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Magnesium requirement of young West African dwarf goats for maintenance

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Abstract

Eighteen growing West African dwarf WAD goats of equal number of sexes, aged 6-7 months with average weight of 6.23 ± 0.50kg were used in a 9-wk feeding trial to study the influence of dietary supplementation of magnesium sulphate ($MgSO_4.7H_2O$) at 0, 1 and 2% in isonitrogenous (11.50%CP) and isocaloric (2.88 ME Mcal/kg) diets with a view to estimating Mg requirement for maintenance. The three levels of supplementation were used to obtain three diets 1, 2 and 3 containing 0.02, 0.13 and 0.22% Mg respectively. The goats were divided into three groups of six animals, and each group was randomly allotted to one of the three diets. Results showed that Mg supplementation had significant ($P < 0.05$) effects on Mg intake, absorption, balance, serum Mg, red blood cell (RBC) and white blood cell (WBC) counts; and highly significant ($P < 0.01$) effects on dry matter intake (DMI), growth rate, serum glucose (GLU), total protein (TP) and haemoglobin (Hb) concentration. Treatment effect on packed cell volume (PCV) was not significant ($P > 0.05$). The general trend depicted an increasing dietary Mg supplementation with decreased DMI, body weight change, serum GLU, TP, PCV, Hb concentration, RBC and WBC counts at 2% Mg level of supplementation. Dietary supplementation of Mg at 1% (D2) however supported best animal performance as evidenced by the outstanding responses of the goats in terms of DMI (0.446 g/day/kgLW), body weight change (30.01g/day), feed conversion ratio (14.48), Mg digestibility (80.51%), Mg balance (0.091 g/day/kgLW), PCV (36%) and TP (70.70g/l). [illegible] model relating Mg intake to balance gave Mg minimum requirement of young WAD goats for [illegible] kgLW with significant ($P < 0.05$) correlation coefficient ($r = 0.98$). Dietary [illegible] H_2O however must not exceed 1% of the total diet to avert a decline in animal [illegible]

[illegible] requirement, goats, maintenance

[illegible] balanced rations in [illegible] minerals and vitamins [illegible] stages in all classes [illegible] importance for optimal [illegible] and good health (Youssef, 1992). In many developing countries the concept of formulating and balancing ruminant livestock rations according to their physiological stages is generally not practiced. Consequently, livestock productivity is low and there is serious infertility in dairy cattle, high

mortality rates in lambs and kids, with general prevalence of metabolic disorder. It is also a common practice for livestock producers in the tropics not to supplement grazing livestock. In some farms livestock are given crop residues and agro industrial by-products with or without mineral supplementation except perhaps common salt. Animals therefore depend solely on the given feeds to supply their mineral requirements and rarely can these feeds completely satisfy their needs. A deficiency in any of the 23 mineral elements considered (Kessler, 1991) essential for goats will limit digestion, absorption and utilization of all dietary nutrients, as will toxic levels of the minerals.
Minerals are interrelated and balanced against each other, and most often cannot be considered as single elements with independent and self sufficient roles in organized bodily processes (McDowell, 1992). However, mineral utilization by goats is yet to be given full attention it deserves as evidenced by fragmentary information in literature. Most of the available data are extrapolated figures obtained from cattle and sheep (Kearl, 1982; Kessler, 1991). This is more complicated by the fact that many goats farming systems and breeds exist in the world. In addition, there are substantial evidences on the unique metabolic differences between goats and other domestic ruminants (Morand-Fehr *et al.*, 1985; Owens and Waheed, 1985) which justify the need for estimating goat mineral requirements for maintenance and production. Magnesium (Mg) is one of the major elements required for important body functions or processes in animal nutrition (Pike and Brown, 1975). Animal diets must therefore contain adequate level of Mg for optimal productivity.
Though few experiments on Mg utilization by WAD goats during gestation (Babayemi *et al.*, 2000), lactation (Bawala *et al.*, 2006) and growth (Sowande and Aina, 2001) have been reported; the present experiment as part of the general study on Mg utilization by WAD goats was undertaken with a view to estimate the requirement for maintenance during growing period.

Materials and Methods

Animal Management and Experimental Design

Eighteen growing WAD goats, 9 does and 9 bucks, aged 6 – 7 months and weighing 6.06 - 6.50 kg, were purchased from local markets. They were quarantined for 3 weeks during which *Panicum maximum* and concentrate were given. The animals were treated against ecto and endo parasites and vaccinated with Tissue Culture Rinderpest Vaccine (TCRV) against *Pestes de petit ruminants* (PPR) about 2 - week post arrival. After certification for good health by the veterinarians, the animals were moved to the experimental site at the Goat Unit of the University's Teaching and Research farm, where they were housed in individual pens. Three experimental diets containing varying levels (0, 1 and 2%) of magnesium sulphate were prepared (Table 1). The animals were randomized into three groups of six goats balanced for body weight and sex. Each group was allotted to one of the three isonitrogenous (11.50% CP) and isocaloric (2.88Mcal/kg ME) concentrate diets (D1, D2 and D3 respectively) in a completely randomized design, for 9wk – feeding trial after one week of adaptation period. Daily feed offered was based on 4% body weight (NRC, 1981; Devendra and Mcleroy, 1982) while animals had unrestricted access to fresh water. The diets were supplied in two split doses, at 008h and 016h daily.

Data Collection

Animals were weighed at the start of the experiment and then once a week before feeding at 008h. Feed offered and residues were weighed

Table 1: Composition (%) of the diets fed to young WAD⁺ goats

Ingredients	Diets 1	2	3
Cassava flour	52.52	51.50	50.49
Groundnut cake	13.48	13.60	13.71
Wheat offal	9.50	9.40	9.30
Grass hay,* chopped	13.00	13.00	13.00
Palm kernel cake	9.00	9.00	9.00
Salt (NaCl)	0.50	0.50	0.50
Oyster shell	1.00	1.00	1.00
Vit./Min. Premix	1.00	1.00	1.00
$MgSO_4.7H_2O$	0.00	1.00	2.00
Total	100.00	100.00	100.00

**Panicum maximum* ⁺WAD: West African dwarf ; Vitamin/Mineral Premix Composition (VitadizSG® for sheep and goats)
Each 2.5kg contains: Vit. A 10,000,000i.u; Vit. D3 2,000,000i.u; Calcium 600mg; Phosphorus 400mg. Iron 100g; Antioxidant 15g; Iodine 1g; Manganese 50g; Selenium 0.2g; Zinc 100g; and Cobalt 0.5g.

daily to estimate feed intake. The last ten days of the feeding trial involved the movement of the animals to individual metabolic cages modified for separate collection of faeces and urine. Daily collection of samples of faeces and urine was done in the morning before feeds and water were served. Total daily faeces and urine were weighed, and 20% of total faeces for each animal was oven dried at 80°C and bulked. The urine sample bottles were rinsed with 3ml of 10% diluted H_2SO_4 as preservative and about 20% of the total urine voided by each animal was stored at -20°C in a deep freezer until required for analysis. With hypodermic needle and 10ml calibrated syringe, blood samples were collected via jugular venipuncture at the start and close of the experiment into test tubes with or without ethylene diamine tetra-acetic acid (EDTA). Serum was harvested by manual centrifuging machine. Harvested sera and whole blood samples were stored at -20°C for biochemical and haematological analyses. Mg balance was calculated by subtracting the values of both faecal and urinary Mg excretion from intake. Requirement of Mg for maintenance was calculated using balance studies method (Akinsoyinu and Akinyele, 1979; Underwood, 1981; Akinsoyinu and Adeloye, 1983; Kessler, 1991) in which Mg intake(Y) values (g/day/kgLW) had a linear relationship with Mg balance (X) as given by the formula:

$$Y = \alpha + \beta X$$

Where,

α = the intercept on the Y axis

β = the linear regression coefficient.

The value of Y when X is hypothetically zero is an index of requirement for maintenance (Akinsoyinu and Akinyele, 1979; Akinsoyinu and Adeloye, 1983; Bawala, 2002). The relationship between Mg intake and sera Mg values was also examined using the above formula.

Chemical analysis

Proximate composition of the diets was determined (A.O.A.C., 1995). Individual samples of diets, faeces, urine and sera were analysed for their contents of Mg (Akinsoyinu and Adeloye, 1983; Bawala, 2002) with atomic absorption spectrophotometer model 420 (Gallenkamp London). Gross energy values of the diets were estimated with Gallenkamp ballistic bomb calorimeter. Haemoglobin concentration, PCV, WBC and RBC counts were determined according to standard procedures (Coles, 1974). Glucose and total protein in frozen sera (Sarko *et al.*, 1979) were determined.

Statistical analysis

Data obtained were subjected to analysis of variance (Gomez and Gomez, 1984). Treatment means were separated where applicable using Duncan Multiple Range Test (Duncan, 1955).

Results

The proximate composition of the diets fed to WAD goats is presented in Table 2. The diets were isonitrogenous (11.50% CP) and isocaloric (2.88 ME, Mcal/kg). The proximate composition of the three diets did not differ ($P > 0.05$). Control diet had the least Mg content (%DM) of 0.02 relative to 0.13 and 0.22 in diets 2 and 3 respectively. Contents (%) of Ca ranged from 1.48 to 1.51 with diet 1 having the least value. Corresponding P values were 0.18 to 0.20 with highest value in diet 3.

The performance characteristics of the goats are presented in Table 3. Dietary Mg highly significantly influenced ($P < 0.05$) dry matter intake (DMI) (kg/day). It increased from diet 1 (0.379) to 2 (0.446) and then declined (0.350) for animals on diet 3. Body weight changes (g/day) followed the same trends as DMI. Goats on diet 2 had significant higher value ($P < 0.05$) of body weight change (30.89) than their counterparts on diets 1 (22.06) and 3 (12.86) respectively. Feed conversion ratio for the diets was not significantly different ($P > 0.05$). Table 4 shows that significant differences exist among the treatment means for Mg utilization. There were significant differences ($P < 0.05$) observed in Mg intakes among the treatments with goats on diet 3 recording the highest value (0.136g/day/kgLW). Similar trends were observed for Mg in faeces and urine of the animals which increased with increasing dietary Mg. Animals on diets 2 and 3 had significantly higher ($P < 0.05$) values of Mg absorbed and balance than their counterparts on diet 1. The least and highest values of Mg balance were observed for goats on diets 1 and 3 respectively. A positive linear relationship existed between Mg intake (Y) (g/day/kgLW) and Mg balance (X). The relationship which was highly significant ($P < 0.01$) with positive correlation coefficient ($r = 0.98$) is described by the equation,

$$Y = 0.021 + 1.12X \text{............equation......(1)}$$

By extrapolation method, the Mg intake required to keep an animal at zero Mg balance is an index of Mg requirement for maintenance. This intake being the intercept on Y axis is 0.021g (21mg)/day/kgLW. Therefore, daily Mg maintenance requirement for a 6.23kg young goat is 130.83mg. Mg digestibility was also influenced by dietary treatments with goats on D1 and D2 having significantly ($P < 0.05$) least 69.47% and highest 80.51% values respectively. Highly significant ($P < 0.01$) negative correlation ($r = 0.91$) also existed between serum Mg level (mg/dl) and Mg intake (g/day/kgLW). Such relationship is represented by the equation below:

$$Y = 1.52 - 34.42X \text{............equation..............(2)}$$

Table 2: Proximate composition (%) of the diets fed to young WAD goats

	Diets		
Parameter	**1**	**2**	**3**
Crude protein	11.50	11.49	11.48
Crude fibre	20.14	20.36	21.52
Ether extract	3.53	3.79	3.86
Nitrogen free extract	57.79	57.25	55.60
Ash	7.06	7.12	7.53
ME (Mcal/kgDM)	2.90	2.86	2.88
$MgSO_4.7H_2O$	0.02	0.13	0.22
Calcium	1.51	1.49	1.47
Phosphorus	0.19	0.18	0.20

Table 3: Performance characteristics of WAD goats fed graded levels of magnesium

	Diets			
Parameter	**1**	**2**	**3**	**SEM**
Mean initial weight (kg)	6.50	6.06	6.13	1.02
Mean final weight (kg)	7.89	7.95	6.94	1.21
Mean live weight (kg)	7.19	7.01	6.54	0.95
Mean weight change (g/day)	22.06^b	30.89^a	12.86^c	1.36
Dry matter intake (kg/day)	0.38^b	0.45^a	0.35^c	0.02
Feed conversion ratio	17.18	14.43	27.24	1.33

^{a,b,c}: Means along the same row with different superscripts are significant (P< 0.05)
SEM: Standard Error of the Means

Serum Mg increased (P < 0.05) linearly with increasing levels of dietary Mg. It ranged from 1.50 to 3.30 (mg/dl) across the treatments (Table 5). Significant (P < 0.05) variations were observed for blood glucose and total protein. Goats on highest Mg supplementation diet 3 however had least values (mg/dl) of 63.30 and 57.40 respectively. Similar trend was also observed for haematological parameters (except WBC counts) with those on diet 3 having consistently lower values of PCV, 30%; Hb concentration, 10.30g/dl; and RBC counts 7.10 $x10^6$/ul than their counterparts on lower Mg supplementation (Table 5). In contrast however the WBC counts ($x10^3$/ul) of goats on diets 1 (13.10) and 2 (12.18) were significantly (P < 0.05) lower than the value of 16.10 obtained for goats on D3.

Table 4: Magnesium utilization (g/day/kgLW) by young WAD goats fed graded levels of magnesium sulphate

	Diets			
Parameter	**1**	**2**	**3**	**SEM**
Mg intake	0.095^{b}	0.118^{a}	0.136^{a}	0.009
Mg in faeces	0.029^{b}	0.023^{b}	0.032^{a}	0.007
Mg in urine	0.002^{b}	0.004^{a}	0.004^{a}	0.001
Mg absorbed	0.066^{b}	0.094^{a}	0.113^{a}	0.020
Mg balance	0.064^{b}	0.091^{a}	0.100^{a}	0.020
Mg in faeces as % intake	30.53	19.49	21.92	
Mg in urine as % intake	2.11	2.54	2.55	
Mg digestibility (%)	69.47^{c}	80.51^{a}	73.08^{b}	1.152

^{a,b,c}: Means along the same row with same superscripts are not significant ($P > 0.05$)
SEM: Standard Error of the Means

Table 5 Serum biochemical and haematological parameters of young WAD goats fed graded levels of magnesium sulphate

Parameter		DI	D2	D3	SEM
Biochemistry					
	X	1.62	2.50	2.25	
Serum Mg (mg/dl)	Y	1.50^{b}	3.01^{a}	3.30^{a}	0.24
	X	65.94	69.54	60.34	
Glucose (mg/dl)	Y	67.95^{b}	70.50^{a}	63.30^{c}	0.92
	X	63.40	69.56	60.25	
Total protein (g/l)	Y	62.60^{b}	70.72^{a}	57.40^{c}	0.42
Haematology					
	X	34.00	35.00	39.00	
PCV (%)	Y	34.00	36.00	30.00	1.17
	X	12.04	11.54	12.02	
Haemoglobin (g/dl)	Y	11.60^{b}	12.50^{a}	10.30^{c}	0.23
	X	13.10	11.50	11.60	
WBC ($x10^{3}$/ul)	Y	13.10^{b}	12.18^{b}	16.10^{a}	0.24
	X	9.40	8.20	8.40	
RBC ($x10^{6}$/ul)	Y	10.40^{a}	8.81^{b}	7.10^{b}	0.19

^{a,b,c}: Means along the same row with same superscripts are not significant ($P > 0.05$)
X and Y: pre and post experimental values respectively
SEM: Standard Error of the Means.

Discussion

The isonitrogenous (11.50% CP) and isocaloric (2.88 ME, Mcal/kg) diets were consistent with the report of Lu and Poitchobia (1988) for growing goats. Except for diet 1 (control) with 0.02%DM Mg level, dietary Mg levels of diets 2 (0.12) and 3 (0.22) are comparable to 0.10 – 0.20% DM recommended (NRC, 1981) for growing and lactating goats respectively. This suggests that 2% dietary Mg supplementation is higher for growing animals. Nevertheless, animals gained weight throughout the period indicating that the Mg inclusion might be adequate. There was higher dry matter intake of animals on diet 2 than those on control (diet 1) and diet 3 diets.

The declined DMI observed for goats on diet 3 could be due to increased dietary Mg supplementation which might have decreased acceptability of the diet. This is in consonance with the findings of Emery *et al* (1986) and Sowande and Aina, (2001).

Conversely, highest DMI value recorded for animals on diet 2 suggests that increasing the dietary Mg supplementation at 1% might increase acceptability of the diet with consequent higher rate of feed consumption. Goats in this study however had sufficient DMI which amounted to 5.5% of their average body weight. This is higher than 3.5 to 4.0% recommended by NRC (1981) but comparable to the range of 4.0 to 6.0% observed for tropical goats (Devendra and Mcleroy, 1982).

Mean weight changes (g/day) of goats were significantly ($P < 0.05$) different. The trend was similar to that of DMI as it decreased for goats on D3. This could be due to high dietary Mg supplementation with concomitant low acceptability. This also confirms the reports of Gentry *et al* (1978) and Babayemi (2000) in which high dietary Mg resulted in instantaneous reduction of DMI and weight gains following dietary Mg fortification from 2 to 4%. Highest daily weight gain recorded for goats on diet 2 (0.13%DM) suggest nutrient utilization that promoted efficient feed conversion rate via improved protein biosynthesis as well as carbohydrate and lipid metabolism (Aikawa, 1981; Bondi, 1987). The trends of Mg intake and utilization were in conformity with other reports (Suttle and Field, 1967 and Chester–Jones *et al.*, 1989). Higher level of faecal Mg excretion by goats on diet 3 could be due to high level of endogenous Mg which Rook and Storry (1962) reported as being substantial in ruminants and may be increased by a greater flow of saliva stimulated by the diet. Absorption of Mg also increased with increasing dietary Mg inclusion levels. The incidence of similar ($P > 0.05$) Mg absorption values for goats on diets 2 and 3 goats suggests a tendency for a decline (Capen and Rossol, 1989) with further increase in dietary Mg, as manifested in Mg digestibility (Table 4). Retention of Mg increased ($P < 0.05$) with dietary levels of magnesium sulphate supplementation. This agrees with an earlier report (Fishwick, 1978) which depicted a similar increase in Mg retention with increase in dietary Mg.

Relationship between Mg intake and balance gave the value (g/day/kgLW) of 0.021 (21mg) as minimum maintenance requirement for young WAD goats. This value is lower than 24.5mg and 0.3g reported for pregnant WAD goats (Babayemi, 1997) and Saanen goats (Pfeffer and Keunecke, 1986) respectively. It should be noted that pregnant animals need higher requirement due to higher physiological activities than the growing ones. The value (21mg) was however higher than a value of 3.5mg/kgLW which Kessler

(1991) reported as minimum endogenous Mg for maintenance. There are scanty pieces of information on Mg requirement of goats, particularly WAD goats in the tropics. The present value could be at variance with others reported elsewhere because the experiments were done under different situations in which breed types are of significant importance.

Serum Mg increased ($P < 0.05$) linearly with increasing levels of dietary Mg. This is similar to the trend reported by Emery *et al* (1986). Serum Mg is a good indicator of Mg status as it reflects dietary Mg adequacy, or deficiency in an animal. Except for goats on diet 3 (2% Mg sulphate inclusion) with highest value of 3.3mg/dl serum Mg values obtained for other groups were within the normal range of 1.8 – 3.2mg/dl (NCMN, 1973). Though no sign of Mg toxicity was noticed, goats on diet 3 tended towards hypermagnesemia thus suggesting that dietary $MgSO_4.7H_20$ supplementation at 2% might be too high for growing WAD goats. Moreover, the group suffered diarrhoea which may probably be a case of intolerance for higher dietary Mg (0.21% DM) level, and this could be detrimental to the health of the growing animals especially with prolonged feeding. The significant ($P < 0.05$) correlation between serum Mg and Mg intake ($r = 0.91$) indicates that serum Mg might take its source from dietary Mg intake.

Values of serum glucose and total protein recorded for the experimental goats, were within the limits (glucose 60.00 – 90.00mg/dl; total protein 5 – 7g/day) reported by Edward *et al* (1966) and Puls (1988) respectively for young goats. This not only signifies adequacy of dietary energy and protein of the experimental goats, but further unveils the roles of dietary Mg in the metabolism and utilization of carbohydrate and protein in the body. It also confirms the reports (Wester, 1987 and McDowell, 1992) that Mg is involved in the regulation of blood sugar levels, energy metabolism and protein synthesis.

Goats on diet 3 had least values for PCV (30%), Hb concentration (10.3g/dl) and RBC counts (7.10×10^6ul). This may be due to harmful effects of high (0.22%DM) dietary Mg content. While the mean values of WBC counts recorded for goats on diets 1 (0.02% DM) and 2 (0.13% DM) Mg levels were within the normal range (4.00 – 13.10×10^6/ul) reported by Duncan and Prasser (1986) for goats, the corresponding value recorded for those on diet 3 was higher ($P < 0.05$) and tended towards leucocytosis. This is not surprising as it would be recalled that the group showed symptoms of diarrhoea during the study which resulted in loss of weight. Affected animals however recovered as soon as the control diet was substituted.

Conclusion and recommendation

The general performance of goats on Mg supplemented diets was not adversely affected by the treatments. However, the following inferences seem to be meaningful from the experiment:

1. The minimum Mg requirement for maintenance of young WAD goats is 22mg/day/kgLW.
2. Supplementation of diets low in Mg can be done effectively with incorporation of supplemental magnesium sulphate ($MgSO_4.7H_2O$).
3. For improved animal performance characteristics such as dry matter intake, good feed conversion ratio and better Mg utilization such $MgSO_4.7H_2O$ supplementation, should not exceed 1% of the total diet (0.12% DM).

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