



## Macromineral requirements for growing Saanen goat kids

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### ABSTRACT

Understanding mineral nutritional requirements is important to providing diets that appropriately meet animals' needs. This study estimates the net requirements of calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na), and potassium (K) for growing goats. Twenty Saanen kids with initial body weights (BW) of 5 kg were used in this experiment. Of these kids, five were slaughtered at the beginning of the experiment, representing the initial body weight. Another six were slaughtered at BWs of 12.5 kg, and the remainder were slaughtered at BWs of 20 kg. All of the animals were fed *ad libitum* with a diet consisting of 50% roughage and 50% concentrate, which was formulated to meet nutritional requirements for gains of 150 g/day, except those that were slaughtered at the beginning of the experiment. The experimental design was completely randomized and used three treatments (slaughter weights). Logarithmized allometric equations were used to calculate the relationships between macromineral quantities and empty body weights (EBWs), and these relationships were observed to be highly significant ( $P < 0.0001$ ). The macromineral body composition per kilogram of EBW increased from 9.9 to 10.9 g of Ca/kg EBW, 8.8 to 9.0 g of P/kg EBW, and decreased from 0.78 to 0.65 g Mg/kg EBW, 2.0 to 1.1 g Na/kg EBW, and 2.7 to 1.6 g K/kg EBW in Saanen kids with BWs that ranged from 5 to 20 kg. The net requirements per 100 g of gained BW decreased from 1012 to 930 mg Ca, 851 to 727 mg P, 63 to 45 mg Mg, 94 to 43 mg Na, and 147 to 74 mg K for Saanen kids with BWs that ranged from 5 to 20 kg. Differences were not observed between Ca, P and Mg net requirements in our study and those that were proposed by NRC, however Na and K net requirements for gain were lower than recommended by NRC indicating that for these minerals, this system may not be the most appropriate for the formulation of goat diets in tropical conditions.

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### 1. Introduction

Despite representing just 4–5% of the body weights of animals, minerals are of vital importance in various tis-

sues for metabolic processes, the maintenance of osmotic pressure, acid–base equilibrium, and cellular permeability. These are also key components in the formation of hormones, enzymes, and tissues, such as bones (Underwood and Suttle, 1999).

Interactions among minerals in the body may result in increases or decreases in their availability, which hamper the maintenance of animals' dietary requirements and may result in metabolic disorders (NRC, 2007). Thus, understanding macromineral nutritional demands is important

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to the rational design of animal production systems so as to provide balanced diets that precisely meet the needs of the animals.

For many years, the mineral requirements of goats have been considered to be an intermediate between those of cattle and sheep (Meschy, 2000), and most feeding systems have recommended mineral consumption values that have been extrapolated from the diets of these two species (ARC, 1980; NRC, 1981; AFRC, 1998). The specific mineral requirements of various goat species have not been not comprehensively evaluated; hence, some of the currently used recommendations may be not be ideal.

Few studies have previously addressed the mineral requirements of goats, and even fewer studies have focused on Saanen goats in their initial growth phase. Therefore, this work estimates the body composition and net requirements of calcium, phosphorus, magnesium, sodium, and potassium for weight gain in Saanen kids.

## 2. Materials and methods

### 2.1. Local

The experimental procedures of this study were approved by the ethics commission of Universidade Estadual Paulista (UNESP), Jaboticabal campus. This study was conducted in the Goat facility of UNESP, Jaboticabal campus, São Paulo, located at 21°14'05" south latitude, 48°17'09" west latitude, and at an altitude of 615 m. During the experimental period, the average temperature was 23.3 °C, the maximum temperature was 30.3 °C, and the minimum temperature was 16.3 °C. The average relative humidity was 61.2%.

### 2.2. Animal and management description

Twenty intact male Saanen kids that had initial body weights (BW) of 5 kg and an average age of 16 days were used in this study. After birth, the kids were identified and housed in cages measuring 0.50 m × 1.00 m. These kids were provided with feeders and drinkers and were distributed in a brick shed with a metal roof and a ceiling height of 4.00 m.

The suckling period was 49 days. During the first three days, the kids received colostrum. From the 4th to 40th day of life, milk was provided at a maximum quantity of 1.5 l, twice a day, at 0700 and 1700 h. From the 41st to the 48th day of life, the kids were suckled only in the afternoon, receiving 750 ml of milk. On the 10th day of life, they were dehorned, and close to weaning, they were given a single dose of 2 ml of injectable iron dextran, containing 10 mg of iron per ml and a dose of 2 ml of ivermectin 1%.

The animals were randomly assigned to one of three treatments, which were defined based on the slaughter weight of the animals (5, 12.5 and 20 kg BW). Five animals with BWs of 5 kg were slaughtered at the beginning of the experiment, six animals were slaughtered when they all reached BWs of 12.5 kg, and the nine remaining animals were slaughtered when they reached BWs of 20 kg. The kids were weighed weekly to monitor development.

### 2.3. Diet

The experimental diet was composed of dehydrated corn plant (*Zea mays* L.) (whole corn plant harvested with a shredder when the kernel milk line was approximately two-thirds of the distance down the kernel, dried for 72 h, and then ground in a 1-cm sieve), soybean meal (*Glycine max* L.), corn meal (*Zea mays* L.), sugarcane molasses (*Saccharum officinarum* L.), soybean oil, mineral core, and calcitic limestone (Table 1). Table 1 depicts the percentage and bromatological composition of the food, which was calculated to meet protein and metabolizable energy needs. This diet allowed the animals to achieve weight gains of 150 g/day, according to the recommendations of the AFRC (1998). The ration was provided during the morning and the afternoon beginning on the 7th day of life of the animals. All of the animals were fed *ad libitum*, and they were offered enough feed to ensure that there was about 15% leftover feed each day. Leftovers were

collected and weighed before the morning feeding in order to estimate daily consumption.

### 2.4. Chemical analyses

The ingredients of the diet were determined as dry matter (DM) (AOAC, 1990; method number 930.15) and ether extract (EE) (AOAC, 1990; method number 920.39). The neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin were analyzed via the methodology described by Van Soest et al. (1991) in an Ankom 200 fiber analyzer (Ankom Technology Corporation) and with the use of amylase in the NDF analysis. The quantity of N was determined via the Dumas combustion method (Leco model FP-528 LC, Leco Corporation), as described by Etheridge et al. (1998). The gross energy was determined using a "PARR" type bomb calorimeter. The digestible energy (DE) and the metabolizable energy (ME) were estimated via Eqs. (1) and (2) (Medeiros, 2001), respectively, with an average DM consumption of 435.43 g during the experiment.

$$DE \text{ (MJ/kg DM)} = 13.084(\pm 0.42) - [0.00128(\pm 0.0006) \times \text{DMI}] \quad (1)$$

$$ME \text{ (MJ/kg DM)} = 11.044(\pm 0.49) - [0.00068(\pm 0.0006) \times \text{DMI}] \quad (2)$$

The mineral analysis was performed by nitric-perchloric acid wet digestion (AOAC, 1990; method number 935.13 A(a)), wherein the solutions of calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), obtained after digestion were analyzed by atomic absorption spectrophotometry and phosphorus (P) was analyzed via the colorimetric method.

### 2.5. Slaughter procedures

When the pre-determined slaughter weight was reached, the animals were subjected to feed fasting for 24 h and water fasting for 16 h. The kids were weighed prior to slaughter in order to obtain the shrunk body weight (SBW). Slaughter was performed using humane electronarcosis stunning procedures followed by bleeding, which was performed at the carotid and jugular arteries, and the blood was collected and weighed. The gastrointestinal tract was removed and weighed before and after the contents were removed in order to obtain the empty body weight (EBW), which was determined by subtracting the weight of the contents of the gastrointestinal tract (CGIT) and the bladder from the SBW. The empty body of each animal was frozen, cut with a band saw, ground, and homogenized, and 500-g samples were collected for chemical analysis. These samples were thawed, and 100-g sub-samples were lyophilized for 48 h and then ground in a blender. Dry matter and mineral analyses in these samples were performed as described above.

### 2.6. Net requirements calculations

Body composition was predicted via a logarithmized allometric equation of the quantity of the minerals that were present in the empty body (g) as a function of the EBW (kg), as per ARC (1980) Eq. (3):

$$\log y = a + b \log x \quad (3)$$

where  $\log y$  = the logarithm of the total amount of minerals of the empty body (g),  $a$  = the intercept,  $b$  = the coefficient of the regression of the mineral content as a function of the EBW, and  $\log x$  = logarithm EBW (kg).

Eq. (3) was differentiated to compute the estimates of the composition of the gain at various EBWs Eq. (4).

$$y' = b 10^a \text{EBW}^{(b-1)} \quad (4)$$

where  $y'$  = is the nutrient per unit of empty weight gain (in g/kg of gain), EBW is in kilograms,  $a$  and  $b$  are coefficients determined from a linear regression Eq. (3).

To estimate the net mineral requirements for BW gain, the values of body composition of gain were divided by the BW to EBW ratio factor.

### 2.7. Statistical analysis

The experiment was set up in a completely randomized, unbalanced design that used three treatments (slaughter weights). The regression equations were obtained using regression procedure of SAS version 9.0 (SAS Inst. Inc., Cary, NC).

**Table 1**

Chemical composition of the ingredients of the diet and the experimental diet (% on dry matter basis).

Ingredient	Ingredient participation	DM	CP	EE	NDF	ADF	Lig	Ca	P	Mg	Na	K	DE <sup>a</sup>	ME <sup>a</sup>
Dehydrated corn plant	46.88	91.21	6.49	0.78	84.63	17.34	5.88	0.2	0.1	0.28	0.14	0.38	–	–
Cracked corn grain	25.91	90.30	10.50	3.50	20.61	1.57	1.26	0.1	0.3	0.13	0.02	0.34	–	–
Soybean meal	19.32	90.57	54.58	0.50	12.84	9.67	1.49	0.2	0.7	0.35	0.14	1.52	–	–
Molasses	4.29	87.56	3.46	–	–	–	–	0.9	0.1	0.47	0.06	0.18	–	–
Soybean oil	0.81	99.00	–	–	–	–	–	–	–	–	–	–	–	–
Mineral supplement	1.99	94.20	–	–	–	–	–	15.7	7.3	5.99	7.86	3.93	–	–
Limestone	0.80	99.99	–	–	–	–	–	33.8	0.1	5.30	5.69	1.27	–	–
Cow milk	–	12.38	28.5	28.13	–	–	–	–	–	–	–	–	–	–
Experimental diet	–	90.88	16.46	1.37	47.5	10.4	3.37	0.77	0.41	0.41	0.30	0.66	12.73 <sup>b</sup>	10.75 <sup>b</sup>

DM = dry matter; CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; Lig = lignin; Ca = calcium; P = phosphorus; Mg = magnesium; Na = sodium; K = potassium; DE = digestible energy; ME = metabolizable energy.

<sup>a</sup> MJ/kg DM.

<sup>b</sup> Medeiros (2001).

### 3. Results

The kids reached predetermined slaughter weights of 5, 12.5, and 20 kg at an average of 15 ( $\pm 8$ ), 66 ( $\pm 10$ ), and 91 ( $\pm 14$ ) days of age, respectively.

The logarithmized allometric equations used to calculate the relationships between macromineral quantities and empty body weights were observed to be highly significant ( $P < 0.0001$ ) and provide an excellent data fit ( $R^2$  varying between 0.92 and 0.98).

The macromineral body composition of each Saanen kid was estimated using the equations presented in Table 2 for all of the investigated BWs (Fig. 1a and b). Ca and P concentrations increased and Mg, Na, and K concentrations decreased as kid BWs increased.

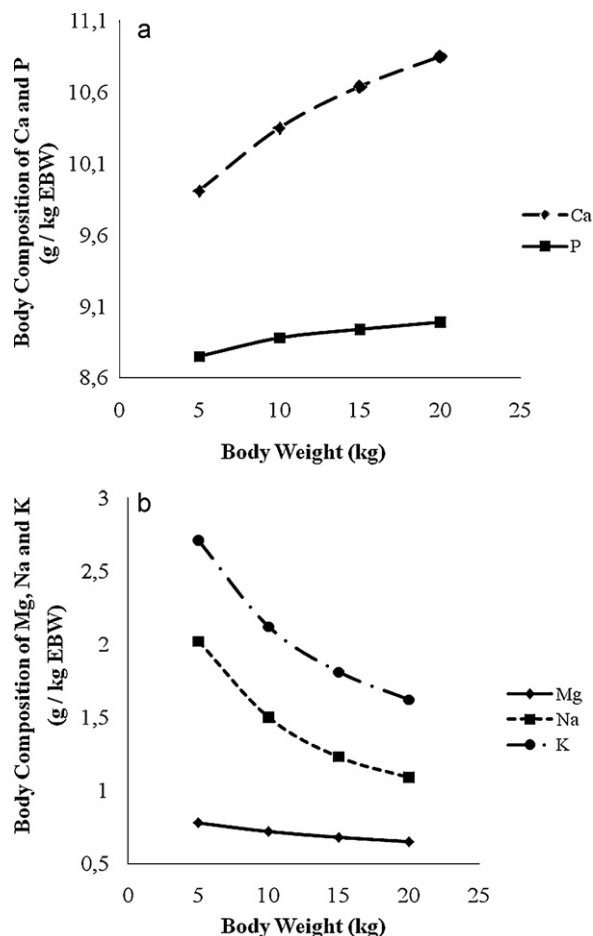
Table 3 depicts the composition of empty weight gain in Saanen kids that had BWs ranging from 5 to 20 kg. As expected, the composition of empty weight gain followed body composition, with increases of approximately 10% for Ca and 2% for P, and decreases of 15% for Mg, 46% for Na, and 38% for K.

In order to calculate the net mineral requirements for BW gain (Table 4), the values of composition of empty weight gain were divided by the correction factors that were determined by the BW/EBW ratio, which were calculated as 1.05, 1.18, 1.23, and 1.25 and corresponded to animals with BWs of 5, 10, 15, and 20 kg, respectively. The data demonstrate a decrease in the net requirements for body weight gain for all of the macrominerals as animal BW increased.

### 4. Discussion

The kids that were used in this study were in the initial stage of growth, wherein bone tissues grow more quickly in relation to general body development, which is also rapid in young animals in comparison to adults (Lawrence and Fowler, 1997). This, together with the fact that more than 90% of the Ca and 80% of the P that are present in the animal are found in the bone tissue (Underwood and Suttle, 1999), may explain the observed increase in the deposition of these two minerals in animals with BWs below 20 kg.

The results obtained for Ca and P are consistent with those that have been reported for Moxotó kids (Araújo



**Fig. 1.** Mineral body composition of (a) calcium (Ca) and phosphorus (P), (b) magnesium (Mg), sodium (Na) and potassium (K), in g/kg of EBW, of Saanen kids at different body weights.

et al., 2010) and Canindé kids (Souza et al., 2010) with BWs ranging from 15 to 25 kg, which were observed to have increasing concentrations of these minerals with increasing BW. Bellof and Pallauf (2007) also observed an increase in the concentration of Ca in German Merino Landsheep as the animals increased in BW.

**Table 2**

Allometric equations to estimate body composition in minerals (calcium, phosphorus, magnesium, sodium and potassium) of Saanen kids.

Variables	Regression equation	R <sup>2</sup>	P
EBW (kg)	EBW = 1.015 + 0.746 × BW	0.98	<0.0001
Ca (g)	Log Ca = 0.94481 + 1.07560 × Log EBW	0.96	<0.0001
P (g)	Log P = 0.92795 + 1.02184 × Log EBW	0.98	<0.0001
Mg (g)	Log Mg = -0.00832 + 0.85217 × Log EBW	0.96	<0.0001
Na (g)	Log Na = 0.64711 + 0.49333 × Log EBW	0.95	<0.0001
K (g)	Log K = 0.72154 + 0.57343 × Log EBW	0.92	<0.0001

Ca = calcium; P = phosphorus; Mg = magnesium; Na = sodium; K = potassium; EBW = empty body weight (kg); BW = body weight (kg).

**Table 3**

Equation to predict and the composition of gain in empty body weight of the calcium, phosphorus, magnesium, sodium and potassium at different BW of Saanen kids.

	Body weight (kg)				Equations
	5	10	15	20	
EBW (kg)	4.75	8.48	12.21	15.94	
Ca (g/kg EBW gained)	10.65	11.13	11.44	11.67	Ca = 9.4717 × EBW <sup>0.0756</sup>
P (g/kg EBW gained)	8.96	9.07	9.14	9.12	P = 8.65631 × EBW <sup>0.02184</sup>
Mg (g/kg EBW gained)	0.66	0.61	0.58	0.56	Mg = 0.83598 × EBW <sup>-0.14783</sup>
Na (g/kg EBW gained)	0.99	0.74	0.62	0.54	Na = 2.1890 × EBW <sup>-0.5066</sup>
K (g/kg EBW gained)	1.55	1.21	1.04	0.93	K = 3.0201 × EBW <sup>-0.42657</sup>

EBW = empty body weight; Ca = calcium; P = phosphorus; Mg = magnesium; Na = sodium; K = potassium.

Interestingly, Teixeira (2004) reported a decrease in the concentrations of Ca and P in F1 Boer × Saanen kids that had BWs ranging from 5 to 25 kg. This discrepancy may be explained by the fact that the Saanen–Boer goat cross that was used in that experiment had a higher proportion of muscle in relation to bone in comparison to dairy goat breeds (Pereira Filho et al., 2008; Yáñez et al., 2009).

It is well known that the Ca:P ratio affects the absorption and excretion of both minerals (Underwood and Suttle, 1999). According to the AFRC (1991), bone tissue has a Ca:P ratio of 2:1, whereas soft tissues have a ratio of 1.2:1. In this study, we calculated a body Ca:P ratio of around 1.2:1.

In contrast to the observed increases in Ca and P concentrations, there were marked decreases in Mg, Na, and K concentrations in the EBW gained weight as BW increased from 5 to 20 kg (Fig. 1b). These decreases in Mg, Na, and K deposition have also been reported in sheep by other authors (Geraseev et al., 2001; Bellof and Pallauf, 2007).

Adipose tissues deposit later in relation to general body development (Berg and Butterfield, 1976; Lawrence and Fowler, 1997); hence, the deposition of fat increases at the

expense of other tissues as the animals age (Mtenga et al., 1996; Pereira Filho et al., 2008). Because there are negligible quantities of minerals in adipose tissue, a dilution effect occurs in the body. Clawson et al. (1991) calculated mineral compositions in the bodies of animals using defatted material and observed that these compositions remain relatively constant throughout the animals' lives; hence, the dilution of mineral composition due to an increased fat deposition has been accounted for in this study. Nour and Thonney (1987) also observed a negative relation between body fat content and mineral contents in the body.

The use of Saanen kids in this study may explain why fat deposition was not sufficient to dilute Ca and P concentrations in contrast to Na, Mg, and K concentrations, because dairy breed animals have high proportion of bone tissue (Berg and Butterfield, 1968, 1976; Pfuhr et al., 2007).

According to Ahmed et al. (2000) Na concentrations usually decline with age, in part due to the decrease in extracellular content that occurs between birth and puberty (Brozek, 1961) because Na is the primary cation in extracellular fluid (Studzinski et al., 2006). Decreasing K

**Table 4**

Net mineral requirements for live weight gain (mg/day) of Saanen kids.

BW (kg)	ADG (g)	Net requirement (mg/day)				
		Ca (mg/day)	P (mg/day)	Mg (mg/day)	Na (mg/day)	K (mg/day)
5	100	1012	851	63	94	147
	200	2024	1702	126	188	294
	300	3036	2553	189	282	441
10	100	944	769	52	63	102
	200	1888	1538	104	126	204
	300	2832	2307	156	189	306
15	100	931	744	47	50	85
	200	1862	1488	94	100	170
	300	2793	2232	141	150	255
20	100	930	727	45	43	74
	200	1860	1454	90	86	148
	300	2790	2181	135	129	222

BW = body weight; ADG = average daily gain; Ca = calcium; P = phosphorus; Mg = magnesium; Na = sodium; K = potassium.

levels may accompany this decrease in Na concentration because the organism needs to maintain a constant Na:K ratio in order to maintain osmotic equilibrium. Throughout this study, the Na:K ratio remained constant at around 0.6, the constant Na:K ratio has also been observed in goat kids (Araújo et al., 2010) and sheep (Geraseev et al., 2001) in a similar body weight.

The AFRC (1998) has not presented data for the mineral composition of gain in kids, and it has recommended the published data by the ARC (1980). According to this feeding system, the mineral composition that is required for 1 kg of empty weight gain for sheep is constant and independent of the weight of the animal, wherein it is specifically 11 g for Ca, 6 g for P, 0.41 g for Mg, 1.80 g for K, and 1.10 g for Na. Contrary to what has been reported by the ARC (1980), we found that the macromineral compositions of the EBW gains that were investigated in this study were not constant and varied as the animals increased in weight. This occurs because tissues have different growth rates throughout the life of the animal, and the destinations of specific nutrients depend on the tissues that are most rapidly developing at that time.

The net requirement recommendations of the NRC (2007) for weight gain in kids are 9.4 g of Ca, 6.5 g of P, 0.40 g of Mg, 1.6 g of Na, and 2.4 g of K per kg of weight gain. These recommendations are similar for Ca, P and Mg and greater for Na and K in our study.

Araújo et al. (2010), working with Moxotó breed goats, observed Ca, P, and Mg net requirements for growth that were similar to those observed in our study; however, the animals that were studied by these authors required more Na and K than the Saanen goats that we studied. This discrepancy may be explained by the fact that this study used confined animals, whereas the goats that were used by Araújo et al. (2010) were kept at pasture. According to McDowell (1992), animals that receive some relief from high temperatures, such as shade, had lower salt requirements due to reductions in perspiration-induced water and Na losses.

To date, few studies have evaluated the body composition and nutritional mineral requirements of goats, and these studies have evaluated animals with different genotypes, animals at different developmental stages, and animals kept in different experimental conditions; hence, a comparison of existing work in the literature is difficult. Therefore, there is a need for new research into the mineral requirements of goats, as well as to develop mathematical models that more efficiently represent the biological behavior of nutrient deposition. It will also be critical to perform studies using different diets, systems of production, sexes, and ages in order to better understand what causes variation in nutritional mineral requirements.

## 5. Conclusions

The body composition of macrominerals per kilogram of empty body weight increased from 9.91 to 10.85 g/kg EBW for Ca, 8.75 to 8.99 g/kg EBW for P and decreased from 0.78 to 0.65 g/kg EBW for Mg 2.01 to 1.09 g/kg EBW for Na, and 1.62 to 2.71 g/kg EBW for K in Saanen goats with BWs ranging from 5 to 20 kg. Mineral net requirements, per 100 g of gained BW, decreased from 1012 to 930 mg Ca, 851 to

727 mg P, 63 to 45 mg Mg, 94 to 43 mg Na, and 147 to 74 mg K for Saanen kids with BWs that ranged from 5 to 20 kg.

This study demonstrates that growing Saanen kids have nutritional mineral requirements for Ca, P and Mg similar from those that have been recommended by the international feeding systems, but Na and K were lower than recommended by NRC (2007) and the data presented herein will help guide future research involving mineral requirements for goats.

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