MINERAL NUTRITION OF GRAZING SHEEP IN NORTHERN CHINA
I. MACRO-MINERALS IN PASTURE, FEED SUPPLEMENTS AND SHEEP

D. G. Masters[1], D. B. Purser, S. X. Yu[2], Z. S. Wang[2], R. Z. Yang[3], N. Liu[3], D. X. Lu[4], L. H. Wu[4], J. K. Ren[5] and G. H. Li[5]

CSIRO Division of Animal Production, Private Bag
P. O. Wembley, W. A. 6014, Australia

Summary

This study determined the macro-mineral levels in plants and sheep, at different times during the year, at three farms in northern China. Samples of plants, animal tissues and faeces were collected at 5 to 8 times during the year from each site. They were analysed for calcium, sodium, phosphorus, magnesium and potassium. Sodium concentrations in plants were below those recommended for optimum animal production at all sites for all or part of the year (0.01-1.66 g/kg DM). Low concentrations of sodium in faeces were measured and signs of sodium deficiency (soil ingestion) were observed on one farm. There were seasonal trends in other mineral levels in plants and animals. Plants were lowest in potassium (2.3-12.4 g/kg DM), magnesium (1.28-4.82 g/kg DM) and phosphorus (0.24-1.62 g/kg DM) in winter and spring. However, high levels of these elements were supplied in the feed supplements used at this time of the year. During the periods of rapid pasture growth, in summer and autumn, supplements of feed and salt are often not provided even though pasture concentrations of phosphorus and sodium are low. It may be at these times that sheep will be most susceptible to deficiencies of these elements.

(Key Words: China, Sheep, Minerals, Sodium, Phosphorus, Potassium, Magnesium, Calcium)

Introduction

The macro-elements sodium, potassium, calcium, phosphorus, chlorine, magnesium and sulphur are all essential for animals (Underwood, 1981). In many parts of the world, disorders in livestock production are due to naturally occurring deficiencies of one or more of these essential elements in forages or feedstuffs.

Phosphorus deficiency is most widespread and is often associated with low soil phosphorus together with a dry seasonal period. The classic studies in the south African veldt country linked low phosphorus intakes with poor growth and fertility in cattle (Underwood, 1981). Calcium deficiency is less likely in grazing ruminants because herbage species contain more calcium than phosphorus in leaves and stem and because calcium deficient soils are less common. However, deficiencies causing poor growth, bone abnormalities and depressed milk production may occur when ruminants are fed diets with a high grain content (Underwood, 1981) or in high producing dairy cows. Deficiencies of potassium and chlorine in grazing ruminants have not been demonstrated unequivocally. By contrast sodium deficiency occurs in many parts of the world, particularly in the tropics and sub-tropics (McDowell et al., 1984; Standing Committee on Agriculture (SCA), 1990). Both rainfall and distance from the sea appear to contribute to the incidence of sodium deficiency.

Magnesium deficiency manifests itself in an acute form known as lactation or grass tetany. This is associated with rapid pasture growth, often

[1]Address reprint requests to Dr. D. G. Masters CSIRO Division of Animal Production, Private Bag P. O. Wembley, W. A. 6014, Australia.

[2]Institute of Animal Science, Chinese Academy of Agricultural Science, Malianwa, Haidianqi, Beijing People's Republic of China.

[3]Xinjiang Institute of Animal Science, Xinjiang Academy of Animal Science, Yiu Hou Rd, Urumqi Xinjiang Uygur Autonomous Region, People's Republic of China.

[4]Inner Mongolia Academy of Animal Husbandry Sciences, The Western Suburbs of Hohhot City, Inner Mongolia Autonomous Region, People's Republic of China.

[5]Chifeng Institute of Animal Science, Chifeng City Inner Mongolia Autonomous Region, People's Republic of China.

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at the time of late pregnancy or lactation. Sulphur is predominantly associated with the essential amino acids methionine and cysteine and a lack of sulphur may cause depressed roughage digestibility in the rumen and reduced nitrogen retention (Bird, 1972; Weston et al., 1988).

Northern China contains vast areas of grasslands in both arid and alpine environments. These are used for grazing animals and support 25-30 million fine wool sheep (McGuirk et al., 1988) as well as goats, horses, yaks and cattle. In most areas, little fertiliser is used to promote pasture production. Feed supplements are often inadequate to maintain live weight of sheep and are usually locally produced (Masters et al., 1990). Under such conditions, grazing animals may be particularly susceptible to mineral deficiencies. The aim of this study was to determine the macro-mineral levels in plants and sheep at different seasonal times at three farms. The farms, Huang Cheng (Gansu Province), Nanshan (Xinjiang Uygur Autonomous Region) and Aohan (Inner Mongolian Autonomous Region) represent major fine-wool sheep growing areas in China.

Materials and Methods

Locations, Environment and Management

The location and a brief description of the farms are shown in table 1; specific details of locations, sheep type, management and production, including amounts of supplementary feeding, are given by Masters et al. (1990). At Huang Cheng and Nanshan, sheep are managed in the traditional, semi-nomadic system. Flocks are accompanied at all times by herdsmen. The sheep graze at the highest elevations in summer and on the lower slopes or desert pastures in the other seasons. In autumn, they may graze improved pastures and, during winter, are housed for most of the time, but are still taken out for grazing each day. At Aohan farm, sheep are also accompanied by a herdsman, but remain in the same area for at least nine months each year. In summer the sheep may be moved to other pastures.

On all farms, ewes are pregnant and lactating in winter or spring. At this critical period, only small amounts of low quality forage are available for grazing. Ewes and lambs are fed supplements of silage, hay or grain-based concentrates during this period. Summer and autumn are times of rapid pasture growth as rain falls almost exclusively during these warm seasons.

Sheep

A representative group of approximately 140 ewes were studied for 12 months on each site. These ewes at Huang Cheng and Nanshan farms were 2.5 to 3.5 years old and most had their second lamb during the experimental period. At Aohan farm, half the ewes were aged 2.5 years and half 1.5 years. The younger ewes had their first lamb during the experimental period. The mating, feeding and grazing management of these sheep were in accordance with the normal procedure on the farms (Masters et al., 1990).

Collections, analyses and recordings

Samples of blood and faeces were collected from 30 ewes six to eight times per year. Five or six ewes were slaughtered and samples of liver, muscle (semitendinosis), kidney, bone (femur), lung and heart were collected five or six times. Pasture, collected five to eight times, was plucked at 100 to 200 metre intervals on a diagonal across the grazing area. The samples were bulked for final analysis. Collections of samples coincided with different seasonal conditions and physiological states of the sheep. Samples of feed supp-

TABLE 1. LOCATION AND ENVIRONMENT OF FARMS

Farm	Huang cheng	Nanshan	Aohan
Province or autonomous region	Gansu	Xinjiang	Inner Mongolia
Terrain	Qilian mountains	Tianshan mountains	East Mongolian grasslands
Elevation (m)	2400 to 3500	900 to 2600	500 to 520
Temperature (℃)	−29 to +32	−31 to +31	−29 to +37
Rainfall (mm)	375	300 to 600	200 to 350

lements were collected at the times they were being used.

Tissue and blood samples were wet digested in a mixture of nitric and perchloric acids (8 ml : 0.6 ml). Pasture and faeces were oven-dried at 70℃, ground and similarly wet digested. All samples were then analysed for calcium, phosphorus, magnesium, sodium and potassium using an Inductively Coupled Argon Plasma Analyser (ICAP 9000 Jarrell-Ash Division, Fisher Scientific Co.). Bovine liver (NBS Standard Reference Material 1577a) was included in the analysis as a standard references.

Comparisons between farms and seasons were made using analysis of variance. When the interaction between farms and seasons was significant, the interaction error value was used to test the effects of farm and season separately.

Results and Discussion

Sodium, Potassium and Magnesium

Sodium concentrations in pasture were below the levels recommended for optimal animal production at all sites for all or part of the year (SCA 1990). Morris and Peterson (1975) suggested that a sodium intake of 0.87 g/kg was required to maintain an adequate Na : K ratio in the parotid saliva of pregnant ewes. Vincent et al. (1986) reported that milk production and lamb growth were unaffected by intakes of sodium as low as 0.1 g/kg, however, at the lowest sodium intakes, the ewes were in negative sodium balance. Only in autumn, at Nanshan, did pastures reach the levels indicated by Morris and Peterson (1975), and for much of the year at Huang Cheng and Aohan, concentrations were below 0.1 g/kg (table 2). Deficiency of sodium is a recognised problem in northern China and salt supplements are usually provided to grazing sheep on State-owned farms. However, it is often difficult to transport such supplements to the mountainous summer pastures and sheep do not receive supplement regularly throughout the year. The concentrations of sodium in faeces at both Aohan and Huang Cheng (0.45-0.93 g/kg, table 2) were below those reported for sodium deficient cattle (1.4 g/kg, Murphy and Gartner, 1974). In winter, when sheep were housed and fed supplements containing higher sodium concentrations (table 4) and salt, faecal sodium was much higher (1.65-2.74 g/kg). There was a significant farm × season interaction effect on sodium in faeces ($p < 0.001$) and a significant difference between farms ($p < 0.05$). Although sodium in faeces is not the most reliable indicator of sodium intake, these data support the conclusions made from the pasture measurements.

Of the three farms, Huang Cheng appears to be most affected by low sodium intakes. There was a significant farm × season interaction ($p < 0.001$) and farm effect ($p < 0.001$) on sodium concentration in plasma. At Huang Cheng these concentrations were always below those at other farms and below the normal concentration of 3300 mg/L reported by Vincent et al. (1986) (table 2). The high faecal potassium concentrations at Huang Cheng (table 2) indicate that potassium, usually excreted in urine, may be replacing sodium in saliva. Widespread, habitual consumption of soil, a characteristic of sodium deficiency, was also observed at Huang Cheng.

Requirements of sheep for potassium in feed are estimated at 5 to 7 g/kg(NRC, 1985). During autumn and summer, pastures contained adequate potassium for sheep (6-22 g/kg table 2), with the highest concentrations on all farms in summer. Potassium concentrations fell as pastures matured at Huang Cheng and Nanshan, and the dead dry pastures of winter and spring contained the least. This is consistent with reported changes in potassium concentrations in plants in other environments (White et al., 1991). While potassium in pastures was below 5 g/kg at all sites in either winter or spring, the feed supplements used during these periods provided significant additional potassium (table 4) and a deficiency at any time of the year is unlikely. This is supported by the values for potassium in plasma. Although significant effects of farm × season and farms ($p < 0.001$) were observed, the concentrations (140- 214 mg/L) were normal compared with those reported by Telle et al. (1964) in deficient sheep (97-135 mg/L).

Magnesium concentrations in all pasture, hay, concentrate and silage samples are above the minimum levels needed for growth and reproduction (0.7-1.0 g/kg, Underwood, 1981). The acute form of magnesium deficiency often occurs in lactating ewes and causes a hypomagnesemic tetany. Clinical signs have been described when

TABLE 2. SODIUM, POTASSIUM AND MAGNESIUM IN PASTURE (g / kg DM), PLASMA (mg / L) AND FAECES (g / kg DM)

Time	Sodium								
	Pasture			Plasma			Faeces		
	HC[1]	NS[2]	AH[3]	HC	NS	AH	HC	NS	AH
Summer	0.09	0.38	0.02	2630	3810	3260	0.93	1.41	0.52
Autumn	0.06	1.66	0.04	2570	3990	3170	0.45	3.19	0.84
Winter	0.20	0.23	0.01	2910	4100	3330	1.65	2.74	1.72
Spring	0.21	0.76	0.01	2520	4160	3380	0.55	3.02	2.16
SE[4]				(26 - 46 - 56)			(0.11 - 0.16 - 0.21)		

Time	Potassium								
	Pasture			Plasma			Faeces		
	HC	NS	AH	HC	NS	AH	HC	NS	AH
Summer	14.9	21.9	15.5	154	202	192	17.4	15.3	5.2
Autumn	8.1	11.6	5.6	159	214	194	12.1	5.9	4.1
Winter	5.1	4.2	12.4	175	211	193	8.1	5.0	3.9
Spring	2.3	11.8	3.2	140	189	195	8.6	9.0	4.0
SE				(1.8 - 3.2 - 3.9)			(0.3 - 0.5 - 0.6)		

Time	Magnesium								
	Pasture			Plasma			Faeces		
	HC	NS	AH	HC	NS	AH	HC	NS	AH
Summer	1.74	2.82	2.63	21.1	20.3	23.1	5.03	6.92	7.01
Autumn	1.80	3.38	1.93	22.2	25.3	22.7	3.34	6.73	5.30
Winter	1.28	2.58	4.82	22.9	22.0	27.0	2.97	3.04	5.20
Spring	1.38	1.63	1.55	16.3	19.9	23.3	4.16	3.99	5.42
SE				(0.3 - 0.5 - 0.6)			(0.09 - 0.13 - 0.16)		

[1] Huang Cheng farm.
[2] Nanshan farm.
[3] Aohan farm.
[4] Standard error of individual means shown as (minimum - mode - maximum).

plasma magnesium falls from the normal of 20 -30 mg/L down to less than 10 mg/L (Suttle and Field, 1969; Grace, 1972). In all seasons, at all farms, magnesium in plasma was above 15 mg/L. However, while no evidence of hypomagnesemia was found, susceptibility is increased when sodium intakes are low and potassium intakes high (SCA, 1990), as occurs in northern China. This, together with the observation of lowest concentrations of magnesium in plasma in spring (during lactation) on both Huang Cheng and Nanshan farms, indicates that the occurrence of hypomagnesemia under such conditions is possible.

Phosphorus and Calcium

It is estimated that 1.5 to 1.7 g P/kg are required by young growing sheep (Underwood, 1981). Slightly higher levels may be needed during pregnancy and lactation. While summer pastures at all sites contained sufficient phosphorus for growth, the concentrations in winter and spring were usually below 0.5 g/kg (table 3). Phosphorus concentrations fall in plants as they mature and the lowest levels are in the dead dry plants such as occurs in northern China in winter and spring. The lowest concentrations measured would restrict animal growth if pastures were the only source of phosphorus and if no other nutrients were limiting. However, as with potassium, the su-

TABLE 3. CALCIUM AND PHOSPHORUS IN PASTURE (g/kg DM), BONE (g/kg DM) AND FAECES (g/kg DM)

Time	Calcium								
	Pasture			Bone			Faeces		
	HC[1]	NS[2]	AH[3]	HC	NS	AH	HC	NS	AH
Summer	6.5	11.7	22.3	273	215	237	19.1	30.1	38.6
Autumn	8.0	13.9	18.8	268	244	246	16.8	37.3	32.7
Winter	5.0	10.2	12.7	277	226	247	8.8	15.6	22.2
Spring	4.4	7.2	14.8	275	240	248	10.8	15.3	17.1
SE[4]					(5.1 - 7.2 - 7.9)			(0.5 - 0.7 - 0.9)	

Time	Phosphorus								
	Pasture			Bone			Faeces		
	HC	NS	AH	HC	NS	AH	HC	NS	AH
Summer	1.55	2.12	1.57	121	99	85	5.29	3.49	1.68
Autumn	0.78	1.08	0.31	109	102	87	2.70	2.69	2.41
Winter	0.29	0.39	1.56	117	101	90	2.12	1.99	3.07
Spring	0.24	1.62	0.38	121	99	86	2.80	3.00	2.48
SE					(1.9 - 2.7 - 2.9)			(0.11 - 0.16 - 0.20)	

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[2] Nanshan farm.
[3] Aohan farm.
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pplements of concentrates, hay and silage, fed during winter and spring provide substantial amounts of phosphorus. More significant are the low or marginal levels observed in autumn (0.31-1.08 g/kg). Early autumn is a period of rapid animal growth as pasture is in excess and no additional feed is provided. During this period a lack of phosphorus may restrict growth.

No clear evidence of a lack of phosphorus was indicated by analysis of faeces or bone at any farm (table 3). There was a significant farm × season interaction on both ($p < 0.001$) and a significant difference in bone concentrations between farms ($p < 0.001$). At Aohan farm, the concentration of phosphorus in bone was similar to that reported in the humerus and femur of phosphorus deficient sheep (Underwood, 1981).

The calcium content of pasture was above the requirement for growing (2.0-5.3 g/kg) or reproducing (3.2-3.9 g/kg, NRC, 1985) ewes at all times and at all sites. Although some concentrated feed supplements contained less than 2.0 g/kg, the composite diet including pasture, hay or silage and concentrates would have provided sufficient calcium. The high calcium in feeds was reflected in the high concentrations in faeces (table 3).

In conclusion, there are differences between farms and also clear seasonal changes in minerals available in pastures at all farms. The farm differences are probably due to differences in soil types, rainfall and pasture species. Seasonal changes would be related to rainfall and growth and maturity of pasture. As the rain falls almost exclusively in the warm seasons of summer and autumn, rapid pasture growth occurs at this time. In late autumn, the annual native pastures die and only dead residues are available for grazing in winter and spring. As a consequence, potassium, magnesium and phosphorus are lowest in winter and early spring. However, pasture at this time is also low in nitrogen (< 1.0% nitrogen), has a low digestibility (38-40%, D.W. Peter, personal communication 1990) and contains little sodium. The lack of protein, energy or sodium is likely to be the primary limitation for production. Salt fed in winter and spring will provide sufficient sodium and, provision of hay, silage or grain based supplements will partially offset the lack of protein and energy. Of these supplements, concentrates contain high levels of phosphorus and both hay and silage contain high levels of potassium (table 4). Severe deficiency of these elements during winter or spring is not likely.

Summer and autumn may be the seasons when sheep are at most risk of a macro-mineral deficiency. Although pasture is plentiful and both protein and digestible energy are higher than at other times of the year, sodium, in both summer and autumn, and phosphorus in autumn are below published requirements. A lack of sodium at this time would cause reduced growth and wool production (Joyce and Brunswick, 1975), and inadequate phosphorus would result in depressed intake growth, bone development and reproduction (Underwood, 1981).

TABLE 4. CONCENTRATION OF MINERALS IN FEED SUPPLEMENTS (g / kg DM)

	Concentrates			Hay			Silage		
	HC[1]	NS[2]	AH[3]	HC	NS	AH	HC	NS	AH
Sodium	0.06	3.56	0.03	0.17	3.21	–	1.31	–	0.46
Potassium	4.23	6.96	4.59	10.1	18.5	–	12.6	–	13.8
Magnesium	1.27	2.55	1.89	0.90	1.93	–	1.57	–	3.12
Phosphorus	2.82	7.01	3.68	0.97	3.32	–	1.48	–	1.21
Calcium	0.68	5.19	0.72	1.45	7.70	–	3.13	–	4.97

[1] Huang Cheng farm.
[2] Nanshan farm.
[3] Aohan farm.

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