Mineral nutrition on settlement (*manyatta*)-based milk camel herds among the Rendille community of northern Kenya

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Declaration

a) This thesis is my original work and has not been presented for a degree in any other university

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b) This thesis has been submitted for examination with our approval as university supervisors

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Dedication

To

My dear wife, Teresia Nyambura, daughters; Pauline Njoki and Grace Wanjiku for

their encouragement that I greatly treasure

Table of Contents

List of Tables

er 6

Chapter 7

List of Figures

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List of Acronyms

AAS	Atomic Absorption Spectrophotometer
ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ADWG	Average Daily Weight Gain
AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of Variance
APRU	Animal Production Research Unit
	Calcium
	Cobalt
	Chlorine
	Copper
	Dry matter
	Dry Matter Intake
	Ethylene Diamine Tetraacetic Acid
	Food and Agricultural Organization
	Iron
	grams per kilogram
	Grams per day
	Majesty Stationery Office
	Least Significant difference
	Meters above sea level

Mg	Magnesium
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
mm	Millimetres
Mn	Manganese
Mo	Molybdenum
NAS	National Academy of Sciences
NRC	National Research Council
Na	Sodium
NaCl	Sodium Chloride
NDF	Neutral Detergent Fiber
NCMN	Netherlands Committee on Mineral Nutrition
P	Phosphorus
pH	Potential of hydrogen
S	Sulphur
Se	Selenium
SPSS	Statistical Package for Social Scientists
UAE	United Arab Emirates
USSR	Union of Soviet Socialist Republic
Zn	Zinc

Abstract

A study was done to investigate the sources of minerals and mineral status of the *manyatta*-based camels in Marsabit district of Kenya.

To document the existing indigenous knowledge on mineral nutrition in camels in the study area, a survey was conducted using a questionnaire. Thirty-three, 28, and 30 respondents were individually interviewed in Kargi, Korr and Ngurunit locations of the district respectively during dry and wet seasons. The respondents included men and boys who were responsible for herding, watering and the general management of camels. During the interviews, important mineral sources for the camels were identified and ranked. The ranking of the identified forage sources was verified through direct field observation of grazing camels.

The mineral sources (water, commercial supplements) and the important feed sources were all sampled for analysis of minerals. The feed resources were also analyzed for CP and fibre to generate supplementary information on their nutritive value. During the survey, blood was sampled from a total of 90 and 88 camels during the dry and wet seasons, respectively. The mineral sources and blood samples were assayed for Na, K Ca, P, Mg, Zn, Cu, Fe and Co.

A combination of rainwater standing on salty soils referred to as *marmar,* and forages growing on such soils were the key sources of mineral supplements to *manyatta*-based camels, with commercial mineral supplements playing only a minor role. Salty water and forages located within a 15 km radius from the *manyatta* were used mainly during the wet season, while commercial salts were used during dry periods. Natural salty

water springs and moderately salty boreholes were also used during the dry season. Over 80% of preferred forage species had Ca, P, Mg, K, Na, Fe and Co contents above the recommended levels during both dry and wet seasons in all the study sites. Eight and 38% of the forage samples were adequate in Zn and Cu, respectively. In comparison with the recommended levels in water, natural springs water had moderate levels of P and Fe, whereas standing rainwater contained reasonable levels of Ca and Fe. Some of the preferred forage species and water sources had limited temporal availability or were located outside the normal grazing radius of settlement-based camels. Plasma levels of Ca, Na, Fe, Zn and Cu were lower than the reported levels. The mean CP and NDF contents of preferred forage species were $13.9 \pm 5.0\%$ and $53.6 \pm 13.7\%$ of DM, respectively.

Rendille pastoralists were aware of the importance of mineral supplementation and could describe the deficiency signs. Forages were the most important sources of minerals for grazing camels followed by water. Apart from Cu and Zn, the forages could potentially satisfy the daily requirements of camels for the studied minerals. The combination of forage species selected by the camels across sites and seasons was adequate in CP content.

After identification of the potentially deficient minerals, an intervention study was conducted in Ngurunit and Kargi locations to determine the effect of mineral supplementation on milk yield, calf growth and plasma mineral concentrations of settlement-based camels. Two mineral supplements were formulated; one comprised of locally collected, ground bones mixed with locally available natural salt and the other of commercial ingredients, mainly sulphates of the respective mineral elements.

Fifty-nine and 56 camels in early lactation and their calves were recruited at Kargi and Ngurunit, respectively. Of these, 22 and 21 camels were randomly assigned the commercial supplement, while 12 and 11 were assigned the local supplement at Kargi and Ngurunit, respectively. There were 25 and 23 control camels in Kargi and Ngurunit, respectively. Each dam was individually fed 200g of mineral supplement daily for 190 days. During the data collection period, milk yield measurements were taken at weekly intervals and calves weighed monthly. Blood samples were also collected on monthly basis for mineral assay.

The supplemented camels produced more milk ($p < 0.05$) than controls in Ngurunit ($3.2ld^{-1}$ versus $2.3ld^{-1}$). In Kargi, the mean milk yields for supplemented and control camels were the same ($2.6ld^{-1}$). Calves from the supplemented dams had higher growth rate ($p < 0.05$) than the controls, gaining $441.3gd^{-1}$ and $424.8gd^{-1}$ compared with $275.7gd^{-1}$ and $307.7gd^{-1}$ for controls in Kargi and Ngurunit, respectively. There was no direct relationship between the supplement and plasma mineral concentrations.

From the results, it appears that mineral deficiencies do exist among the Rendille camels. However, this problem could be reduced by judicial use of locally available raw materials. Factors other than the supplements, which may include but not limited to homeostasis and mineral interactions, appeared to play a more significant role in determining mineral status in the blood.

Chapter 1

General introduction, justification, objectives and hypotheses

General Introduction

Camels belong to the order Artiodactyla and family Camelidae. They are divided into two genera, that is, the camelids (old world camels) and the llamoids (new world camels) (Gauthier-Pilters and Dagg, 1981). The two known species of camelids are *Camelus dromedarius* (one humped) and the *Camelus bactrianus* (two humped). Dromedaries are commonly found in the hot deserts of Africa, while bactrians are found in the cold deserts of Asia. The llamoids consist of the species; Guanaco (*Lama guanacoe*), Vicuna (*Vicugna vicugna*), Llama (*Lama glama*) and Alpaca (*Lama pacos*) all found in South America.

Camels were first introduced into Africa after domestication in southern Arabia between 1 and 4 B.C (Bulliet, 1975) and later found their way into Kenya through Somalia. Kenya has an estimated camel population of 830,000 (FAO, 2001), which constitutes 6% of domestic herbivore biomass but more than 25% in the arid lands where they are kept (Chabeda, 2002). Overall, North Eastern Province (mainly Wajir and Mandera) is the most important camel producing area in the country, keeping 54% of the national herd. Eastern Province (Isiolo, Marsabit and Moyale districts) supports a further 29% of the herd. Formerly restricted to the northern districts (Field, 1979), camels have in the recent past spread into the Rift Valley and the southern rangelands (Evans *et al*., 1995). Today, Rift Valley and Coast Provinces host 13% and 4% of the Kenya's camel population, respectively. Camels have also been integrated into commercial ranching systems where their unique feeding niche complements that of other domestic stock, effectively increasing the sustainable stocking rate of the ranches.

The camel is considered to be potentially the most important animal source of food in pastoral areas (Schwartz and Dioli, 1992). Unique physiological, anatomical and ecological adaptations enable the camel to produce and supply milk to pastoral households throughout the year (Stiles, 1987; Farah, 1996). While a camel has the potential to produce 5-10 times as much milk per lactation as a cow in a similar environment (Farah, 1996), the total amount of protein and energy produced annually by camels under traditional management is about 2½ times the quantity produced by cattle (Vittorio *et al.*, 1999). The fat content of camel milk is lower and protein content slightly higher than of other domestic animals (Yagil, 1982). The milk is rich in vitamin C, ranging between 5.7 and 9.8 mg% or about three times the level in cow's milk. Camel milk has also been reported to have therapeutic value in the treatment of a variety of diseases such as tuberculosis (Köhler-Rollefson, 2000).

Due to its intorelance to humidity (Köhler-Rollefson, 2000), the dromedary camel is mainly confined to the arid and semi arid areas of the world. The relatively large size of this camel makes mountainous areas unsuitable for it (Dong, 1984). The dromedary is by preference a browser, thus prefers areas with browse forage species (Coppock *et al.*, 1986). The Rendille pastoralists graze their camels in the relatively hot lowland areas, avoiding the mountains, which are also associated with disease causing agents. The camels mainly graze on shrubs and dwarf shrubs that dorminate these areas. Some areas within the wider grazing area of the Rendille have thick bush. The herders deliberately avoid such areas due to wildlife menace.

Among camel keeping pastoralists in Kenya, camel milk constitutes almost 100% of total milk consumption in households during the dry season and drought periods.

Traditionally, camels are seldom slaughtered for home consumption due to their large size. However, fat castrates are reserved for times of drought when they may be slaughtered for the household (Salih, 1988). With over 70% of Kenya being classified as arid or semi-arid (FAO, 2004), a rapidly growing human population and increasing overgrazing of the herb layer by cattle and sheep, the role of camel as a source of food is likely to continue growing. In spite of its importance in food security, it is only relatively recent that the camel started getting attention from livestock researchers. Thus, the role of nutrition among other important factors in camel productivity is poorly understood. Of the nutrients required by camels, minerals have received the least attention.

The Rendille herders appreciate the importance of mineral nutrition in camels and have developed criteria for assessing mineral deficiency. They perceive inadequate rumen fill, reduction in milk yield and lack of frothiness, licking of urine and soil, restlessness, chewing of bones and night enclosure construction woody materials among others as signs of mineral deficiency in camels.

Minerals are involved in a wide range of functions in the animal body ranging from enzyme and hormonal activities, acid-base balance, feed digestion, metabolism and uptake at cell level among others (McDowell, 1997). Animal body systems therefore cannot function properly without adequate supply of minerals. In Kenya, camels obtain minerals from naturally occurring sources and mainly forages (Simpkin, 1998; Kuria *et al*., 2004). However, studies on evaluation of mineral levels in feedstuffs commonly available to camels and mineral status in camels are very scanty. This is despite the fact that such information is necessary in attempts to improve nutrition and thus productivity of camels through mineral supplementation. The extent and distribution of mineral deficiencies in the camel diet in Kenya is thus, poorly understood (Faye and Bengoumi, 1997).

This study was initiated with the main objective of investigating mineral nutrition as one of the possible factors adversely influencing the performance of the settlement-based camels in Kargi, Korr and Ngurunit locations of Marsabit district of Kenya (Figure 1).

The specific objectives were to;

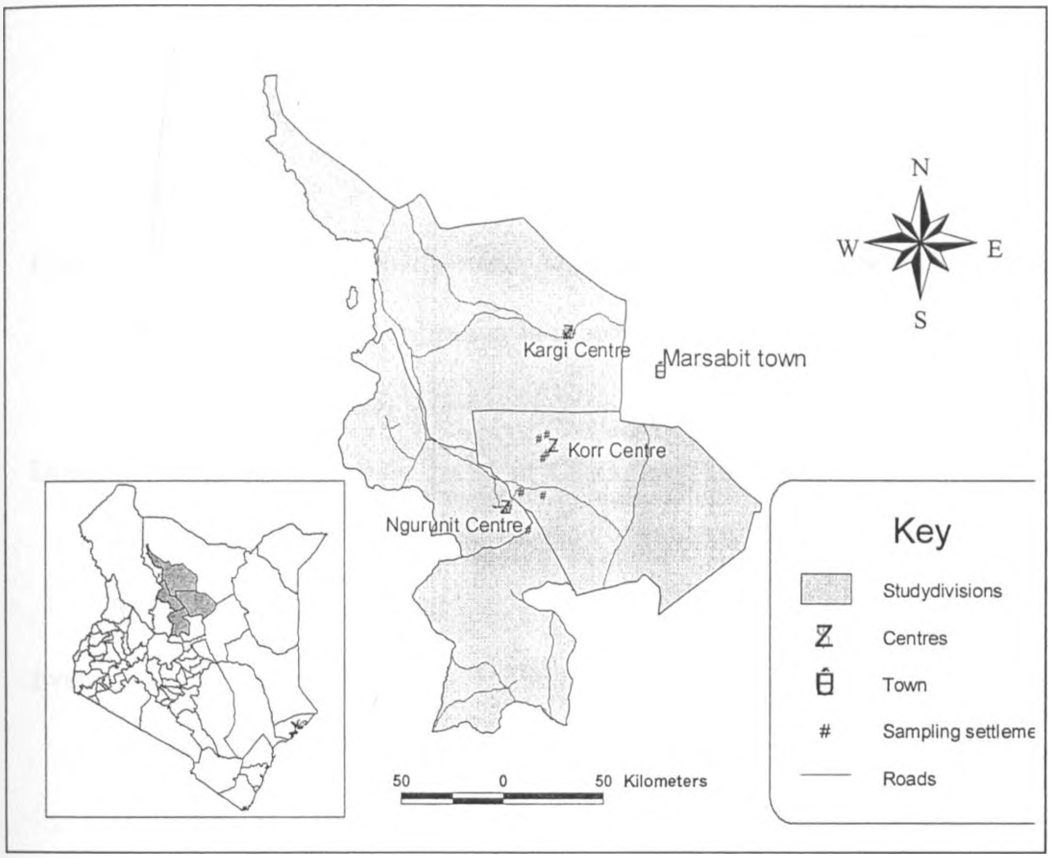
a) Document mineral supplementation practices and indigenous knowledge on settlement-based camel herds by Rendille pastoralists of Marsabit district during different seasons;
b) Determine the mineral content of various mineral sources available to the camels over different seasons in the study area;
c) Determine the mineral profile in the blood plasma of camels during different seasons;
d) Formulate mineral supplementation or other suitable strategies to be used by local pastoralists;
e) Quantify the effect of mineral supplementation on milk yield, growth rate of calves and plasma mineral concentration.

The hypotheses that were being tested in this study were that;

1. Mineral deficiencies does exist among commonly grazed forage species and the Rendille camel herds.

2. Mineral supplementation does increase milk yield, calf growth rate and plasma mineral concentrations in camels.

Figure 1: Map of Kenya showing the study areas



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Chapter 2

The origin and role of the camel, its management and mineral nutrition

Origin and domestication of camels

The fossil records indicate that the family camelidae and their immediate ancestors evolved almost exclusively in North America. From the upper Eocene time through the Tertiary period into the Pelcitocine epoch, about 40 million years ago, they evolved from the size of small rabbits into the modern beasts over 2 meters tall today (McKnight, 1969). From North America, camelids dispersed to other parts of the world, developing into the six camel types known today (McKnight, 1969).

There are two theories on the domestication of one humped camel. One says it was first domesticated in the southeastern Arabian Peninsula, a move stimulated by the need for transport animals to carry copper to the coast (Köhler-Rollefson, 1993). In a settlement located on the island of Umm an-Nar (Oman) off the Abu Dhabi coast and dated to 2700 B.C, a large number of camel bones were found whose age profile suggested incipient domestication (Hoch, 1979). The second theory suggests that the camel was first domesticated in southern Arabia for the purpose of milk production (Bulliet, 1975). This theory however lacks archeological evidence. Information about the early stages of domestication of the Bactrian camel indicates that it was first domesticated in southern Turkmenistan in the 3rd millennium B.C with clay figurines suggesting that it was initially used for hauling of carts (Kohl, 1984). However, there are still a few wild herds of bactrians today found roaming the Gobi desert and in the mountains of China and Mongolia. Among the llamoids, the Llama and Alpaca have been domesticated in South America while Guanaco and Vicuna are largely wild.

Population and distribution of camels in the world

According to the FAO (2001) estimates, there are over 19 million camels in the world of which 15 million (80%) are found in Africa. Limited by intolerance to humidity and incidence of disease transmitting insects, the one-humped camel is distributed between approximately 16° West and 77° East, reaching its most northern point in Kazakhstan at 52° North and its Southern limit in Northern Kenya at 13° North (Köhler-Rollefson, 2000). In Africa, a gradual southward expansion into Tanzania has occurred in the recent past. The high altitude cold deserts of central Asia represents a typical habitat of the two-humped camel (Dong, 1984). This camel can cope with mountainous territory and can also withstand very low temperatures. It is largely confined to Mongolia, China, parts of the former Soviet Union and the highlands of Afghanistan, Iran and Pakistan (Chapman, 1985). Camels have been exported to many parts of the world outside this area including Europe, Southern Africa, the Caribbean, the Southwest of the United States and to Australia (Leese, 1927).

In Africa, the highest camel concentration is found in the arid areas of over ten countries as indicated in Table 1.

Table 1: Number and distribution of camels in Africa over the years

	Number ('000)				Percentage of the world total
Country	**1989-1991**	**1999**	**2000**	**2001**	
Somalia	6600	6000	6100	6200	32.6
Sudan	2743	3031	3108	3200	16.8
Mauritania	950	1206	1230	1230	6.5
Ethiopia		1050	1060	1070	5.6
Kenya	850	812	825	830	4.4
Chad	549	715	720	725	3.8
Mali	231	467	467	467	2.5
Niger	360	404	410	415	2.2
Algeria	123	220	235	240	1.3
Tunisia	233	231	231	231	1.2
Egypt	136	116	120	120	0.6
Libya	135	70	71	72	0.4
Djibouti	59	66	66	70	0.4
Morocco	33	36	35	36	0.2
Total	**13002**	**14424**	**14678**	**14906**	**78.5**

Source: FAO production year book Volume 55 - 2001

Somalia is the leading camel keeping country in Africa and the world with about a third of the world population. Kenya has fifth largest population in Africa. While the world's camel population has increased steadily since 1991, that of Kenya declined between 1991 and 1999 after which it exhibited an upward trend.

Types of camels in Kenya

Camel populations are traditionally named after the different pastoral communities that keep them. Three main types, namely Turkana, Rendille/Gabbra and Somali are common in northern Kenya. Pastoralists inhabiting Turkana, Marsabit and Garissa/Wajir/Mandera/Moyale districts, respectively, keep these camels. These communities clearly distinguish their different camel populations and these have often been referred to as breeds. Results from previous studies indicate that genotypic (Mburu *et al.*, 2003) and phenotypic differences (Simpkin, 1995; Simpkin, 1998; Kaufmann, 1998; Hülsebusch *et al.*, 2002) exist between these types of camels. A few Pakistani camels (imported from Pakistan within the last decade) are also found in Kenya though confined in commercial ranches in Laikipia district.

Productivity of camels

Camel reproductive rate has been described as low (Novoa, 1970). Compared to other livestock species, a camel has low reproductive performance due to late maturity (Zafar, 2000). Female camels attain sexual maturity at the age of 3 years but are usually not mated until they are 4 to 5 years old (Bodenheimer, 1954; Yasin and Wahid, 1957; Evans and Powys, 1979; Simpkin and Guturo, 1995; Tefera and Gebreah, 2001). Breeding activity in the male dromedary camels in nomadic herds starts at 5 – 6 years of age and continues until 14 – 15 years with some minor differences according to breed and geographical location (Hartley, 1979; El-Wishy, 1990; Tefera and Gebreah, 2001). However, full reproductive prowess is not developed until 6 to 9 years of age (Novoa, 1970; Hartley, 1979; Tefera and Gebreah, 2001). Alpacas are bred at 2 years of age (Novoa, 1970). Being seasonal breeders (Yagil and Etzion, 1980), camels mate during the rainy or cold season. The calves are born during rainy seasons when feed availability is high. This enhances their chances of survival. Both rutting season and consequent births coincide with adequate water and feed supplies.

The male dromedary can serve 50 to 80 females in a season when in good condition (Yasin and Wahid, 1957) compared to a bactrian male camel which mates 10 females per season (Terentjev, 1951). Tefera and Gebreah (2001) reported a bull: dam ratio of 1: 25 in Ethiopia. The fertilization rate of dromedary camels in pastoral herds is considered low and unlikely to be higher than 50% (Yuzlikaev and Akhmediev; 1965; Keikin, 1976; Mukasa-Mugerwa, 1981). However, under intensive management, 80-90% fertilization has been reported (Arthur *et al.*, 1986; Abdel-Rahim and El Nazier, 1990). Calving rate of 50% with a 50% survival rate of the newborn calves have been reported in Ethiopia (Tefera and Gebreah, 2001). Abortion rate of 26% and a calving rate of 21% have been reported in Kenya (Simpkin and Guturo, 1995).

Data on milk production of camels are not very accurate for purposes of judging the milk giving capabilities of camels since it is hard to estimate the amount suckled by the calf among other reasons. However, it is clear that the camel has the ability to maintain lactation for a much longer period than cattle (Knoess, 1977). The lactation period for the dromedary varies from 9 to 18 months, with most of the milk being produced within the first 7 months of lactation (Lakosa and Shokin, 1964; Farah, 1996; Yagil, 2000). This is in comparison with 14 to 16 months for the bactrian (Dong, 1979). In Kenya and Ethiopia, a lactation period of one year has been reported (Field, 1979a; Tefera and Gebreah, 2001). The milk yield varies from one part of the world to the other depending on forage availability. Farah (1996) and Yagil (1987) reported daily milk yield of 3 to 6 liters and 40 liters, respectively. Tefera and Gebreah (2001) reported a daily yield of 2.5 liters in Ethiopia while Hartley (1979) reported an average daily yield of 4 kg in northern Kenya. Dong (1981) reported an average daily yield of 5 kg for bactrian camels. The lactation yield ranges from 1254kg in China (Dong, 1981) to 13560kg in Pakistan (Yasin and Wahid, 1957). Field (1979a) reported lactation yield of 1897kg in northern Kenya. The dromedaries produce more milk than the bactrians (Dong, 1979), the latter being mostly used as working animals.

The camel has an average calving interval of 2 years (Evans and Powys, 1979; Tefera and Gebreah, 2001) and produces about 8 calves in a lifetime (Yasin and Wahid, 1957). The gestation period of a dromedary female is 365 to 395 (Yasin and Wahid, 1957; Evans and Powys, 1979; Simpkin and Guturo, 1995) while that of the bactrian averaged 402 days (Chen and Yuang, 1979). Tibary and Anouassi (1997) reported 30kg and 42kg birth weights for dromedary and bactrian camels respectively. Field (1984) reported average calf growth rates of 0.58kg/day and 0.14kg/day for intensively managed and pastoral herds, respectively. Field (1984) and Shalash (1984) reported average mature weight of camels of 400kg. Terentjev (1951) and Dong (1979) recorded 970kg in USSR and 800kg in China, respectively. The mature weight attained by camels depends on the breed.

Adaptations of the camel to arid areas

The camel enjoys anatomical, physiological, behavioral and ecological adaptations, which enable it to survive in the arid areas of the world better than other livestock species. The camel feet are broadened to walk on sand, the long eye lashes protect eyes from wind blown sand, nostrils close to keep sand out, while lips are thickened to withstand the coarsest of desert plants (Yagil, 2000). Calluses are present on knees and other parts of the body, which come into contact with the hot sand when the animal sits down while short, sparse hair helps in heat regulation (Schmidt-Nielsen, 1964). Its height enables it to graze from ground to about 2 meters above ground (Yagil, 1994). This height advantage enables it to browse on plant and plant parts beyond the reach of other livestock species, thus reducing competition for feed.

Camels have long digestive system that retains low quality feed for long periods to allow digestion (Heller *et al.* 1986; Stevens and Hume, 1995). The body can withstand dehydration of up to 30% (McFarlane *et al.*, 1971; Yagil *et al.*, 1974) and quick re-hydration (Zine-Filali, 1987; Dahlborn *et al.*, 1989) due to uniqueness of its erythrocytes, which easily shrink and expand without damage. The body temperature varies with ambient temperature to minimize water loss through sweating (Schmidt-Nielsen *et al.*, 1967). Camels have the ability to feed on salty plants and drink salty water (Yagil, 2000), recycle urea and water (Engelhardt *et al.*, 1978). Camels cuddle together and sit while facing the sun to minimize the body surface directly exposed to the sun in order to reduce heat gain (Schmidt-Nielsen, 1964). Camels also tend to disperse over wide areas while feeding (Stiles, 1987; Yagil, 2000) a grazing behavior that prevents overgrazing, excessive trampling of pastures and the subsequent damage to the environment. Their soft feet pads break grasses and disturb the soil less than hoofed animals.

Socio-economic importance of the camel

Camels throughout the arid areas of the world are considered more reliable milk producers than other classes of livestock during dry seasons and drought periods. During prolonged droughts, milk production in cattle and goats ceases at higher proportions (52% and 75% respectively) than camels (22%) (Hashi, 1988; Herren, 1990). During such times, camel milk may contribute up to 50% of total nutrient intake of some pastoralist groups.

The other global uses of the camel include meat, blood, recreation (camel rides, safari treks, and entertainments e.g. wrestling), racing, wool and fibre production, draught and transport, leather production, dung for fuel, urine as disinfectant, bones for manufacture of jewelry. Camels also have cultural and religious significance among the communities keeping them (Köhler-Rollefson, 2000) and were also used in warfare by Arabs from the 9th century B.C. onwards (Bulliet, 1975).

Among the Rendille community, camels are important for subsistence (milk, blood and occasionally meat), transport, religious and social obligations. The Rendille women earn cash income from milk sales, which they use to buy other household requirements. Men, particularly those with many and large size camels, enjoy a great deal of prestige in the society. The community refers to the camel as the "other half of God". The age set structure of the tribe is based on the generation time of the camel. The Rendille also use camels in payment of fines and dowry (Simpkin and Guturo, 1995).

Camel management

Management of camels differs widely between countries and across regions. On the Arabic peninsula, high priced racing camels are kept under controlled conditions receiving high energy feed rations and human like medical care (Yagil, 1982; Köhler-Rollefson, 2000). In Pakistan and former USSR, camels are managed fairly intensively with feed supplementation and health care, mainly for the purpose of milk production and transport (Knoess *et al*., 1986). In Pakistan where camels are preferred for draught power than tractors, the camels also receive veterinary care and feed supplementation to some extent (Knoess *et al*., 1986). However, the vast majority of the world's camels are maintained in traditional management systems by resource-poor pastoralists trying to eke out a living under inhospitable conditions (Köhler-Rollefson, 2000). Mobile pastoralists keep majority of camels in Africa under extensive management on communal pasture (unimproved natural rangeland), where they neither receive feed supplementation nor significant veterinary inputs (Yagil, 1982).

Grazing camels can be herded or set free to roam and fend for themselves depending on prevailing range conditions. Certain behavioral characteristics predispose the camel to this kind of extensive management system. Camels are known to develop attachments to places, which they associate with certain experiences (Köhler-Rollefson, 1984). Pregnant camels tend to return to the place where they first gave birth for all future calvings and can therefore be left unguarded during last days of pregnancy. Camels separated from the rest of the herds return to the place where they were separated and can often wait there for weeks (Gauthier-Pilters, 1974). Pastoralists also make an effort to strengthen the attachment of camels to homesteads by feeding them with tidbits and by habituating young camels to human contact. Camel pastoralists balance the nutritional requirement of their camels with the need to prevent overgrazing and maintain range productivity (Köhler-Rollefson, 2000). Life form, species diversity from one area to another, camel preferences in different seasons, plant saltiness, the flowering time of different plant species are all understood and incorporated in the camel grazing management. From experience, pastoralists can identify plant species, which increase milk production when eaten by the camels, or tell from the milk odour the plant species that camels consumed.

Camel pastoralists actively manage the reproduction of their camels, not only in terms of selective breeding, but also with regard to pregnancy intervals and infant survival (Köhler-Rollefson, 2000). In cultural settings where milk is the prime product and its supply essential for human survival, the interval between pregnancies may be extended. Some cultures even kill newborn male calves to minimize competition for milk (Janzen, 1980; Elmi, 1989). If the production goal is to increase the herd, she camels are mated early in the lactation.

Pastoralists manage the breeding of their camels objectively, selecting for specific traits depending on the production goals mainly through the male breeding animals (Köhler-Rollefson, 1993; Kuria *et al.*, 2002). Some pastoralists also practice progeny testing (Elmi, 1989). There is a large body of ethno-veterinary knowledge on camels derived from generations of interaction with this animal. Camel pastoralists rarely have access to modern veterinary care and have continued to rely on their own system of disease prophylaxis, diagnosis and treatment (Bollig, 1992; Claus, 1994). They emphasize prophylaxis, avoiding areas that are infested with ticks or camel fly (Elmi, 1989).

The Rendille camel production system in northern Kenya is characterized by both sedentary and mobile camps, an arrangement necessitated by the need to access government and mission-based social services e.g. health, schools, and also to take advantage of forage and water resources located far from the settlements. The size of sedentary camel herd varies from none (for some households) to 10 milking camels per household depending on the overall herd sizes of individual pastoralists and forage availability near the settlements.

The *manyatta*-based herd grazes within a radius of 10 to 15km from the settlements and is mostly on forage of lower nutritional value since the vegetation around settlements tends to be degraded mainly due to human influence (Simpkin and Guturo, 1995). The herd is watered from shallow wells or boreholes around the settlement areas, which are predominantly fresh water. Elderly men, young boys or unmarried men (*morans*) water the camels (Ndung'u *et al.*, 1999). The watering interval is about 5 days and the herd only rarely has access to natural salty water or plants located in distant areas, which are a major source of minerals (Kaufmann, 1998). They are therefore more vulnerable to mineral deficiencies. The milking dams are retained in the settlements as long as they are in milk and until such a time when there is a chance to swap with others in the mobile herd. This happens during traditional ceremonies when all camels are brought to the settlements (*Solio*).

The mobile herd that comprises the main herd and some lactating dams can graze as far as 200km from the settlements (O'Leary, 1985) and is shifted from place to place in response to forage availability and quality (Simpkin, 1995). In the satellite camps are the unmarried men *(morans)* who provide security in the camps and older children who do the herding. The herd is taken home 2 or 3 times in a year either during the wet season or traditional ceremonies (like *Solio)*. The camels graze on high quality forage and are therefore in better body condition than the sedentary herd (Simpkin and

Guturo, 1995). However, the mobile herd camels sometimes trek long distances for water, thereby using substantial amounts of energy.

Mineral nutrition in domestic animals

Minerals are inorganic elements contained in all animal tissues and feeds in widely varying amounts and proportions (Underwood and Suttle, 1999). They constitute the ash that remains after burning of organic matter and naturally occur as oxides, carbonates and sulphates. By 1981, 15 mineral elements were believed to be essential, with practical significance in the nutrition of domestic livestock (Underwood, 1981). These comprised 7 major and 8 trace elements. The major elements were calcium, phosphorus, potassium, sodium, chlorine, magnesium and sulphur. The trace elements were iron, iodine, zinc, copper, manganese, cobalt, molybdenum and selenium. In addition, there were 7 'newer' trace elements, described as essential but with nebulous functions in the animal body (Underwood, 1981). These are chromium, tin, vanadium, fluorine, silicon, nickel and arsenic. All plant and animal tissues reportedly also contain a further 20-30 mineral elements in small and variable concentrations but with no known vital functions (Underwood and Suttle, 1999). To safeguard the functional and structural integrity of the tissues, the concentrations of essential elements must be maintained within narrow limits.

Functions of minerals in the animal body

Functions of minerals can be categorized into four; structural, physiological, catalytic and regulatory (Underwood and Suttle, 1999). Minerals form structural components of body organs and tissues e.g. calcium, phosphorus, magnesium and fluorine in bones and teeth, phosphorus and sulphur in muscle proteins. Minerals occur in body fluids and tissues as electrolytes, concerned with maintenance of osmotic pressure, acid-base balance and membrane permeability e.g. K, Na and Cl. Minerals act as catalysts in enzyme and hormone systems or as components of metalloenzymes. Examples of metalloenzymes are succinate dehydrogenase, cytochrome oxidase and alkaline phosphatase, which contain Fe, Cu and Zn, respectively. Minerals have also been found to regulate cell replication and differentiation. Zinc influences transcription while iodine regulates production of the hormone thyroxin. Cobalt is used in synthesis of vitamin B_{12}. All these functions can only be fulfilled if the amounts of mineral elements ingested are commensurate with the body needs for growth and development, reproduction, replacement of minerals harvested as products or lost during the process of living (Underwood and Suttle, 1999).

Mineral nutrition in camels

There has been little scientific investigation of mineral nutrition and metabolism in camels (Pugh, 1996; Faye and Bengoumi, 1997) and reference has often been made to results drawn from studies with cattle (Wilson, 1989). However, laboratory analysis of whole blood or serum and in some instances, organ tissue analysis has been performed on groups of camels to help establish reference ranges, but the actual requirements and effects of deficiencies or toxicities are not precisely known (Pugh, 1996).

Among the Rendille community of northern Kenya, camels rely on the locally available plants and salty water to meet their nutritional requirements for minerals (Simpkin, 1998) and are rarely fed commercial mineral supplements (Kaufmann, 1998). Under natural grazing conditions, camels select more of forage trees than grasses (Field, 1993). The leaves from trees are generally richer in minerals than grasses (Basmael, 1989; Faye & Tisserand, 1989; Rutagwenda *et al.*, 1990; Wardeh, 1991; Field, 1995). It has been shown that forages selected by grazing Rendille camels (mainly shrubs) have the recommended levels of important mineral elements and can potentially meet the nutritional needs of the camels (Kuria *et al.*, 2004).

Mineral requirements and sources in camels

Camels mainly depend on natural pastures to satisfy their mineral needs. However, since the mineral content of forage species vary, the amounts supplied depend on what the camels select from the grazing field. In addition to forages, camels obtain some supplementary minerals from water, soil and commercial salts. The importance of soil minerals as dietary sources for all grazing ruminants depend on the amount of soil ingested and the ability of the ruminant to solubilize and absorb the soil derived minerals (Mayland *et al.*, 1975). Drinking water is normally not a major source of minerals to livestock except saline water whose level of Na and Cl exceed the animal body requirements of these elements (Shirley, 1978). This author further observed that some 'hard' waters also supplies significant amounts of Ca, Mg and S, and occasionally other minerals.

Faye and Bengoumi (1994) observed that the exact mineral requirements for camels are not well established. However, the requirements have been shown to vary with breed, locality, age, sex, nutritional and health status (Abdalla *et al.*, 1988). Nagpal *et al.* (1998) also observed that the mineral requirements in camels varied with parity, stage of lactation and pregnancy.

Interaction between minerals is also known to influence bioavailability and thus dietary mineral requirements by animals, camels inclusive (Church and Pond, 1988). Wilson (1984) estimated that salt (NaCl) requirements for maintenance alone is between 6-8 times higher for camels than for other livestock. This author further observed that camels have the capacity to withstand very high levels of salts in their feed and water, (a physiological adaptation to arid environments), recommending daily intakes of 120-140 gd^{-1}. Lower intakes of 57-112gd^{-1} have been considered adequate by other authors (Leese, 1927; Garden, 1971). Low intakes of 30-60gd^{-1} predispose camels to the characteristic deficiency syndrome, associated with arthritis (Wilson, 1984). This author also observed that when given salt in quantities equivalent to 140gd^{-1}, there is an immediate improvement in this condition.

In a study with the South American llamoid, guanaco, Hastings and Gascoyne (1992) reported plasma Cu levels of 8.0 ± 1.0 µmol/l. Additionally, plasma Fe level $\leq$ 29.0 ± 9.5 µmol/l in the guanaco was in the lower end of the range 29.6-33.7µmol/l, recommended in cattle (NRC, 1984). The authors suggested that satisfactory plasma levels of Mn and Co in guanaco are also lower than those reported in other livestock. Abdalla *et al.* (1988) concluded that the requirements for macro elements in camels may be higher than for other domestic livestock. In comparison with the bovine, Faye and Bengoumi (1997) reported that trace mineral requirements of camels are lower. For example, they suggested a level of 0.54ppm as the plasma deficiency threshold for both Cu and Zn in camels, with the corresponding levels in cattle being double this amount.

Consequences of mineral inadequacy in animals

Continued ingestion of diets that are deficient, imbalanced or excessively high in a mineral induces changes in concentration of that mineral in the body tissues and fluids so that it falls below or rises above the tolerable limit (Underwood and Suttle, 1999).

A large number of livestock in many parts of the world consume such diets (McDowell *et al.*, 1993). In such circumstances, physiological functions are affected adversely and structural disorders may arise depending on the element in question, the degree and duration of dietary deficiency (Chesters and Arthur, 1988) or toxicity and the age, sex and species of animal involved. Nutritional disorders then arise, ranging from acute or severe mineral deficiency or toxicity diseases characterized by well marked clinical signs, pathological changes and high mortality, to mild and transient conditions. The mild conditions, which include unthriftness, unsatisfactory growth, production and fertility, are difficult to diagnose with certainty (Underwood and Suttle, 1999). In many parts of the world, animal productivity is primarily limited by shortages of available energy and protein, infectious and parasitic diseases and genetic inadequacies in the animal. As these limitations are increasingly rectified, local mineral deficiencies and imbalances are likely to become more apparent and critical (Suttle, 1991).

Consequences of mineral deficiency on productivity

Zinc and Cu deficiencies in camels have been reported in Djibouti (Faye *et al.*, 1990). Selenium deficiency has also been reported in the Mongolian camels of China (Zhang *et al.*, 1988;). In Kenya, P, Co, Cu, Mg, Na and Zn deficiencies have been reported (McDowell *et al.*, 1983, 1984; Faye *et al.*, 1990; Vittorio *et al.*, 1999). Inadequate intake of minerals in ruminants can impair feed intake and digestibility leading to decreased growth rates and milk production (Anenkov, 1981). Reproductive failure is one of the adverse economic results of mineral deficiency in livestock (McDowell, 1976). The minimum mineral intake by an animal must therefore be sufficient to ensure the long-term maintenance of the mineral reserves of the body tissues and the amount of those minerals in the edible products of the animal (Faye and Bengoumi, 1997).

Wilson (1984) observed that the implications of mineral deficiency in the general health and productivity of camels are considerable. Minerals are important in the growth and milk production of camels (Hussein, 1993) and inadequacy in the diet reduces milk yield and calf growth (Conrad *et al*., 1982; Hashi, 1984 and Newman, 1984). Sodium chloride, for example, is an important component in water conservation of camels (Leitch, 1940; Yagil and Etzion, 1985). Its inadequacy could result in a decline in milk yield due to changes in the hydration status of the camel and the subsequent growth of calves. This is recognized by traditional camel owners who routinely take camels to salty areas to effect a 'salt cure' although intervals between salt cures may be as long as 2-8 months (Hussein, 1993). Leonard (1984) observed that salt intake affected both milk yield and quality.

The consequences of P and Ca deficiency are intertwined due to their functional relationship. Inadequate supply of phosphorus affects the animal's physical well being and its productive performance (McDowell, 1997). The initial effect is a fall in blood plasma phosphate levels, followed by the response mechanism of Ca and P being withdrawn from the animal's bones. This often results in reduced resistance to infection, loss of appetite and a reduction in live weight gain due to impaired feed conversion efficiency. Calcium deficiency reduces growth rate and the milk production of all animals. Bone fragility symbolizes severe Ca and P deficiency (McDowell, 1997).

Evaluation of body mineral status

Several methods have been used to assess the mineral status of grazing ruminants. These include clinical and pathological changes, but these are often non-specific and indistinguishable from those resulting from inadequate energy, protein or vitamins; from parasitism or toxic plants (McDowell, 1985). Thus, to adequately determine mineral deficiencies, this is not a reliable method. Grazing livestock obtain the bulk of their mineral requirements from forage plants. Assessment of forage species mineral content in relation to the animals' requirements has also been used (Kuria *et al.*, 2004). However, as Fick et al. (1979) observed, this assumes that the sample collected and assayed for mineral content is representative of what animals consume. Use of soil analysis as an indirect indicator of mineral status in animals is also eliminated due to lack of a significant relationship between the mineral content of soil and the herbage growing on it (Vander Veen, 1973; Gitter *et al.*, 1975).

Concentration of minerals in the blood does not give the true dietary mineral status when the homeostatic system is functioning properly (Miller, 1975) since most minerals are tightly regulated in the body through a variety of homeostatic processes (Van Saun, 1999). However, examination of body fluids and tissues most accurately portray the contribution of the total environment in meeting the mineral requirements of grazing animals (McDowell, 1985). This is because excess minerals travel through the blood to the kidney from where they are excreted (Herdt *et al.*, 2000). Minerals mobilized from the storage organs and structures are transported through the blood to their respective points of use (Faye and Bengoumi, 1997). Thus, plasma mineral profile is generally accepted as a good indicator of an animal's body mineral status.

Effect of mineral supplementation on productivity and blood mineral profile

Where deficiencies exist, mineral supplementation has been shown to have beneficial effects on livestock in terms of improved production parameters (Miles and McDowell, 1983). The apparent production response to mineral supplementation is the best way of determining the level of deficiency in camels (Ghosal and Shekhwat, 1992). Hammadi *et al.* (1998) reported differences in calf growth rate between supplemented and non-supplemented female camels. Vittorio *et al.* (1999) reported increased milk yield in camels following mineral supplementation. Wangoh *et al.* (1998) and Vittorio *et al.* (1999) also reported improved milk quality as a result of mineral supplementation. Effect of mineral supplementation on blood mineral profile depends on the homeostatic control (Doyle *et al.*, 1990). However, while Vittorio *et al.* (1999) observed that plasma levels of P and Mg of lactating camels were not affected significantly by supplementation, Ingraham *et al.* (1987) reported increased plasma Mg and Cu following mineral supplementation.

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Chapter 3

Indigenous camel mineral supplementation knowledge and practices on manyatta based camel herds by the Rendille pastoralists of northern Kenya

Indigenous camel mineral supplementation knowledge and practices on *manyatta* based camel herds by the Rendille pastoralists of northern Kenya

Abstract

A study was conducted to document the traditional mineral supplementation strategies on *manyatta*-based camel milking herds by the semi-settled Rendille pastoralists of Marsabit district in Kenya. During the survey, 33, 28, and 30 respondents were individually interviewed in Kargi, Korr and Ngurunit locations of the district, respectively. The results indicated that a combination of rain water standing on salty soils referred to as *marmar,* and forages growing on such soils were the key sources of mineral supplements to *manyatta*-based camels, with commercial mineral supplements playing only a minor role. Salty water and forages located within a 30 km grazing radius of the camels were used mainly during the wet season, while commercial salts were used during dry periods. Natural salty water springs and moderately salty boreholes were also used during the dry season. The findings suggested that while Rendille pastoralists knew the importance of mineral supplementation and could describe the deficiency signs, the major salty water springs in the area were beyond the reach of most of *manyatta*-based camels, predisposing them to multiple mineral deficiency. Enhanced grazing and watering management could ameliorate this problem in the short term. In the long term however, there was need for a mineral supplement to be availed to the *manyatta*-based camels in order to meet their mineral requirements.

Key words: Indigenous knowledge, camel, mineral, pastoralists

Introduction

The Rendille are semi-nomadic pastoralists living in Marsabit district of Kenya. They keep camels under extensive grazing systems characterized by *manyatta* (settlement) and 'satellite' (mobile) camps. The former type of production system is necessitated by the increasing need to settle in order to take advantage of government and mission-based services e.g. health, schools and sometimes relief food (Kaufmann, 1998). The *manyatta*-based herd represents about 25% of the total Rendille camel population but it determines the amount of milk available to the household (Garmagar, 2001). The herd grazes within a radius of 10 to 15 km from the *manyattas*, mostly on forage of lower nutritional value since the vegetation near settlements tend to be degraded mainly due to human interferance (Simpkin and Guturo, 1995). Rendille camels mainly rely on natural mineral sources available in the area for mineral supply, the key ones being salty[1] water and plants. The salty water is found naturally in springs and wells or collected in ponds after rains. The *manyatta*-based herd often does not have access to the key natural mineral sources because the sources are located far (Kaufmann, 1998), thus the camels are more vulnerable to mineral deficiencies than the mobile herds.

Mineral supplementation is an important management aspect for production and productivity of camels (Simpkin, 1998). The Rendille herders appreciate the importance of mineral nutrition in camels and have developed criteria for assessing mineral deficiency. Current mineral supplementation strategies are based on local knowledge of mineral-rich forages, water and soils.

[1] Pastoralists distinguish salty water and plants by camel response after drinking and taste

Research efforts geared towards improving mineral supplementation practices in camels in these areas should build on the existing local knowledge. A socio-biological study was conducted to document indigenous knowledge on mineral supplementation practices on the *manyatta*-based camel herds by Rendille herders during different seasons.

Materials and methods

Description of the study area

The Rendille pastoralists occupy Laisamis and Loyangalani administrative divisions of Marsabit district between 2° and 3° north and 37° and 38° east. The area comprises of sedimentary plains about 350m a.s.l. (Bake, 1983). To the East of Rendille area is mount Marsabit (1865m) while to the West and North are Mt.Kulal (2335m) and Hurri hills (1685m), respectively. All these landforms are of volcanic origin. To the southern side are the metamorphic basement rock mountain ranges of Nyiru (2752m), Ol Donyo Mara (2067m) and Ndoto (2637m) while to the South West are the Matthew's ranges (3170m). The area receives a mean annual rainfall of 250mm on the plains and 800mm on the slopes of the mountains (Schwartz *et al.*, 1991) and follows a bimodal distribution pattern. Long rains are received in March/April, whilst short rains come in October through December. The mean monthly temperatures vary from 27 to 29°C while the mean minimum and maximum daily temperatures are 20°C and 35°C, respectively.

The study was conducted in Ngurunit (01°44.125N 037°17.454E; 802 m.a.s.l), Korr (02°00.192N 037°30.295; 566 m.a.s.l and Kargi (02°30.567N 037°34.481; 460 m.a.s.l), located in western Marsabit district. Ngurunit is located on the mountain slopes while Korr and Kargi are in the plains. Soils in Kargi area are of volcanic origin while those in Ngurunit and Korr are metamorphic in nature (Bake and Kekem, 1984). Vegetation of the area is dorminated by shrubs interspersed by annual grasslands and trees with the bush being thicker in Ngurunit area and sparse towards Kargi. The study covered an area of 30km radius from the settlements.

A semi-structured questionnaire was designed, pre-tested and administered through a language translator on semi-settled Rendille camel herders in the three study sites during the dry and wet seasons. The respondents were mainly boys and men who are directly involved in camel management and a few women numbering 33, 28 and 30 in Kargi, Korr and Ngurunit, respectively. Individuals interviewed in the dry season were re-interviewed during the wet season to capture seasonal variations. Five to eight respondents were selected at random from 4 to 5 randomly selected *manyattas* at the 3 sites. The questionnaire captured data on: perceived importance of mineral supplementation in camels and sources of such supplements, pastoralists' decision making criteria on the use of various mineral sources and the perceived mineral deficiency signs in camels (Appendix).

Analysis of the questionnaire

The collected data was coded and frequency summaries obtained using Windows based SPSS (Norman *et al.*, 1975). Chart(s) were drawn using Excel 2000 for Windows (Maria, 1999).

Results and Discussion

Perceived mineral deficiency signs

All the respondents interviewed during both wet and dry seasons were aware that camels required mineral salts, lack of which would result in deficiency signs. The respondents identified several signs indicative of mineral deficiency in camels (Table 1). These were grouped into four categories i.e. those pertaining to camel behavior, production, physiological and physical changes.

Table 1: Deficiency signs observed by respondents expressed as a percentage of total **responses (n)

Category of symptoms	Observed signs	Percentage of responses		
		Korr	Kargi	Ngurunit
Behavioral	Restlessness	10.7	18.1	10.0
	Chewing *Boma** construction woody material	0	2.2	0
	Chewing bones	0	0	4.0
	Licking soil	4.7	10.8	10.4
	Licking urine	12.8	22.4	10.9
Production	Reduced milk yield	26.8	19.8	23.9
	Lack of frothiness in milk	0	1.3	1.5
Physiological	Drink little water	2.7	0	0
Physical appearance	Inadequate rumen fill	36.9	23.0	39.3
	Dullness	5.4	3.4	0

n = the sum of dry and wet season responses in a site (Korr =149; Kargi =232; Ngurunit = 201);

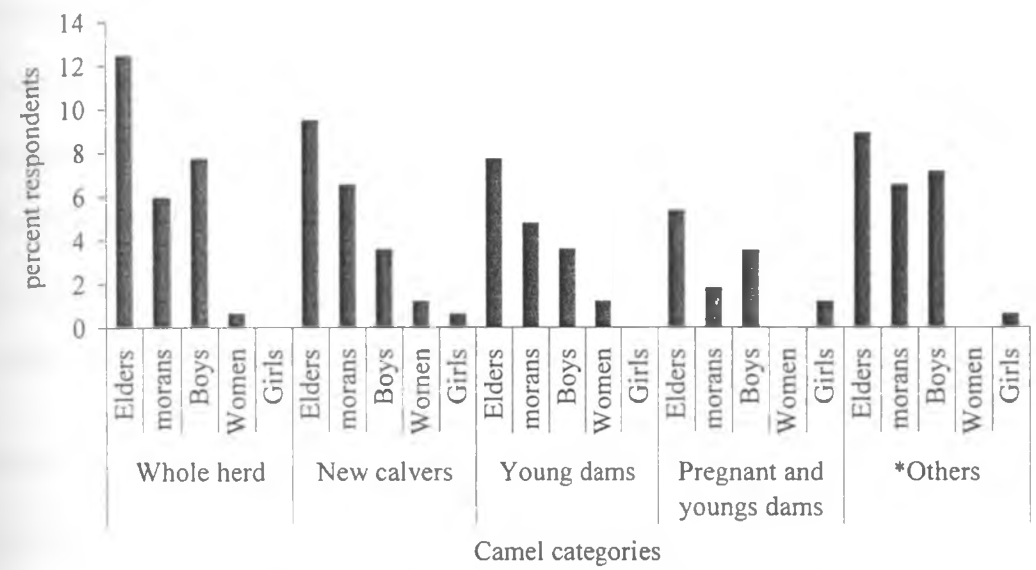
* Boma - a night enclosure for livestock; ** a respondent could give more than one answer to a question, hence responses could be more than respondents

In order of importance, inadequate rumen fill, reduction in milk yield and licking of urine were perceived as the top three mineral deficiency signs by the respondents in all the three sites in agreement with Kaufmann (1998). Kargi herders registered the highest variety of mineral deficiency signs. Only eight respondents from Ngurunit recognized chewing of bones as a sign of mineral deficiency in both wet and dry periods. There was however a long-standing belief among the Rendille community that bones chewing by livestock was an indication of bad omen (Garmagar, 2001). This may have contributed to the zero response in Korr and Kargi, as the herders would fear mentioning this sign even if observed. Low understanding of the intricacies of mineral nutrition could also partly explain this anomaly. If the respondents were aware that bones contained Ca, P and Mg, they would have linked this camel behavior to mineral deficiency. Seasonal variations in the sites were noted in Kargi and Korr with most of the signs being observed in the dry season. The reverse was, however, true for Ngurunit.

Figure 1 shows the respondents gender perception on the specific camel categories in a herd that shows deficiency signs. There were a total of 169 responses on this question from 169 respondents. The respondents comprised 74 elders, 44 *morans*[1], 41 boys, 6 women and 4 girls. For every category of camels, each bar represented the percentage of total respondents giving that particular answer e.g. 12.5% of 169 elders observed deficiency signs on the whole camel herd.

[1] Morans are initiated but unmarried men

Figure 1: Respondents gender perception on specific camel categories in a herd that show deficiency signs



*Represented high milk yielding dams, old dams with big calves, lactating dams of one family line and unspecified camels in a herd

Twenty six percent of the respondents observed deficiency signs in the whole herd while 21.3% observed in new calvers. Approximately 17.2%, 11.8% and 23.1% of respondents observed the symptoms in young dams, young pregnant dams and other groups of camels, respectively. Elders, *morans* and boys noted mineral deficiency signs on all camel categories, whereas women respondents observed the signs on whole herd, new calvers or young dams. Girl respondents, on the other hand, observed deficiency symptoms on new calvers, young pregnant dams and the ‘other’ camel categories. This difference between the male and female gender could be due to the fact that the former were more involved in camel husbandry than the latter. Boys also generally had more knowledge on mineral deficiency than the *morans*, possibly because the former herded camels more than the latter. Boys milked most of the times and therefore had more time to observe the camels.

For the new calvers, young pregnant dams, high milk yielding and old dams with big calves, respondents thought that the body demand for minerals had increased and hence the higher incidence of deficiency signs. Based on experience, Kargi and Korr respondents believed that a camel needed to utilize the natural mineral sources, particularly, Korole water[1] for 7 consecutive years to attain the required body mineral threshold. After this period, camels would use fresh water for longer periods without showing any signs of mineral deficiency. In this respect, young dams were more vulnerable to mineral deficiencies than the older camels.

Importance of mineral supplements in camels

Pastoralists from the three study sites were knowledgeable about the importance of mineral supplementation and its benefits to camels. They concurred that effects of supplementation were easily detectable through assessment of observable and measurable signs. These factors could be broadly categorized into changes in production characteristics, behavior of the camels, physiological and physical changes on the camel body. The observed effects as perceived by pastoralists are listed in Table 2.

[1] Natural water from Korole springs located on the edge of Chalbi desert in Marsabit district, Kenya

Table 2: Respondents perception of effects of mineral supplementation on camel performance

Category of changes	Perceived effects	Percentage of responses		
		Korr (*n)	Kargi	Ngurunit
Production	Higher milk yield	34.7	29.1	33.3
	Stronger calves	0	9.3	0
	Better milk and meat taste	1.7	7.0	0
	Higher conception rate	0.8	4.1	3.0
	Tasty body fat	0	2.3	0
Physiological	Better feeding appetite	13.6	4.7	19.3
	Better dehydration resistance	1.7	4.7	0.7
Physical appearance	Bigger camels of better body condition	38.1	28.5	33.3
	Cleaner and shiny hair coat	1.7	1.7	3.7
Behavior	Better mothering	0	0.6	0
Others	Higher disease resistance	6.8	5.2	2.2
	Fewer external parasites and occurrence of skin diseases	0	2.3	0.7
	Lower worm load	0.8	0.6	3.7

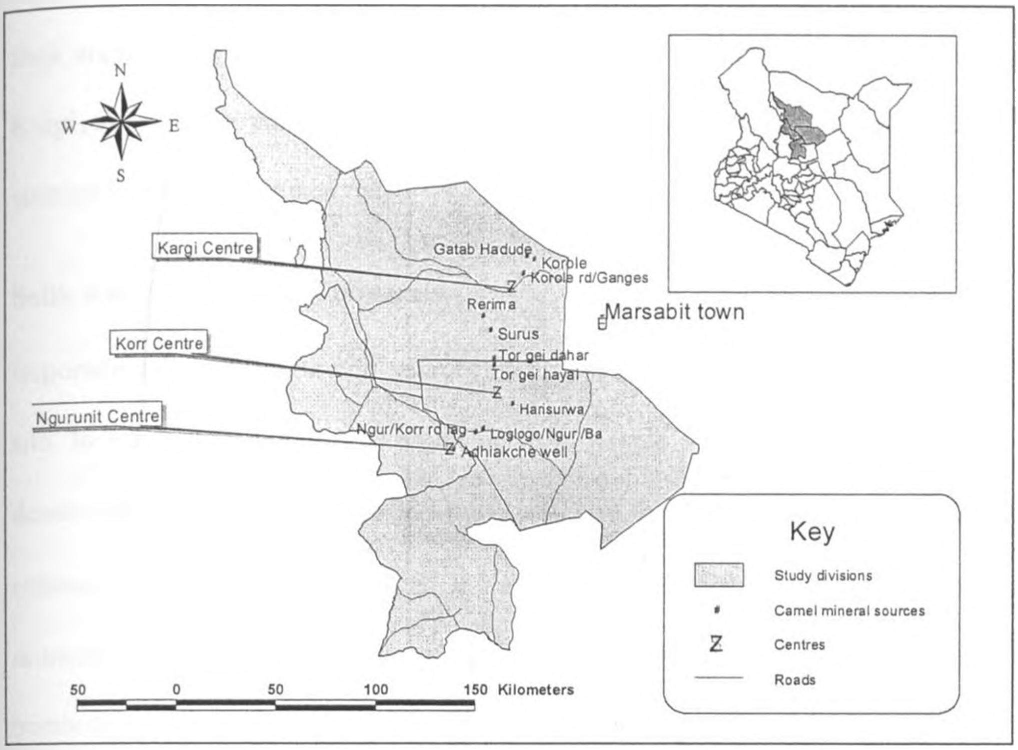
*n = sum of dry and wet season responses in a site (Korr=118, Kargi=172, Ngurunit=135)

The respondents perceived production and physical changes as the most important indicators of adequate mineral supplementation. This was attributed to the fact that such changes were easily observed and were of direct benefit to herders. Changes in feeding appetite were also easy to note and had direct bearing on daily milk yield. Other changes were less obvious to the respondents probably because they were of less immediate importance.

Sources of mineral supplements for camels

The respondents' perception of the ability of different mineral sources to satisfy the mineral needs of camels varied from site to site, depending on the particular source that was accessible to the herders. In the dry season, 30.4% and 90.3% of the Korr and Kargi respondents, respectively, used a combination of salty water and salty plants (evergreen type) while none of Ngurunit respondents used any of these sources. Due to their proximity to the Korole springs, Kargi respondents had better access to water sources of mineral supplements in the dry season. In general, reliance on mineral supply from salty plants and water was very high compared to commercial salts across the sites. Eighty-eight point five (88.5%), 100% and 47.6% of the respondents in Korr, Kargi and Ngurunit, respectively in the wet season, used salty water and plants while commercial sources were used in combination with salty water and plants by 72.7% of respondents in Ngurunit. Figure 2 shows the geographical location and distribution of water and plant sources of minerals perceived as important by the local pastoralists in the study area.

Figure 2: Map of the study area showing location and distribution of water and plant mineral sources perceived as important by local herders



*On the map: Gatab Hadude - Gatab Hadude, Kargi; Loglogo/Ngur/Ba - Loglogo/Ngurunit/Bayo junction; Ngur/Korr rd lag - Ngurunit/Korr road lagga; Korole rd Ganges - Korole road/Lagga Gangesa junction

Approximately 22%, 12% and 11.5% of the respondents across the various sites during both wet and dry seasons (n = 174) believed that Korole water, *marmar*[1] water from Kargi area and the Red Magadi[2], respectively could individually meet all the mineral needs of camels. However, 37.3% were of the view that combinations of at least two types of mineral sources gave better results. Both standing rainwater and salty plants gained importance during the wet season, this being the time when both sources were available in abundance. These two sources were found in common grazing areas used by the *manyatta*-based herds. Permanent salty water sources and commercial salts were mainly used during the dry season when salty water and plants

[1] Rain water standing on salty soil
[2] Raw unprocessed salt from lake Magadi in Kenya

were not available. Commercial salts (Red Magadi and NaCl) were mostly used in Ngurunit, and to a limited extent at, Korr. Respondents from these two sites perceived their areas as not having rich natural mineral sources. In contrast, respondents from Kargi did not use commercial salts at all, since they viewed the natural mineral sources in their area as adequate.

Salty water as sources of minerals

Important salty water mineral sources identified by respondents varied from site to site. In Kargi, salty water was available from Korole springs at the edge of Chalbi desert (02°38.5 N 037°40.6 E: 389 masl) and also the *marmar.* Gatab Hadade, (geo-referenced: 02°39.2 N 037°38.4 E: 380 masl) was one of the largest ponds that held rainwater during wet periods in Kargi. In Korr, the major source was *Harisurwa* borehole and the standing rainwater in the surrounding areas while in Ngurunit, the sources were Adhiakche, Siangan and Merti Dorob shallow wells.

According to the Ngurunit respondents, camels mainly drank *marmar* water for 2-3 weeks following commencement of the rains when it was readily available. Their experience was that camels showing deficiency signs needed to drink the water for 2-3 consecutive weeks for the signs to disappear. Camels also intensively fed on the evergreen salty plants during this period, a behavior attributed to the continuing forage scarcity early in the wet season. In addition, the readily available drinking water mitigated the usually perceived bitterness of salty plants, thus enabling camels to consume more of these during this period. By the end of third week after the start of the rainy season, conventional forages fully regenerated and the camels appeared to lose appetite for salty plants.

Salty water mineral sources preferred by respondents on seasonal basis

During the dry season, 97% of the Kargi respondents preferred taking their camels to Korole springs for supplementary minerals, while in the wet season, 78.8% of the same respondents preferred using *marmar* water. Camels were watered from Korole once in three months and from the other less salty water sources near the *manyattas* at other times. Three months was the perceived residue period beyond which deficiency signs reappeared, a clear indication that the major reason for taking camels to Korole was mineral supplementation. This was consistent with Kaufmann (1998) who reported that 58% of Rendille herders (n = 48) took their camels to salt sources on observing deficiency signs. Although the respondents in Kargi appreciated that their camels would benefit from more regular visits to Korole, the frequency could not be increased due to inadequate labor.

At Korr, 75% of respondents preferred watering their camels from *Harisurwa* borehole in the dry season while 82.1% opted for standing rain water around the borehole during the wet season. On the other hand, 63.3% of Ngurunit respondents preferred Adhiakche's well in the dry season while 46.7% of the respondents opted for *marmar* water in *Harisurwa* area during the wet season. Unlike the respondents in Kargi, those in Ngurunit and Korr watered their camels from the permanent salty water sources every 6 – 10 days suggesting that the major reason for doing so was normal watering.

Respondents across the three sites chose to use specific water sources, disregarding others available within the camel grazing area. Several factors, either singly or in tandem affected the preference of salty water source by the respondents. These included availability, distance of the source from the *manyatta,* labor and perceived response of the camels after using the source. Kargi pastoralists preferred Korole water during dry season despite presence of nearby shallow wells. The reasons were that the natural springs at Korole were accessible and the camels responded well after drinking the water. In the wet season, the same respondents preferred standing rain water (*marmar)* due to its availability together with the perceived good camel response. Respondents from Korr on the other hand preferred using borehole water (*Harisurwa)* during the dry season as opposed to the equally accessible shallow wells. This was because of the proximity of the borehole to the *manyattas* and more importantly, the respondents' perception that the borehole water was better for camels in terms of improved body condition and milk yield. Standing rainwater (*marmar)* was the most important water source in the wet season across the study sites.

Due to the good camel response after watering from Korole springs, Rendille herders far from this source were aware of this advantage (Bake, 1991). In the present study, the respondents named and ranked twelve (12) springs within the wider Korole area. The ranking was based on perceived differences in camel response attributed to mineral content of the springs. During the ranking exercise, one respondent could rank a certain spring number 2, a second respondent could rank the same spring number 3 while a third respondent could still rank the same spring number 1. The perceived mineral content of a certain spring's water therefore varied from one respondent to the other. Hence, to determine the perceived best spring, responses supportive of a certain spring as ranking either as 1, 2 or 3 in the three study sites were summed up. Percentages of the total responses were then computed for each spring. The results were as shown in Table 3.

Table 3: Ranking of Korole springs by pastoralists

Spring	Percent of Respondents (n = 240)
Hirgelcha	28.3 (1)
Garuga	20.4 (2)
Nyirkhoharaw	15.8 (3)
Hayo	13.3 (4)
Dakhan	12.9 (5)
Hereya	2.5 (6)
Hiditupcha	2.1 (7)

Based on this ranking (Table 3), *Hirgelcha*, *Garuga*, *Hayo* and *Dakhan* were considered to be superior springs. Five other springs namely *Hadado*, *Woroadi*, *Isobori*, *Kholokholokh* and *Barbar* were also identified but ranked low. In a study to evaluate the traditional sources of mineral supplements in the Rendille area, laboratory analysis of water samples from the various Korole springs confirmed differences in mineral content of the springs (Kuria *et al*., 2004).

In Kargi and Korr, 85.2% of the respondents were aware that many springs existed at Korole though they could not recall the names. According to the respondents, when camels were taken to Korole for watering, they did not drink from one spring but were taken round to the perceived important springs to benefit from the variety of minerals. In Ngurunit, 67.0% of the respondents were not aware that there were multiple springs at Korole. This was consistent with the fact that Korole was an important mineral supplement source, but almost exclusively for the camel herds in Kargi due to its accessibility.

Salty plants

The major salty plants identified by the respondents in the three sites are summarized in Table 4.

Table 4: Perceived important salty plant species in Kargi, Korr and Ngurunit

	Number of respondents (n)					
	Korr		Kargi		[b]Ngurunit	
	Dry	Wet	Dry	Wet	Dry	Wet
Salvadora persica (Hayai) [a]	28.3[c]	18.1	20.9	28.3	41.2	8.9
Ficus species (Arabharis)	9.4	18.1	8.7	26.1	17.6	31.1
Salsola dendroides (Hadum)	7.5	5.6	18.3	0	17.6	17.8
Dactylotenium bogdanii (maho)	17.0	19.4	5.2	17.4	0	6.7
Maerua oblongifolia (Geigiri)	18.9	0	13.9	6.5	0	0
Cadaba mirabilis (Khadu)	0[d]	12.5	10.4	15.2	0	0
Lycium europaem (Surus)	0	16.7	0	6.5	0	26.7
Cadaba glandulosa (Gurangur)	11.3	9.7	7.8	0	23.5	0
Maerua classifolia (Ndume)	7.5	0	5.2	0	0	8.9
Sporobolus spicatus (Arfug)	0	0	4.3	0	0	0
Boscia coreacea (Yoror)	0	0	2.6	0	0	0
Cadaba farinosa (Geiguku)	0	0	2.6	0	0	0

[a]In brackets are Rendille names of the forage species; [b]At Ngurunit, Samburu language was commonly used hence local names of forage species would change; [c]Figures in the table represent the percentage of respondents who mentioned a certain forage species as important; Korr dry and wet – 28, Kargi dry – 33, Kargi wet – 27, Ngurunit dry – 30, Ngurunit wet – 28; [d]not mentioned as important during the indicated season

Salty plants, as in the case of salty water, were considered important by the respondents if; camels responded positively after eating it, available and easily accessible and in addition, the growth form (evergreen, deciduous, annual or perennial). Growth form determined availability of the plant species. Seasonal changes in the perceived importance of a plant species was attributed to availability especially for deciduous and annual species, perceived palatability and presence or absence of alternative species.

Among the three sites, *Salvadora persica, Ficus species* and *Salsola dendroides* were ranked 1, 2 and 3, respectively in importance as plant sources of minerals to Rendille camels. Results of laboratory analysis of the said plant species for nine minerals did not correspond with the respondents' ranking of the salty plants except for *Salsola dendroides,* which had exceptionally high levels of copper and zinc during dry and wet seasons respectively (Kuria *et al.*, 2004). However, the mineral content of a salty plant (inferred from response of camels) was only one of the several factors the respondents considered in ranking the salty plants.

About 67% of these plants were evergreen shrubs. They were therefore available throughout the year although pastoralists viewed them as more important during the dry season. This was possibly because, in the dry season, such plants served the dual roles of supplying minerals to camels and also acted as important components of the basal feed. Deciduous shrubs (*Ficus species, Lycium europaem)* and perennial grasses *(Dactylotenium bogdanii, Sporobolus spicatus)* were considererd to be more important in the wet season. The respondents stressed that camels tended to take advantage of the leaves before they were shed off. Although the number of species and availability of salty plants was much higher during wet seasons, camels showed low preference suggesting low palatability. In addition, other forage species preferred by the camels were available in abundance during the wet season. Camels then appeared able to largely satisfy their mineral needs from these forages although the respondents perceived them as low in mineral levels.

Conclusions and Recommendations

Rendille pastoralists were aware of the importance of minerals in camel nutrition and could describe deficiency signs. The pastoralists were also aware of the importance of supplementation for which they invariably relied on salty plants and water. In the rainy season, salty plants were eaten only in small quantities by the camels. However during the dry season, these were consumed in larger quantities, especially by the freshly watered camels, most probably due to low availability of the normally preferred forages. *Manyatta* based camels could not rely on naturally occurring mineral sources due to the following reasons: 1) salty plants were abundant during wet periods and only sparsely available during dry periods, 2) salty water sources like *marmar* were seasonal depending on rainfall, 3) key salty water and plant resources were far from *manyattas,* beyond the normal grazing radius of camels. The distribution of the sources in space was poor and hence inaccessible to many camels. Consistent with fact that the camels cannot rely on natural mineral sources, there is need to avail a mineral preparation to the *manyatta*-based Rendille camels.

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Chapter 4

Evaluation of mineral sources for camels in western Marsabit, Kenya

Evaluation of mineral sources for camels in western Marsabit, Kenya

Abstract

A survey to identify mineral sources for settlement-based camels was carried out in the semi-arid rangelands of southwestern Marsabit district of Kenya during dry and wet periods. The respondents included men and boys who were responsible for herding and watering of camels in the area and a few women. Identification of the sources was followed by field verification of forage sources, sampling and analysis of forage plants for minerals. The available water sources were also sampled and subjected to similar analysis. A table of mineral composition of the various sources was compiled. Over 80% of preferred forage species had Ca, P, Mg, K, Na, Fe and Co contents above the recommended levels for camels during both dry and wet seasons in all the study sites. Eight (8) to 50% of the forage samples were adequate in terms Cu and Zn. Although some forages perceived as important mineral sources by pastoralists had high mineral levels, they were not consumed by camels, mainly due to limited availability or low palatability. Natural spring water had high levels of P and Fe, whereas standing rainwater contained high levels of Ca and Fe. Some of the preferred forage species were available sometimes and scarce during other times, while some of the water sources were located outside the normal grazing radius of *manyatta*-based camels. It was concluded that forage species were the most important sources of minerals for grazing camels followed by water. Mineral supplementation was minimal. Apart from Cu and Zn, the forage species can potentially satisfy the daily requirements of camels for the studied minerals. A need to create awareness among the camel herders about the mineral contents of forage species or water as a guide to grazing and watering management of camels was noted.

Key words: Camel, plant mineral sources, non-plant mineral sources, Kenya

Introduction

The semi-nomadic Rendille pastoralists who keep camels and small stock, among other livestock species, inhabit the western part of Marsabit district. They use locally available salty water and plants as sources of mineral supplements for their camels (Simpkin, 1998) with minimal use of commercial supplements (Kaufmann, 1998). Under normal conditions, camels have the capacity to choose their forages efficiently, with more browsing than grazing (Field, 1993). Browse species are generally richer in minerals than herbage (Basmael, 1989; Faye and Tisserand, 1989; Rutagwenda *et al.*, 1990; Wardeh, 1991; Field, 1995). However, wide variations in mineral contents of natural pastures have been reported and seem to depend on season and physiological state of the constituent plant species (Long *et al.*, 1972).

Studies on assessment of nutritional requirements of camels remain scanty, and as such, requirements are often inferred from cattle studies (Wilson, 1989). Mineral deficiencies and toxicities in camels have not received adequate attention (Farid, 1989), except for sodium chloride and calcium/phosphorus ratio, although these mineral aspects are known to limit productivity (McDowell, 1985). In the Rendille area of Marsabit district, information on the mineral profiles of the major sources is lacking (Bake, 1991). Subsequently, the extent and distribution of their deficiencies is poorly understood (Faye and Bengoumi, 1997), thus limiting any attempt to improve camel productivity through manipulation of mineral supplementation. This study was designed to identify the sources of minerals for *manyatta*[1]–based camels, and to determine their mineral content.

[1] *Manyatta* = a settlement comprising several households

Materials and Methods

A description of the study area is presented in Chapter 3.

Identification of the mineral sources

Thirty respondents were selected in each of the three study locations and individually interviewed using a semi-structured questionnaire during the dry and wet seasons. The respondents were mainly boys aged between 8 to 20 years and men who were directly involved in herding and/or watering of camels. Mineral sources were identified and also ranked in order of the perceived importance by the respondents. The information regarding forages was confirmed through direct field observation of grazing camels. Thirty- (30) camels were observed per season per site (5 – 6 camels per day) in 5 – 7 consecutive days. Camels and the grazing areas were randomly selected such that each camel was exposed to similar array of forages from which they selected their diets. None of the camels was alien to the area, thus, all had equal chances of selecting the best combination of forages using their past experience. The observations were carried out by myself and a technician with each of us observing 2 - 3 camels daily, between 10.00 am and 12.00 noon. Each camel was observed for 15 minutes, recording the number of bites made by the camel on various forage species. Bites made on particular forage species by different camels were summed up to get the site totals. The species were ranked on the basis of the proportion of bites by site and season. This ranking suggested the order of forage species preferences by the grazing camels. Field observations also facilitated assessment of plant parts eaten by the camels for purposes of sampling.

Sampling

Identified water sources in each site were sampled using plastic containers. For shallow wells[1], the water was disturbed first followed by sampling. This was to take care of the disturbance that usually occurs during watering, either directly by the camels or people scooping the water. This causes mixing of water from different depths of the well. Forage parts commonly eaten by the camels were sampled, weighed, sun dried for five days, packed in paper bags and stored for laboratory analysis. Forages that registered at least a bite by a grazing camel were all sampled (a bite was counted every time a camel raised up the head for purposes of chewing). In addition, forage species perceived as important by the respondents were sampled for mineral analysis. Naturally occurring solid salts and commercial mineral supplements used by the respondents were also sampled for analysis.

Laboratory analysis

Preparation of the forage samples for mineral analysis was done in accordance with AOAC (1995) procedures. Atomic Absorption Spectrophotometric method (Bellanger, 1971; Bellanger and Lamand, 1975) was used to determine the mineral concentration of forage material. The samples were assayed for Na, Ca, K, P, Mg, Fe, Cu, Zn and Co through AAS. Water samples were filtered through 0.45µm membrane and the minerals directly analyzed using AAS. Solid salts and commercial salt samples were initially ground using a mortar and pestle, then sieved through a 20mm filter. The ground material was digested using hydrochloric and sulphuric acids (AOAC, 1995) to extract the minerals, followed by filtration. This was followed by direct analysis for the minerals from the filtrate using AAS.

[1] Shallow wells are manually dug and up to 30 feet deep

Data management and descriptive statistics

The data was entered in SPSS for Windows (Norman *et al.*, 1975). Frequencies and percentages for bite counts were then computed.

Results and Discussion

Forage mineral concentration

Camels spent over 85% of their dry season grazing time on five main forage species per site per season (Table 1) except in Ngurunit during the dry season where the forage species were more than five. The mineral content of these forage species is shown in Table 2. Apart from these five plants per site, other forage species (eaten) registered low number of bite counts and were assumed to be unimportant in the overall camel mineral nutrition. However, across sites and seasons, there were forage species that were perceived as important by the herders but were not eaten by camels during field observation. Their mineral composition is shown in Tables 3 and 4 for dry and wet seasons, respectively.

Table 1: Growth form, name (botanical and local) and bite counts (%) of preferred forage species in northern Kenya during dry and wet seasons

Site	Growth form	Forage species	Local name	[1]Bite counts percent Dry season	Wet season
Kargi		*Acacia reficiens*	***Khasah***	0	2.6
	Shrubs	*Acacia mellifera*	***Bilhil***	0	2.8
		Ficus species	*Arabhalis*	28.0	0
		Indigofera spinosa	*Khoro*	15.5	79.9
	Dwarf shrubs	*Indigofera cliffordiana*	*Hanhanis*	0	6.5
		Duosperma eremophilum	Yabah	0	8.1
		Dactylotenium bogdanii	*Maho*	22.9	0
	Herbs	*Digitaria velutina*	***Kulusum***	12.6	0
		Aristida adscensiosis	***Maad***	8.9	0
Sub-total				**87.9**	**99.9**
	[2]Others			**12.1**	**0.1**
Korr		*Indigofera spinosa*	Khoro	23.3	42.3
	Dwarf shrubs	*Duosperma eremophilum*	Yabah	22.0	13.0
		Sericocomopsis hilderbrantii	*Giib*	0	9.5
		Indigofera cliffordiana	*Hanhanis*	0	5.2
		Heliotropium studineri	*Thubarar*	34.2	0
	Herbs	*Portulacea oleracea*	*Yamheso*	12.5	0
		Heliotropium species	*Okomi*	0	16.0
	Climbers	*Maerua oblongifolia*	*Geigiri*	2.4	0
Sub-total				**94.4**	**86.0**
	Others			**5.6**	**14.0**
Ngurunit		*Lawsonia inermis*	*Lgiria*	13.8	0
		Cordia sinensis	***Lgoita***	**10.0**	0
		Balanites aegyptica	***Khulum***	7.7	0
	Shrubs	*Justicia exigua*	*Lamanera*	0	46.9
		Opilia campestris	Lpukenyi	*0*	5.2
		Commiphora boiviniana	***Layamai***	**0**	4.9
		Grewia tenax	*Lkogomi*	0	4.3
	Dwarf shrubs	*Indigofera spinosa*	*Khoro*	16.8	0
		Duosperma eremophilum	Yabah	*11.5*	27.4
Sub-total				***59.8***	**88.9**
	Others			***40.2***	**11.1**

[1]Total bite counts for all the forage species were: Kargi dry = 515, Kargi wet = 617, Korr dry = 657, Korr wet = 831, Ngurunit dry = 651, Ngurunit wet = 718

[2]Others - include forages whose combined bite counts were 14% and below of the total except in Ngurunit, dry season (40.2%) where the list of consumed forage species was long.

A zero value in Table 1 implies that that forage species was not eaten by the camels either because it was absent in the grazing field or was present but unpalatable. During the dry season, shrubs and dwarf shrubs were present in all sites, but were either too dry or had dropped the leaves, and thus not eaten. The herbaceous species had died off during this period, hence unavailable to the grazing camels. In the wet season, zero bite count implied that the forage species, irrespective of the growth form, was not present in the specific area where grazing observations were carried out, but was present in other areas within the study sites.

The plant parts preferred by grazing camels varied with the growth form. While grass species were eaten whole, in the case of forbs, leaves, stems or whole plants were selected. Pods, flowers, tender spines and stems/twigs and pods were preferred from shrubs (dwarf or otherwise) whereas leaves and tender stolons were selected from climbers.

On the basis of bite counts and the mineral contents, *Indigofera spinosa* and *Duosperma eremophilum* were the most important sources of minerals for camels across the three study sites in both seasons. This was in terms of relative contribution to the daily mineral supply of grazing camels. These results were in agreement with earlier reports by Field (1979), Wangoi (1984), and Kuria (1996). After a two-year diet preference study, Wangoi (1984) concluded that camels in the Rendille area had special preference for dwarf shrubs mainly *Indigofera spinosa* and *Duosperma eremophilum*. The author further noted that camels also fed on a few trees, shrubs and grass species. During a camel feeding observation study at Kargi, Field (1979) reported that *Indigofera spinosa* was the most important plant species in the diet of camels, while Kuria (1996) reported a 32.8% relative density for *Duosperma eremophilum* at Ngurunit. This implied that these two dwarf shrubs were the major contributors to the daily mineral supply of camels in the study area by virtue of their high intake. These two forage species were also the most readily available. Other relatively less important forages were *Commiphora species*, *Sericocomopsis hilderbrantii*, *Grewia tenax* and *Heliotropium species*. There was considerable variation in preference for the other forage species between sites and seasons. For instance, *Heliotropium species* (*Thubarar and Okomi*) were selected during both dry and wet seasons at Korr. *Ficus* species and *Dactylotinium bogdanii* were preferred at Kargi during dry season whereas *Lawsonia inermis* and *Portulacea oleracea* were valuable dry season forages at Ngurunit and Korr, respectively.

Table 2: Macro and micro mineral content of five most preferred forage plants by camels in northern Kenya during dry and wet seasons

Plants	Macro elements (g/kg DM)						Micro elements (mg/kg DM)		
	Ca	P	Mg	K	Na	Fe[1]	Co	Cu	Zn
Kargi – dry season									
Ficus species[a]	9	1	10	8	27	1	8	14	5
Indigofera spinosa[b]	30	2	5	4	1	1	7	8	7
Dactylotenium bogdanii[c]	4	1	3	4	17	1	5	13	1
Digitaria velutina[c]	1	1	1	4	11	0	4	11	5
Aristida adscensiosis[c]	8	1	3	4	1	1	6	6	6
Kargi – Wet season									
Acacia mellifera[a]	7	1	5	11	1	1	37	10	27
Acacia reficiens[a]	7	2	3	14	1	2	17	12	21
Indigofera spinosa[b]	25	1	8	6	1	3	78	7	12
Duosperma eremophilum[b]	35	2	16	20	4	1	66	10	19
Indigofera cliffordiana[b]	21	2	6	15	1	2	44	7	13
Korr – dry season									
Indigofera spinosa[b]	31	2	5	4	2	12	44	10	15
Duosperma eremophilum[b]	118	3	34	32	2	15	1.4	18	27
Heliotropium studineri[d]	41	2	9	28	7	14	127	17	45
Portulacea oleracea[d]	26	2	10	43	3	14	47	11	45
Maerua oblongifolia[e]	14	2	10	22	3	7	40	11	12
Korr – wet season									
Sericocomopsis hilderbrantii[b]	12	3	12	46	1	1	61	6	38
Duosperma eremophilum[b]	34	3	21	23	10	1	52	9	18
Indigofera cliffordiana[b]	26	2	9	18	4	1	11	5	21
Indigofera spinosa[b]	4	24	10	12	1	2	92	4	21
Heliotropium species[d]	28	3	7	17	1	2	15	7	17
Ngurunit – dry season									
Lawsonia inermis[a]	10	2	6	13	3	19	25	11	10
Cordia sinensis[a]	40	3	6	20	6	17	9	0	20
Balanites aegyptica[a]	17	2	6	6	5	17	6	16	7
Indigofera spinosa[b]	24	2	4	6	2	17	7	16	29
Duosperma eremophilum[b]	69	2	18	12	1	16	1.2	15	12
Ngurunit – wet season									
Justicia exigua[a]	8	3	3	21	1	1	39	4	8
Opilia campestris[a]	32	3	25	39	1	1	23	7	28
Commiphora boiviniana[a]	10	3	7	14	0	1	27	5	15
Grewia tenax[a]	15	3	10	31	3	1	38	4	15
Duosperma eremophilum[b]	32	2	19	31	3	1	22	9	23
Recommended mineral level in diet	**3***	**1-3****	**2***	**6–8***	**0.6***	**0.03***	**0.1***	**10***	**30***

* Source: McDowell 1985; ** NRC 1989;

a –shrub; b – dwarf shrub; c – grass; d – forb; e - climber

[1]Fe is a microelement albeit the units used are g/kg DM

Compared to the recommended mineral levels in various forages utilized by grazing ruminants (McDowell, 1985; NRC, 1989), at least 97% of the forage samples had adequate Ca, P, Mg, Na, Fe and Co in all the sites and seasons. About 80% of the samples had adequate K. Across the sites, 50% of the samples had below the recommended level of Cu, mainly during the wet season. Zinc was inadequate in 90% of the samples across sites. Thus, depending on the grazing management, diet selection and intake, there was potential for the grazing camels to get enough of the mineral elements from these forage species with exception of Zn and Cu. The ratio of Ca: P, was however quite high (1:1 to 39:1 compared to the recommended 1:1 to 2:1). Excess Ca or P renders the other unavailable and may also decrease the availability of microelements (McDowell, 1997; Lukhele and Van Ryssen, 2003). In this study, no obvious signs of P deficiency (osteophagia) and other mineral elements were observed on the camels perhaps due to their versatility (Faye and Bengoumi, 1997) that makes them less affected by mineral deficiencies compared to bovines and small stock. Iron concentration in Korr and Ngurunit forage species during the dry season was notably high. It was however lower than the 0.25g/kg required to interfere with Cu absorption (Humpries *et al*., 1983; Suttle and Field, 1983) which would in turn induce secondary imbalance of Fe (Cu facilitates Fe absorption).

These results were partly consistent with the 1974 Latin American Tables of Feed Composition, which reported the mineral elements Co, Cu, Mg, P, Na and Zn as inadequate in most tropical forages with P being the most widespread and economically important. Contrary to the reports of McDowell and Conrad (1990) and Judson (1996) that Co is among the most widespread microelement deficient in tropical forages, Co levels in the present study were above the recommended level.

Thus, with moderate bioavailability, camels in the study area were unlikely to suffer from Co deficiency. Across the study sites, a few forage species had high levels of some mineral elements. Among others, *Indigofera spinosa* in Korr, during wet season, had 8 times the recommended level of P. *Salsola dendroides* from Kargi area in the dry season had 40 times the recommended level of Cu and 126mg/kg Zn or 4.5 times the recommended level during the wet season. *Heliotropium species* from Korr area during wet season and *Justicia exigua* from Ngurunit in wet season also had a high level of P, whereas *Ficus species* and *Duosperma eremophilum* from Korr had high levels of Cu during the dry season.

Table 3: Macro and micro mineral content of forage species perceived as important by Rendille herders of northern Kenya in dry season

Plants	Macro elements (g/kg DM)						Microelements (mg/kg DM)		
	Ca	P		K	Na	Fe[3]	Co	Cu	Zn
Kargi – dry season									
Barlaria proxima[a]	31	1	8	9	4	1	9	14	9
Cordia sinensis[a]	17	1	3	5	6	1	7	14	7
Crotolaria deserticola[a]	7	0	5	6	7	1	7	10	7
Sericocomopsis hilderbrantii[a]	24	1	7	13	7	1	6	10	6
Cadaba glandulosa[1b]	31	1	18	35	1	2	9	6	9
Salvadora persica[b]	46	1	17	5	22	0	8	8	8
Boscia coreacea[b]	22	1	13	7	1	0	9	9	9
Cadaba mirabilis[b]	18	1	14	78	2	0	8	9	6
Maerua classifolia[b]	11	1	16	13	6	0	5	6	4
Salsola dendroides[b]	9	1	7	14	56	17	7	28	7
Blepharis linariifolia[c]	17	1	3	2	1	3	9	7	8
Neuracanthus species[c]	57	0	11	9	1	2	12	11	14
Sporoborus spicatus[d]	2	2	3	4	9	32	4	12	3
Maerua oblongifolia[e]	13	2	7	11	4	0	8	5	3
Cadaba farinosa[e]	11	2	6	9	8	1	4	15	9
Korr – dry season									
Indigofera cliffordiana[a]	28	1	10	5	1	11	76	9	15
Salvadora persica[b]	12	1	12	7	4	7	1	10	15
Cadaba glandulosa[b]	28	1	18	23	4	8	8	14	16
Ficus sp. [b]	12	1	7	11	27	11	53	17	28
Maerua classifolia[b]	33	1	26	28	1	12	7	11	13
Cadaba ruspoli[b]	22	0	14	18	2	20	51	9	13
Cadaba mirabilis[b]	33	1	30	53	6	7	80	12	13
Boscia coreacea[b]	19	2	13	8	1	9	127	7	20
Balanites orbicularis[b]	8	3	4	27	2	10	1	13	7
Cadaba farinosa[d]	7	1	3	16	3	6	60	9	9
Ngurunit – dry season									
Craibia inurentii[a]	33	1	7	11	0	8	68	13	11
Tarenna graveolena[a]	21	1	6	8	1	7	14	9	15
Ormacarpum trichocarpum[b]	26	1	14	9	6	23	50	14	7
Boscia coreacea[b]	19	0	10	5	0	22	0	5	1
Dobera glabra[b]	36	1	11	9	2	23	8	10	3
Cadaba glandulosa[b]	27	1	18	16	3	22	6	10	12
Maerua oblongifolia[e]	21	1	17	18	8	15	2	10	10
Cadaba farinosa[e]	9	2	5	12	4	19	28	12	7
Heliotropium studineri[f]	22	2	4	9	3	18	2	13	21
Barlaria proxima[f]	41	1	6	8	2	11	40	15	27
[2]*Acacia tortilis*[h]	26	2	6	14	4	12	38	16	16
Recommended mineral level in diet	**3***	**1-3****	**2***	**6-8***	**0.6***	**0.03***	**0.1***	**10***	**30***

* Source: McDowell 1985; ** NRC 1989
a–shrub; b–salty shrub; c–grass; d-salty grass; e-salty climber; f–forb; h-tree
[1]Pastoralists presumed that salty plants during the dry season were also salty in the wet season
[2]Tree species are only important as forages for camels when young or in form of pods
[3]Fe is a microelement albeit the units used are g/kg DM

Table 4: Macro and micro mineral content of forage species perceived as important by Rendille herders of northern Kenya in wet season

Plants	Macro elements (g/kg DM)						Microelements (mg/kg DM)		
	Ca	P	Mg	K	Na	Fe[1]	Co	Cu	Zn
Kargi – wet season									
Barlaria proxima[a]	23	2	7	21	2	2	18	9	20
Cordia sinensis[a]	15	20	4	16	12	1	87	11	19
Salvadora persica[b]	43	1	13	7	15	1	20	7	50
Lycium europaem[b]	3	2	3	8	24	1	33	8	60
Cadaba mirabilis[b]	11	2	24	53	3	1	0	5	10
Salsola dendroides[b]	5	1	6	16	54	1	98	8	12 6
Cadaba glandulosa[b]	15	1	17	31	1	3	40	7	11
Ficus sp.[b]	6	1	14	11	46	1	41	7	17
Maerua classifolia[b]	19	1	37	24	2	1	42	5	5
Boscia coreacea[b]	5	2	5	18	0	1	43	6	12
Sporoborus spicatus[c]	1	2	2	7	12	1	74	5	5
Dactylotenium bogdanii[c]	6	1	5	10	28	2	39	4	12
Maerua oblongifolia[d]	10	1	13	27	4	1	46	7	9
Korr – wet season									
Cadaba glandulosa[b]	11	1	19	24	1	2	35	4	12
Ficus sp.[b]	4	2	6	12	39	2	3	9	52
Cassia sp.[b]	6	3	3	17	2	2	6	11	27
Maerua classifolia[b]	15	1	22	31	1	1	32	3	11
Lycium europaem[b]	7	2	6	16	35	1	5	9	45
Salvadora persica[b]	49	2	6	15	10	1	57	6	16
Dactylotenium bogdanii[d]	2	2	3	8	17	2	28	3	17
Cadaba farinosa[e]	5	1	5	24	1	2	20	5	18
Maerua oblongifolia[e]	5	1	6	26	1	1	56	5	11
Indigofera hochstetteri[f]	25	3	8	19	1	2	65	5	16
Heliotropium studineri[f]	33	3	16	31	0	1	50	8	31
Blepharis linariifolia[f]	18	3	8	23	1	2	35	8	22
Portulacea oleracea[f]	19	3	21	55	3	2	51	7	19
Ngurunit – wet season									
Indigofera spinosa[a]	21	2	6	6	1	1	54	5	17
Commiphora paolii[a]	15	2	8	8	0	1	37	3	16
Maerua classifolia[b]	12	1	24	33	0	1	26	3	8
Sclerocarpus africanus[b]	14	4	6	30	3	1	25	13	14
Balanites aegyptiaca[b]	11	3	5	17	0	1	40	10	18
Ficus sp.[b]	5	1	8	14	55	0	49	2	20
Kedrostis gijef[b]	63	3	8	15	1	2	96	9	18
Salvadora persica[b]	9	2	3	28	1	2	37	7	28
Combretum mole[e]	15	2	5	14		1	23	7	24
Recommended mineral level in diet	**3***	**1-3****	**2***	**6-8***	**0.6***	**0.03***	**0.1***	**10***	**30***

* Source: McDowell 1985; ** NRC 1989

a–shrub; b–salty shrub; c–grass; d-salty grass; e-salty climber; f–forb

[1]Fe is a microelement albeit the units used are g/kg DM

For forage species perceived as important by the respondents, between 92 and 100% of the samples were adequate in Ca, P, Mg, K, Na, Fe and Co. However, only 38% and 8% of the samples had the recommended levels of Cu and Zn, respectively. Regarding the mineral content, these forages were, therefore, similar to those selected by the camels. Camels did not necessarily consume forage species perceived as important by the herders during field observations due to unavailabity, resulting from poor spatial distribution within a site and low palatability. While some forage species lacked leaves/tender twigs or were too dry to be eaten by camels, the distribution of forage species in space was such that certain species were only found in specific grazing areas within a site.

Seasonal dynamics of minerals in forage species

There was no clear trend in the specific mineral element concentration in forage species between seasons. There were variations from site to site and from one mineral element to the other, in agreement with McDowell and Conrad (1990) and Judson (1996). Variations between forage species were also pronounced. However, P increased and Cu decreased from dry to wet season in all the three sites. At Kargi and Ngurunit, Zn, Co, K and Mg increased from dry to wet season. The reverse was however true for Korr possibly because more than 50% of forage species eaten and thus sampled during the dry season were the evergreen type.

Differences between sites could be attributed to soil differences as earlier indicated. Within a site, differences between forage species could be explained by the internal mineral dynamics of individual plants (Long *et al.*, 1972) and/or growth form. Close to ground type of forages are likely to be contaminated by the soil (McDowell, 1997) and thus have higher than expected concentration of minerals. For forage species that were eaten during the wet and dry seasons, age factor may explain the variations. Mature plants are usually low in minerals due to translocation of nutrients to the root system {Tergas and Blue (1971). Underwood (1981)}. The evergreen forage species are able to continue growing early into the dry season due to their capacity to draw water from the deeper soil layers which may also contribute to the observed variations in mineral content.

Mineral content of non- plant sources

The mineral content of non-plant sources for grazing camels is shown in Table 5.

Table 5: Mineral composition of traditional non-plant sources

Location	Source	[b]Mineral contents								
	Water	Ca	P	Mg	K	Na	Co	Cu	Fe	Zn
Kargi environs	Marmar	57.0	7.8	13.6	1.6	17.4	0.2	0	0.3	0
Kargi-Kurkum	Shallow wells	2.6	4.8	30.0	33.8	61.6	0.1	0.1	0.1	0.2
Kargi center	Shallow wells	2.6	7.9	3.0	3.0	5.2	0	0	0	0.1
Korr	Shallow wells	2.6	4.8	9.8	14.2	13.0	0	0.1	0	0.2
Lalapasi-Ngurunit	Shallow wells	0.9	1.9	4.6	3.0	20.8	0.1	0.1	0	0.2
Mirgish-Ngurunit	Shallow wells	2.6	1.9	4.6	10.8	6.0	0.1	0.1	0	0.2
Adhiakche-	Shallow wells	3.0	4.5	25.9	17.0	39.2	0.1	0.1	0	0.1
Siangan-	Shallow wells	2.1	19.0	25.0	26.0	66.0	0.2	0.1	0.2	0.2
Kargi center	Borehole	1.0	7.9	7.1	21.0	43.4	0	0.1	0	0.3
Korr	Harisurwa borehole	0.2	1.9	1.5	7.6	34.8	0	0.1	0	0.1
Korolle-Chalbi	Garuga spring	0.2	132	0.4	22.0	73.8	0.1	0	0.1	0.2
Korolle-Chalbi	Isobori spring	0.4	62.0	1.0	46.2	37.2	0	0.1	0.2	0.1
Korolle-Chalbi	Hereya spring	0.5	54.0	1.9	24.2	47.0	0	0.4	0.2	0.1
Korolle-Chalbi	Kholokholokh spring	0.7	37.0	2.1	20.0	35.8	0	0	0.4	0.1
Korolle-Chalbi	Hayo spring	0.3	9.8	0.2	8.6	49.0	0.1	0	0.1	0.2
Korolle-Chalbi	Dakhan spring	0.2	43	0.9	15.4	27.0	0.1	0.1	0.1	0.1
Korolle-Chalbi	Hirgelcha spring	0.1	7.9	0.2	8.2	42.6	0	0	0.1	0.1
Korolle-Chalbi	Nyirkhoharaw spring	0.1	24.5	0.3	9.8	53.0	0	0.1	0	0.1
Korolle-Chalbi	Heditubcha spring	0.1	19.9	1.6	24.6	40.0	0	0.1	0	0.2
Korolle-Chalbi	Hadado spring	1.6	19.8	0.3	19.4	8.6	0.1	0	0.1	0.1
Korolle-Chalbi	Woroadi spring	0.2	24.8	0.2	9.2	32.2	0	0	0.1	0.2
Chalbi desert	**Chalbi salt**	3000	1000	5000	4000	290000	21	28	2000	29
Commercial	**Red Magadi**[a]	2000	1000	0	4000	330000	106	2	24000	2.5

[a]Raw unprocessed salt from Lake Magadi, Kenya; [b]Units for water are mg/l while those for Chalbi and Red Magadi salts are mg/kg

Of the water sources assessed, those from Kargi and Korole area had the highest mineral content followed by those from Ngurunit. Thus, if a sufficient amount of water from these sources was consumed, it could contribute significantly to the mineral requirements of the camels. Chalbi and the Red Magadi salts were traditionally used as mineral supplements for camels especially in Ngurunit. Compared with water, both sources had higher mineral contents with sodium taking the highest percentage. The water sources were low in microelements with 52%, 43% and 38% of the sources having no quantifiable Co, Fe and Cu, respectively.

Conclusions

Forage plants are a major source of minerals for grazing camels in the study area with *Indigofera spinosa* and *Duosperma eremophilum* being the most important in the three study sites in both seasons. Between 80 and 100% of the forage samples were adequate in Ca, P, Mg, K, Na, Fe and Co during both dry and wet seasons in all the sites. While 38 to 50% of the forage samples were adequate in Cu, a paltry 8 to 10% had the recommended level of Zn. Thus, there is potential for the grazing camels to get enough of the mineral elements from these forage species except Zn and Cu. Water, especially natural springs and standing rainwater were the other important sources, but because of infrequent use, these were unlikely to contribute significantly to the camel' mineral requirements. Chalbi salt and the Red Magadi played a minor role.

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Chapter 5

Mineral profiles in the plasma of free ranging camels in Marsabit, Kenya

Mineral profiles in the plasma of free ranging camels in Marsabit, Kenya

Abstract

A study was conducted in Marsabit District of Kenya to document plasma profile of some mineral elements in lactating camels during dry and wet seasons. A total of 90 and 88 camels (age 7 to 23 years, lactation stage 7 – 17 months) were sampled during the dry and wet seasons, respectively. Blood samples were collected once from each camel between 6.00 and 8.30 am before the camels were released for grazing. The samples were centrifuged at 4000 rpm for 10 minutes for purposes of collecting plasma. The plasma was assayed for Na, K, Ca, P, Mg, Zn, Cu, Fe and Co, which are among important minerals in grazing livestock. Results showed that Ca, Na, Fe, Zn and Cu were below the previously reported range. The results suggested that, while camels were likely to suffer from Ca, Na, Fe and Zn deficiencies during the wet season, Cu could be deficient in the dry season. The plasma mineral levels were influenced by physiological status of the camel such as lactation stage, level of dehydration, age and parity, among other factors.

Key words: Minerals, plasma, camels, Kenya

Introduction

The mineral elements such as Na, Ca, P, Mg, K, S, Co, Cu, Fe and Zn, among others, are of major importance in grazing ruminants (NCMN, 1973; Egan, 1975; Underwood, 1981). The macro elements Ca, P and S are used for structural purposes while Na, K and Cl are commonly involved in the maintenance of the acid-base balance (Nagpal and Sahani, 1999). Phosphorus, Ca, Na and Mg are used in energy transfer, transmission of nervous impulses and activation of enzymes. Copper and Zn are major components of the enzymes (Bengoumi *et al.*, 1998). Cobalt and I are essential in hormones and vitamins, respectively, while Fe is required for synthesis of haemoglobin, required in transportation of oxygen in the body (Bengoumi *et al.*, 1998).

The expediency of using blood mineral concentrations to estimate mineral nutritional status of ruminants depends on the relative degree of homeostatic control (Herdt *et al.*, 2000). The blood mineral concentrations above or below the reported range thus can provide a basis for assessing dietary excess or deficiency of particular minerals (Underwood, 1981). For mineral elements such as Ca, Fe and Zn, mineral absorption from the gut decreases significantly when the nutritional status is adequate, thus no more minerals get into the blood to affect serum concentrations. In this case, blood concentrations are not very good indicators of mineral status in the body (Herdt *et al.*, 2000; McDowell, 2003). The absorption of other minerals like Mg and Se is relatively less regulated in the gut and homeostasis is achieved by renal excretion of the excess mineral. Blood or serum concentrations in this case are good indicators of the nutritional status since the excess must flow through the blood to the kidney (Herdt *et al.*, 2000). Homeostatic control of minerals is also achieved through mobilization from the storage structures such as bones and the liver. Low serum mineral concentration may imply exhaustion of the reserves (Faye and Bengoumi, 1997).

The minimum mineral intake by an animal must be sufficient to ensure the long-term maintenance of the mineral reserves of the body tissues and the amount of those minerals in the edible products of the animal (Faye and Bengoumi, 1997). Wilson (1984) observed that the implications of mineral deficiency in general health and productivity of camels are considerable. Inadequate intake of minerals by ruminants can impair feed intake and digestibility leading to decreased growth rates and milk production (Anenkov, 1981). The most devastating economic effect of mineral deficiency in livestock is reproductive failure (McDowell, 1976).

Mineral requirements in camels are reported to vary with season, breed, locality, age, sex, nutritional and health status (Abdalla *et al.*, 1988). Nagpal *et al* (1997) also observed that the mineral requirements of camels varied with parity, stage of lactation and pregnancy. Mineral deficiencies reportedly recur more often in wet season due to the animals' increased requirements for growth and/or lactation (McDowell *et al.*, 1995). Since the majority of camels are kept in desert and sub-desert areas, where feed resources are scarce and of poor quality, with no provision for mineral supplementation, occurrence of mineral deficiencies in camels is common (Faye and Bengoumi, 1994). Other than clinical expressions of deficiencies, the real extent and distribution of mineral deficiencies in camels is unknown (Faye and Bengoumi, 1997). This study was designed to assess the levels of important macro and micro minerals and factors influencing these in the plasma of lactating camels kept by the Rendille pastoralists in Kenya.

Results and discussion

The overall, dry and wet season mean plasma mineral concentrations in camels are presented in Table 1.

Table 1: Overall, dry and wet season mean plasma mineral concentrations in camels

	Concentration (mg/l)			
Mineral elements	Dry season (n = 90)	Wet season (n = 89)	Overall mean	Reported range*
Ca	82±8	67±16	75±15	87-106
Mg	62±14	75±18	69±17	18-36
K	278±54	212±50	245±62	41-274
Na	3627±161	3398±379	3513±313	3691-4290
P	42±7	47±10	45±9	35-65
Fe	0.9±0.5	0.9±0.4	0.9±0.5	0.6-1.4
Cu	0.7±0.4	0.8±0.1	0.8±0.3	0.5-1.2
Zn	0.8±0.4	0.6±0.2	0.7±0.3	0.7-1.2
Co	0.1±0.0	0.1±0.0	0.1±0.0	0.03-0.13

*Source: Singh *et al.* (1986), Faye *et al.* (1986), El Tohamy *et al.* (1986), Burenbayer (1989), Faye and Mulato (1991), Morin (1992), Faye and Bengoumi (1994), Belknap (1994), and Wernery *et al.* (1999)

The overall average plasma Ca and Na concentrations were below, while the mean K, P, Fe, Cu, Zn and Co were within the reported ranges. However, in 20%, 68% and 15% of the sampled camels, plasma concentrations of Fe, Zn and Cu, respectively, were below the reported ranges. Magnesium concentrations were all above the reported levels. Calcium, P, Fe and Cu levels observed in this study were consistent with reports of Abu Damir *et al.*, (1983), Abdalla *et al.*, (1988) and Faye *et al.*, (1995). Plasma K, Na, Mg and Zn concentrations were, however, higher than those reported by Abdalla *et al.*, (1988) for race camels.

The mean plasma concentrations of Ca, K, Na and Zn were lower in dry than wet season. While it was vice versa for Mg, P and Cu, plasma mean Fe and Co concentrations in both dry and wet seasons were similar. Sodium concentration was below the range during both dry and wet seasons.

Seasonal fluctuations in blood plasma mineral concentrations have been reported (Judson, 1996; Burenbayer, 1989). However, Cuesta *et al.*, (1996) noted that variations in serum mineral concentrations from time to time were not consistent. Judson (1996) and Burenbayer (1989) attributed the seasonal variations to changes in forage mineral concentrations. The increase in plasma Mg and Cu concentrations in the wet season was consistent with the results of Cuesta *et al.*, (1996). On the basis of the reported range of plasma mineral concentrations, results of the current study suggest that mineral deficiencies were more likely to be observed in camels during the wet season probably due to increased requirements for milk production, in harmony with McDowell *et al.*, (1995).

Other factors influencing plasma mineral concentrations

The results are presented in Table 2.

Table 2: Effect of type of water, hydration and physiological status, lactation stage, parity anc concentration

		Mineral concentratio					
		Ca	**Mg**	**K**	**Na**	**P**	**F**
Water type	Salty	84±6	64±11	266±43	3640±170	43±9	0
	Fresh	81±9	63±15	285±68	3570±231	42±7	1
Hydration status	≤ 4 days	83±7	61±13	273±50	3621±157	42±8	0
	≥ 5 days	78±11	67±17	299±69	3655±183	43±6	1
Physiological status	Lactating	80±11	65±15	274±56	3592±159	42±7	0
	Lactating-pregnant	69±15	71±19	224±59	3456±369	48±11	1
	Dry-pregnant	71±19	79±16	230±32	3450±350	45±5	0
Lactation stage	≤ 10 months	82±9	62±14	273±52	3615±165	44±11	0
	≥ 11 months	68±16	72±18	227±63	3432±381	46±8	1
Parity	≤ 5	74±15	70±17	251±64	3481±336	45±9	0
	≥ 6	74±15	71±14	246±63	3600±201	44±8	0
	≤ 10 years	75±17	74±19	250±61	3558±178	47±12	1
Age	11 – 15 years	74±13	70±16	252±66	3424±378	43±7	0
	≥ 16 years	72±16	67±16	247±64	3556±308	44±9	0

The plasma concentrations of Ca, Mg, Na, P, Cu and Co seems slightly higher in the camels, which had consumed water perceived as salty by the local herders. Salts such as sodium chloride have been reported to change the electrolyte balance and intracellular pressure in the body, producing a form of dehydration, which prompts the animal to drink more of such water (NAS, 1972). Mineral concentration in the plasma of the camels appeared to increase with increasing levels of dehydration, except for Ca, Cu and Co in agreement with Abdalla *et al.*, (1988). These authors also noted that restriction of water intake in camels increased the concentration of both macro and microelements in the blood. Singh *et al.*, (1986) also observed that the level of K and Na in a camel body may increase with increasing level of dehydration.

Differences were noted in the plasma mineral concentrations between lactating, lactating-pregnant and dry-pregnant groups of camels. Although there was no consistent trend, Ca and Cu were lower in the in-calf-lactating camels than camels in other physiological stages. Camels that were only lactating had the highest level of Ca, K, Na, Fe, Cu and Zn, suggesting high mineral demands in the other two categories of camels. According to Nagpal *et al.*, (1997), both macro and micro mineral elements fluctuate in the blood of camels depending on the physiological state. Vittorio *et al.,* (1999) also reported variations in plasma mineral concentrations with physiological state of the camels.

While Ca, K, Na and Zn concentration in the blood plasma declined with advancing stage of lactation, Mg, P, Fe and Cu increased. Cobalt remained constant. Potassium, P and Cu were low in the plasma of camels with higher parity, while the reverse was true for Na and Mg. Aged camels had slightly lower Ca, Mg, K, P and Fe plasma concentrations than the young camels but the latter were lower in Cu and Zn. Judson (1996) reported declining levels of Ca, P and increasing concentrations of Cu with advancing age in agreement with results of the current study. The author however reported increasing plasma Mg with advancing age in contradiction with results of the present study.

Conclusion

Compared to the reported range of plasma mineral concentration in camels, the elements; Ca, Na, Fe, Zn, and Cu were low in the current study, which may suggest a deficiency of these elements. Mineral deficiencies were more likely to be observed on camels during the wet season. Mineral levels in the plasma were influenced by factors such as physiological status, lactation stage, level of hydration, age and parity among others. The latter two observations have important nutritional management implications.

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Chapter 6

Effect of mineral supplementation on milk yield, calf growth rate and plasma mineral concentrations in camels in northern Kenya

Effect of mineral supplementation on milk yield, calf growth rate and plasma mineral concentrations in camels in northern Kenya

Abstract

A study was conducted in Ngurunit and Kargi locations of Marsabit district in Kenya to determine effect of mineral supplementation on milk yield, calf growth rate and plasma mineral concentrations of settlement-based camels. No mineral mixture was available in the market that could address deficits determined in this study. Thus, two mineral supplements were formulated: one comprised of locally collected, ground bones mixed with locally available natural salt and the other of commercial ingredients. Fifty-nine and 56 camels in early lactation and their calves were recruited at Kargi and Ngurunit, respectively. Of these, 22 and 21 camels were randomly assigned the commercial mineral supplement while 12 and 11 were randomly assigned the local mineral supplement at Kargi and Ngurunit, respectively. The remaining 25 and 23 camels in Kargi and Ngurunit, respectively, served as control. Each dam was individually fed 200g of mineral supplement daily for 190 days. Milk yield measurements were taken at weekly intervals, and calves were weighed and blood samples taken on monthly basis. The supplemented camels produced higher ($p < 0.05$) amount of milk than controls in Ngurunit ($3.2 ld^{-1}$ versus $2.3 ld^{-1}$). In Kargi, the mean milk yield for supplemented and control camels were similar ($p > 0.05$) at $2.6 ld^{-1}$. Calves from the supplemented dams grew significantly faster ($p < 0.05$) than those in control, gaining $441.3 gd^{-1}$ and $424.8 gd^{-1}$ compared with $275.7 gd^{-1}$ and $307.7 gd^{-1}$ for controls in Kargi and Ngurunit, respectively. There seemed not to be direct relationship between diet (supplement) and plasma mineral concentrations. Other factors that may include homeostasis and mineral interactions appeared to play a more significant role in determining mineral status in the blood. The overall results suggested that specific mineral deficiency existed among the Rendille camels and that this problem could be reduced by judicial use of locally available raw material. The commercial supplement may also be required by those whose circumstances cannot allow preparation of the local supplement, both in the short and long run.

Key words: Mineral supplementation, camel performance, plasma, Kenya

Introduction

The importance of camels in arid and semi-arid areas of the world cannot be over-emphasized. In these areas, where availability of water is scarce and ambient temperatures high, camels provide milk to households throughout the year and in quantities greater than that from other domestic animals (Farah, 1996). Camel milk is an important source of nutrients for humans in the arid and semi-arid areas and often represents the only protein source (Vittorio *et al.*, 1999). However, the camel is not only faced with the daunting problem of water scarcity, but also limited nutrient availability from forage species.

In tropical countries, mineral deficiencies, imbalances and toxicities severely limit productivity of grazing livestock and are often of more significance than infectious diseases (McDowell, 1985). This is in the backdrop of serious difficulties to provide camels with supplemental feeds due to scarcity of raw materials locally and prohibitive transportation costs (Vittorio *et al.*, 1999). Camels, therefore, almost exclusively rely on the scarce natural forages for all their nutritional needs including minerals (McDowell and Conrad, 1990).

The Rendille are semi-nomadic pastoralists inhabiting the western part of Marsabit district in Kenya. Their camel grazing system is extensive, with both settlement[1]-based and mobile[2] herds. The settlement-based herd size is relatively small compared to the mobile herd, but is the source of milk to the vulnerable household members, i.e., young children and the aged (Garmagar, 2001).

[1] Settlement based herd comprise of 2 – 10 lactating camels that graze within 30km from homesteads
[2] Mobile herd comprise of heifers, bulls, dry, pregnant and some lactating dams grazing far from homesteads

The settlement-based camel herd grazes within a radius of 30 km from the settlements, an area whose vegetation tends to be degraded and of low nutritive value (Simpkin and Guturo, 1995). The herd is, therefore, more vulnerable to mineral deficiency due to its restricted grazing area, which limits access to natural salty water or plants located outside this radius (Kaufmann, 1998).

McDowell and Conrad (1990) reported that the level of productivity influences mineral requirements in livestock. In the low producing indigenous animals like the Rendille camels, mineral deficiencies tend to remain sub-clinical in contrast to the high producing animals, which easily express deficiency signs. Underwood (1981) reported that mild and transient mineral disorders are difficult to diagnose since they are easily confused with effects of energy and protein deficiencies and various types of parasitism. As the production level of camels improve, mineral deficiencies that are often marginal are likely to become more important, with the symptoms becoming more evident. It is important therefore to devise strategies to deal with mineral deficiencies alongside other camel productivity improvement efforts.

This was an intervention study based on the results of Kuria *et al.* (2004), which established inadequacy of Na, Ca, K, Zn and Cu, during both dry and wet seasons on the basis of mineral content of forage species consumed by camels and plasma levels of minerals in camels. The objective of this study was to determine the effect of mineral supplementation on milk yield, calf growth rate and plasma mineral concentrations of camels kept by the Rendille in settlement areas.

Materials and methods

Study area

Unlike the survey that covered three sites, this study was only conducted in Kargi and Ngurunit. These two sites were distinct in terms of weather conditions, soils, vegetation, composition of camel breeds kept and some aspects of husbandry e.g. watering regimes, milking management. These factors were likely to influence the efficacy of the mineral supplements. Korr was intermediate regarding these factors and was therefore deliberately excluded. A description of these sites is presented in Chapter 3.

Preparation of mineral supplements

Kuria *et al.* (2004) reported mineral levels in forage plants preferred by camels in the study area. This report indicated deficits in some mineral elements based on the recommended minimum level in forage plants (McDowell, 1997). To determine deficits of specific mineral elements, the camels' daily requirements of the elements (g) were first estimated from the DMI (kgd^{-1}) and the recommended minimum level in forage species (%). The DMI was estimated as 2% of live weight, assumed to be 450kg (Simpkin, 1995) in line with Richard (1989), Gerald and Richard (1989) and Kamoun *et al.* (1989). The daily intake of each element (g) by the camels was then estimated from the forage species' dry season mean content, corrected for preference (%) and the DMI. Preference was estimated from the bite counts recorded for various forage species during field observation of grazing camels. The difference between the camels' daily requirement and the estimated intake was assumed to be the deficit for the various elements, to be supplied in the supplement. The deficits are presented in Table 1.

Kargi dry season deficit values were used as they were higher than those of the wet season and also dry and wet seasons in Ngurunit (Table 1).

Table 1: Deficits of the mineral elements at Kargi and Ngurunit

	Kargi		Ngurunit	
	Dry season	Wet season	Dry season	Wet season
Element	*D (g)	*D (g)	*D (g)	*D (g)
Ca	20	(-)	9.0	13
P	13	12	13.0	12
Mg	3	(-)	1	(-)
K	55	47	52	38
Co	(-)	(-)	(-)	(-)
Cu	0.04	0.04	0.04	0.04
Fe	0.30	0.30	0.30	0.30
Zn	0.30	0.28	0.29	0.28
Total	91.65			

*D – deficit; (-) in the table means no deficit that season e.g. for cobalt during dry season

The need for tailor-made mineral supplemements was realized as there was no ready-made mineral mixture in the market that could address deficits determined in this study.

Commercial supplement

Deficits for the eight minerals totaled 91.65 grams. Chemical compounds to supply various elements were identified (Table 2). The amount of each chemical (g) required to meet estimated deficits in supply of mineral elements was computed based on their molecular weights (Table 2). Sodium chloride (14.5g) was added to the mixture to improve palatability. Packaging was in single dose sachets weighing 200g as recommended by Vittorio *et al.* (1999). Table 2 summarizes the composition of the supplement.

Table 2: Composition of the commercial supplement

Element	Source	Estimated amount supplied in feed (g)	Deficit to be supplied in supplement (g)	Amount of ingredients (g)
Ca	Calcium carbonate	9.00	20.00	30.70
P	Di-Calcium phosphate	1.00	13.00	16.90
Mg	Magnesium sulfate	4.00	3.00	15.00
Cu	Copper sulfate	0.01	0.05	0.13
Fe	Ferrous oxide	0.00	0.30	0.43
Zn	Zinc oxide	0.00	0.30	0.37
K	Potassium Sulfate	5.00	55.00	122.00
Sub-total				185.5
Na	Sodium chloride			14.5
Total per camel per day				200.0

As the deficits of various elements in both sites were similar (Table 2), the same formulation was used.

Local supplement

This supplement was formulated using livestock bones collected from the settlement area, and, salt collected from Chalbi desert. These raw materials were readily available locally with the bones being collected from the study sites. Chalbi salt was bought from a local market where it is sold as mineral supplement for livestock. The bones were cooked in drums using firewood for 4 -5 hours (to reduce the risk of botulism and soften the bones) and crushed while still hot using timber pestles. The crushed bones were sieved through a 1.5 mm wire mesh. Chalbi salt was similarly sieved to remove large particles. Based on the mineral content of the raw materials and the estimated deficits, they were thoroughly mixed in a ratio of 2 parts (ground bones): 3 parts (Chalbi salt), weighed and packaged into 200g sachets.

Unlike the commercial supplement, the local supplement did not cover the estimated deficit for all the minerals due to low levels of some of the target elements in the raw materials. However, the cost of this supplement was low due to the local availability of raw materials. The composition of a 200g sachet of local supplement is shown in Table 3.

Table 3: Composition of the local supplement

Element	Chalbi salt (%)	Charred bone meal (%)	[a]Deficit (g) to be supplied in supplement	Amount supplied by 200g of supplement (g)
Ca	0.33	30.10	20.00	24.50
P	0.08	14.00	13.00	11.30
Mg	0.54	0.59	3.00	1.13
Na	28.5	0	6.00	34.30
K	0.43	0.16	55.00	0.64
Fe	0.17	0	0.30	0.21
Cu	0.003	0	0.05	0.003
Co	0.002	0	-	0.003
Zn	0.003	0	0.30	0.003

[a]Calculated from mineral content of preferred forages and the estimated minimum requirement of the various minerals

Experimental animals

In both sites, 115 camels in early lactation and their calves were recruited, 56 from Ngurunit and 59, Kargi. Forty-nine (49) and 54 camels were recruited at the beginning at Kargi and Ngurunit, respectively, while the rest joined the experiment at the start of second month of study. The number of camels in early lactation in the settlements was low in both study sites (a limitation of on-farm research). Thus, the recruitment process could not effectively control for variations in breed, stage of lacatation, parity, number of camels per site etc. The average stage of lactation of the supplemented camels at recruitment was 1.2 months and 19 days in Kargi and Ngurunit, respectively, while that of the control camels in both sites averaged 1.1months. In Kargi, 58 of the 59 camels that were recruited were of Rendille breed with only one Rendille x Somali cross. However, in Ngurunit, experimental camels comprised 24 Rendille, 30 Somali, 1 Rendille x Somali cross and 1 Turkana breeds. Recruited camels were randomly assigned the two mineral supplements. A control group was included. Of the supplemented camels, 22 were on commercial in each site, while 12 were on local supplement in Kargi and 11 in Ngurunit. There were 25 and 23 control camels in Kargi and Ngurunit, respectively. Individual camels represented the experimental units, while a group of camels under each treatment represented replications. By the end of the experiment, 11 and 4 camels had dropped off the experiment in Kargi and Ngurunit, respectively. Owners had withdrawn majority of the camels, while a few had died.

Feeding of the supplement

Two hundred grams of the supplements were offered to each camel daily. The contents of a 200g satchet were emptied into a plastic container, mixed with water to a semi-solid paste and orally administered to a restrained camel. This was fed every morning for 190 days.

Data collection

During the study period, milk yield measurements were taken weekly, while calves were weighed once a month to generate data on calf growth rate. Blood samples were also taken from the experimental dams once a month to determine the plasma mineral concentrations. Milking was done between 6.00 and 8.00 am following an overnight separation of the calves from their dams. Full, half or three quarters udder was milked depending on individual camel owners normal milking methods (Simpkin, 1994; Kaufmann, 1998). The milk was measured using an ordinary household cup of known volume. The yield estimates for the morning milking were standardized to a full udder, and then to a day. The blood samples were collected after milking, before the camels were released for grazing. Bleeding was done via the jugular vein (Fick *et al.*, 1979) using 20 gauge vacutainer® needles and 10ml vacutainer® tubes with EDTA Na as anticoagulant. To ensure thorough mixing with the anticoagulant, the tubes were gently inverted several times. After collection, the blood samples were centrifuged at 4000 rpm for 10 minutes (HMSO, 1979) to separate the plasma. Using disposable plastic pipettes, the plasma was siphoned, expelled into cryovials, and then temporarily stored in a cool box in the field. The samples were later transferred to the laboratory and stored at $^{-}4$ °C pending analysis. Calves of the experimental camels were weighed using a clock balance suspended on a tree branch with the help of straps and a gunny bag.

Laboratory analysis

Plasma samples were assayed for Na, K, Ca, P, Mg, Zn, Cu, Fe and Co content using the method of Bellanger and Lamand (1975) with AAS (Model CTA - 2000). Phosphorus was analyzed using colorimetric method described by Sigma Chemical Company (1991).

Data analysis

Multiple regression analyses were performed to test whether the independent variables of site, type of supplement and time affected the dependent variables of calf growth rate, milk yield and plasma mineral concentrations in camels. The model used was as follows;

$MY/CG/PMC = \mu_1 + \beta_2 site + \beta_3 supplement + \beta_4 time + \varepsilon$ where;

MY/CG/PMC = milk yield/calf growth/plasma minerals concentration

μ_1 = population mean

$\beta_2$site = effect of site

β_3 supplement = effect of supplement type

β_4 time = effect of time

ε = random error

For the plasma mineral concentrations, correlation analysis was also done to test for interactions between elements. Further statistical analysis carried out included ANOVA (Sneddecor and Cochran, 1980) to test for treatment effects and LSD to determine treatment means that were significantly different. Charts were drawn in Excel (Maria, 1999).

Results and discussion

Milk yield

The mean milk yield data of camels from the two sites under the two-supplementation treatments are summarized in Table 4.

Table 4: Mean milk yield of camels by site and treatment

Site	Treatments/supplements	Mean (liters)	Standard error
Kargi	Control	2.56^{a}	0.02
	Commercial	2.52^{a}	0.03
	Local	2.74^{a}	0.04
Ngurunit	Control	2.31^{a}	0.03
	Commercial	3.13^{b}	0.05
	Local	3.42^{b}	0.07

In every site, column means followed by the same letter superscript are similar ($p > 0.05$)

The average milk yield of control camels (n = 48) in both Kargi and Ngurunit in the current study was estimated at $2.4 \pm 0.03ld^{-1}$. The range was $0.6 - 6.4ld^{-1}$ with a 160 days lactation total yield of 387 liters. These estimates compared favorably with $2 - 4ld^{-1}$reported by Schwartz and Dioli (1992) and Field (1993) in Kenya. The mean was, however, lower than the $4.5ld^{-1}$ and $10ld^{-1}$ for pastoralists' and ranch camels in Kenya, respectively (Wangoh *et al.*, 1998), $9ld^{-1}$ for Neggas (Kamoun, 1997), and $13.3ld^{-1}$ for India and Pakistani camels (Knoess *et al.*, 1986). These variations in milk yield of camels may have resulted from differences in the milking management such as frequency of milking, milking speed, number of teats milked and period of dam and calf separation. Other factors may include stage of lactation, feeding and watering regimes and breed (Farah, 1996). The mean for supplemented camels was 3.0 ±

$0.05ld^{-1}$ with a range of $0.5 - 8.9ld^{-1}$.

Factors affecting milk yield

Site effect

The average milk yield at Ngurunit was higher ($p < 0.05$) than at Kargi ($2.9ld^{-1}$ and $2.6ld^{-1}$, respectively). This difference could be attributed to differences in vegetation, watering regimes and breed. There were more Somali type camels in Ngurunit. Ngurunit's higher altitude, rainfall and lower temperatures promoted higher vegetation growth, resulting in higher forage availability than in Kargi. Ngurunit camels were also watered more regularly (4 – 7 days) than Kargi (7 – 14 days). Water intake has been reported to positively affect milk yield of camels (Yagil, 1982). Additionally, while a 100% of the supplemented and control camels at Kargi, were of Rendille breed, 70% of the supplemented and 35% of control camels at Ngurunit were of Somali breed. In similar environmental and management situations, Somali camels produce more milk than Rendille camels (Simpkin *et al.,* 1998). Variations in milk yield with locations in Kenya has been reported by Onjoro (2003) and mainly attributed to site differences in forage mineral content and water availability.

Supplementation effect

Camels receiving either of the mineral supplements (Table 4) produced more ($p < 0.05$) milk than the control camels in Ngurunit ($3.4ld^{-1}$ and $3.1ld^{-1}$ for local and commercial supplements compared to $2.3ld^{-1}$ for control). The interaction between site and supplement type was significant ($p < 0.05$). This is attributed to the site factors discussed above. At Kargi, the mean milk yield for supplemented and control camels were similar ($p > 0.05$) i.e., $2.7ld^{-1}$ and $2.5ld^{-1}$, respectively, compared to $2.6ld^{-1}$ for control. While Mg is involved in metabolism of carbohydrates, lipids and protein synthesis, Na and Co are essential for nutrient uptake at cellular level and Vitamin B_{12}

synthesis by rumen microbes respectively (McDowell, 1997). Copper and Fe are important in body metabolic functions through enzyme activity and oxygen supply to the body cells, respectively. Thus, by having the required mineral supply to camels, functions such as feed digestion, absorption and the ultimate metabolism at cellular level improve and subsequently, milk yield increases.

The increase in milk yield as a result of mineral supplementation in the present study (2.7% to 49.3%) was in accordance with Miles and McDowell (1983) and Vittorio *et al.* (1999). Miles and McDowell (1983) observed that mineral supplementation increased milk and all the other production parameters in livestock. Vittorio *et al.* (1999) reported increased milk yield in camels following mineral supplementation. They observed that supplementation with micro elements alone did not affect milk yield in dairy camels and recommended a combination of macro and microelements. The increased milk yield in camels in this study confirms that camels were suffering from mineral deficiency. Ghosal and Shekhwat (1992) also concluded that production response to mineral supplementation is the best way of determining the level of micronutrient deficiency in camels. McDowell (1997) stated that the higher the level of deficiency, the higher the response to specific mineral supplementation.

While the mean milk yield for supplemented camels at Ngurunit was within the $3.0ld^{-1}$ to $6.0ld^{-1}$ range reported by Bachmann and Schultess (1987) and Farah (1996) for unsupplemented camels under similar environmental conditions, the mean for supplemented camels at Kargi was below this range. This could be explained by differences in forage quantity and quality, the breed of the camels and differences in milking management of the pastoralists including inconsistency in time of calf and dam separation, level of udder stripping and milking skills of the pastoralists in harmony with Kaufmann (1998). Figures 1 and 2 (fitted graphs) illustrate how the milk yield of experimental camels changed with time.

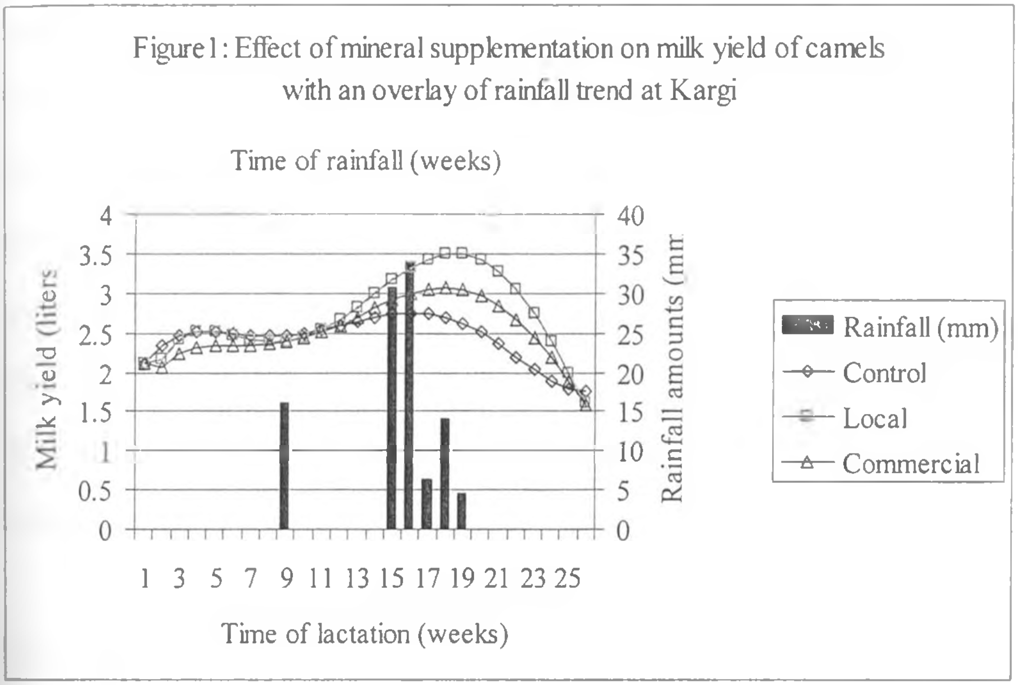


Figure1: Effect of mineral supplementation on milk yield of camels with an overlay of rainfall trend at Kargi

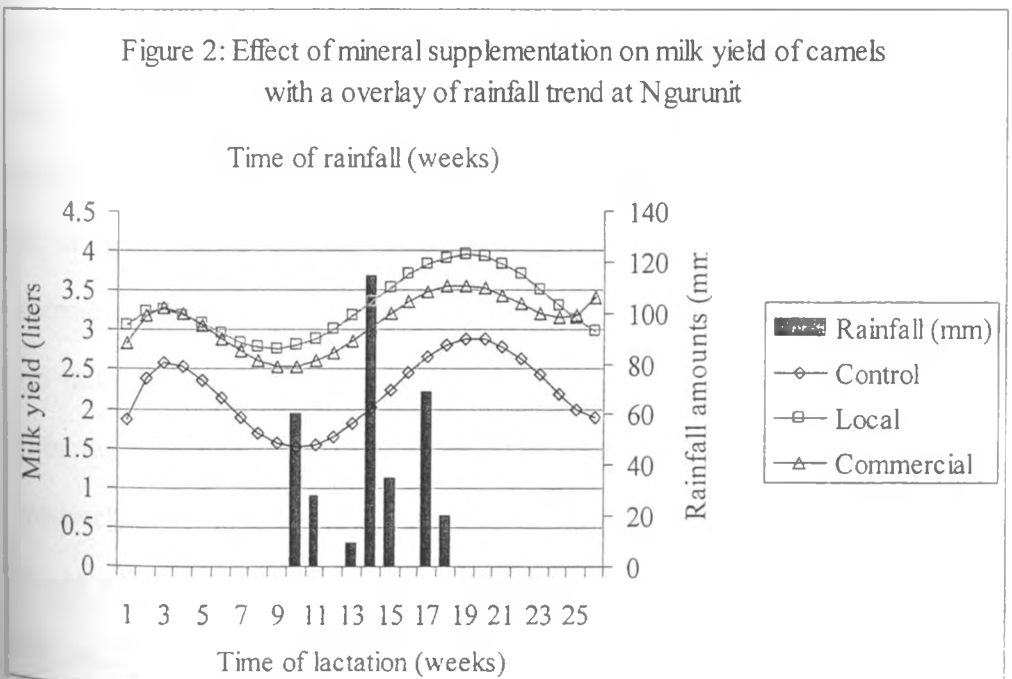


Figure 2: Effect of mineral supplementation on milk yield of camels with a overlay of rainfall trend at Ngurunit

The initial milk yield of the supplemented and control camels (Fig 1 and 2) was low, increased and then declined. Low forage and water availability due to a dry spell during early lactation depressed the milk yield of both supplemented and control camels. This implied that the positive effects of mineral supplementation might have been masked by the protein-energy deficiency during this period (Lamand, 1985). Thus, quality basal diet is crucial for effects of mineral supplementation to be realized. The impact of dry spell on milk yield of camels was higher in Ngurunit than in Kargi. This may have been due to the fact that the experimental camels in Ngurunit were predominantly of Somali breed, which are less adapted to dry conditions than the Rendille breed in Kargi (Kaufmann *et al.*, 2002). Kargi herders were also observed to shift their camels more regularly in search of pastures.

During the first 11 weeks of the experiment, no differences in milk yield were noted between the control and supplemented camels in Kargi (Fig 1). There was low or no rainfall during this period. Forage and water were also scarce. Thereafter, the supplemented camels yielded more milk than the control. During this period, rainfall had improved. In Ngurunit, milk yield of the supplemented (Fig 2) was higher than that of the control camels throughout the experiment. Peak milk yield for supplemented and control camels at Ngurunit (Fig 2) occurred in the 20th week of study (after 5 months of lactation). At Kargi however, the milk yield peaked earlier i.e. in the 19th and 16th week of study for supplemented and control camels, respectively. This suggested that supplementation increased persistence in milk yield at Kargi. Similar results were reported by Vittorio *et al.* (1999) who observed peak yields on the 13th and 13th to 20th week for control and supplemented camels, respectively. Early milk yield peak in Kargi could be attributed to temperature stress unlike in Ngurunit, which is cooler and has better water availability. The peak milk yields were 3.0ld^{-1}, 3.5ld^{-1}, and 2.7l$d^{-1}$for commercial, local supplements and control camels, respectively in Kargi. At Ngurunit, peak milk yields for supplemented camels were 3.6ld^{-1} and 4.0ld^{-1} for commercial and local supplements, while that of control camels was 2.9ld^{-1}.

In Kargi, commercial and local mineral supplements increased the daily milk yield of experimental camels by 2.7% and 10.6%, respectively, over the controls. In Ngurunit, the increments were 39.7% (commercial) and 49.3% (local) over the controls. The level of mineral deficiency and hence, the response to supplementation, is a function of body requirements. Thus, the Somali breed in Ngurunit being higher yielding is more susceptible to mineral deficiencies than the low yielding Rendille camel breed at Kargi.

The local supplement supplied 123% Ca, 572% Na, 87% P, 69% Fe, and 37% Mg of the daily requirements of camels. Levels of Cu, Co and Zn in the mixture were too low and attempting to meet their requirements would mean feeding impossibly large amounts of the mineral mixture daily. It was expected that due to the presence of balanced minerals in the commercial supplement, the camels in this group would perform better. However, there was no difference ($p > 0.05$) in the milk yields between the two supplements. This may suggest that the shorfalls in mineral supply to the grazing camels by the preferred forage species were underestimated. This agrees with Faye and Bengoumi (1994) who observed that camel mineral requirements are not well established. As in many grazing studies, it was difficult to estimate the dry matter intake of camels, the mineral content of consumed forages (sample representation) and, therefore, the daily intake of mineral elements.

Apart from improvement in milk yield, the local pastoralists observed that mineral supplementation also improved body condition score, increased body water retention capacity and reduced the subsequent watering interval of the camels. Additionally, it improved the milk quality as evidenced by froth on the milk. However, no data was collected to support these pastoralists' observations.

Calf growth rate

The average daily weight gain of the calves of experimental dams, which had received the two mineral supplements at the two sites, is presented in Table 5.

Table 5: Average daily weight gain of calves in Kargi and Ngurunit study sites

Site	Treatments	Mean (gd^{-1})	Standard error
Kargi	Control	275.7^a	16.4
	Commercial	446.3^b	22.7
	Local	436.4^b	37.2
Ngurunit	Control	307.7^a	22.8
	Commercial	427.7^b	15.8
	Local	421.8^b	26.4

In every site, column means followed by the same letter superscript are similar ($p > 0.05$)

The initial live weight of the control calves in the study (n = 49) was 35.1± 1.0kg while the weight at end of the study was 78.8±1.8kg. The calves gained an average of 43.7kg during the study period. The average weight gain was 291.7 ± 19.6gd^{-1} with a range of 215.1gd^{-1} to 367.6gd^{-1}. This was lower than 580 gd^{-1} recorded by Field (1984) under commercial ranch conditions. Field (1984) however reported 140gd^{-1} for similar calves on pastoral management systems. This author further observed that variations in calf growth result from nutrition, particularly milk allowance to the calf, among other factors. The mean daily weight gain for supplemented camels' calves was 333.0 ± 25.5g.

Factors influencing calf growth rate

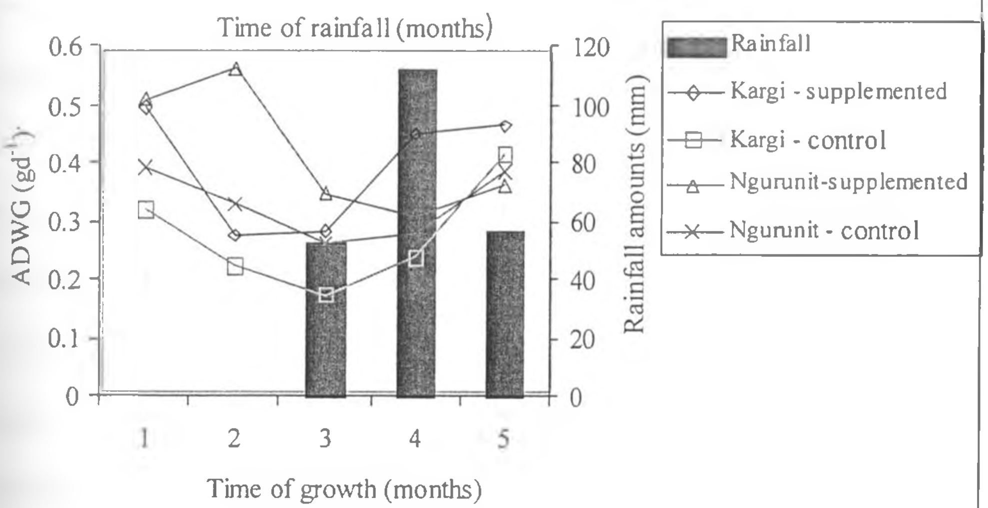
Site

Regression analysis indicated that the growth rates of camel calves in Kargi and Ngurunit were similar ($p > 0.05$), (275.7gd^{-1}, 446.3gd^{-1} and 436.4gd^{-1} in Kargi versus 307.7gd^{-1}, 427.7gd^{-1} and 421.8gd^{-1} in Ngurunit for control, commercial and local supplements, respectively). The model was significant ($p < 0.05$), meaning that given the indipendent variables, the dependent variables can be accurately estimated using equation of the relationship.

Supplement type

Calves from the supplemented dams (Table 5) grew faster ($p < 0.05$) than those of dams in control group (446.3gd^{-1}, 436.4gd^{-1}, 275.7gd^{-1} in Kargi and 427.7gd^{-1}, 421.8gd^{-1}, 307.7gd^{-1} in Ngurunit for commercial, local supplements and control, respectively). The interaction between site and supplement type was insignificant ($p > 0.05$), meaning that the mineral supplements influenced the daily weight gain of calves in the same way in both sites. Mineral supplementation of dams increased the growth rate of their calves by 60.1% and 38.1% in Kargi and Ngurunit, respectively. The higher daily weight gain of calves from supplemented dams was due to higher amount and quality of milk available to the calves. Other researchers have arrived at similar conclusions (Field, 1984; Wangoh *et al.*, 1998; Vittorio *et al.*, 1999). Hammadi *et al.* (1998) reported differences in calf weight gain between supplemented and unsupplemented female camels. These authors attributed these differences to differences in milk production between the two groups of camels. Calves from the supplemented dams in Kargi gained more weight than those in Ngurunit, suggesting that they had access to higher amounts of milk. The ADWG of experimental calves at Kargi and Ngurunit are shown in Figure 3.

Figure 3: Effect of mineral supplementation on ADWG (gd^{-1}) of calves in Kargi and Ngurunit with an overlay of rainfall data



Camel calves responded to mineral supplementation of their dams quite fast in both sites (Fig 3). An average daily weight gain of over $500gd^{-1}$ was attained in the first month of the experiment among the supplemented camels. Calves from the control dams had an average weight gain of $370gd^{-1}$ during the same period. Daily weight gain of calves from the supplemented camels at Kargi peaked in the first month, while in Ngurunit, peak weight gain occurred in the second month of the study. The weight gain in both calves of supplemented and control camels closely followed seasonal changes in forage quantity and quality, being lowest at the peak of dry season ($230gd^{-1}$ in control; $300gd^{-1}$ in supplemented dams' calves). Following commencement of the long rains, there was evidence of compensatory growth for both groups with the daily weight gain increasing to 385gd^{-1} and 420gd^{-1} in unsupplemented and supplemented dams' calves, respectively. Calves of the unsupplemented dams appeared to catch up with those of supplemented dams in terms of the daily weight gain, suggesting that the supplements were more beneficial during the dry season.

During the wet season, the calves were over four months old and were grazing. Mares (1954) and, Yagil and Etzion (1980) had made a similar observation. The compensatory growth observed in calves during this period (evidenced by the high daily weight gains) was attributed to higher milk supply by the dams, mainly as a result of availability of higher quality forage and the mineral supplements. The observed trend in calf growth agreed with that of Nagpal and Sahani (1998), who reported that phosphorus supplementation increased the average daily weight gain of *Bikaneri* camel calves, attributing the increase to improved nutrient absorption and utilization. Phosphorus is essential for proper functioning of rumen microorganisms, especially those, which digest, plant cellulose (McDowell, 1997). The ADWG of calves in the present study declined during the peak of dry spell due to limited forage supply to the dams, which, in turn lowered the milk production of dams and hence the supply to the calves. Faye *et al.* (1991), working with camels in Djibouti recorded weight losses of up to 75gd^{-1} in camels fed nutritionally poor mangrove leaves and supplemented with trace elements. Thus, the effect of supplementation may not be realized if quality of basal diet is low.

Plasma mineral conentrations

The mean plasma concentrations of mineral elements at the start, during and end of the supplementation period are presented in Table 6.

Table 6: Mean plasma mineral concentrations at the start and during the supplementation period

	Starting/ Control	2nd and 3rd month	4th and 5th month	6th and 7th month	Reported range*
Mineral element	Concentrations (mg/l)				
Na	6240±2050	7370±2310	5640±2510	3810±990	3690-4290
K	640±360	1630±840	1350±300	1710±670	41-274
Ca	42±14	64±40	63±42	30±6	87-106
P	73±29	79±40	78±36	81±32	35-65
Mg	26±5	36±9	42±11	41±11	18-36
Zn	2.1±1.0	7.7±6.2	12.3±3.4	2.4±1.5	0.7-1.2
Cu	0.6±0.2	0.6±0.1	0.6±0.1	0.6±0.1	0.5-1.2
Fe	0.7±0.3	0.8±0.3	0.9±0.2	0.9±0.2	0.6-1.4
Co	0.1±0.0	0.1±0.0	0.1±0.1	0.1±0.0	0.03-0.13

*Plasma mineral concentration range for camels obtained from the literature

The mean plasma concentrations of the trace elements-Co, Fe and Cu-were within the reported range throughout the experimentation period and did not change significantly with supplementation. Plasma Zn concentration increased from the start to the 5th month and decreased significantly during the last two months of supplementation. Sodium and Ca concentration in the plasma increased during the 2nd and 3rd months of supplementation and then declined consistently to the end of the experiment. While K concentration increased rapidly, P and Mg concentration increased marginally with the supplementation. The observed range (Table 6) of all the macro minerals and Zn was wider than the reported range. The increase in plasma concentration of Zn, Na, K and Mg, and the wider range may have resulted from the mineral supplements fed to camels among other factors.

Factors affecting plasma mineral concentrations

Regression analysis indicated that plasma mineral concentrations were influenced by supplementation and month of sampling/time ($p < 0.05$). Supplementation appeared to influence plasma concentration of the macro more than the microelements. As no significant differences were observed in plasma mineral concentrations between commercial and local mineral supplements and between sites, the data was combined for subsequent analysis.

Correlation analysis

The analysis revealed significant positive correlations between Ca and Zn ($p = 0.025$; $r = 0.82$) and, Ca and Na ($p = 0.025$; $r = 0.82$) but showed a significant negative correlation between Ca and P ($p = 0.04$; $r = -0.78$).

Supplementation and time of sampling

Figures 4 and 5 represents the mean monthly plasma micro and macro mineral contents, respectively, under the two-supplementation treatments.

Figure 4: Mean monthly plasma micro mineral concentrations during the supplementation period

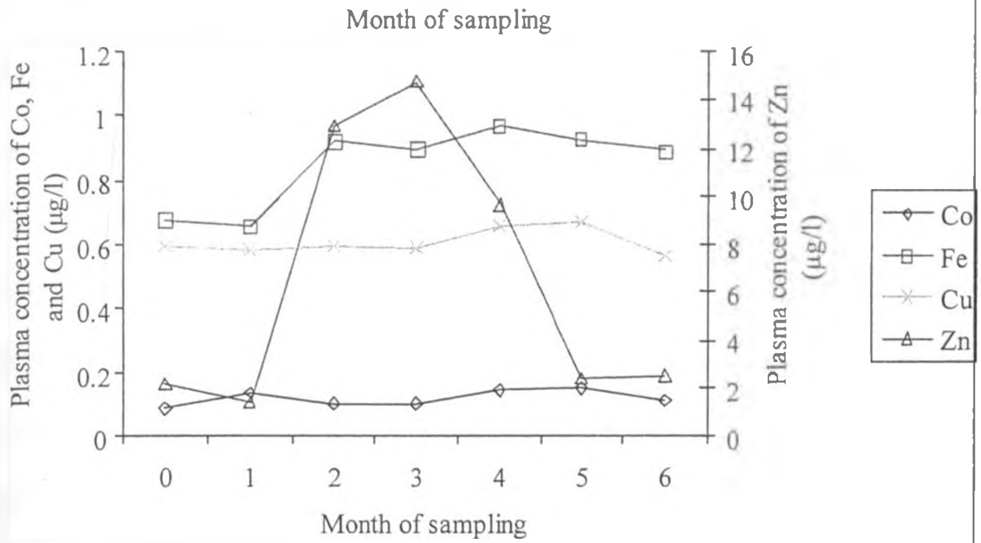
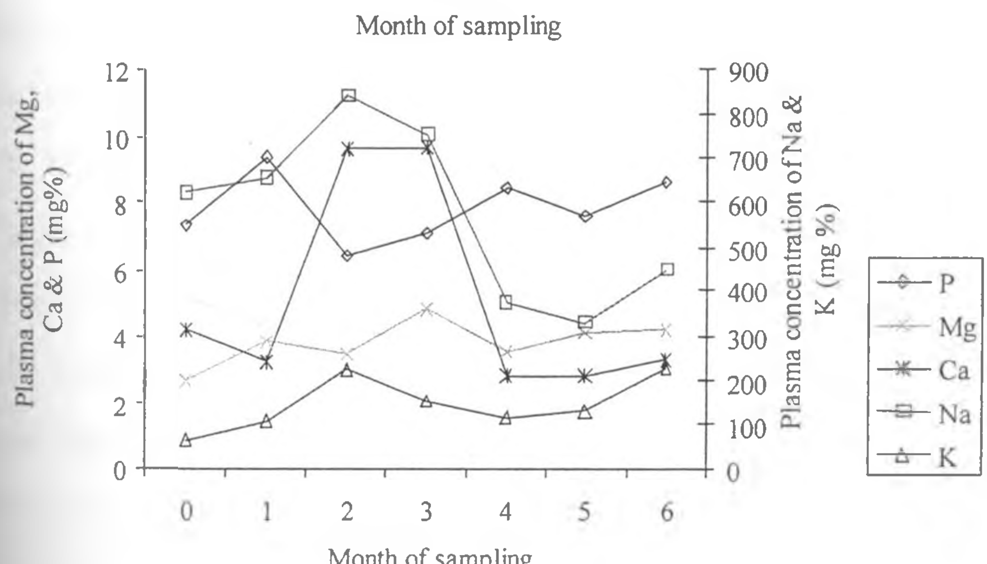


Figure 5: Mean monthly plasma macro mineral concentrations during the supplementation period



Sodium and K are mainly involved in maintenance of osmotic pressure and acid base balance in the body (McDowell, 1997). These elements are not stored in the body and must be supplied daily in feed. The mean plasma Na concentration in camels at beginning of the experiment was above the reported range. This increased with supplementation attaining maximum level during the second month, then declined to reported range by end of the fourth month. The mean plasma K concentration in camels at beginning of the experiment was above the reported range and increased with supplementation with the mean level being maintained above reported range. The observed rise in plasma concentrations of Na and K despite homeostatic control may suggest higher concentration of both minerals in these particular camels or interaction with other minerals.

Calcium and Na may have influenced the initial rise in plasma concentration of each other as a consequence of significant positive interaction between the two elements observed in this study. There is however no biochemical explanation for this interaction and may require further investigation. Camels are reported to show elevation of Ca, Na and K in the plasma as a result of dehydration (Ayoub and Saleh, 1998). The peak plasma concentration of these minerals in this study coincided with the height of a dry season. High plasma concentration of Na during this time may be necessary as it is involved in water re-absorption in the kidneys (Ben Goumi *et al.*, 1993). Sodium is actively re-absorbed, increasing the salt concentration in kidney tissues. This triggers diffusion of water from gromerular filtrate into the surrounding tissues down in the loop of henle.

Calcium, P and Mg are structural components, mainly stored in bones and teeth (McDowell, 1997). Plasma concentration of Ca declined during the first month, increased to reported range during the second and third months of supplementation, then declined and remained below the reported range. The initial plasma concentration of P was above the reported range. This increased marginally with supplementation attaining maximum level during the first month, declined to reported range in the second month, then continued rising gradually up to the end of supplementation period. The plasma concentration of Mg at beginning of the experiment was within the reported range. This increased with supplementation to a level above the reported range.

The trend for P was inverse to that of Ca and was reflected in a negative correlation between these elements. Due to the roles of Ca and P in formation of bones during which the optimal 2 (Ca): 1 (P) ratio (McDowell, 1992) must be maintained, there is mutual inhibition of absorption of whichever element may be in excess from intestinal tract (Georgievskii, 1982). This inhibition occurs by way of a chemical reaction between the two mineral elements, forming an insoluble complex. Vittorio *et al.* (1999) observed that Ca is one of the mineral elements that are strongly controlled by homeostasis and is not expected to fluctuate much with diet. Cunha (1973), McDowell (1997) and Lukhele and Van Ryssen (2003) also reported significant negative interaction between Ca and P. These authors observed that excess of either P or Ca in the diet interfere with absorption of the other leading to lower plasma concentration. In this study, for reasons that are not clear, Ca/P ratio was lower than the optimum throughout the supplementation period, P being in excess of Ca. The gradual increase in plasma concentration of Mg is attributed to supplementation in agreement with Ingraham *et al.* (1987).

Zinc is a major component of metalloenzymes, both as part of molecules and activator (McDowell, 1997). Although plasma Zn concentration was above the reported range at the start of experiment, it increased with supplementation attaining a maximum level of 14.7μg/kg in the fourth month, then declined to a low level of 2.4μg/kg by the end of supplementation period. This element was regulated above reported range throughout the study period. The observed trend for Zn is attributed to increased supply (from the supplement) in harmony with Asif *et al.* (1996) and McDowell (1997). Asif *et al.* (1996) observed that normal concentration of trace elements in different tissues mainly depend on the dietary concentration, absorption and homeostatic control mechanisms of the body. McDowell (1997) observed that though Zn is stored in the liver, this is only in small amounts and it should be supplied regularly in feed to enable the body maintain required level in the blood.

The high levels and rapid increase in plasma concentration of Zn between second and fourth months of supplementation is attributed to a positive Ca/Zn interaction observed in this study. Asif *et al.* (1996) reported positive correlation between these mineral elements. In non-ruminant animals, Ca interacts with Zn in a negative way owing to formation of phytate complexes (Georgievskii, 1982; Larsen and Sandstrom, 1992). However, microbial organisms in ruminants (camels inclusive) produce phytase enzyme, which degrade phytate complexes (Spears, 2003). Thus, as supplementation continued, Zn absorption in small intestines continued unabated resulting to high plasma concentration.

Copper is an essential component of metallo-enzymes and is involved in bone formation and proper cardiac function, while Co is, required by rumen microorganisms for vitamin B_{12} synthesis (McDowell, 1997). These minerals are stored in the liver. Iron plays a vital role in cellular respiration and is a component of haemoglobin and myoglobin (McDowell, 1997). The plasma concentrations of Cu, Co and Fe were within reported range at beginning of the experiment. There were minor fluctuations but the concentrations were maintained within this range during supplementation through homeostatic mechanisms (Doyle *et al.*, 1990). Vittorio *et al.* (1999) similarly reported a non-significant increase in plasma concentration of Fe with supplementation of camels. Lack of plasma response following oral mineral supplementation has been linked to efficient specific elemental homeostasis (Doyle *et al.,* 1990). The observed trends suggest that the reported range was reflective of body requirement of these minerals.

The plasma Co and P concentrations displayed a seasonal trend, declining during dry season. In wet season, when the forage availability improved, plasma concentrations of these minerals increased. This observation was in agreement with Faye *et al.* (1991) and Cuesta *et al.* (1996). Faye *et al.* (1991) observed that there is a high interaction between mineral absorption and quality of diet. A diet that is well balanced in energy and protein (common during wet seasons) is therefore crucial in avoiding mineral deficiencies in animals (Faye *et al.*, 1991). Cuesta *et al.* (1996) observed that serum concentrations of most minerals in animals varied with season and sampling month.

Economics of mineral supplementation

Camel keepers would expect to realize extra income from supplementation resulting from higher growth rate (meat) and milk. With the available data, a simple cost benefit analysis combining commercial and local supplements was done for camels in the Ngurunit area.

The average weight gain of the calves from supplemented dams was $430gd^{-1}$ compared to $308gd^{-1}$ for control calves, an additional $122gd^{-1}$ (3.66kg/month). Assuming a dressing percent of 55 (Shalash, 1979; Staatz, 1979), this would translate to an extra 2.01kg meat/month. The supplemented camels consumed 120g of Chalbi salt and 80g of bone meal. The cost of chalbi salt at the local market was Ksh 30/kg. Cost of collecting bones was assumed to be zero (if the bones are proven useful, a cost will need to be attached). Cost of charring was estimated at Ksh 12/kg (cost of firewood) and a labor cost of Ksh 21/kg. Thus to feed a camel on the supplement would cost Ksh 6.24/d (Ksh 187/month).

The cost of camel meat in local butcheries at that time was Ksh 110/kg, thus an extra income of Ksh 221 is realized at a supplement cost of Ksh 187/month. Extra income to the camel keeper resulting from supplementation would be Ksh 34 per month. The other benefit to the camel keeper is in additional milk. The average milk yield increase in Ngurunit was 44.5% compared to the control. At the yield of 72 liters/month for control camels, the extra milk realized from supplemented camels was 32.0 liters. At the price of milk of Ksh 14/litre, the extra income realized would be Ksh 448/month.

Conclusions

The lactation milk yield of camels increased as a result of mineral supplementation irrespective of site or type of the supplement. The average daily weight gain of calves also increased following mineral supplementation of the dams. These positive responses were suggestive of existence of mineral deficiency among the Rendille camels. The Rendille pastoralists could ameliorate mineral deficiency in their camel herds through the use of locally available raw materials. There was no direct relationship between diet (supplement) and plasma mineral concentrations. Other factors, which may include but not limited to homeostasis and mineral interactions, appeared to play a more significant role in determining mineral status in the blood.

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Chapter 7

Nutritive value of key range forage species to camels in Marsabit, Kenya

Nutritive value of key range forage species to camels in Marsabit, Kenya

Abstract

A study carried out in the semi-arid rangelands of Marsabit during dry and wet seasons assessed the content and seasonal variation of CP and fibre among important forage species commonly utilized by camels. Through a semi-structured questionnaire, herders were interviewed and the important forage species consumed by camels identified. The respondents were mainly men and boys responsible for camel herding in the area. The identified forage species were verified through direct field observation of grazing camels. All plant species thus identified were sampled and analysed for CP, Ash and fibre. The results indicated that camels preferred dwarf shrubs during the wet season, herbaceous forage species in the dry season. The mean CP and NDF contents of preferred forage species were 13.9±5.0% and 53.6±13.7% of DM, respectively. Shrubs were lower in NDF (51.0±12.6%) and ash (15.5±7.2%) and higher in DM (50.0±18.2%) and CP (14.7±4.9%) compared to grasses (NDF = 60.4±14.3%, ash = 18.5±5.2%, DM = 49.7±17.8%, CP = 12.0±5.0%). From the study, it was concluded that the combination of forage plant species selected by the camels across sites and seasons was adequate in CP.

Key words: Nutritive value, range forage species, camels, Kenya

Introduction

In the arid and semi-arid zones of the world, it is inevitable for livestock to be well adapted to the harsh grazing conditions (Abbas *et al.*, 1995). Camels are able to survive in such environments due to their unique morphology and physiology. The physiology of camels enables them to survive on very fibrous and low protein diets (Heller *et al.*, 1986, Lechner-Doll *et al.*, 1990). They reportedly retain such feed material for longer periods in the rumen and thus utilize these better than cattle, sheep and goats (Mousa *et al.*, 1983). The height of camels allows them to utilize feed resources inaccessible to other livestock species (Field, 1979). The cleft upper lip enables camels to select diets better than other livestock species (Rutagwenda *et al.*, 1990). Due to these adaptive features, camels are important in the subsistence of pastoral peoples inhabiting the harsh areas through provision of milk and some blood (Field and Simpkin, 1984). Despite the socio-economic importance of the camel in the arid and semi-arid rangelands of the world, efforts to improve its productivity have lagged behind other livestock species (Bahgat, 1991).

Coppock *et al.* (1986) observed that the dromedary was, by preference, a browser of trees and shrubs and sometimes hard-thorny and bitter plants that grew naturally in the desert and other semi-arid areas. Camels browse selectively, preferring the more nutritious browse materials, with high moisture and electrolyte contents (Newman, 1975; Field, 1995). Field (1979), Coppock *et al.* (1986) and Rutagwenda *et al.* (1990) reported that on thorn bush savannah pasture, camels spent more than 80% of their feeding time on highly digestible dicotyledonous plants. Wangoi (1984) and Field (1995) observed that the browse selected by Rendille camels was predominantly comprised of dwarf shrubs, shrubs and trees. However, they also noted seasonal variations such that trees, shrubs and dwarf shrubs dominated camel diet in the wet season, but the percentage of trees and shrubs noticeably declined during the dry season when most of these species shed the leaves. Rutagwenda *et al.* (1990) further reported that during the wet season, Rendille camels successfully selected the dicotyledons, while in the dry season, more than 90% of feeding time was spent on monocotyledons. Wangoi (1984) reported that grass species made a small proportion of camel diet.

As with minerals, the crude protein and fibre contents of most forage species selected by camels in the Rendille grazing area have not been evaluated (Field, 1995). Yet, all nutritional factors (minerals, crude protein, fibre, energy, etc) and their seasonal changes in forage species collectively determine the quality of diet available to the camels (Kayongo-Male *et al.*, 1978). The ultimate diet quality directly affects camel performance and of importance to this study, their response to mineral supplementation. This paper reports the seasonal profile of CP and fibre fractions of important forage species utilized by camels in the Rendille area.

Materials and Methods

A description of the study area is presented in Chapter 3.

A semi-structured questionnaire was designed, pre-tested and administered through a language translator on semi-settled Rendille camel herders in Ngurunit, Korr and Kargi during the dry and wet seasons. The respondents were mainly boys and men who were directly involved in camel management and a few women. The respondents numbered 33, 28 and 30 in Kargi, Korr and Ngurunit, respectively. Individuals interviewed in the dry season were re-interviewed during the wet season to capture seasonal variations. Five to eight respondents were selected at random from 4 to 5 randomly selected *manyattas* in the three study sites.

Identification of preferred forage species

During the administration of questionnaire, the respondents were asked to identify five forage species preferred by camels during both the dry and wet periods. The identification was followed by verification through direct field observation of grazing camels. Thirty camels were observed during each season (5 – 6 camels per day) for a period of 5 – 7 consecutive days. The observations were conducted by myself and a technician with each of us observing 2 - 3 camels daily, between 10.00 am and 12.00 noon. Each camel was observed for 15 minutes, recording the number of bites made by the camel on various plant species. Bites made on any particular forage species by different camels were summed up to get the site totals. The species were ranked on the basis of the proportion of bites by site and season.

Sampling of plant parts of preferred forage species

The ranking lists of preferred forage species were used as a guide to determine which species were to be sampled for laboratory analysis. Where the camels utilized 10 or less species during the observation, they were all selected for sampling. However, where the number of plant species utilized was more than 10, those taking 90 - 100% of camels' grazing time were chosen for sampling starting from the one with highest score. Sampling targeted plant parts eaten by the camels during the field observation. Forage species that are perceived as important by herders were also sampled, regardless of whether they were eaten during field observation or not. Plant parts selected for sampling were mostly the leaves and soft stems. A total of 55 forage species were sampled in the three sites during the dry season of which 36 had been confirmed eaten by the camels. In the wet season, 54 forage species were sampled, out of which, camels had been observed utilizing 29. Wet weight of all the forage samples was taken after harvesting and the samples packed in polythene bags for laboratory analysis.

Laboratory analysis

Dry matter content of the samples was determined according to the standard AOAC (1995) methods. The samples were dried at 60°C for two days, weighed, ground and then stored for analysis. Crude protein was determined following the Kjeldal procedure described in the AOAC (1995). Fibre content was determined according to the procedures of Van Soest (1963). Ash was determined according to the AOAC (1995) procedure of igniting known amounts of the dried, ground samples in a furnace at 600°C for two hours, followed by weighing.

Results and Discussion

Forage species preference

Table 1 shows the forage species selected by camels per site and their relative contribution to the daily diet of camels in dry and wet seasons.

The camels showed preference for dwarf shrubs especially in Kargi (94.5% bite counts) and Korr (70% bite counts) during the wet season, while in the dry season, they selected more of herbaceous species (46.7% in Korr, 53.0% in Kargi) in addition to the dwarf shrubs. Compared with the herbs and climbers, tall shrubs and dwarf shrubs in this study were lower in fibre and ash (15.5% against 18.5%) and higher in dry matter and CP. These quality attributes made the tall shrubs and dwarf shrubs more palatable, in harmony with El Shaer and Gihad (1994) and were thus preferred by the grazing camels. These findings were consistent with those of Wangoi (1984), Rutagwenda *et al.* (1990) and Field (1995). Wangoi (1984) observed that camels preferred a diet dominated by browse - 96% in the wet season. The percentage of browse in the diet, however, declined in the dry season as the forage species shed off the leaves. Field (1995) also reported that dwarf shrubs constituted the most important plant species in the diet of camels. During the field observation, it was noted that among the preferred forage species in the Rendille area, *Indigofera spinosa* was the most abundant. In Ngurunit, camels mostly grazed on shrubs in both dry (61.8%) and wet (66.8%) seasons, possibly because shrubs dominated the vegetation.

The high number of bite counts recorded in *Indigofera spinosa* (79.9% and 15.5% in Kargi, 42.3% and 23.3% in Korr, 1.8% and 16.8% in Ngurunit) during wet and dry seasons, respectively and *Dusoperma eremophilum* (8.1% in Kargi – wet season, 13% and 22% in Korr, 27.4% and 11.5% in Ngurunit during wet and dry seasons, respectively) reflected the relative abundance of both dwarf shrubs on the ground. Forage species like *Lawsonia inermis* (13.8%) and *Cordia sinensis* (10%) in Ngurunit, *Heliotropium studineri* (34.2%) and *Portulacea oleracea* (12.5%) in Korr, *Ficus species* (28%) and *Dactyloteniun bogdanii* (22.9%) in Kargi recorded fairly high bite counts although they were not abundant on the ground. This suggested that the forage species were preferred and therefore sought after by the camels. This was in agreement with Osolo *et al.* (1994) who reported high preference for some plants that were not the most abundant in the study area. In addition, all these forage species were moderate in DM (mean = 43.3$\pm$13.3%), CP (mean = 12.1$\pm$3.7%) and ash

Table 1: Forage species selected by camels during the dry and wet seasons in the three study sites and their contribution to the camel diet

Site	Growth	Forage species	Bite count %	
			Dry season	Wet season
Kargi	Shrubs	*Cordia sinensis*	*(1.4)	0
		Acacia mellifera	0	2.8
		Acacia reficiens	0	2.6 **(5.4)**
	Dwarf shrubs	*Ficus species*	28.0	0
		Indigofera spinosa	15.5	79.9
		Crotolaria deseticola	1.6	0
		Sericocomopsis hilderbrandtii	0.6	0
		Duosperma eremophilum	0	8.1
		Indigofera cliffordiana	0 **(45.7)**	6.5 **(94.5)**
	Herbs	*Blepharis linariifolia*	0.4	0
		Heliotropium species	0	0.2
		Dactyloteniun bogdanii	22.9	0
		Digitaria velutina	12.6	0
		Aristida adscensiosis	8.9	0
		Sporobolus spicatus	8.2 **(53.0)**	0 **(0.2)**
Korr	Shrubs	*Cadaba mirabilis*	2.0	0
		Maerua classifolia	1.7	0
		Cadaba farinosa	0.6	**(2.6)**
		Balanites orbicularis	0.6 **(4.9)**	0
	Dwarf shrubs	*Indigofera spinosa*	23.3	42.3
		Duosperma eremophilum	22.0	13.0
		Indigofera cliffordiana	0.8	5.2
		Cadaba glandulosa	0.3	0
		Sericocomopsis hilderbrandtii	0 **(46.4)**	9.5 **(70.0)**
	Herbs	*Heliotropium studineri*	34.2	4.1
		Portulacea oleracea	12.5	0
		Heliotropium species	0	16.0
		Blepharis linariifolia	0	3.5
		Indigofera hochstetteri	0	2.2
		Dactyloteniun bogdanii	0 **(46.7)**	0.01 **(25.8)**
	Climbers	*Maerua oblongifolia*	**(2.4)**	0
ªNgurunit	Shrubs	*Lawsonia inermis*	13.8	0
		Cordia sinensis	10.0	3.1
		Balanites aegyptiaca	7.7	0
		Boscia coriacea	6.8	0.1
		Maerua species	6.5	0
		Craibia inurentii	2.2	0
		Tapinanthus sansibarensis	1.8	0
		Cadaba farinosa	1.2	0
		Salvadora persica	0.9	0
		Justicia exigua	0	46.9
		Opilia campestris	0	5.2
		Commiphora boiviniana	0	4.9
		Grewia tenax	0	4.3
		Momordica trifoliolata	0	1.5
		Maerua classifolia	0 **(50.9)**	0.8 **(66.8)**
	Dwarf shrubs	*Indigofera spinosa*	16.8	1.8
		Duosperma eremophilum	11.5	27.4
		Cadaba glandulosa	1.1 **(29.4)**	0 **(29.2)**
	Herbs	*Barlaria proxima*	**(4.8)**	0
	Climbers	*Maerua oblongifolia*	**(4.0)**	0
		Combretum molle	0	**(3.9)**

*Growth form totals; ªIn Ngurunit-dry season, a plant species known by Samburu language as *Lkerpei* with proportional bite count of 10.9% was excluded due to lack of botanical name.

(mean = 18.1±5.1%). El Shaer and Gihad (1994) observed that forage species with 14% ash had high palatability. While moderate moisture content makes feed more palatable and may increase dry matter intake, excessive moisture depresses dry matter intake of grazing animals (Linn, 2004).

Crude protein and fibre contents

Tables 2 and 3 shows the DM, CP and fibre contents of the forage species selected by camels during dry and wet seasons, respectively, whereas the nutritive values of other forage species, perceived as important by the respondents are presented in Table 4.

The preferred forage species had an overall (all sites combined) mean DM of 60.8±17.8% and 40.0±9.1% during dry and wet seasons, respectively. The overall average CP content of these forage species was 12.1±4.7% (4.2 – 25.6%) and 16.2±4.4% (8.3 – 27.8%) of DM in dry and wet seasons, respectively. The mean CP for shrubs was 13.2±4.7% (7.1 – 25.6%) while that of herbaceous species and climbers was 9.3±3.8% (4.2 – 15.0%) during the dry season. In wet season, the average CP for shrubs was 16.6±4.5% (11.3 – 27.8%) compared to 15.5±4.2% (8.3 – 20.8%) for herbaceous species and climbers. The CP thus increased from dry to wet season and was higher in shrubs than other forage species categories. The average NDF of preferred forage species was 55.9±13.9% (23.5 – 81.8%) and 50.7±13.0% (19.4 – 81.3%) during dry and wet seasons, respectively. Shrubs had a mean NDF content of 51.0±12.6% (19.4 – 80.4%) while herbaceous species and climbers had 60.4±14.3% (41.7 – 81.8%) (Tables 2 and 3). The NDF declined from dry to wet season and was higher in herbaceous species than in shrubs. Ash content of the forage species (Tables 2 and 3) averaged 15.3±6.4% (6.9 – 31.3%) and 17.7±7.2% (6.8 – 35.6%) during dry and wet seasons, respectively.

Table 2: Chemical composition of the preferred forage species by site during the dry season

Site	Growth form	Forage species	DM %	CP %	Ash %	NDF %	[a]ADF %	[b]ADL %
Kargi	Shrubs	*Cordia quercifolia*	57.0	13.2	7.4	47.8	42.0	23.4
		Ficus species	26.5	11.4	19.1	47.2	31.8	8.1
		Sericocomopsis hilderbrandtii	59.7	9.6	13.1	64.7	43.4	10.8
		Indigofera spinosa	71.0	8.1	17.6	69.4	53.4	17.6
		Crotolaria deserticola	83.9	7.1	10.8	64.9	50.7	8.4
	Herbs	*Sporobolus spicatus*	57.6	7.1	22.2	74.4	41.0	7.0
		Dactylotenium bogdanii	58.3	6.7	19.0	63.1	38.1	6.2
		Aristida adsensionis	84.7	5.9	22.2	75.7	50.2	6.6
		Digitaria velutina	-**	4.2	11.6	76.2	47.4	7.1
		Blepharis linariifolia	70.6	7.2	25.6	81.8	59.3	16.8
Korr	Shrubs	*Balanites orbicularis*	46.8	25.6	6.9	52.4	32.3	11.3
		Cadaba mirabilis	59.8	18.4	31.3	48.5	30.9	12.7
		Maerua classifolia	56.3	17.1	23.2	35.6	22.6	11.4
		Cadaba farinosa	64.8	15.2	7.0	80.4	59.5	24.9
		Duosperma eremophilum	78.1	12.6	18.7	46.9	30.0	14.6
		Indigofera spinosa	82.7	11.5	7.6	46.2	24.8	19.6
		Indigofera cliffordiana	82.8	9.2	8.1	49.6	32.9	21.7
		Cadaba glandulosa	57.5	15.8	20.4	47.5	31.1	14.0
	Herbs	*Heliotropium studineri*	34.6	13.3	19.0	44.9	33.8	9.0
		Portulacea oleracea	31.5	9.3	16.6	56.0	38.2	6.8
	Climbers	*Maerua oblongifolia*	56.2	15.0	11.3	65.9	45.6	16.7
Ngurunit	Shrubs	*Craibia inurentii*	53.3	22.6	14.1	49.7	32.6	12.0
		Tapinanthus sansibarensis	57.3	18.7	8.4	54.4	30.5	15.4
		Cordia quercifolia	32.1	16.1	17.5	60.4	51.6	22.3
		Cadaba glandulosa	87.9	14.7	17.7	51.0	31.3	15.0
		Boscia coreacea	68.7	14.5	18.1	54.7	34.7	12.9
		Cadaba farinosa	61.2	14.3	7.3	73.1	45.7	20.0
		Balanites aegyptiaca	50.1	11.9	7.5	60.9	41.5	19.4
		Salvadora persica	31.3	11.3	16.4	33.4	16.4	4.4
		Maerua species	42.1	10.7	27.4	32.0	19.3	12.7
		Duosperma eremophilum	75.1	9.3	19.5	50.7	31.2	24.4
		Indigofera spinosa	78.9	8.8	7.6	68.5	51.0	20.0
		Lawsonia inermis	42.9	7.8	8.1	46.1	35.1	16.5
	Herbs	*Barlaria proxima*	85.2	9.6	12.3	60.5	44.4	19.3
	Climbers	*Maerua oblongifolia*	55.8	14.5	17.0	54.2	32.9	16.7

[a]ADF - acid detergent fibre; [b]ADL – acid detergent lignin; **DM value for this plant mistakenly not recorded

Table 3: Chemical composition of preferred forage species by site during the wet season

Site	Growth form	Forage species	DM %	CP %	Ash %	NDF %	ADF %	ADL %
Kargi	Shrubs	*Acacia mellifera*	33.0	27.8	6.8	63.7	44.8	13.9
		Acacia reficiens	56.7	17.9	7.5	40.2	26.2	14.7
		Duosperma eremophilum	36.4	14.4	24.3	49.2	32.0	12.1
		Indigofera cliffordiana	52.1	13.1	13.0	64.9	39.7	11.4
		Indigofera spinosa	52.1	11.3	10.1	58.9	43.6	14.9
	Herbs	*Heliotropium species*	46.6	10.6	14.9	81.3	43.7	12.4
Korr	Shrubs	*Cadaba glandulosa*	49.0	20.6	16.8	45.6	29.8	13.6
		Cadaba farinosa	48.3	18.2	8.1	60.6	40.9	21.1
		Sericocomopsis hilderbrandtii	38.2	16.0	16.3	63.7	27.4	4.0
		Duosperma eremophilum	33.9	14.9	21.4	50.3	26.8	8.4
		Indigofera cliffordiana	32.9	13.9	19.0	48.9	36.8	8.8
		Indigofera spinosa	27.9	12.7	22.9	55.7	45.1	8.9
	Herbs	*Dactylotenium bogdanii*	39.7	8.3	16.0	76.3	41.1	7.9
		Heliotropium studineri	26.7	20.8	29.0	41.7	31.6	12.9
		Portulacea oleracea	28.7	19.5	22.3	44.1	28.1	15.7
		Blepharis linariifolia	37.8	16.5	21.7	46.3	27.5	4.8
		Indigofera hochstetteri	38.0	15.8	24.6	52.2	32.0	7.1
		Heliotropium species	44.0	14.6	17.2	47.5	34.4	7.4
Ngurunit	Shrubs	*Opilia campestris*	31.9	24.4	28.1	28.9	16.7	8.4
		Grewia tenax	29.9	23.4	17.3	38.8	22.4	8.0
		Commiphora boiviniana	25.7	19.3	14.2	50.5	36.9	13.9
		Maerua species	29.5	16.5	35.6	19.4	7.9	3.3
		Momordica trifoliolata	35.6	15.4	10.6	38.1	24.2	7.9
		Justicia exigua	43.0	13.9	9.3	51.1	30.9	14.2
		Cordia sinensis	41.2	13.8	18.9	56.6	43.3	18.9
		Duosperma eremophilum	45.8	12.4	25.2	43.4	25.0	9.2
		Indigofera spinosa	55.2	11.3	12.7	57.8	44.6	14.9
	Climbers	*Combretum molle*	48.8	17.6	11.3	44.6	30.1	8.5

Table 4: Chemical composition of other forage species perceived as important by the respondents

Site	Season	Growth form	Forage species	DM %	CP %	Ash %	NDF %	ADF %	ADL %
Kargi	Dry	Shrubs	*Cadaba mirabilis*	32.2	20.7	26.8	33.1	22.6	14.8
			Salsola dendroides	51.9	14.8	39.1	41.9	15.5	7.4
			Boscia coreacea	58.3	14.6	12.8	49.7	29.4	-*
			Maerua classifolia	48.2	13.9	11.7	57.2	37.3	22.0
			Cadaba farinosa	69.4	13.6	8.4	66.9	44.2	23.1
			Salvadora persica	28.4	11.9	22.7	39.9	21.5	5.23
			Barlaria proxima	67.4	10.4	11.8	42.2	37.1	16.4
			Cadaba glandulosa	62.8	5.8	23.0	43.5	29.2	14.5
		Herb	*Neuracanthus species*	77.2	8.9	20.8	64.9	47.4	17.0
		Climber	*Maerua oblongifolia*	62.0	12.5	10.1	63.3	42.1	14.0
	Wet	Shrubs	*Boscia coreacea*	42.5	24.7	9.9	44.1	27.9	8.0
			Cadaba mirabilis	38.8	21.8	23.4	38.5	24.9	12.7
			Cadaba glandulosa	76.2	19.5	22.3	36.2	22.8	15.4
			Maerua classifolia	42.6	18.4	27.5	35.1	18.1	7.1
			Cordia sinensis	49.4	18.1	14.4	57.1	51.4	23.9
			Salsola dendroides	30.9	17.2	36.4	44.1	14.4	7.8
			Barlaria proxima	46.4	16.3	15.7	58.4	36.4	14.2
			Ficus sp.	29.6	13.9	21.0	55.8	37.5	12.9
			Lycium europaem	43.4	12.9	7.8	72.6	51.3	22.3
			Salvadora persica	34.5	10.7	33.4	40.5	20.8	5.9
		Herbs	*Dactylotenium bogdanii*	20.3	11.6	18.2	66.8	39.2	5.7
			Sporoborus spicatus	53.9	9.6	11.0	39.2	18.5	10.2
		Climbers	*Maerua oblongifolia*	39.7	15.0	15.7	52.6	33.8	13.0
Korr	Dry	Shrubs	*Cadaba ruspoli*	65.1	18.8	14.6	49.0	30.6	15.0
			Ficus sp.	66.9	14.4	11.0	67.6	50.1	13.8
			Salvadora persica	37.3	-*	49.5	32.0	15.4	3.9
			Boscia coreacea	58.8	17.4	13.9	48.5	29.2	15.2
	Wet	Shrubs	*Ficus sp.*	20.4	19.4	21.1	56.8	37.4	9.3
			Cassia/Crotolaria sp.	39.2	18.4	8.3	54.2	39.2	8.1
			Maerua classifolia	47.7	17.7	21.3	41.4	24.7	8.5
			Salsola dendroides	30.9	13.4	22.3	55.2	27.4	5.21
			Salvadora persica	28.9	10.0	43.1	31.9	19.9	5.3
Ngurunit	Dry	Trees	*Acacia tortilis*	46.6	14.7	10.5	52.2	42.5	18.7
		Shrubs	*Ormacarpum trichocarpum*	33.9	12.1	16.6	52.5	32.0	12.3
			Dobera glabra	48.2	10.2	14.2	64.9	35.3	13.1
			Tarenna graveolena	80.2	9.0	8.1	45.2	32.9	14.3
		Herbs	*Heliotropium studineri*	61.2	11.7	13.9	53.7	38.3	7.1
	Wet	Shrubs	*Sclerocarpus africanus*	31.0	15.8	19.2	41.2	24.6	-*
			Ficus sp.	31.6	15.2	22.5	45.9	27.3	7.6
			Kedrostis gijef	25.3	13.9	40.3	42.8	24.4	7.18
			Commiphora paolii	29.8	13.5	14.9	53.1	28.4	9.4
			Balanites aegyptiaca	48.7	12.1	9.2	46.7	28.0	16.3
			Salvadora persica	31.3	10.5	41.6	32.8	11.7	3.9

*Values mistakenly unrecorded

The CP range in the present study was higher than what had been reported for range forage plantss in other countries by APRU (1978): 5.3 to 11.6% in Botswana, El Shaer and Gihad (1994): 6.2 to 13.2% in Egypt. El Shaer and Gihad (1994) reported an NDF range of 35 – 39% for forage species selected by sheep and goats, which is narrow. compared to the range obtained in this study for camel diets. The increase in CP from dry to wet season was in agreement with Kayongo-Male (1986), Field (1995) and Abbas *et al.* (1995). During a study on quality of forage species selected by Zebu cattle in Ngurunit - Oltorot area of Marsabit district, Kayongo-Male (1986) observed a declining trend in CP and a concomitant increase in the fibre fraction from wet to dry season. Field (1995) observed that the CP of forage species selected by camels peaked in the wet season. The author reported wet season CP content in the range of 15 - 16%, similar to results of the current study. Abbas *et al.* (1995) reported CP content of forage plants during dry season that was 73% lower than in the wet season. The increase in fibre content of forage species recorded in this study was consistent with earlier reports by Van Soest (1982) and Wilson (1982) who noted that when forage species matured (dry season), fibre content increased while protein level declined.

To estimate the amount of nutrients available to the camels daily, computations were done for an average camel (450kg live weight consuming 2% of the live weight feed – Field, 1993) and the results are shown in Table 5. These were computed from the list of preferred forage species, their bite counts and nutrient content.

Table 5: Calculated percent of CP, NDF and the daily CP and NDF intake for a 450kg camel consuming 2% of live weight dry matter

Site	Dry season		Wet season	
	CP	NDF	CP	NDF
Kargi	8.1%	66.5%	15.9%	59.7%
	(0.7kg)	(6.0kg)	(1.4kg)	(5.4kg)
Korr	15.4%	52.2%	16.0%	52.7%
	(1.4kg)	(4.7kg)	(1.4kg)	(4.7kg)
Ngurunit	12.8%	51.5%	16.8%	42.9%
	(1.2kg)	(4.6kg)	(1.5kg)	(3.9kg)

Protein requirements of ruminants include protein and/or nitrogen requirements for the ruminal microbial population (Huston *et al.*, 1981). The microbial requirements are met at 6 – 8 % CP, while the animal CP requirements range from 7 – 20% depending upon species, sex and physiological state (Milford and Haydock, 1965; Huston *et al.*, 1981). Kearl (1982) estimated 11 – 13% CP in the diet to be adequate for maintenance and growth requirements of sheep and goats, while 7 – 8% is enough to cover the requirements of ruminal microorganisms. In this study, camels selected diets adequate in CP with the exception of Kargi during the dry season. Across sites and seasons, the mixture of forage species selected by the grazing camels had average CP content that was within the range recommended for microbial activities and milk production. Out of 64 forage species analysed, 84.4% had CP contents above 8%. This confirmed an earlier observation by Abbas *et al.* (1995) that dromedaries generally select protein-rich forage species.

Neutral detergent fibre is the major determinant of the overall forage quality and digestibility, and has a direct effect on the animal performance (Linn, 2004). High NDF lowers the voluntary dry matter intake of grazing animals (Van Soest and Jones, 1968: Kandil and El Shaer, 1990). The higher the NDF, the lower the neutral detergent solubles i.e. starches, sugars, fats, CP. El Shaer and Gihad (1994) estimated 35 – 40% NDF range to be within the normal range of good quality fodders. The NDF content of forage species selected by camels in this study was beyond this range in both seasons and across sites (Table 5). However, 50% of the selected forage species had NDF level of 50% or less, suggesting moderate level NDF for the selected diet. Unlike other ruminants, however, camels have a higher capacity to utilize fibrous feed material by retaining it in the rumen for longer period, allowing for better digestion (Lechner-Doll *et al.*, 1990). This mitigates the negative effects of high fibre content in camel diets.

Conclusions

Grazing camels preferred dwarf shrubs especially in Kargi and Korr during wet season while in the dry season, they selected more of herbaceous species. Across sites, *Indigofera spinosa* and *Dusoperma eremophilum* were the most peferred. The CP content of selected diet increased from dry to wet season and was higher in shrubs than other forage categories. Conversely, NDF declined from dry to wet season and was higher in herbaceous and climbers than in shrubs. Across sites and seasons, the combination of forage species selected by the grazing camels was adequate in CP. The diet was however of medium quality with respect to NDF and DM.

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Chapter 8

General Discussion, Conclusions and Recommendations

Introduction

Presence of milking camels in Rendille settlements is critical as they supply milk to the households, supplementing energy sources with high quality protein. This is so due to recurrent droughts and prolonged dry spells, which necessitate the mobile camel herds to remain far from the settlements for most part of the year (Kuria *et al.*, 2004a). The mobile herds act as reservoirs, providing replacements for the settlement-based herds. Maintaining camels in the settlements is, however, constrained by inadequate feed resources, lack of herding labour and high challenge from external and internal parasites and predators. Settlement-based camels, thus, tend to be in poor body condition compared to those in the mobile camps.

While problems of forage quantity, labour, parasites and predators are obvious to the herders, those relating to forage quality, particularly mineral deficiencies, are hard to conceptualize unless the effects are at advanced stages. They are, therefore, unnoticed or are noted too late, yet, economic losses resulting from mineral deficiencies are enormous (Kasongo *et al.*, 1997). Pastoralists have attempted to address the constraints to camel rearing in the settlements with varying degrees of success. Difficulties in timely diagnosis of deficiency and supply of minerals to the camels have made solutions to mineral deficiency related constraints elusive.

This study has made an attempt to understand the strategies employed to supply minerals to the settlement-based camels. Data was initially collected on the existing knowledge of mineral nutrition in the study area. In the course of collecting this data, samples of sources of minerals for camels (forage species, water, and commercial salts) were collected and analysed for their contents of various macro and microelements. Blood samples were collected for purposes of determining plasma mineral levels of camels in the area. In order to get a broader picture of the nutritive value of forage species, the forage samples used for mineral analysis were also analysed for crude protein and fibre contents. Protein and fibre contents of the diets have a direct influence on camel performance. Based on knowledge of preferred sources, mineral intake by camels was estimated. Using literature values of the recommended mineral levels in forage species (main source), deficiencies were estimated and appropriate supplementation schedules for various minerals prepared. The effectiveness of these supplements, their effect on milk production, calf growth and plasma mineral profiles was studied.

Indigenous pastoral knowledge in camel mineral nutrition

Traditionally, pastoralists had their criteria of detecting mineral deficiencies in the settlement-based camels and had identified remedies for this nutritional problem in different seasons (Chapter 3). Inadequate rumen fill, reduction in milk yield and licking of urine were some of the indicators of mineral deficiencies. The most important remedies to alleviate the mineral deficiencies cited included rainwater in areas with salty soils and plants growing in these types of soils during the wet season and early into the dry season. Camels drink salty water and feed on the salty plants. During the dry seasons, camels were taken to drink water from salty springs and boreholes. These sources were, however, not easily accessible to all camels due to poor distribution in space and time, which subsequently limited their reliability. It is recommended that the local pastoralists should make deliberate efforts to ensure their settlement-based camels regularly access distant mineral sources (like Korole springs and Harisurwa borehole) during the dry season. The alternative would be to, either, buy commercial supplements for the camels or make one using locally available materials. In the wet season, they should take full advantage of the standing rainwater and the associated plants.

Forage species and plasma mineral profiles

This study evaluated the major sources of minerals for the settlement-based camels to establish the mineral elements likely to be inadequate in the study area (Chapter 4). Plasma mineral profile of camels was also assessed to determine the relationship between mineral concentrations in the sources and in the body (Chapter 5). On the basis of the concentration of minerals in the various sources and the relative contribution of each source to the daily mineral requirements of camels, it was concluded that forage species were the major dietary source followed by water. Comparison between mineral concentrations in consumed forage species and the expected dietary levels (from literature), indicated that the camels were receiving adequate Ca, P, Mg, K, Na, Fe and Co from the plants during dry and wet seasons. However, these forage species were deficient in Cu and Zn. A comparison between the plasma mineral concentrations of experimental camels and profiles reported in the literature indicated that the former were deficient in Ca, Na, Fe, Zn and Cu in both dry and wet seasons. This suggested lack of direct relationship between concentration of minerals in forage plants and in the plasma.

It has been reported that mineral concentrations in plants affect the mineral status of grazing livestock (Towers and Clerk, 1983). However, no nutrient is absorbed and utilized to the full due to losses during digestion and metabolism. These losses may be due to the overall digestibility of the available forage material from which the nutrients are to be extracted, the actual digestibility of the nutrient itself or interaction with other minerals (Blezinger, 2000). These factors determine bioavailability of the various minerals. The digestibility of *Indigofera spinosa* and *Duosperma eremophilum*, which were the key forage species eaten by camels in the area was moderate, estimated at 40 – 45% (Said, 1980; Kuria, 1996). The bioavailability of Ca, Zn and Cu ranges from 40 to 70% while that of P and Fe is 85 - 92% (Rasby *et al.*, 1998). These mineral elements were all below the plasma levels quoted in literature.

This study also reported high fibre content in forage species preferred by camels, which may have reduced their digestibility, and the subsequent minerals bioavailability. The ratio of Ca: P in the preferred forage species was much higher than the recommended 2: 1. This may partly explain the low level of plasma P and Fe (Lukhele and Van Ryssen, 2003). While Cu is rapidly released from forage material during digestion, Ca and P are slowly released (Blezinger, 2000).

Effect of mineral supplementation on milk yield, calf growth and blood mineral levels

Results of the first phase of the current study indicated low plasma mineral levels. Based on the estimated deficits, two mineral supplements were formulated and prepared (Chapter 6). One supplement was prepared using commercial mineral sources, while the other was made using local sources. Milk yield, calf growth and plasma mineral concentrations were determined for supplemented and non-supplemented camels for 190 days. Results indicated that mineral supplementation increased milk yield and calf growth by 26.0% and 49.1%, respectively. An important observation was that the commercial and locally formulated supplements had similar effects on milk yield and calf growth. Additionally, both supplements influenced the plasma mineral concentrations albeit to a limited extent. The economic analysis of supplementation showed that there is potential for the local pastoralists to realize up to Ksh. 480 per month from each camel if they were to adopt feeding of the local supplement to their camels.

The commercial supplement was assumed to be better balanced to provide the assessed shortfall in mineral supply from the diet and, camels receiving this were expected to perform better than those on the locally formulated supplement. However, both supplements had similar results despite the commercial supplement being more expensive. Mineral requirements of camels are not well established (Van Saun, 1996). The inability to balance minerals in animal rations and supplements is further aggravated by interaction among minerals, influence of stress, environment, stability of the minerals, age of animals and production level among other factors (Underwood, 1977; McDowell *et al.*, 1983; NRC, 1989). Due to this wide range of variables, science has not been able to definitely determine the absolute mineral requirements for animals under every condition. Different authors have therefore drawn differing conclusions regarding the absolute mineral requirements of animals and have made different recommendations on the concentrations of various mineral elements in diets or supplements. There is also considerable difference in bioavailability of minerals from different sources, but in general, organic sources (bones) are reportedly more bio-available than inorganic sources (Greene, 2000).

Forage samples used for mineral analysis were hand picked following field observations. Compared to hand clipped samples, animal selected samples have been shown to not only have higher mineral content (Mayland and Lesperance, 1977), but also more accurately depict the dietary profile of important minerals. Such samples reduce the chances of underestimating the mineral intake by grazing animals and subsequently, help in formulating and preparing a supplement that more closely meets the animal requirements. With hand clipped samples like those used in this study, mineral intake by animals is often underestimated. However, the method has been widely used in the past where fistulated animals are not available as was the case for this study, and also due to the fact that it is less costly.

The current study showed that the plasma concentrations of some minerals were consistently below or above the reported levels during the supplementation phase. This suggested that the reported means might be either too high or too low. Where commercial ingredients must be used in mineral supplement formulation, preference should be given to sulphate salts, which are reported to be more bio-available (McDowell, 1999), while avoiding oxides. In this study, iron and zinc oxides were used due to lack of alternatives in the market. The commercial supplement was formulated on the basis of estimated live weight of camels, dry matter intake and mineral content of forage species. Thus, it may not have met the requirements of camels. This uncertainty coupled with potentially higher bioavailability of minerals from bones (Ca, P, and Mg) in the locally formulated supplement may partly explain the similarity of responses exhibited by camels on the two supplements.

Animal bodies have a significant storage capability for most of the important mineral elements (Adams *et al.*, 1978). Most of the minerals are also tightly regulated in the body through a variety of homeostatic processes (Van Saun, 2000). Blood concentration of minerals is, thus, not wholly reflective of the dietary status unless the body endogenous reserves are substantially depleted (Miller, 1975) or the homeostatic system is not functioning properly. However, examination of body fluids and tissues including blood has been reported to accurately portray the contribution of all sources of minerals (feeds, water, soils, commercial supplements) to the mineral requirements of grazing animals (McDowell, 1985). Analysis of liver and bone samples may have given a better indication of animal mineral status particularly for minerals elements that are stored in the body (Faye and Bengoumi, 1997; Miller, 1975), but were not done as no camels were slaughtered during the study period. Additionally, for minerals whose homeostasis is achieved by renal excretion of the excesses, such as magnesium, blood concentrations are good indicators of the nutritional status, since the excess must pass through the blood to the kidney (Herdt *et al.*, 2000). Minerals that are mobilized from storage organs and structures also pass through the blood to the intended points of use (Faye and Bengoumi, 1997). Blood mineral analyses, therefore, give reasonable estimates of the body mineral status.

Effect of environment/time on blood mineral concentrations

Seasonal variations in mineral concentrations were exhibited in blood mineral profiles of control camels. At both sites (Kargi and Ngurunit), the plasma levels of P, Na, K and Zn were higher during phase II (Chapter 6) than phase I (Chapter 5), i.e. 7.3±2.9mg% versus 4.9±1.0 mg%; 623.8±205.1 mg% versus 339.3±42.4 mg%; 63.8±36.0 mg% versus 20.6±4.1 mg%; 2.1±1.0 versus 0.5±0.2, respectively. Phase II of the study coincided with the wet season. The feed available then was of a higher quality with lower crude fibre content. thus higher bioavailability of mineral elements and higher levels of P, Na, K and Zn (Blezinger, 2000; Kuria *et al.*, 2004b). This suggests that the blood concentrations of these elements among others are sensitive to dietary intake. In contrast, Adams *et al.* (1978) reported that the body homeostatic mechanism tightly regulates blood levels of some macro-elements including Ca and Cl and that these may not change with dietary levels. Such differences highlight the practical difficulties of assessing the mineral status of grazing animals under different production environments.

Conclusions

1. Rendille pastoralists knew the importance of mineral supplementation in camels and could describe the deficiency signs.
2. Forage species were the most important sources of minerals for grazing camels. Except for Cu and Zn, the common local forage species had the potential to meet the daily requirements of minerals by camels.
3. Compared with reported ranges of plasma mineral concentration in camels, elements such as Ca, Na, Fe, Zn and Cu were likely to be deficient among Rendille camels especially during the wet season.
4. Apart from trekking camels to areas with naturally occurring mineral sources for supplementation, Rendille pastoralists could prepare mineral supplements for their camels using locally available materials.
5. Mineral supplementation increased milk yield, calf growth rate and the plasma concentration of some mineral elements confirming existence of mineral deficiency among the Rendille camels.

Areas of further research

a. In order to benefit more camel keepers, this research work need to be extended to other communities keeping camels in Marsabit and the wider northern Kenya by way of promoting strategic mineral supplementation.
b. While conducting this study, as is common with most on-farm studies, it proved difficult to effectively control factors such as time of calf and dam

separation, milking intensity, milking skills, variations in breed, parity, lactation stage, number of camels per treatment among others. For scientific reasons, there is need to refine the results on, "effect of mineral supplementation on milk yield and calf growth", obtained in this study through a small-scale, on-station experiment. Local pastoralists, however, do not require the refined results for purposes of adopting this technology since they would operate under constraints faced during this study

c. As an incentive for commercial camel producers and pastoralists to adopt this mineral supplementation technology, accurate information on the expected margins should be made available. Considering the simplistic nature of the economic analysis conducted in this study, a more detailed economic evaluation of the technology is recommended.

d. It is necessary to test the efficacy of traditional mineral supplementation strategy that involved utilization of natural mineral sources. This would be done by monitoring the performance of a camel herd regularly visiting those sources. Performance indicators may include milk yield, calf growth, body mineral status and body condition score. While conducting this study, tissue biopsy especially liver and bones should be considered as they give a more accurate body mineral profile than the blood.

e. Froth on milk was reported by pastoralists as one of the traditional indicators of mineral status in camels. It would be interesting to establish the correlation between froth and mineral content of milk.

f. The preliminary analyses of water perceived as important for camels indicated that these could supply substantial amounts of minerals to grazing camels if regularly utilized. However, a comprehensive water chemistry analysis is required including that of recognized water quality constituents such as: total dissolved solids, electrical conductivity, pH, fluorine, nitrates, chlorine, sulphates, arsenic, cadmium, manganese, selenium, and mercury. These elements are recognized as having a high incidence of occurrence in the aquatic and subterranean environment and impacting on animal health. While carrying out such a study, seasonal changes in water quality need to be considered. Data on daily water intake of camels, corrected for body weight should also be collected in order to estimate the contribution of water to the daily mineral requirements of camels. Representative soil samples should be taken and analysed alongside water. Additionally, Inductively Coupled Argon Plasma Optical Emission Spectrometer (ICP/ICAP-OES) other than AAS should be used for mineral analysis. The AAS as was used in this study may not be adequately sensitive to detect trace concentrations of microelements.

g. The role of interactions in rendering mineral in forage species unavailable to camels was not considered in this study. Future related studies should consider elements with antagonistic relationship to other minerals like Mo, Se and S when evaluating mineral status of forages.

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Appendix

Survey Questionnaire

Date ______________ Enumerators name ______________________

Name of interviewee______________________Gender ______________

Location ____________ Manyatta ___________ Sampling season _______

1. Are you aware that there are different kinds of salt?

Yes

No

2. If the answer to 1) is yes, elaborate

____

____

3. Are you aware that camels require mineral salts?

Yes

No

4. If the answer to 3) above is yes, why do you think salt is necessary in camels?

____

____

____

5. How do your home-based camels get mineral salts?

Salty water

Salty plants

Salty soils

Commercial salts (specify) ____________

All

Any other (specify) ____________

6. How do you decide on the kind of 'salt' to give your camels?

Availability

Distance from 'home'

Cost

Any other (specify) ____________

7. If the answer to 5) is salty water, where is the water found?

Shallow well

Borehole

Korole

Others (specify) ____________

8. How far is the source from 'home'? (Km) ____________

9. How often do you take your home-based camels to the salty water source?

____

10. While at the salty water source, how do the camels drink water?

Self-watering

Watered from a trough/basin

11. If the answer to 10) above is self-watering, how long (hours) do the camels take at the well drinking water?

____

12. If the answer to 10) is watered from a trough, can you estimate the amount of water each camel drinks (number of basins of known volume)?

____

13. If the answer to 5) above is salty plants, can you name (vernacular) the plants?

Hadum (*Salsola dendroides*)

Geigiri

Maha

Arabharis

Hayai (*Salvadora persica*)

Gurangur

Khadu (*Cadaba ruspalii*)

Surus

Ndume

Others (specify)

14. Where are the salty plants located? (Km from 'home'/manyatta)

____

15. Out of the list of salty plants, which ones do you specifically feed your camels on?

____

____

16. Why do you feed your camels on the above specific salty plants and not the others?

Nearer to the *manyatta* than others

Are the best (elaborate)

Are more abundant

Any other reason (specify)

17. If the answer to 5) above is commercial salts, where do you get it from?

____

____

18. Which commercial salt(s) do you in particular use?

Chalbi salt

Magadi

Sodium chloride from the shops (also used by human)

Others (specify)

19. How do you decide on the type of commercial salt to use?

Price

Availability

Recommendation of extension officer (s)

Camels respond better (how?)

Any other (specify)

20. What quantity of commercial salt do you give to each camel? (handful, spoonful etc)

____

21. How frequently do you supplement the camels with the commercial salt?

____

22. How do you present the commercial salt to the camels?

Mix with water

Licking

Other methods (specify)

23. Are there naturally occurring salty soils where the camels are taken to lick?

Yes

No

24. If answer to 23) above is yes, where are the soils located? (Km from *manyatta*)

____

____

25. How often do you take your camels to the salty soils to get the supplement?

____

____

26. If the answer to 25) is regularly, why?

____

____

____

27. If the answer to 25) above is less regularly, why?

____

____

____

____

28. To what extent would you go to ensure that the camels get salts? (trek the camels far, sell a goat to buy magadi/Chalbi salt etc)

____

____

____

29. What symptoms if any do you associate with salt deficiency?

____

____

____

____

30. Do the above symptoms show in all the home camels or just a few?

____

31. Do the symptoms disappear after you give the salts?

Yes

No

32. Based on your experience, is there one type of salt (water, plants etc) that make all the symptoms disappear?

____

33. After you feed the salt supplements to camels, after how long (days, weeks or months) do the different symptoms disappear?

____

____

34. If you compare your *fora* with home-based camels, which ones do you think require more mineral supplementation?

Fora

Home-based

Same

35. If the answer to 34) is *fora,* why?; if home-based, also say why

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____

____

36. Which are the most preferred plant species by camels within the grazing area? (differentiate between wet and dry seasons)

____

____

____

____

37. How many types of Korolle water do you know?

38. Name the various types of Korolle water

39. Rank the water types in order of importance with respect to the camels