth, body composition and energy utilization in preruminant goat kids. Effect of dry matter concentration in the milk replacer and animal age. **Small Ruminants Research**, v. 49, n. 1, p. 61-67, 2003.

SANTOS, G. R. A.; BATISTA, A. M. V.; GUIM, A.; SANTOS, M. V. F.; SILVA, M. J. A.; PEREIRA, V. L. A. Determinação da composição botânica da dieta de ovinos em pastejo na Caatinga. **Revista Brasileira de Zootecnia**, v. 37, n. 10, p. 1876-1883, 2008.

TEDESCO, M. J.; GIANELLO, C.; BIASSANI, C. A.; BOHNEN, H.; VOLKSWEISS, S. J. **Ground analysis, plants and other materials**. 2. ed. Porto Alegre: UFRGS, 1995. p. 174.

TILLEY, J. M.; TERRY, R. A. A two stage technique for the *in vitro* digestion of forage crops. **Journal of British Grassland Society**, v. 18, n. 1, p. 104-111, 1963.

Received on April 9, 2012.

Accepted on August 31, 2012.