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Mineral Status of Sheep and Goats Grazing in the Arid Rangelands of Northern Kenya

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Abstract: A study was conducted in dry and wet season to determine macro and micro mineral status of growing sheep and goats in arid rangelands of northern Kenya. Forty four, 22 each of sheep and goats (1-2 year old), randomly purchased from three herds/flocks in study area, were sacrificed for whole liver and 12th right and left ribs. Homogenized liver samples pooled from all the lobes and defatted bone ash from whole left and right 12th ribs were used for determination of Ca, P, Mg, Cu, Fe, Zn and Mn status. Liver mineral analysis, showed that in sheep Cu (303 vs. 184 mg/kg DM), Zn (94.1 vs. 83 mg/kg DM) and Mn (13.2 vs. 7.5 mg/kg DM) were higher ($p<0.05$) in wet than dry season. In goats, season had no effect on Cu (274.28 vs. 236 mg/kg DM) and Fe (183 vs. 171 mg/kg DM), but had significant influence on Zn (102 vs. 126 mg/kg DM) and Mn (13.6 vs. 6.8 mg/kg DM). Sheep grazing in different pastures showed variation ($p<0.05$) in hepatic Zn, Cu and Mn contents, while goat varied ($p<0.05$) in hepatic Cu, Fe and Mn concentrations. Rib analysis indicated that season had significant effect ($p<0.05$) on sheep and goats DFF% ash. The rib Ca (359 vs. 362 mg/g), P (157 vs. 147 mg/g) and Mg (9.56 vs. 8.54 mg/g) contents of sheep was not influenced by season and grazing area ($p<0.05$), whereas goats rib Ca (360 vs. 326 mg/g), P (142 vs. 165 mg/g) content was affected by season and grazing area ($p<0.05$), but Mg showed no seasonal variation. In the wet season, liver and bone tissue of sheep and goats indicated adequate body status of Ca, Mg, Cu, Zn, Fe and Mn. However, in the dry season, sheep showed deficient levels of Zn, goats in Cu, while both species suffered from low liver Mn and rib Zn reserves. With the exception of P which was marginal in all seasons, mineral deficiencies affected animals mostly in the dry season. The liver and rib bone of sheep and goats has demonstrated seasonal fluctuation in tissue mineral reserve. Evaluation of specific minerals in different periods and body pools can be useful in the diagnosis of mineral status of animals. It can be concluded that, sheep and goats would benefit from P, Cu, Zn and Mn supplementation, particularly in the dry season.

Key words: Mineral status, bone and liver, sheep and goats, arid lands, northern Kenya

INTRODUCTION

In the low-rainfall areas of Africa and Asia, small ruminant production represents the principal economic output, contributing a large share of the income of farmers (Ben Salem and Smith, 2008). Sheep and goats are integral component of food production and livelihood systems of many pastoral and agro-pastoral farmers, most of who are found in Northern Kenya. The pastoralists keep these livestock to broaden their animal asset base and also to tap the product synergy derived from the two species.

The main breeds raised by the pastoralists in Northern Kenya are the Small East African goat, the Galla goat and Black Head Somali sheep (personal observation) and they are well adapted to the arid conditions found in this area. To meet the demand for meat demand by the emerging markets, farmers are seeking for ways that will lead to improved productivity of their livestock. Nutritional supplementation has been aimed at rectifying energy and protein deficiency in local feeds. The low performance of sheep and goats could be linked to disorders in other nutrients such as minerals. Throughout the tropics, mineral deficiencies and imbalances exert a significant effect on health and productivity of livestock (Aregheore *et al.*, 2007). Minerals have been recognized as potent nutrients and deficiency can impair utilization of other nutrients (Szefer and Nriagu, 2007) and thereby animal performance.

Minerals play an important role in growth, health and reproduction functions of livestock (Gonul *et al.*, 2009). Consequently, mineral deficiencies and imbalances can affect the productivity of ruminants (Kincaid, 1999). Sub-optimal mineral deficiency that affects growth and production is more serious than the manifested mineral deficiency showing clinical signs that can be corrected (Underwood, 1977).

In the arid areas of Kenya, sheep and goats depend on natural forages, salt licks and occasionally commercial supplements for their mineral requirements. However, there is considerable variability in the level of minerals in forages and mineral mixes (Corah, 1996). Only rarely can pasture forages completely satisfy all mineral

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requirements of grazing ruminants (McDowell *et al.*, 1993). The balanced mineral supplements promoted to improve livestock production in the Arid and Semi-Arid Lands (ASALs) of Kenya, may not correct the mineral deficits of small ruminants kept in specific regions. Prior to formulation of mineral supplements, thorough knowledge on mineral status of diets and body tissues of animals would be necessary. Of the body tissues, the liver and bone are the most commonly used in the assessment of micro and macro element levels in animals respectively (Underwood and Suttle, 1999). The liver is the primary storage for many of the essential minerals, which can augment diagnosis of mineral deficiency and adequacy in animals (Hall, 2005). The hepatic tissue often represents the status of several trace elements in animals (McDowell, 1992). The bone has proved a good indicator for the level of Ca, P and Mg concentrations in animals (Beighle *et al.*, 1993).

There is limited information on the mineral nutrition of sheep and goats in the pastoral production systems of Kenya. The objective of the study was to determine the levels of macro and micro-elements in the liver and rib of sheep and goats as indicators of their status.

MATERIALS AND METHODS

Study site: The study was conducted in Merille location (1°39'-55'N, 37°64'-85'E, 520 m asl) of Marsabit South district in northern Kenya. The area is inhabited by Rendille and Arial pastoral communities. The area is characterized by an arid climate. Rainfall records taken at the nearest station in Marsabit South show an annual mean of 275 mm (Xiaogang, 2005) and temperatures range between 28-42°C. The annual precipitation is distributed between two seasons, the short rains occurring from November to December and the long rains from March to May.

The landscape of the area is characterized by basement hill outcrops, a prominent seasonal river originating from Mathew ranges and the sedimentary plain sloping towards the east. The seasonal riverine valley forms an integral grazing ecosystem for small ruminants though out the year. The soil texture derived from basement system of rocks range from deep sandy, sandy loam to stony sandy loam and show high amounts of calcium, than the pH ranges from 7.0-8.5 (Touber, 1991). The study area, has acidic soils with pH of 6.0 and low P of 4.5 ppm (Lelon *et al.*, 2010).

The major vegetation types found in the locality are riverine woodland, dwarf shrub and shrub grass land. The dominant vegetation along the riverine includes *Acacia tortilis*, *Cordia sinensis*, *Salvadora persica* and under storey of annual grasses and herbs. In the sedimentary plains and hills, the woodland vegetation consists of *Acacia* and *Commiphora* communities and dwarf shrubs of *Indigofera spinosa*, *Sericocomopsis hildebrandtii* and *Barleria acanthoides*.

Flock/herd and animal sampling: Three semi-sedentary flocks/herds grazing different pastures in Merille location (namely Kamotonyi, Lorora and Salt lick) were selected for sampling of tissues in the dry and wet seasons. In each of the grazing sites, farmers willing to sell their 1-2 yr old uncastrated males Somali Black Head sheep and Small East African goats were identified. Twenty of each were then randomly selected from a list of all the available animals and purchased for slaughter. From each carcass, the liver and the left and right 12th rib were obtained for mineral determination.

Liver and rib bones samples: After slaughter, the right and left 12th whole ribs and the whole liver were removed from each carcass. The fresh liver and rib samples were packaged in tightly sealed nylon bags and immediately frozen at -20°C awaiting analysis. Sampling precautions taken included slaughtering animals on same day, peeling off the gall bladder from whole liver and minimizing blood contamination in tissues.

Mineral determination in liver and bone tissues: Sterile surgical gloves and blades were used to skin the capsule from whole liver tissues.

In each of the four quarters of the liver, i.e. the right, left, caudate and quadrate lobes, samples of about 20 g were collected in different sub sites of each lobe and pooled. During sampling, precautions were taken to avoid the fibrous tissues, fat and blood vessels. Pooled liver samples were placed in centrifuge tubes and homogenized by use of an utra-Turrax homogenizer (IKA model T25).

Homogenized samples were used for wet digestion (AOAC, 1998) and subsequent mineral analysis. The samples were digested overnight in 20 ml mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HCLO_4$) in the ratio of (3:1). The digested sample mixture was placed on hotplate until it turned clear. The solution was cooled, filtered, diluted to a final volume of 50 ml with deionized water and analyzed for copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) using an atomic absorption spectrophotometer (Perkin Elmer A Analyst 100, USA).

Stainless surgical blades and sterile gloves were used to remove flesh and cartilage from whole 12th right and left ribs. Whole ribs were cut into smaller pieces, pooled to one sample and oven dried to constant weight at 105°C. The bones were defatted by washing with petroleum ether, re-dried in the oven and ashed at 550°C for 12 hrs. The ashed bones were crushed to a fine powder by a pestle and mortar. Samples of ash weighing were digested in 1 ml concentrated hydrochloric acid, diluted to a final volume of 100 ml with deionized water and analyzed for calcium (Ca), phosphorus (P), magnesium (Mg) and zinc (Zn). The bone Ca and Mg, Zn and were analyzed by use of the AAS (Perkin Elmer A Analyst 100, USA). Phosphorus was determined calorimetrically by mixing 2 mls of extracted ash solution with 15 mls of mixed solution (vanadate-molybdate reagent) and diluted to a final volume of 50 ml. Standards ranging from 0-10 ppm were prepared with dipotassium phosphate (K_2HPO_4) and sample absorbance and standards were read at 450 nm using Beckman visible double beam spectrophotometer.

Statistical analysis: Liver and bone mineral data were analyzed by two-way ANOVA (GenStat 12th Edition, 2010) with season and herd as main factors and differences in mineral concentration between seasons and herds were separated by $LSD_{(0.05)}$.

RESULTS AND DISCUSSION

Trace mineral concentration in sheep liver: The hepatic concentration of Cu, Fe, Zn and Mn in sheep liver is shown in Table 1. Other than zinc, the mineral concentrations in the liver were higher ($p<0.05$) in the wet season than in the dry season. Also, with the exception of iron, the concentration of Cu, Zn and Mn varied ($p<0.05$) with the grazing area.

The mean hepatic copper content was 184 mg/kg DM of tissue during the dry season. This increased to 303 mg/kg DM in the wet season, a 65% increase. The effect of season on hepatic copper concentration affected by the grazing site. Thus, in Kamotonyi and Lorora, the copper levels were three and a half times higher in the wet season than in the dry season. However, in Salt lick grazing site, copper levels were lower in the wet season than in the dry season. The mineral concentration in the liver reflects the dietary status of animals (Webb *et al.*, 2001). Thus, differences between seasons and grazing sites could be attributed to variation in dietary Cu contents.

The concentration of liver Cu was within the range reported by Radositis *et al.* (1994) and similar to that analyzed by Ziehank *et al.* (2008) for sheep. In the dry season, copper levels in liver obtained in this study were similar to those reported by Bakhiet *et al.* (2007). The higher hepatic Cu in wet season could be ascribed to consumption of green plants higher in Cu by sheep. The increase in forage Cu during the wet season was associated to new plant tissues that are capable of extract soil copper, but as plants mature Cu was translocated to the root system (Sousa, 1978). In the dry season, sheep from Kamotonyi and Lorora grazing sites had liver Cu levels below normal of 182 mg/kg DM reported by Radositis *et al.* (1994) and can be considered to be Cu deficient.

The mean iron concentration in sheep liver were 187 and 213 mg/kg DM, in the dry and wet season, respectively. There was a consistently higher liver iron level during the wet season than in the dry season for the three grazing sites. This implies sheep consumed and deposited more Fe in the wet than dry season. The concentration of iron in the sheep liver was above the marginal band of 69.9-100.1 mg/kg DM considered as deprivation in sheep (Underwood and Suttle, 1999). The increase in liver Fe during the wet season was due to increased extraction of soil Fe by plants and thus elevated concentration of iron in forages (Shamat *et al.*, 2009).

Higher zinc levels were observed in the dry season than in the wet season in Larora and salt lick sites, while the reverse was observed in Kamotonyi grazing area. In wet season, sheep liver Zn was closer to values reported by Gartenberg *et al.* (1990). The levels of liver Zn were lower than the range of 116.7-130.5 mg/kg DM reported by Ziehank *et al.* (2008). The variation in grazing site on liver Zn could be due to differences in individual animal Zn metabolism and pasture Zn contents. The mean liver Zn content during the dry (83.3) indicates that the sheep were deficient in this mineral during that season. However, in wet season, the level of Zn was above 90 mg/kg DM considered normal in sheep (Underwood and Suttle, 1999).

The mean manganese concentration in sheep liver was 7.54 and 13.24 mg/kg in the dry and wet season, respectively. In the wet season, the liver manganese

Table 1: Sheep liver mineral concentrations ($mgkg^{-1}$DM) in dry and wet seasons in three grazing sites of Merille Location, Kenya

	Element							
	Cu		Fe		Zn		Mn	
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Grazing area								
Kamotonyi	93.73^a	326.88^b	193.32^a	205.49^b	36.13^a	93.36^a	7.99^a	15.61^a
Lorora	85.65^a	306.08^b	182.08^a	231.10^b	100.32^b	84.18^a	6.94^b	13.23^b
Salt Lick	325.65^b	276.40^b	186.05^a	202.74^b	106.01^b	104.79^a	7.65^a	10.87^c
Mean	184.07^d	303.12^f	187.04^d	213.11^f	83.34^d	94.11^d	7.54^d	13.24^f
Pr>F Season	<0.001		0.026		0.119		<0.001	
Pr>F Grazing area	0.025		0.498		0.002		0.019	
Pr>F Season x Grazing area	<0.001		0.351		0.001		0.107	
*Normal range (mg/kg DM)	182-360		100-1000		90-225		9-15	

Means along a column for grazing area (abc) or a row for season (df) with different letters differ ($p<0.05$), *(Radositis *et al.*, 1994; Underwood and Suttle, 1999)

Table 2: Goat liver mineral concentrations (mgkg^{-1}DM) in dry and wet seasons in three grazing sites of Merille Location, Kenya

	Element							
	Cu		Fe		Zn		Mn	
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Grazing area								
Kamotonyi	287.65[a]	267.72[a]	159.86[a]	183.12[a]	128.14[a]	105.49[a]	6.24[a]	10.06[a]
Lorora	255.93[a]	159.25[b]	135.88[a]	196.65[a]	103.64[a]	101.60[a]	6.13[a]	20.93[b]
Salt Lick	278.01[a]	281.89[a]	207.40[b]	171.17[a]	143.23[a]	100.02[a]	7.85[a]	9.96[a]
Mean	236.29[d]	274.28[d]	171.69[d]	183.64[d]	126.83[d]	102.37[f]	6.85[d]	13.65[f]
Pr>F Season	0.220		0.235		0.012		<0.001	
Pr>F Grazing area	0.048		0.309		0.214		0.015	
Pr>F Season x Grazing area	0.333		0.003		0.180		0.015	
*Normal range (mg/kg DM)	>244		135-900		>90		>7	

Means along a column for grazing area (abc) or a row for season (df) with different letters differ (p<0.05), *(Radositis *et al.*, 1994; Underwood and Suttle, 1999)

concentration was 75% higher than in the wet season. The interaction of grazing site and season had no influence (p>0.05) on sheep hepatic manganese. The wet season manganese level was above the value of 8-9 mg/kg DM considered marginal in sheep (Underwood and Suttle, 1999). However, in the dry season the mineral level fell to 7.54 mg/kg DM which is considered marginal in sheep. In the different grazing areas and seasons, animals had varied in liver Mn (Table 1), which could be attributed to differences in pasture manganese. All sheep flocks in the dry season were deficient in manganese, but had adequate Mn in wet season.

Trace mineral concentration in goat liver: The concentration of Cu, Fe, Zn and Mn in goat liver is shown in Table 2. The season had no effect on Cu and Fe but affected Zn and Mn concentration (p<0.05) in goat liver. Grazing area had significant influence on liver copper and manganese levels, but no effect (p>0.05) on iron and zinc concentration.

The mean copper concentration was 236.3 and 274.3 mg/kg DM in the dry and wet season, respectively. In the wet season, goats grazing in Lorora area showed significantly lower (p<0.05) Cu levels of 159.3 mg/kg DM compared to 281.9 and 267.7 mg/kg DM in Salt lick and Kamotonyi herds, respectively. Liver copper level in the two seasons was lower than 315±15 mg/kg DM reported by Solaiman *et al.* (2001). Bakhiet *et al.* (2007) reported lower levels in wet weight of 65.5ppp in Sudan goat. The constancy of Cu levels during both seasons in goats could be attributed to their feeding behaviour (of grazing and browsing) and utilization of diverse plant species high in Cu content. However, goat's liver Cu was within the normal range in wet season, but was below the reference range in the dry season. Liver Cu levels observed in goats were below the concentrations of >405mg/kg DM considered to cause Cu poisoning (Underwood and Suttle, 1999).

Hepatic iron concentration in goats was not affected by season (p>0.05), 171.7 mg/kg DM and 183.6 mg/kg DM for dry and wet season respectively. However, there was a significant (p<0.01) interaction between season and grazing site. In the dry season, goats grazing in Salt lick area, deposited relatively higher (p<0.05) Fe levels of 207.4 mg/kg DM compared to 135.88 mg/kg DM and 159.86 mg/kg DM in Lorora and Kamotonyi grazing areas, respectively.

The mean liver Fe content was lower than that reported by Bakhiet *et al.* (2007) in Sudan goats. Iron deficiencies, except in young ruminants, rarely occurs in ruminants because of the ubiquitous nature of the mineral (Mollerberg, 1975).

In the dry season, liver zinc concentration was 126.8 mg/kg DM, higher (p<0.05) than 102.3 mg/kg DM for the wet season (Table 2). However, the grazing site had no influence (p>0.05) on liver Zn concentration. The concentration of liver Zn was relatively closer to the level reported for kids and calves (Underwood and Suttle, 1999). The liver zinc was lower than 177±99 mg/kg DM reported by Haenlein (1980) in goats. Zinc, as with other trace elements, is actively involved in enzyme functions, most notably metalloenzymes (Corah, 1996). The seasonal differences in goat liver Zn could be ascribed to dietary variations in Zn pasture contents. The intensity of Zn deposition in the liver depends on its concentration in the diet (Georgievskii *et al.*, 1981). Thus, during the dry season increased Zn accumulation in the liver of goats could be associated to intake of forage plants which were higher in Zn. However, mean seasonal liver Zn content in goats for both seasons were within the normal range considered adequate in goats.

Liver Zn although affected by factors such as stress, disease, age of the animal and levels of other storage pools can be used to verify Zn status of the body (Hall, 2005).

The mean liver Mn concentration was significantly (p<0.001) lower in the dry season (6.85) than in the wet season (13.65) (Table 2). There was a significant (p<0.05) interaction between grazing site and season. In the wet season, the liver Mn was higher than 10 mg/kg DM considered normal for goats (Anke *et al.*, 1988), while in the dry season, it was lower than the expected normal level (Underwood and Suttle, 1999). Wet season liver Mn was comparable to 13.2 mg/kg DM reported by Haenlein (1980) in male goats. In the wet season, goats grazing in Lorora area showed higher Mn level of 20.93 mg/kg DM compared to 9.96 and 10.06 mg/kg DM in Salt Lick and Kamotonyi areas respectively (Table 2). Of the body tissues the liver is considered the most indicative of body Mn status (Kincaid, 1999).

Tissue Mn is highly responsive to dietary Mn (Underwood and Suttle, 1999). The observed decrease in goat's liver Mn could be due to low diet intake and antagonism with other elements. Low P diet has been reported to affect the concentration of Mn in the liver (Neathery *et al*., 1990). In young growing goats, symptoms of Mn deficiency includes slow growth, staring coat, offspring weak at birth and impaired health (Naylor and Ralston, 1992).

Mineral content in 12th rib of sheep carcass: The ash and mineral profile of the dried fat free (DFF) 12th rib of sheep is shown in Table 3.

The mean ash content of the 12th rib was 62.4% in the dry season, higher ($p<0.05$) than 60.8% obtained in the wet season. Grazing area and season had significant effect ($p<0.05$) on ash dry fat free ash in sheep. The bone ash DFF% was higher in dry than wet season (Table 3). The mean dry and wet season ash content of 62.41 and 60.79%, respectively were comparable to those reported by Williams *et al*. (1990) for the 12th rib of 7-30 months old beef cattle. The mean ash % was slightly lower than values of 68 and 69% reported by Felix *et al*. (2008) in lambs. In the wet season, sheep grazing in Lorora site had significantly ($p<0.05$) lower ash content of 57.9% than those grazing in Salt lick area with 64.4% ash. Kamotonyi sheep had lower ash content in the rib that Lorora and Salt lick herd in dry season (Table 3).

The mean rib bone Ca content was 360.6 mg/g (Table 3) with season and grazing site having no effect ($p>0.05$). This is similar to that of Beighle *et al*. (1993), who reported 346.3 mg/g calcium in the 12th left rib of cattle. The seasonal rib bone Ca was slightly higher than the value of 333.23±163.02 mg/g reported by Gonul *et al*. (2009) in dry bones of cattle and Espinosa *et al*. (1982) in sheep. The rib bone Ca concentration was lower than those reported by Felix *et al*. (2008) in lambs. The bone Ca concentration of sheep in the current study indicates adequate body status. This would be expected since calcium deficiency is rare in grazing animals.

The season and grazing site had no effect ($p<0.01$) on rib bone phosphorus. The P seasonal values were 147.0 and 157.0 mg/g in wet and dry season, respectively. The mean P concentration was however lower than that of 183.4 mg/g reported by Beighle *et al*. (1993) in bovine 12th rib but was relatively closer to value by Williams *et al*. (1990) in the rib bone of heifers. Rib bone P concentration reflects the animal mineral reserve (De Waal and Koekemoer, 1997). In both seasons the low P in sheep, which was below the expected value of 180 mg/g ash, was indicative of marginal deficiency. Phosphorus deprivation is predominantly a chronic condition of grazing cattle and also small ruminants, arising from a combination of soils, climate and forage P content (Underwood and Suttle, 1999).

The mean bone Mg content was 9.05 mg/g ash. The season and grazing site had no effect ($p>0.05$) on bone Mg content. This level of bone Mg was comparable to 9.51 mg/g ash reported by Beighle *et al*. (1993), but higher than value of 2.38±0.32 mg/g reported by Gonul *et al*. (2009) and Espinosa *et al*. (1982) in sheep. In ruminant livestock (6-12 months old) the Mg content in the rib bone was <12 mg/g ash. Therefore sheep in the study area, with mean levels of 9.56 and 8.54 mg/g ash in dry and wet season respectively were adequate in Mg.

The Zn content in the 12th rib was 0.15 mg/g ash in the dry season which significantly ($p<0.001$) increased to 0.219 mg/g in the wet season (Table 3). The Zn content in sheep rib declined by 93.2% during the dry season. In wet season, Zn content was relatively closer to that reported by Espinosa *et al*. (1982) in sheep (0.02% ash). It could imply that growing sheep adequately consumed and deposited more Zn in wet than dry season.

Table 3: Mineral content in the 12th rib of sheep carcass

			Element (mg/g ash)							
	Ash (%)		Ca		P		Mg		Zn	
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Grazing area										
Kamotonyi	61.29^b	60.38^c	358.0^a	381.1^a	155.7^a	129.1^a	8.56^a	8.16^a	0.015^a	0.293^b
Lorora	62.59^a	57.93^b	351.2^a	344.1^a	179.5^a	146.4^a	11.19^a	8.74^a	0.013^a	0.170^b
Salt Lick	63.12^a	64.35^a	368.3^a	361.3^a	135.9^b	165.5^b	8.93^a	8.72^a	0.017^a	0.195^b
Mean	62.41^d	60.79^f	359.3^d	362.0^d	157.0^d	147.0^d	9.56^d	8.54^d	0.015^d	0.219^f
Pr>F Season (S)	0.012		0.715		0.201		0.084		<0.001	
Pr>F Grazing area (G)	0.003		0.078		0.108		0.080		0.349	
Pr>F (S x G)	0.219		0.209		0.006		0.218		0.359	

Means along a column for grazing area (abc) or a row for season (df) of same variable with different letters differ ($p<0.05$)

Table 4: Mineral content of 12th rib of goat carcass

			Element (mg/g ash)							
	Ash (%)		Ca		P		Mg		Zn	
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Grazing area										
Kamotonyi	63.46[a]	60.32[b]	357.7[a]	280.0[ab]	111.1[a]	172.0[b]	9.23[a]	8.83[a]	0.018[a]	0.198[b]
Lorora	62.06[a]	60.23[b]	364.2[a]	351.6[b]	175.0[b]	178.0[b]	8.78[a]	9.44[a]	0.040[a]	0.215[b]
Salt Lick	61.67[a]	61.31[a]	359.6[a]	348.4[b]	141.7[c]	147.7[a]	8.42[a]	8.89[a]	0.015[a]	0.212[b]
Mean	62.32[d]	60.62[f]	360.5[d]	326.0[f]	142.7[d]	165.9[d]	8.81[d]	9.05[d]	0.026[d]	0.208[f]
Pr>F Season (S)	<0.001		0.002		0.01		0.584		<0.001	
Pr>F Grazing area (G)	0.355		0.004		0.004		0.665		0.526	
Pr>F (S x G)	0.014		0.011		0.15		0.581		0.790	

Means along a column for grazing area (abc) or a row for season (df) of same variable with different letters differ (p<0.05)

Mineral content in 12th rib of goat carcass: The ash, Ca, P, Mg and Zn in goat 12th rib are shown in Table 4. The ash content was 62.3% in the dry season, which was lower (p<0.05) than 60.6% obtained in the wet season. However, the grazing site did not affect (p>0.05) the ash content in the rib. The ash level reported in this study was close to 63% reported by Cooper *et al*. (1998) and Underwood and Suttle (1999) in cattle calves.

Season, herd, interaction between herd and season had significant effect (p<0.05) on rib bone calcium. Dry season Ca level of 360.5 mg/g was significantly higher (p<0.05) than the wet season value of 326.7 mg/g ash. In the wet season, herds varied in bone Ca content, with lower bone contents of 280.0 mg/g exhibited by Kamotonyi and higher calcium levels of 351.6 mg/g observed in Lorora herd. The mean rib Ca was relatively close to those reported by Gonul *et al*. (2009) in cattle and Beighle *et al*. (1993) in bovine rib bones. However, the mean goat rib bone Ca was slightly higher than those reported by Espinosa *et al*. (1982) in sheep. The concentration of Ca observed in the ribs of goats in this study indicate adequate body reserve of Ca.

In the dry season, the mean P content in the 12th rib was 142.7 mg/g DM which was lower (p<0.05) than 165.9 mg/g DM obtained in the wet season. In the dry season, goats grazing in Larora had higher P than those grazing in Salt lick or Kamotonyi areas. This trend was seen also seen in the wet season. The bone P in the wet season was closer to the mean value of 185.74 mg P/g ash reported in young bovines by Beighle *et al*. (1993). Little and Shaw (1979), in a study of rib bone P in grazing cattle, concluded that P levels of about 120 mg/ml in the 12th rib indicate P deficiency while levels over 150 mg/ml indicate adequacy. Since ash/unit volume is roughly similar to ash/unit dry fat-free weight, the low P in herds grazing Kamotonyi area in the dry season indicate P deficiency. Sheep appear to be efficient in P metabolism in dry season, whereas goats on contrary are better in bone P deposition in wet season. During periods of deficiency P is resorbed from the bones and may offset any dietary deficiency (Ternouth, 1990). Long term P deficiency results in poor reproductive performance, impaired immune response, bone abnormalities and pica (Kincaid, 1999).

The Mg content in rib bone of goats was not influenced (p<0.05) by season and grazing area. The mean Mg content was 9.05 mg/g in the wet season and 8.81 mg/g in the dry season and was within the range 7-12 mg/g ash reported in rib bone of ruminant livestock (Underwood and Suttle, 1999). The rib bone Mg contents were slightly higher than those reported by Espinosa *et al*. (1982) in Llamas and Felix *et al*. (2008) in lambs. However, the mean rib Mg was in agreement with that reported by Beighle *et al*. (1993) in 12th rib of bovine. Espinosa *et al*. (1982) reported mean magnesium value of 0.68% ash in sheep rib bone. Thus, rib Mg content of goats indicates adequate body status.

Rib Zn content was significantly influenced (p<0.001) by season, while the grazing site had no effect (p>0.05). The rib Zn content drastically declined (by 87.5%) in wet season from 0.208 mg/g to 0.026 mg/g in the dry season. In the case of deficiency, Zn in the bone and muscle tissues is redistributed to other body pools to perform vital body processes such as enzyme function (Underwood and Suttle, 1999). Wet season Zn content was comparable to 0.02% of ash reported by Espinosa *et al*. (1982) in Llamas, but higher than those reported by Heinlein (1980) and Underwood and Suttle (1999) in goat rib. In this study, goats had adequate bone Zn in wet season, but are at risk in rib Zn during the dry season.

Conclusion and recommendation: The mineral concentration in liver and rib bone of sheep and goats in the study area has demonstrated seasonal fluctuation in tissue mineral reserve. The variation in tissue mineral content could be ascribed to the mineral concentration of forages consumed by animals in dry and wet seasons. The study has shown that evaluation of specific minerals in different periods and body pools can be useful in the diagnosis of mineral status of animals. In the wet season, liver and bone tissue of sheep and goats indicated adequate body status of Ca, Mg, Cu, Zn, Fe and Mn. However, in the dry season, sheep showed deficient levels of Zn, goats in Cu, while both species suffered from low liver Mn and rib Zn reserves. With the exception of P which was marginal in all seasons, mineral deficiencies affect animals mostly in the dry season. It can be concluded that, sheep and goats would benefit from P, Cu, Zn and Mn supplementation, particularly in the dry season.

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REFERENCES

Aregheore, E.M., D. Hunter, D. Perera and M.T. Mautoatasi, 2007. The soil-plant-animal phenomena: Serum mineral status of Fuji fantastic sheep grazing Batiki grass(*Ischaemum aristatum* Var. *indicum*) and Pangola grass (*Digitaria decumbens*) in Samoa. J. Anim. Vet. Adv., 6: 349-357.

AOAC, 1998. Official methods of Analysis of the Association of Official Analytical Chemistry. 16th Edn., Vol. I, pp: 32.

Anke, M., B. Groppel, U. Krause, L. Angelow, A. Regius, T. Masaoka, T. Kosla and M. Langer, 1988. Diagnostic possibilities of the status of Zinc, manganese, copper, iodine, selenium, molybdenum, cadmium, nickel, lithium and arsenic. Proc. Macro and trace Elements Seminar, University Leipzig-Jena, Germany, Dec. 20-21, pp: 368.

Bakhiet, A.O., A.A. Mohammed, E.S.M. Siham and M.A. Samia El Badwi, 2007. Some trace-elements profile in the liver of camels, cattle, sheep and goats. Int. J. Trop. Med., 2: 1-2.

Ben Salem, H. and T. Smith, 2008. Feeding strategies to increase small ruminant production in dry environments. Small Ruminant Res., 77: 174-194.

Beighle, D.E., P.A. Boyazoglu and R.W. Hemken, 1993. Use of bovine rib bone in serial sampling for mineral analysis. J. Dairy Sci., 76: 1047-1052.

Corah, L., 1996. Trace mineral requirements of grazing cattle. Anim. Feed Sci. Technol., 59: 61-70.

Cooper, S.R., D.R. Topliff, D.W. Freeman, M.A. Collier and O.K. Balch, 1998. Evaluation of bone mineral contents in Equine cadavers and pregnant Mares. Animal Science Research Report, pp: 125-131.

De Waal, H.O. and G.J. Koekemoer, 1997. Blood, rib bone and rumen fluid as indicators of phosphorus status of grazing beef cows supplemented with different levels of phosphorus at Armoedsvlakte. S. Afr. Tydskr. Veek, 27: 76-84.

Espinosa, J.E., L.R. McDowell, J. Rodriguez, J.K. Loosli, J.H. Conrad and F.G. Martin, 1982. Mineral status of Llamas and sheep in the Bolivian Altipiano. J. Nutr., 112: 2286-2292.

Felix, T.L., L.R. McDowell, G.A. O´Connor, N.S. Wilkinson, J. Kivipelto, M. Brennan, R.K. Madison, L.K. Warren and J.H. Brendemuhl, 2008. Effects of dietary aluminium source and concentration on mineral status of feeder lambs. Small Ruminant Res., 80: 1-7.

Georgievskii, V.I., B.N. Annenkov and V.T. Samokhin, 1981. Mineral nutrition of Livestock. Butterworth and Co publishers, UK, pp: 192-196.

Gonul, R., A. Kayar, T. Bilal, O.R.M. Erman, D.V.M. Parkan, H.T. Dodurka, T. Gulyasar and B. Barutcu, 2009. Comparison of mineral levels in bone and blood serum of cattle in Northwestern Turkey. J. Anim. Vet. Adv., 8: 1263-1267.

Gartenberg, P.K., L.R. McDowell, D. Rodriguez, N. Wilkinson, J.H. Conrad and G. Martin, 1990. Evaluation of the trace mineral status of ruminants in northeast Mexico. Livestock Research for Rural Development, Vol. 2. No. 1.

GenStat software 12th edition, 2010. www.vsni.co.uk/.

Hall, J.O., 2005. Appropriate Methods of Diagnosing Mineral Deficiencies. Mid-South Ruminant Nutrition Conference, pp: 21-26.

Haenlein, G.F.W., 1980. Mineral nutrition of goats. J. Dairy Sci., 63: 1729-1748.

Kincaid, R.I., 1999. Assessment of trace mineral status of ruminants: A review. Proceedings of the American Society of Animal Science, pp: 1-10.

Lelon, J.K., M.O. Muga, D.W. Odee, C. Wekesa and B. Ndakwe, 2010. Effect of chemical properties of soils on gum elementary compositions from *Acacia Senegal* variety *kerensis* in Samburu and Marsabit districts. Afr. J. Plant Sci., 4: 021-025.

Little, D.A. and N.H. Shaw, 1979. Superphosphate and stocking rate effects on native pasture overs own with *Stylosanthes humilis* in central Queensland. 5. Bone phosphorus levels in grazing cattle. Austr. J. Exp. Agric. Anim. Husbandry, 19: 645-651.

McDowell, L.R., J.H. Conrad and F.G. Hembry, 1993. Minerals for grazing Ruminants in Tropical Regions. Animal science department, University of Florida, pp: 2-70.

McDowell, L.R., 1992. Minerals in Animal and human nutrition. Academic press, New York.

Mollerberg, L., 1975. A hematologic and blood chemical study of Swedish purchased calves. Acta Vet. Scand., 16: 170-177.

Naylor, J.M. and S.L. Ralston, 1992. Recent advances in mineral nutrition of goats. In: Large animal nutrition. Mosby book Publ. St.Lous, pp: 339-355.

Neathery, M.W., N.A. Crowe, W.J. Miller, C.T. Crowe, J.L. Varnadoe and D.M. Blackmon, 1990. Influence of dietary Aluminium and phosphorus on zinc metabolism in dairy calves. J. Anim. Sci., 68: 4326-4333.

Radositis, O.M., D.C. Blood and C.C. Gay, 1994. Veterinary medicine. VII Edn., Bailliere Tindall London, pp: 1379-1394; 1495-1499.

Sousa, J.C. de., 1978. Interrelationships among mineral levels in soils, forage and animal tissues on ranches in Northgen Mato Grosso, Brazil. Ph.D dissertation, University of Florida, Gainesville, Florida.

Shamat, A.M., I.A. Bakiker, A.M.S. Mukhtar and F.A. Ahmed, 2009. Seasonal and regional variation in mineral content of some important plants species selected by Camels (*Camelus dromedaries*) in Arid and Semi-arid Lands (ASAL) of Sudan. J. Applied Sci. Res., 5: 1676-1684.

Solaiman, S.G., M.A. Maloney, M.A. Qureshi, G. Davis and G. D'Andrea, 2001. Effects of high copper supplements on performance, health, plasma copper and enzymes in goats. www.ncbi.nlm.nih.gov/pubmed/11445421.

Szefer, P. and J.O. Nriagu, 2007. Mineral components in Foods. CRC press, Taylo and Francis Group, USA, pp: 123.

Ternouth, J.H., 1990. Phosphorus and beef production in northern Australia: Phosphorus in cattle - A review. Trop. Grasslands, 24: 159-169.

Touber, L., 1991. Landforms and Soils. In: Range management handbook of Kenya, Vol II, 1, Nairobi, Kenya, pp: 5-24.

Underwood, E.J. and N.F. Suttle, 1999. The mineral nutrition of livestock, 3rd Edn., CAB international, willingford, UK.

Underwood, E.J., 1977. Trace elements in humans and animal nutrition, 3rd and 4th Edn., Academic Press, New York.

Williams, S.N., L.A. Lawrence, L.R. McDowell, A.C. Warnick and N.S. Wilkinson, 1990. Dietary phosphorus concentrations related to breaking load and chemical bone properties in heifers. J. Dairy Sci., 73: 1100-1106.

Webb, E.C., J.B.J. Van Ryssen, M.E.A. Erasmus and C.M.E. McCrindle, 2001. Copper manganese, cobalt and selenium in liver samples from African buffalo (*Syncerus caffer*) in the Kruger National Park. J. Monit., 3: 583-585.

Xiaogang Sun, 2005. Dynamics of continuity and change in pastoral subsistence among the Rendille in northern Kenya: With special reference to livestock management and responses to social-economic change. Afr. Study Monographs, suppl. 31: 1-94.

Ziehank, E.H., M. Ganter, I.H. Pauka and A. Binder, 2008. Trace mineral status and liver and blood parameters in sheep without mineral supply compared to local roe deer (*Capreolus capreolus*) populations. Small Ruminant Res., 75: 185-191.