International Journal of Scientific & Engineering Research, Volume 5, Issue 3, March-2014 1236
ISSN 2229-5518

Mineral-Mineral Interactions as a possible limiting factor to livestock production in Uasin Gishu County, Kenya

Shisia K.Silvanus[1*], Ngure Veronica[1], Nyambaka Hudson[2]

Abstract— A study was conducted in Uasin Gishu County, Kenya between January 2010 and December, 2012 to determine the effect of mineral-mineral interaction on mineral concentrations and its contribution to mineral deficiencies in grazing cattle in the county. Samples of soil, pasture and blood samples were collected from selected farms in the region. The trace and major mineral elements were analyzed using atomic absorption spectrometry except Molybdenum which used UV-Vis spectrometry. The study revealed severe deficiencies of copper, zinc in soils; sodium, potassium calcium, magnesium, phosphorus, iron, copper, zinc in pasture species and iron, manganese, copper, magnesium in animal blood. The mineral-mineral element interaction was a major contributor to the mineral deficiencies reported in the region. There was evidence of possible magnesium, manganese, copper and zinc deficiencies due to Ca-Mg, P-Mn, Fe-Cu, Cu-Mo and Fe-Zn interactions respectively. These interactions reach potential importance when the first mineral is in excess compared to the second. The negative interaction of metal ions is one of the major dietary factors that causes low bioavailability of these nutrients. The study recommends immediate mineral manipulation in feed rations for grazing cattle in the county.

Index Terms— *Grazing cattle, Mineral concentrations, Mineral deficiencies, Mineral interactions, Feed rations, Low bioavailability*

1 INTRODUCTION

There are a number of methods to establish the likely existence of specific mineral deficiencies for grazing ruminants, in which determination of concentrations of minerals in dietary components along with clinical, and biochemical examination of animals' appropriate tissues and fluids are commonly used for diagnosis of mineral status of grazing animals [1], [2]. The productivity of grazing livestock is dependent on the adequacy and availability of essential mineral elements from pastures [3], [4], [5]. One of the nutritional challenges that cattle producers face is to satisfy the mineral requirements of the cow herd [6]. As the genetic progress of the herd improves, mineral supplementation strategies become more complex and are influenced by a variety of factors, including forage mineral bioavailability, mineral interactions, and even breed [7]. .Animal nutritionists would probably agree that all dietary nutrients are interrelated to some degree and that there is an optimal concentration for each nutrient in relation to the levels of all others to obtain the most efficient desired animal response [8], [9].

Minerals are much more likely to interact than other nutrients due to their lability and tendency to form chemical bonds [10]. Mineral interactions may be multiple as in the case of copper-molybdenum-sulfur or one-on-one as observed with molybdenum and copper.

Interactions may be one-way, such as the negative effect of zinc on copper, in which the reverse effect is not observed [11]. Reciprocal interrelationships are also found in which both elements influence the metabolism of the other [12], [13]. Antagonistic interactions of two nutrients decrease the bioavailability of the limiting one, and such interactions occur frequently among mineral nutrients [14]. The number of possible metal-metal interactions is extremely large, so a theoretical basis for prediction of interaction is needed [15], [16]. There are six macro elements whose ionic forms are dietary essentials, namely, sodium, potassium, magnesium, calcium, phosphorus and chlorine [16]. The trace elements recognized as essential for animals are iron, zinc, copper, manganese, selenium, chromium, molybdenum, fluoride and iodine. Physiological and pharmacological interactions between pairs of these ions have been recognized for many years, but nutritional relationships are less well defined [16], [17].

Uasin Gishu is one region that used to produce high quantities of meat and milk, a trend that is declining due to mineral deficiencies [18], [19]. Grazing ruminants are more prone to signs of toxicosis or deficiency resulting from mineral interactions [16]. Consumption of needed quantities of mineral supplements cannot be guaranteed by every individual within a grazing herd of livestock and, consequently, problems arising from interactions are still observed under field conditions. In this study, we have focused on interactions between essential minerals, and we present suggested levels at which an excess of a mineral can significantly alter the

[1*]Department of Chemistry, Laikipia University, Kenya; PhD student at Kenyatta University, Kenya shisias2003@gmail.com

[1]Department of Biological Sciences, Laikipia University, Kenya; vngure@yahoo.com

2Department of Chemistry, Kenyatta University, Kenya nyambaka.hudson@ku.ac.ke

metabolism of another mineral for several of the known competitive interactions

2. MATERIAL AND METHODS

The study area comprises of six divisions Soy and Moiben; Turbo and Kapsaret; Kesses and Ainabkoi divisions [20]. A total of 28 soil and forage samples and 28 blood serum from lactating cows were collected from the six divisions.

The study focused on macro elements Na, K, Ca, Mg, P and trace elements Fe, Mn, Cu and Zn in soils, pastures and animal blood due to their interaction mechanisms. Available trace elements and macro elements in soils were determined by Lakanen and Ervio (1971) method [21], wet digestion was applied for mineral concentrations in forages and blood serum [22]. Molybdenum was determined by UV-Vis Spectrometer. Forage species collected were mainly Rhodes (*Chloris gayana*), Kikuyu (*pennistum clandestinum*) while animal blood was sampled based on cattle breed. Statistical analyses were done using generalized linear model (GLM) of statistical analysis system in which ANOVA, spearman's rank correlation. and regression coefficients for stipulated variables were used to estimate relationships between parameter values observed in soils, forages and blood serum [23].

3 RESULTS AND DISCUSSION

Mineral element concentrations represented here is the mean of mineral concentrations from the three regions of the county. The region revealed high concentrations of macro and trace elements which were above recommended levels [24], [25]. Only 14% and 4% of samples were deficient in Cu and Zn (Critical Level=2) respectively (Table 1).

Table 1 Soil macro and trace elements concentrations (mg/kg DM)

Parameter	**Mean SD**	**Range**	**Critical level**	**% samples deficient**
Na	101.00 ± 32.00	58.13 - 155.00	55.00	0
K	709.00 ± 24.40	189.10 -1135.00	60.00	0
Ca	720.00 ± 33.30	280.00 -1840.00	71.00[a]	0
Mg	330.00 ± 11.90	161.30 - 627.70	30.00	0
Fe	551.00 ± 22.80	228.30 -1198.30	30.00[b]	0
Mn	630.00 ± 34.50	703.00 -1583.50	10.00[c]	0
Cu	3.30 ± 0.90	1.60 - 5.13	2.00[d]	14
Zn	6.70 ± 0.40	1.97 - 22.06	2.00[d]	4

CL source: a [26]; b [2]; c [25]; d [24]

The findings in the table indicate that soils had low concentrations of Cu and Zn. Excessive dietary Zn can negatively affect Cu status through the absorption process [14], [27]. High iron intake is known to reduce zinc levels [27]. The Ca and Mg deficiencies were revealed in 86% and 89% of samples collected while Cu and Zn deficiencies were discovered in 93% and 39% of samples (Table 2).

Table 2 Forage macro and trace elements concentrations (mg/kg DM)

Parameter	Mean ± SD n=28	Range n=28	**Critical level**	**% samples deficient**
Na	1.00 ± 0.39	0.55 - 2.12	-	-
K	11.80 ± 5.00	3.73 - 20.53	-	-
Ca	0.57 ± 0.19	0.15 -1.17	0.8-15	86
Mg	1.35 ± 0.72	0.10 - 3.13	2.10	89
P	6.34 ± 3.22	1.83 -14.41	-	-
Fe	56.00 ± 0.53	10.25 - 231.00	<13	7
Mn	105.00 ± 0.58	38.25 - 246.50	<13	0
Cu	5.32 ± 2.84	2.00 -15.50	<9	93
Zn	19.50 ± 8.20	8.30 - 39.78	<18	39

Macro elements Ca, Mg and trace elements Cu, Zn were present in lower concentrations. High potassium intake increases the requirement for sodium. Nutritionally, excess dietary calcium decreases magnesium absorption and status in animals [27]. The detrimental effect of high calcium relates to decreased magnesium absorption and this is reflected in depressed growth rate [16]. Consumption of excess phosphorus as well as of calcium accentuates the signs of magnesium deficiency and decreases magnesium absorption [16], [27].

Copper is affected negatively by excess dietary zinc and iron, as well as the copper molybdenum-sulfur interaction [28]. High dietary concentrations of zinc will induce synthesis of metallothinein protein in the intestinal cells to protect the animal against zinc toxicosis. Copper has a higher affinity for the protein than zinc and it was speculated originally to cause a secondary copper deficiency. Manganese competes with iron for binding sites on the plasma iron carrier protein transferrin, inhibiting mobilization and transport of iron [12]. Excess dietary phosphorus, and to a lesser extent, calcium have an antagonistic effect on absorption of manganese in swine, poultry and dairy calves [29].

Most mineral levels in lactating cows were above critical levels except for Mg (21% samples were deficient) while Mn and Cu recorded deficiencies in 100% and 42% of samples (Table 3).

Table 3 Serum macro (g/l) and trace elements (μg/ml) concentrations

Parameter	Mean ± SD n=28	Range n=28	**Critical level**	**% samples deficient**
Na	2.38 ± 0.61	1.13 - 4.04	-	-
K	0.39 ± 0.06	0.28 - 0.58	-	-
Ca	0.81 ± 0.32	0.49 - 2.16	0.08	0
Mg	0.02 ± 0.01	0.003 - 0.04	0.02	21
P	0.15 ± 0.05	0.07 - 0.22	-	-
Fe	2.43 ± 1.53	0.40 - 6.10	<1.00	29
Mn	0.26 ± 0.14	0.10 - 0.70	<1.00	100
Cu	0.60 ± 0.17	0.20 - 1.00	<0.65	42
Mo	0.36 ± 0.35	0.07 - 1.31	-	-
Zn	3.71 ± 1.63	0.65 - 6.84	<0.70	4

The low Mg levels may be because of the fact that excess dietary calcium decreases magnesium absorption nutritionally and status in animals [16]. On the other hand, low Mn and Cu could be due to high phosphorus and iron arising from P-Mn and Fe-Cu respectively [29]. Also Cu-Mo interactions contribute towards deficiencies. A copper-molybdenum ratio of 6:1 or greater is ideal. Ratios from 2:1 to 3:1 as in this study, are borderline and toxic if less than 2:1. High levels of molybdenum cause binding of copper in the digestive tract, and thereby reduce copper availability to the animal [27].

The study also investigated the influence of mineral interactions in specific forage species (Table 4) and cattle breeds (Table 5).

Forage species revealed that Kikuyu species had highest mineral concentrations which agree to other studies [19]. The selected supplements were also rich in most minerals except Mg, Zn and Cu. This is due to physiological differences between the plant species [30]. Sufficient concentration of the minerals must be available in the diet and/or supplement to be biologically beneficial to the animal [30], [31].

Table 4 Mean element concentrations (g/kg DM) of forage species

Parameter	Concentrations (g/kg DM)			
	Pasture species		Selected supplement species	
	Rhodes	Kikuyu	Maize	Wheat
Na	1.03	1.01	0.83	0.81
K	14.93	5.29	10.58	13.07
Ca	0.61	0.49	0.42	0.47
Mg	1.51	1.93	1.13	1.15
P	7.29	9.38	4.50	4.50
Fe	43.84	51.75	47.08	25.75
Mn	101.30	129.10	58.00	61.42
Cu	6.06	6.50	3.00	3.30
Zn	21.64	23.64	14.93	12.75

While excessive intakes of trace minerals should always be avoided because of the relatively high toxicity effects, the more common problem is that of inadequate and consistent intakes of minerals. Inclusion of mineral supplement in the ration at a level sufficient to meet the animal's requirements is the preferred method of satisfying this dietary requirement [30], [32].

Table 5 Macro and trace elements concentrations in various cattle breeds

Parameter	Cattle breeds (g/l)	
	Friesian	Ayrshire
Na	2.35 ± 0.45	2.58 ± 0.78
K	0.41 ± 0.06	0.38 ± 0.07
Ca	0.70 ± 0.10	0.99 ± 0.50
Mg	0.03 ± 0.01	0.02 ± 0.01
P	0.15 ± 0.05	0.16 ± 0.05
Fe	2.90 ± 1.12	2.20 ± 1.97
Mn	0.24 ± 0.12	0.30 ± 0.17
Cu	0.59 ± 0.20	0.66 ± 0.12
Mo	0.34 ± 0.05	0.37 ± 0.40
Zn	4.59 ± 0.99	3.24 ± 1.03

The two breeds revealed no significant differences in concentrations of mineral elements although low levels in Mn were observed in cows (Table 5). This could be due to efficiency of absorption of minerals from the diet [32]. The differences could also be due to the type of feed given to the animal. In this case lactating cows depend wholly on forages which contain higher mineral content [32], [33].

4. CONCLUSION

This study revealed deficiencies of Cu and Zn in soils; forages showed deficiencies in all elements except Mn while animal serum had Mg, Fe, Mn and Cu deficiencies. Negative interaction is exemplified best by the zinc-copper antagonism, in which excess zinc has a severely detrimental effect on the bioavailability of copper. Excess zinc induces copper deficiency, which, in turn, has an adverse effect on iron metabolism. Excess zinc also has a direct negative effect on iron utilization. No doubt the major effect of antagonistic mineral interactions is exerted at the intestinal absorption site. The detrimental effect of high calcium relates to decreased magnesium absorption, and this is reflected in depressed growth rate. Consumption of excess phosphorus as well as of calcium accentuates the signs of magnesium deficiency and decreases magnesium absorption

5 RECOMMENDATIONS

Blood plasma copper levels alone are not totally reliable in diagnosis of copper deficiency. Copper levels in hair samples are highly variable, while liver copper profiles provide a better indicator of the copper status of the animal. Diagnosis of trace mineral deficiencies should be based on a complete assessment of the animal group, feed and water analysis and evaluating of blood and animal tissues (liver biopsy). Single criteria or individual animal diagnosis is generally not sufficient to adequately address trace mineral deficiency problems. Our recommendation to producers must be to start first with soil, forage analysis (Cu, Zn, Mn, Fe, S, Mo, Se), second with a water analysis (Fe, S), followed by serum sampling (Se) and a liver biopsy (Cu, Zn, and Mo) to ascertain mineral interactions before recommending certain feed rations

ACKNOWLEDGEMENT

I wish to acknowledge the assistance from Kenyatta University staff and University of Nairobi for providing technical expertise and laboratory space. I wish also to thank Kenya Agricultural Research centre KARI, Kenya for partly funding the project.

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