Mineral Problems in Sheep in Northern China and Other Regions of Asia

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Editors: D.G. Masters, Yu Shunxiang, Lu De-Xun and C.L. White

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Foreword

China has vast areas of arid and semi-arid pastoral land in its northern provinces. The economy of the region depends heavily on sheep grown for meat and wool. Poor mineral nutrition is a significant factor in limiting production, and over the past 10 years ACIAR and the Chinese Ministry of Agriculture have funded research to determine to what extent mineral nutrient problems constrain production and to develop practical ways to supply supplements. The research has involved the CSIRO Division of Animal Production in Perth, Western Australia, the Beijing Institute of Animal Science, the Inner Mongolia and Xinjiang Academies of Animal Science, the Lanzhou Institute of Traditional Chinese Veterinary Medicine and the Chifeng Institute of Animal and Veterinary Science.

This publication describes the major findings of that project research, focusing on the mineral deficiencies encountered and identified as constraints, especially to fine-wool growing in areas of northwest China. The authors recommend solutions to overcome the constraints and increase the efficiency of utilisation of natural pastures. Background information also provides a basis for further research on mineral nutrition in the region and on the development, evaluation and use of supplements for improving wool and meat production from grazing sheep.

The publication is one of two resulting from an international workshop on mineral nutrition of grazing sheep held in Beijing in September 1995. The companion volume is published as ACIAR Monograph No. 37, titled 'Detection and Treatment of Mineral Nutrition Problems in Grazing Sheep'. It is hoped that together these publications provide valuable assistance to researchers, extension practitioners and farmers in Asia and elsewhere.

J.W. Copland
Research Program Coordinator, Animal Sciences
ACIAR

Nutritional Problems in the Sheep Industry in China

Lu De-Xun[1]

Abstract

Sheep production in northern China varies between regions and seasons, with similar patterns in all regions. The nutritional problems mainly arise from both predictable and unpredictable seasonal deficits in the amount and quality of forage available. Predictable deficiencies occur during the winter–spring seasons in northern China. Unpredictable deficiencies result from natural calamities, such as drought and heavy snow. These problems prevent high production from sheep.

SHEEP in China will continue to derive most of their nutrients by harvesting their own herbage. However, as sheep are forced into more difficult terrain, productivity is likely to be increasingly improved by a sound supplementation strategy. There is considerable opportunity for overcoming the nutritional limitations through new supplementation strategies that stimulate the intake of poorer quality forage and/or increase the rate and level of rumen digestion.

According to some archaeological studies, sheep domestication in China dates back to 6000 BC. Before the founding of new China the development of the sheep industry was very slow, but since 1949 the sheep industry has developed dramatically. Sheep numbers in China increased more than four-fold between 1949 and 1994, and China now has the second largest sheep flock in the world after Australia. In 1949 there were almost no sheep in China producing fine-wool. By the end of 1992, the population of fine-wool sheep and its crosses had increased to 29.1 million, about 26% of the total population. There were 16.6 million semi-fine wool sheep, about 15% of the population. A group of new fine and semi-fine wool sheep breeds has been developed. The annual production of greasy wool in China has increased from 33 000 t in 1949 to 255 000 t in 1994, containing 67% fine and semi-fine wool. The average greasy wool production per sheep in 1988 was 2.2 kg compared with 1.2 kg in 1972, while the average fine and semi-fine wool production in 1988 reached 3.9 kg and 3.2 kg per head respectively.

The sheep industry in China is distributed between three zones, i.e. pastoral, cropping and mixed cropping–pastoral zones. The major regions for sheep are Inner Mongolia, Xinjiang, Tibet, Qinghai Plateau and some parts of Gansu Province. The area of grassland in these regions is about 240 million ha. This represents 84% of the total area of grassland in China. The cold, arid environment is harsh by any standards. The pasture production is severely limited and the sheep, accounting for 65% of the total sheep population in China, depend on pasture for most of their nutrient supply. Green feed is usually available for only five months (approximately mid May to mid October) and dry pasture residues and low quality hays are the main sources of fodder for the remaining seven months of each year.

A comparison between the sheep industries of China and Australia in 1993 is presented in Table 1. The differences in figures for raw wool production between China and Australia suggest that there is substantial potential for increased productivity in the Chinese sheep industry. While around 140 million sheep in Australia produce more than 700 000 t of greasy wool per year, China's 110 million sheep produce just 240 000 t. As well, the clean wool yield following scouring is just 40–45% in China, compared with nearly 65% in Australia.

Further substantial increases in sheep productivity and in wool quality in China through improvement of management and feeding systems can only be achieved when there is a clear understanding of the nutritional problems. The objective of this paper is to describe those problems, based on studies carried out recently by Chinese and Australian scientists from

[1] Inner Mongolian Academy of Animal Sciences, Huhehot, Inner Mongolia, 010030 People's Republic of China

ACIAR projects 8454 'Mineral nutrition studies of small ruminants in northwestern and northeastern China', 8555 'The effects of helminths and nutrition on sheep production in northern China' and 8911 'Identification of mineral elements limiting sheep production in northern China', as well as by other Chinese scientists.

Table 1. Comparative statistics on sheep population and production in China and Australia in 1993.

	China	Australia
Total population (million)	109.7	138.1
Greasy wool (thousand t)	240	717
(kg/head)	2.19	5.19
Mutton production (thousand t)	1436	748
Carcass wts (kg/head)	11.0	20.0
Slaughtering rate (%)	57.0	23.9

Source: FAO (1993).

Seasonal Fluctuation of Nutrient Supply

Seasonal patterns in chemical composition and digestibilities of pastures are well recognised (Wang et al. 1992a, Yang pers. comm). The protein content of pasture declines with increasing maturity, while the contents of neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin increase. In consequence, their nutrient digestibilities and digestible energy (DE) as well as metabolisable energy (ME) concentrations drop markedly (Table 2).

It is clear that sheep in the major regions of China must be able to survive and produce with a 7-month period of low quality forages between October and May. This period of low feed availability encompasses pregnancy and lactation for ewes and a period of potential rapid growth in the lambs. The poor coordination of nutrient demand and forage supply in the pastoral regions is the cause of low production of meat and wool. Nutrient supply may be limited by low feed availability or low forage quality, by the level and the characteristics of the forage fibre, the presence of deleterious substances, or a lack of essential nutrients.

In ewes the amount of nutrients required to satisfy the energy need is highest during lactation. With a high fibre diet, the feed requirement of the non-lactating ewe, or of the pregnant ewe prior to the 90th day of gestation, is about 54 g/kg liveweight$^{0.75}$ and this increases through 75 g/kg liveweight$^{0.75}$ at the 125th day to about 92 g/kg liveweight$^{0.75}$ at the end of pregnancy. However, during the peak of lactation about 126 g feed/kg liveweight$^{0.75}$ is needed (Weston and Hogan 1986). Compared with the data in Table 3, it was found that the achieved dry matter (DM) intake of the ewes kept in the Inner Mongolian pastoral area is only sufficient for maintenance of bodyweight in non-pregnant ewes from May to August. The forage available in December and February is grossly inadequate to meet the energy demands of late pregnancy and lactation. The ewes with twin foetuses would be in a desperate nutritional situation if such low quality forage was the sole feed in late pregnancy. During lactation tissue stores would be heavily drawn on to sustain milk production. The resulting under-nutrition would be accompanied by a substantial loss of the ewe's bodyweight and poor body condition of the ewes, as well as by reduced birthweight and decreased survival of offspring. Even with supplementary feeding, intake is still insufficient to prevent weight loss in late pregnancy and lactation.

Protein under-nutrition of the ewes, caused by seasonal deficits in protein supply from pasture, is another nutritional problem in China. According to Wang et al. (1992b) an adult sheep weighing 50 kg and producing 1.2 kg milk daily should have a digestible crude protein (DCP) requirement of 186 g/day. This is well above the amount available from pasture during early lactation between February and May (Table 3). During late pregnancy DCP requirement of the ewe with one foetus is 80 g/day and the value increases to 100 g/day with twin foetuses, which again is above the amount available during pregnancy in December and February (Table 3).

Table 2. Seasonal changes of nutrient contents in natural pasture.

Chemical composition (% dry matter (DM))	May	August	December	February
Crude protein (CP)	17.6 ± 1.9	13.7 ± 0.1	5.3 ± 1.1	5.0 ± 0.6
Neutral detergent fibre (NDF)	50.4 ± 4.5	49.2 ± 1.1	64.6 ± 5.1	68.1 ± 4.7
Lignin	4.8 ± 3.62	6.1 ± 0.83	11.8 ± 0.70	7.6 ± 1.5
NSC*	12.5	21.0	13.5	15.4
DM digestibility (%)	64.7 ± 14.7	43.2 ± 2.6	37.5 ± 1.9	45.4 ± 1.0
ME concentration (MJ/kg)	10.3 ± 1.74	7.9 ± 0.08	5.5 ± 0.28	6.5 ± 0.25

*Calculated by difference i.e. NSC (non-structural carbohydrate) = DM−(NDF+CP+EE+ash); EE = ether extract; ME = metabolisable energy.
Source: Wang et al. (1992a).

Table 3. Dry matter (DM) and digestible crude protein (DCP) intakes of ewes grazed in the Inner Mongolian pastoral area. Ewes are mated September–October and lamb February–March.

	May	August	December	February
DM intake (g/kg liveweight$^{0.75}$/day)				
From pasture	56	75	37	22
From supplement	62	0	31	68
Total	118	75	68	90
DCP intake (g/day)				
From pasture	99	71	17	12
From supplement	106	0	18	106
Total	205	71	35	118

Source: Wang et al. (1992a).

Table 4. Energy and protein supplies relative to needs of Tibetan ewes grazing on alpine meadow in the west of Qinghai province.

	Early pregnancy (August)	Mid pregnancy (Sept.–Oct.)	Late pregnancy (Nov.–Dec.)	Lactation (Jan.–April)
Energy (%)	+34.3	−16.0	−29.6	−46.2
Protein (%)	+31.7	−26.1	−67.4	−70.2

Source: Zhao et al. (1991a,b).

Table 4 shows that there are considerable deficits in energy and protein supplies to grazing ewes, especially in winter and spring. Zhao et al. (1991a,b) indicated that the malnutrition suffered by breeding ewes was mainly caused by poor nutrient utilisation in most seasons throughout the year (Tables 5 and 6).

Table 5. Efficiency of utilisation (%) of dietary energy in grazing ewes in different phenological periods of pasture measured in the alpine regions in the west of Qinghai province.

	Phenological periods			
	Withered (April)	Green up (June)	Flourishing (Aug)	Withering (Dec)
DE/GE	48.1	78.6	66.3	56.8
ME/DE	80.2	81.2	77.4	75.6
NE/ME	<0	29.6	26.8	<0
NE/GE	<0	18.6	13.8	<0

Source: Zhao et al. (1991a).
GE = gross energy
DE = digestible energy
NE = net energy
ME = metabolisable energy

In Table 5, the quite low efficiency of utilisation of dietary energy in grazing ewes is attributed to significant losses of energy in faeces, urine and gases (methane and hydrogen) and as heat (Table 7).

Similarly, the main avenue for the dietary protein loss is through faeces and urine (Table 8). The cell wall constituents in pasture are the major dietary components influencing the digestion of proteins in April, and accordingly increase the protein loss in faeces.

Malnutrition Arising from Overgrazed, Degraded Grassland

China has 420 million ha of grassland covering 42% of the total land area, and 290 million ha are available as pasture. The natural pasture areas are classified as meadow, steppe, desert steppe and desert. Estimates of pasture production and utilisation in China are presented in Table 9.

It was found (IMAGRD 1988) that 64% of the grassland was heavily stocked, and the stocking rates were up to 120–140% of the acceptable level. In the Inner Mongolia Autonomous Region the grassland in 86% of counties or banners was overgrazed (Table 10).

Table 6. Efficiency of utilisation (%) of dietary proteins in grazing ewes in different phenological periods of pasture measured in the alpine regions in the west of Qinghai province.

	Phenological periods			
	Withered (April)	Green up (June)	Flourishing (Aug.)	Withering (Dec.)
Crude protein (CP) digestibility	19.1	75.4	66.8	24.1
CP deposited/digestible CP	<0	50.5	54.3	<0
CP deposited/CP intake	<0	38.1	36.1	<0

Source: Zhao et al. (1991b).

Table 7. Avenues of loss of dietary energy (% of estimated daily intake) in the grazing ewes measured in the alpine regions in the west of Qinghai province.

Avenue	Phenological periods			
	Withered (April)	Green up (June)	Flourishing (Aug.)	Withering (Dec.)
Energy loss in faeces	52.0	21.4	33.7	43.2
Energy loss in urine	5.99	6.33	9.02	9.58
Energy loss in methane	3.54	8.46	5.96	6.00
Energy loss as heat	73.7	45.0	37.5	46.8
Total energy loss	135.2	81.2	86.2	105.6

Source: Calculated from data of Zhao et al. (1991a).

Table 8. Avenues of loss of dietary proteins (% of estimated daily intake) in the grazing ewes measured in the alpine regions in the west of Qinghai province.

Avenue	Phenological periods			
	Withered (April)	Green up (June)	Flourishing (Aug.)	Withering (Dec.)
Protein loss in faeces	80.9	24.5	33.5	73.4
Protein loss in urine	83.8	37.3	30.3	53.3
Total protein loss	164.6	62.0	63.9	126.7

Source: Data of Zhao et al. (1991b).

Table 9. Current pasture production and utilisation in China.

Type of grassland	Available area ('000 ha)	Area utilised (%)	Pasture production	
			kg/ha[b]	Total (million t)[c]
Natural pasture				
meadow	60000	—[a]	1650–2250	990–1350
steppe	108700	<100	450–825	734–1834
desert steppe	76000	<100	300–750	342–855
Pasture in mountain areas				
South China	44700	45	3750–5250	2513–3518
North China	16700	10	5250–7500	1313–1880
Artificial pasture	2400	—	7500–15000	270–540
Others	12540	—	1800–11250	27–360

Sources: NFIO and CFIA (1994).

[a] No information available. [b] Average dry matter per year. [c] Total annual dry matter production.

Stocking rate is the major determinant of efficient utilisation of pasture and sufficient nutrient intake of grazing sheep. The consequence of overgrazing is an increased competition for feed and a decrease in production per head. Under extreme conditions the animals can no longer derive sufficient feed from the pasture to survive and the system becomes non-viable. The nutritional deficiencies associated with an increased stocking rate would reduce the output of the breeding flock through impaired reproduction, high lamb mortalities and metabolic disorders in the female (Davies 1964, 1968), and it eventually results in lower performance of the grazing sheep in China.

Some results (Han et al. 1991) are available to show the effects of higher stocking rates on individual species of plants (Table 11). Table 11 shows that when stocking rates are high, overgrazing (continued overuse) occurs and good grazing species, such as sedges and grasses, decrease. At the same time the area becomes progressively occupied by some unpalatable forbs and this eventually results in degeneration of the grassland. At present, the degraded pasture areas in China have reached 87 million ha, occupying about one-third of the national available pasture areas. Pasture areas are steadily degenerating at an annual rate of 3%.

Mineral Disorders

Studies of mineral disorders indicate that deficiency and/or excess of some elements, such as phosphorus, sulfur, sodium, potassium, selenium, copper, zinc, iron and molybdenum, are important nutritional problems for grazing sheep in China. The severity of these problems changes with location and seasons. More detailed discussion can be found in the papers by Masters et al. and Yu in these proceedings.

Table 10. Current stocking rates of the grassland in Inner Mongolia.

Municipality or league	Available area (000' ha)	Stocking rate (sheep unit*/ha)		Counties or banners where grassland is overgrazed	
		Acceptable level	Current level	Number	%
Huhehot	149.3	3.06	5.00	3	100
Baotou	424.4	1.55	2.28	3	100
Wuhai	125.1	0.28	0.26	0	0
Chifeng	4641.4	1.28	2.08	11	100
Hulunbeier	9980.5	1.48	0.37	0	0
Xingan	2612.2	1.53	1.55	3	60
Zhelimu	3713.6	1.65	1.93	7	88
Xilinguole	17661.0	0.65	0.64	8	73
Wulanchabu	5084.4	0.65	1.34	15	100
Yikezhao	4789.2	0.71	1.08	8	100
Bayiannuor	4624.4	0.54	0.81	7	100
Alashan	9785.7	0.21	0.24	2	66
Total	63591.1	0.86	0.88	67	86

* 1 sheep unit = 1 adult dry sheep, 1.1 adult goat, 0.3 ass, 0.2 cattle or mule, 0.16 horse, 0.14 camel.
1 adult animal = 3.3 young.
Source: IMAGRD (1988).

Table 11. The effects of different stocking rates on biomass composition of individual species of plants on alpine meadow measured in the west of Qinghai province.

Stocking rates (sheep/ha)	Individual species (%)				Poisonous weeds	Standing dead and litter
	Sedges	Grasses	Forbs	Shrubs		
5.35	14.7	9.9	51.6	16.9	1.4	5.6
4.30	17.6	16.2	37.2	18.9	1.6	8.4
2.55	18.8	28.3	21.7	19.5	0.6	11.1

Source: Han et al. (1991).

Conclusion

Sheep production in China varies between regions and seasons, with some similarities between all regions. The nutritional problems mainly arise from both predictable and unpredictable seasonal deficits in the amount and quality of forage available. Predictable deficiencies occur during the winter–spring season in northern China. Unpredictable deficiencies result from natural calamities such as drought and heavy snow. Those problems can prevent the achievement of high levels of sheep production.

Doubtless the sheep population of China will continue to derive most nutrients by grazing pastures. However, as the sheep are forced into more difficult terrain, productivity is likely to be increasingly improved by appropriate supplementation strategies. There is considerable opportunity for overcoming the nutritional limitations through a new supplementation strategy that stimulates the intake of poorer quality forage and/or increases the rate and level of rumen digestion (Lu De-Xun 1993).

References

Davies, H.L. 1964. Lambing losses in south-western Australia. Proceedings of the Australian Society of Animal Production, 5, 107–112.

— 1968. Studies in pasture management for the breeding ewe. 1. Effects of ewe liveweights, evidence of pregnancy toxaemia, lamb birthweights, and neonatal mortality. Australian Journal of Agricultural Research, 19, 605–620.

FAO 1993. FAO Production Yearbook Volume 47.

Han Fa, Ben Guiying, Shi Shengbo and Wang Qiji 1991. Effect of stocking rate on plant growth and productivity of alpine meadow. In: Liu Jike and Wang Zuwang, ed., Alpine Meadow Ecosystem Fascicula No. 3, Science Press, Beijing, 81–88.

IMAGRD (Inner Mongolian Academy of Grassland Reconnoitring and Designing) 1988. Statistics of the grassland resources in Inner Mongolia Autonomous Region. Inner Mongolian Academy of Grassland Reconnoitring and Designing, Huhehot, 413–417.

Lu De-Xun 1993. IMNS — a new feeding strategy for improving utilization of low quality roughages in ruminants. In: Proceedings of the International Conference on Increasing Livestock Production through Utilization of Local Resources, 2126–2221.

NFIO (National Feed Industry Office) and CFIA (Chinese Feed Industry Association) 1994. The strategy for development of feed industry in China during 1990–2020. China's Science and Technology Press, Beijing, 115.

Wang Hongrong, Feng Zhongci, Lu Dexun, Ren Jiakong, Li Hengron, Peter, D. W., Lindsay, J. and Purser, D. B. 1992a. Some aspects of seasonal dynamics of nutritive values of pasture influencing on feed intake and production of grazing sheep. Inner Mongolian Journal of Animal Sciences and Production, No. 3, 25–33.

Wang Wenyuan, Hao Junxi and Wang Shouging 1992b. Feeding standard for Inner Mongolian fine wool sheep. A document of the Regional Standardization Bureau, Inner Mongolian Autonomous Region, Huheot, P.R. China.

Weston, R.H. and Hogan, J.P. 1986. Nutrition of herbage fed ruminants. In: Alexander, G. and Williams, O.B., ed., The Pastoral Industries of Australia, Sydney University Press, 183–210.

Zhao Xinquan, Pi Nanlin and Feng Jinhu 1991a. Studies on the energy metabolism of ruminants. Measurement on the efficiency of energy utilization and requirement for breeding Tibetan sheep. In: Liu Jike and Wang Zuwang, ed., Alpine Meadow Ecosystem, Fasc. 3, Science Press, 97–102.

— 1991b. Studies on protein metabolism of reproductive Tibetan ewes. In: Liu Jike and Wang Zuwang, ed., Alpine Meadow Ecosystem, Fasc. 3, Science Press, Beijing, 330–331.

Review of Mineral Research in Grazing Sheep in China

Yu Shunxiang[1]

Abstract

Mineral nutrition problems were suspected in grazing sheep in China for many years, but only recently were they recognised and identified. China and Australia undertook a collaborative research project from 1985 to 1989, and this paper reports on project studies into mineral nutrition of sheep in northern China. The research revealed the existence of nutritional problems arising from imbalances of mineral and trace elements (phosphorus, sodium, potassium, sulfur, selenium, copper, zinc, manganese, iron and molybdenum).

MINERALS are required in the correct amounts to raise healthy sheep. A number of research activities and practices from developed sheep-raising countries around the world showed that an imbalance (deficiency or excess) of minerals or trace elements reduces wool growth, weight gain and reproduction of sheep, and if serious may even cause death (Underwood 1981). Many scientists are now addressing the problems of mineral nutrition in grazing sheep.

There are vast areas of grassland in China, totalling 420 million ha and accounting for 42% of China's total area. Many of these grasslands used to graze sheep are in northern China where the cold dry conditions in winter and spring leave only pasture plant residues for grazing for about 7 months each year. The pasture species available are predominantly native and grown without any inorganic fertiliser.

By comparison with developed countries, the research into minerals in grazing sheep in China began relatively recently and there were few research reports published in China before 1980. This is inappropriate, as China faces the duel challenges of a large population and shortage of food. It is thus imperative for the Chinese people to develop the vast area of grassland and increase sheep production, and it has become a top priority for scientists to undertake research on mineral nutrition in grazing sheep. Scientists need to know what has already been done in this field in China, to serve as a link between past and future. The literature reveals there has been some research work on mineral nutrition in China.

Mineral Nutrition in Grazing Sheep in China

Selenium deficiency and toxicosis

Reports show that selenium deficiency is widespread in China and still exists in many animals. An investigation of a lamb disease in northern China was made in the 1930s, and a report entitled 'A Study on Pathological Histology of Muscular Rheumatism' was published in *The Japanese Journal of Pathology* (Yoshikawa Shiichi 1936). White muscle disease was reported on Longridang farm, Aba Tibetan Autonomous prefecture, Sichuan Province in 1958 (Feng 1958), and subsequently on 850 farm, Baoquanling farm and Fuerji farm in Heilongjiang Province, northeast China (Qiu 1964). These reports have one point in common — the diagnoses were based on autopsy and pathological histology of dead sheep. It was said that the mortality of the lambs then was as high as 67%. Experiments carried out at the time showed that Vitamin E appeared to cure the disease.

Selenium deficiency was then unrecognised. Pastures, feedstuffs and body tissues were not analysed for selenium and it was not until 1978 that sodium selenite was introduced for disease control

[1] Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing 100094, People's Republic of China

and prevention (Anon. 1979; Zou and Niu 1980; Chang 1991). These reports described how selenium was used to cure deficiency in lambs and claimed it was better than any other medication.

A national investigation of plant material and animal feedstuffs undertaken in China from 1982 to 1983 (Liu et al. 1985) found that two-thirds of the counties in China had areas deficient in selenium—including Heilongjiang Province in northeast China, Qinghai Province in northwest China and Sichuan Province in southwest China. Effects of location were considered in the study, but seasonal differences which influence the selenium content were not considered. Besides the areas of selenium deficiency, investigations showed selenium toxicity in Ziyang county in Shanxi Province and Enshi county in Hubei Province. The selenium contents of corn from Enshi and Ziyang county were 18–29 mg/kg and 0.3–0.8 mg/kg, respectively (Cheng et al. 1980; Cheng 1981).

Zinc deficiency

Zinc deficiency of sheep in Tongliao region in the eastern part of Inner Mongolia was reported in 1987 and analysis of the pasture and the plasma of sheep determined zinc content in the range of 14.6–16.1 mg/kg and 8.6–15 μmol/L, respectively. Significant differences of seasons and locations were observed where pregnant and lactating ewes were susceptible to the deficiency (Zhong, pers. comm.).

Copper deficiency

It was reported that sheep in Xinjiang had a deficiency of copper, with 80% of lambs showing swayback (Zheng et al. 1978; Yi et al. 1985). Copper glycinate was used to prevent the disease (Zheng et al. 1981). Since then there has been no report of copper deficiency from that area. Copper content of pasture in eastern Inner Mongolia was found to range from marginal to deficient 1–5 mg/kg DM (Wu 1986). Another report showed copper deficiency was induced by drinking water high in fluorine in western Inner Mongolia (Guo et al. 1990). Copper deficiency caused by high molybdenum content of polluted water and grass was reported in Shanxi and Jiangxi provinces (Li et al. 1994; Fan et al. 1983).

Iodine deficiency

Research on iodine deficiency in humans has been reported from some areas of China, but only a few reports showed that livestock, especially sheep, have the same problem. An experiment in Shandong Province showed that urine of sheep in an area lacking sufficient iodine for humans contained more iodine than the minimum requirement for sheep and the total intake of iodine probably met the sheep's normal requirement. It was suggested that this was because the total feed intake of sheep was higher than humans (Chang and Yang 1994). An investigation showed that sheep in those areas which have low iodine concentration in the water (3 μg I/L), probably suffered from iodine deficiency leading to morphological change in the thyroid (Sun et al. 1983).

Fluorosis

Reports by Gao and Liu (1984), Guo et al. (1990) and Wang et al. (1992) showed that fluorosis in sheep, caused either by industrial pollution or by a high natural level of fluorine in drinking water, is a serious problem in parts of northern China.

Collaborative Project Results

China has raised sheep for far longer than Australia (about 5000–8000 years), but there is a great disparity between the performance of sheep in China and Australia. One factor may be mineral nutrition. There are 316 million herbivores in China, of which 130 million are sheep that graze the natural pastures in northern China. Feed supplements, usually produced locally, are often inadequate.

Minority nationalities in China mainly inhabit the pastoral areas, and sheep are very important not only for their livelihood but also as the mainstay of production in China. Increased production of sheep is a priority of the Ministry of Agriculture, and great attention is paid to the research on minerals in grazing sheep.

Australia has a history of mineral deficiencies, including selenium, cobalt, iodine, copper, zinc, manganese, phosphorus and calcium. Australian scientists have made significant contributions to the accumulated knowledge on the topic. On this basis the Chinese Academy of Agricultural Sciences (CAAS) and Australian Centre for International Agricultural Research (ACIAR) signed an agreement that enabled scientists from the Institute of Animal Science of CAAS and the CSIRO Division of Animal Production to collaborate in the project entitled 'Study on Mineral Nutrition of Small Ruminants in Northern China'. From 1985 to 1989, 21 scientists (three Australian and 18 Chinese) participated in the research work of the project.

Three farms — Huang Cheng farm in Gansu Province, Nanshan farm in Xinjiang Uygur Autonomous Region and Aohan farm in the Inner Mongolian Autonomous Region—were selected for field experiments. On each farm a representative group of approximately 140 breeding ewes was studied for 12 months. Details of the farms, sampling procedures and methods of analysis are reported in Masters et al. (1990, 1993a,b).

Major mineral elements

Sodium

Sodium concentrations in pasture were below the levels recommended for optimal production (0.7–0.9 g/kg dry matter (DM) (SCA 1990)) at all sites at some time during the year. Only in autumn, at Nanshan, did the levels in pasture reach those required by sheep (>0.9 g/kg DM). Of the three farms, Huang Cheng appeared to be the most affected by low sodium intakes with low concentrations of sodium in sheep plasma and faeces and widespread licking and ingestion of soil. The early sign of sodium deficiency is pica or abnormal appetite with licking of wood, soil and sweat (Underwood 1981). Although sodium deficiency is recognised in northern China and salt supplements are used, particularly on State-owned farms, the results indicated that the salt supplements used may be insufficient and should be provided regularly in many areas.

Potassium

Sheep require 5 g potassium/kg DM (SCA 1990). During autumn and summer, pastures contained adequate potassium (6–22 g/kg) for sheep, with all farms recording the highest concentrations in summer. The concentrations fell as pastures matured at Huang Cheng and Nanshan, and the dead dry pastures of winter and spring contained as little as 2 g/kg DM. Although the winter and spring pastures often contained less than 5 g/kg DM most sheep received some concentrate supplements that provided extra potassium during this period. The analysis of potassium in plasma indicated that the concentrations on all farms (3.6–5.5 mmol/L) were always above those reported in deficient sheep (2.4–3.5 mmol/L, Telle et al.1964).

Magnesium

Concentrations in all pasture, hay, concentrate and silage samples ranged from 0.9 to 4.8 g/kg DM and were above the minimum levels needed for growth and reproduction (0.7–1.0 g/kg, Underwood 1981) on all farms throughout the year. The acute form of magnesium deficiency often occurs in lactating ewes and causes a hypomagnesaemic tetany. Clinical signs have been described when plasma magnesium falls from the normal 0.8–1.2 mmol/L down to less than 0.4 mmol/L (Suttle and Field 1969). Magnesium in plasma ranged from 0.7 to 1.1 mmol/L and was always above 0.6 mmol/L. While no evidence of hypomagnesaemia was found, susceptibility is increased when sodium intakes are low (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, indicated that the occurrence of hypomagnesaemia is a possibility in some years.

Phosphorus

Sheep require 1.3–2.5 g phosphorus/kg DM (SCA 1990). Phosphorus in summer pastures ranged from 1.6 to 2.1 g/kg—concentrations that should be sufficient to support growth of young sheep. The concentrations in winter and spring pastures ranged from 0.24 to 1.62 g/kg. These lower concentrations are consistent with the senescence that occurs in pasture plants during winter. As with potassium, additional phosphorus was given to sheep in the form of concentrates and hay in winter and spring. The concentrates contained 2.8–7.0 g phosphorus/kg. For this reason deficiency of phosphorus is unlikely in winter or spring if concentrated feed supplements are provided. Phosphorus deficiency may be more likely in autumn (0.31–1.08 g phosphorus/kg dry pasture) when there is abundant green pasture but no mineral supplementation.

Calcium

The calcium content of pasture ranged from 4.4 to 22.3 g/kg DM and 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. Supplements of calcium could only be considered if sheep were fed high levels of concentrates (0.6–5.2 g calcium/kg) during winter and spring.

Trace elements

Selenium

On all farms selenium concentrations in pasture were within or below the marginal range for sheep (SCA 1990) of 30–50 μg/kg DM at some times of the year. The low concentrations in pasture were reflected in plasma and liver. At both Huang Cheng and Nanshan farms the concentrations of selenium in the liver fell below 1.14 μmol/kg wet tissue during the year. Normal concentrations are above 1.3 μmol/kg wet tissue (Judson et al. 1987). Concentrations of selenium in plasma were between 0.25 and 0.50 μmol/L on Huang Cheng all year and at Nanshan at all times other than autumn. These are below the critical concentration of 0.5 μmol/L to support wool growth suggested by Langlands et al. (1994) and Whelan and Barrow (1994).

Zinc

Zinc levels in pasture ranged from 4 to 37 mg/kg DM. The lowest values were below the recommended intakes for sheep (9–15 mg/kg DM, SCA 1990). Some low zinc values of faeces were also observed, particularly on Aohan farm. The concentration of zinc in faeces would usually be 2–4 times higher than in the ingested feed. On this basis the estimated concentration of zinc in pasture consumed at Aohan farm was 7–15 mg/kg DM throughout the year. These low values in pasture and faeces may also be indicative of a lack of zinc for optimum pasture growth (Robson and Gartrell 1979).

Despite the low zinc intake, particularly at Aohan farm, the concentrations of zinc in plasma did not indicate clinical deficiency (6.1 μmol/L, Mills et al. 1967). Nor did they fall below those observed by Masters and Fels (1980), who reported reproductive responses to zinc supplements in grazing ewes (approximately 7.6 μmol/L).

Copper and iron

The lowest concentrations of copper in the liver were at Huang Cheng farm (59 μmol/kg wet weight). This is below the deficient level reported by Paynter (1987) of 79 μmol/kg wet weight and the concentration at which Hogan et al. (1971) reported depressed wool and body growth and connective tissue lesions (135–224 μmol/kg). Copper in plasma ranged from 11.0 to 17.3 μmol/L and did not fall as low as observed during severe deficiency (<4.7 μmol/L) but approached the levels associated with marginal deficiency (9.4 μmol/L) (Paynter 1987). Copper deficiency can be induced by a lack of copper (Underwood 1981), by high intakes of molybdenum and sulfur (Dick 1953) or by high intakes of iron (Humphries et al. 1983).

As copper in pasture rarely fell below requirements for sheep (<5 mg/kg DM, SCA 1990) at any of the farms and copper concentrations in tissues were not related to the time of the year or physiological state of the ewes, the low concentrations in liver were probably caused by an interaction of copper with iron or molydbenum and sulfur. Iron in pasture was extremely high at Nanshan and Huang Cheng for part of the year. The highest concentration of 4 g/kg DM was 100 times the requirement of 0.03–0.04 g/kg DM (SCA 1990) and higher than the concentrations of iron shown to reduce copper status in other experiments with sheep (Wang and Masters 1990).

These high pasture concentrations led to high concentrations in faeces, with up to 7 g/kg DM at Huang Cheng and Nanshan. Much of the iron measured in faeces may have originated from soil contamination of pasture and, at Huang Cheng, from the habitual consumption of soil caused by lack of sodium (Masters et al. 1993b). Consumption of high iron soils has previously been shown to reduce copper status in sheep (Suttle et al. 1984). Molybdenum in pasture was sufficiently high to interact with copper (Suttle and McLauchlan 1976) but not as high as observed to cause severe copper deficiency (Hogan et al. 1971).

References

Anon. 1979. The clinical effect of sodium selenite on controlling and preventing white muscle disease of lambs. Communication of Science and Technology of Animal Husbandry and Veterinary Science, 1, 51–53.

Chang, Z.L. 1991. The importance of supplementing selenium to sheep according to animal production of Sanjiaocheng Sheep Farm. Qinghai Journal of Animal Husbandry and Veterinary Science, 3, 20–21.

Chang, Q.C. and Yang, J.Z. 1994. Study on nutrition problems of iodine in sheep. Chinese Sheep Feeding, 1, 12–13.

Cheng, J.Y., Xu, C.P., Liu, J.J., Long, J., Li, S.Q., Zhou, Y.M. and Mei, Z.Q. 1980. The second seleniferous area investigated in China (Ziyang County, Shanxi Province). Reports of Scientific Research 1970–80, Vol. 2, (Endemic Disease), 93–101.

Cheng, J.Y. 1981. Selenium in environment of Shanxi Province related to human and animal health. Chinese Journal of Veterinary Medicine 12, 14–15.

Dick, A.T. 1953. The control of copper storage in the liver of sheep by inorganic sulphate and molybdenum. Australian Veterinary Journal, 29, 233–239.

Fan, P., Wu, Z.L., Wang, J.Y., Liu, X., Dai, Q.W., Gong, Q.J., Pan, Z.J., Hu, Y.X., Fang, M.H., Liu, T.F. and Liu, Y.L. 1983. The study on molybdenum toxicity of farm buffalo and cattle. Chinese Journal of Veterinary Medicine 19, 5–7.

Feng, Z.G. 1958. A report of white muscle disease of lambs. Chinese Journal of Veterinary Medicine 11, 518–523.

Gao, D and Liu, H.W. 1984. An investigation of effect of fluoride from fluorine-polluted area on goats. Chinese Journal of Veterinary Science and Technology, 11, 32–34.

Guo, Y.X., Xu, J.G. and Cui, K. 1990. An investigation on chronic fluorosis in cattle in Jirem Meng, Inner Mongolia. Chinese Journal of Veterinary Medicine 16, 14–15.

Hogan, K.G., Money, D.F.L., White, D.A. and Walker, R. 1971. Weight responses of young sheep to copper and connective tissue lesions associated with grazing of pastures of high molybdenum content. New Zealand Journal of Agricultural Research, 14, 687–701.

Humphries, W.R., Phillipo, M., Young, B.W. and Bremner, I. 1983. The influence of dietary iron and molybdenum on copper metabolism in calves. British Journal of Nutrition, 49, 77–86.

Judson, G.J., Caple, I.W., Langlands, J.P. and Peter, D.W. 1987. Mineral nutrition of grazing ruminants in southern Australia. In: Wheeler, J.L., Pearson, C.J. and Robards, G.E., ed., Temperate Pastures—their Production, Use and Management. Melbourne, Australian Wool Corporation/CSIRO, 377–384.

Langlands, J.P., Donald, G.E., Bowles, J.E. and Smith, A.J. 1994. Selenium concentrations in the blood of ruminants grazing in northern New South Wales. IV. Relationship with tissue concentrations and wool production of Merino sheep. Australian Journal of Agricultural Research, 45, 1701–1714.

Li, S.Q., Long, J., Han, W.M., Zhou, Z.L., Niu, Y.D., Liu, J.J., Zhao, Z.Y. and Yang, J.M. 1994. An environmental distribution of high concentrated molybdenum and molybdenum poisoning. Acta Zoonutrimenta Sinica, 6 (1), 55–60.

Liu, C.H., Lu, Z.H. and Su, Q. 1985. Chinese Journal of Agricultural Science, 4, 76.

Masters, D.G. and Fels, H.E 1980. Effect of zinc supplementation on the reproductive performance of grazing Merino ewes. Biological Trace Element Research, 2, 281–290.

Masters, D.G. Purser, D.B., Yu, S.X., Wang, Z.S., Yang, R.Z., Liu, N., Wang, X.L., Lu, D.X., Wu, L.H., Rong, W.H., Ren, J.K. and Li, G.H. 1990. Production of fine wool sheep in three areas in Northern China. Asian-Australian Journal of Animal Science, 3, 305–312.

Masters, D.G. Purser, D.B., Yu, S.X., Wang, Z.S., Yang, R.Z., Liu, N., Lu, D.X., Wu, L.H., Ren, J.K. and Li, G.H. 1993a. Mineral nutrition of grazing sheep in northern China. I. Macrominerals in pasture, feed supplements and sheep. Asian-Australasian Journal of Animal Science, 6, 99–105.

—1993b. Mineral nutrition of grazing sheep in northern China. II. Selenium, copper, molybdenum, iron and zinc in pasture, feed supplements and sheep. Asian-Australasian Journal of Animal Science, 6, 107–113.

Mills, C.F., Dalgarno, A.C., Williams, R.B. and Quarterman, A.C. 1967. Zinc deficiency and the zinc requirement of calves and lambs. British Journal of Nutrition 21, 751–768.

NRC (National Research Council) 1985. Nutrient requirements of sheep. 6th Edition. National Academy Press, Washington USA.

Paynter, D.I. 1987. The diagnosis of copper insufficiency. In: Howell, J.McC. and Gawthorne, J.M., ed., Copper in Animals and Man. Boca Raton, CRC Press Inc., 110–116.

Qiu, Z.D. 1964. An investigation of white muscle disease. Acta Veterinary et Zootechnica Sinica, 7 (4), 273–283.

Robson A.D. and Gartrell, J.W. 1979. Plant requirements for mineral nutrients in Western Australia. In: Purser, D.B., ed., Mineral Requirements of Sheep and Cattle. Australian Society Animal Production, Perth, Australia, 1–7.

SCA (Standing Committee on Agriculture) 1990. Feeding Standards for Australian Livestock: Ruminants. CSIRO, East Melbourne, Australia.

Sun, R.G., Tian, S.L., Chang, Q., Xu, X.W., Bai, J.X., Zheng, Z. and Ding, S.H. 1983. Observation of effect of consuming different levels of iodine on the function and morphology of thyroid . Chinese Journal of Veterinary Medicine, 9, 17–18.

Suttle, N.F. and Field, A.C. 1969. Studies on magnesium in ruminant nutrition. 9. Effect of potassium and magnesium intakes on development of hypomagnesaemia in sheep. British Journal of Nutrition, 23, 81–91.

Suttle, N.F. and McLauchlan, M. 1976. Predicting the effects of dietary molybdenum on the availability of copper to ruminants. Proceedings of the Nutrition Society, 35, 22A–23A.

Suttle, N.F., Abrahams, P. and Thornton, I. 1984. The role of soil x sulphur interaction in the impairment of copper absorption by ingested soil in sheep. Journal of Agricultural Science, Cambridge, 103, 81–86.

Telle, P.P., Preston, R.L., Kintner, L.D. and Pfander, W.H. 1964. Definition of the ovine potassium requirement. Journal of Animal Science, 23, 59–66.

Underwood, E.J. 1981. The Mineral Nutrition of Livestock, 2nd edition. Commonwealth Agricultural Bureaux, Slough.

Wang, Z.S. and Masters, D.G. 1990. Effects of supplementary iron on tissue trace elements and plasma folate and vitamin B_{12} in young sheep. Proceedings of the Nutrition Society of Australia, 15, 142.

Wang, J.D., Cheng, Y.F., Zhan, C.W., Li, J.X., Yin, G.R., Hong, J.P. and Wang, W.F. 1992. A study on damages of industrial fluoride pollution to hard tissues of goats. Acta Veterinaria et Zootechnica Sinica, 23 (2), 141–145.

Whelan, B.R., Peter, D.W. and Barrow, N.J. 1994. Selenium fertilisers for pastures grazed by sheep. II. Wool and liveweight responses to selenium. Australian Journal of Agricultural Research, 45, 877–887.

Wu, L.H. 1986. Study on determination of copper content of pasture, feedstuffs and tissues of sheep and experiment of copper supplement to sheep. MSc thesis of Inner Mongolia College of Agriculture and Animal Sciences.

Yi, J.G., Yin, L.W., Chang, Y.L. and Ma, Y.L. 1985. Study on pathology of swayback of lamb. Chinese Journal of Veterinary Science and Technology, 1, 14–17.

Yoshikawa Shiichi 1936. Study on pathological histology of muscular rheumatism of lambs. Japanese Journal of Pathology 26, 81.

Zheng, S.Y., Hu, Y.D., Deng, P.H. and Wu, X.Q. 1978. An investigation of copper deficiency of lambs in reed grassy marshland in Xinjiang and its ecology. Publication of the Xinjiang August First College of Agriculture Sciences, 1–12.

Zheng, S.Y., Hu, Y.D. and Wang, M.C. 1981. Copper deficiency of domestic animal and the experiment of its preventing with copper glycinate. Publication of the Xinjiang August First College of Agriculture Sciences, 4, 11–16.

Zou, Y.C. and Niu, J.Y. 1980. Prevention of abortion of purebred Corriedale sheep with sodium selenite and vitamin E. Science and Technology of Animal Husbandry in Heilongjiang Province, 2, 38–39.

Pedogeochemical Environment of China and Protection and Treatment of Endemic Diseases of Humans and Animals

Gong Zitong and Huang Biao[1]

Abstract

Pedogeochemistry of China is controlled by factors such as biology, climate, parent material, topography and anthropogenesis, forming special soil geochemical types and distribution. The different geochemical types are formed under the different conditions of soil formation which have different concentrations of elements. The soils and elements have a zonal distribution from northwest to southeast China under the influence of bio-climate, while differences in local areas may be attributed to influences of parent material, topography and anthropogenesis.

The excess and deficiency of elements in the soil environment obviously affects human and livestock health and may result in endemic diseases of humans and animals. These endemic diseases may be controlled by either increasing or reducing an element or other related elements in order to provide protection and treatment. Methods to improve element concentration in the environment include fertilisation and control of drinking water standards. Appropriate measures will gradually help to improve the health of humans and the quality of livestock.

DEFICIENCY or excess of certain elements in soils influences human and animal health. Some endemic diseases are related to special soil environments in parts of the world. The soil is not just a medium for growing plants and the basis of animal livelihood, humans also depend on it for survival. In the past 20–30 years the soil has also received more attention as a medium for absorption and desorption of pollution material (Fortescue 1980; Gong 1982).

Four geochemical regions are identified in China. These are the saline, carbonate, siallitic and ferrallitic soil regions (Gong and Luo 1992; Gong and Huang 1994). They extend from the northwest to the southeast regions of China. Saline, carbonate, siallitic and ferrallitic soils are typical of four soil regions according to zonal distribution. There are also some soil types associated with local factors such as topography and parent material. The areas of different soil types are shown in Figure 1.

[1] Institute of Soil Science Academia Sinica (ISSAS), Nanjing, 210009, People's Republic of China

Characteristics of Geochemical Regions

Saline soil region

The distribution of saline soils in the inland arid areas of western China includes the northern Qingzang Plateau which is 27% of the total land area of China (Gong and Luo 1992; Gong and Huang 1994). In this region the soils appear alkaline, textures are coarser, mainly sandy and sandy loam, and secondary minerals are mostly hydromicas. Saline and gypsic soils are the most commonly distributed in this region with siallitic and carbonate soils distributed in the alpine–subalpine area where the climate is moist. The soils are rich in salts, including chloride and sulfates, and lower in carbonate, nitrate and borate in local areas (ISSAS 1986; Xiong and Li 1991). In the saline region, soils are rich in either total or available phosphorus. The deficient area comprises 63% of the region (IANRR-CAAS 1986) and is rich in water-soluble fluorine, especially in the alkaline soils (Huang et al. 1994). The deficient elements in the soils include zinc, iron, manganese and iodine — 80% are low in available zinc and manganese, and 50% in available iron. Available selenium is also deficient in the region (Gong and Huang 1994).

In the saline soils region, spatial differentiation of some elements in the soil takes place with transport of clay and migration of water from high to low altitudes due to undulating topography. For example, from the Qilian Mountains to Juyanhai (salt lake) sequences of salts ($CaCO_3$, $CaSO_4$, Na_2SO_4 and NaCl) accumulate from mountain to the salt lake with increasing solubility of salts. The concentrations of selenium, fluorine and iodine increase at the lower altitudes (depressions) showing the geochemical characteristics of elements in the saline soils region.

Carbonate soil region

This region extends southwest from the Inner Mongolian Plateau to the Tibetan Plateau, and is 23% of the total land area of China. The soils appear alkaline, the texture is mainly loam and secondary minerals which are hydromicas and/or chlorites. Carbonate soils are the main types in the region. Siallitic soils are formed under the condition of moisture in high altitudes, while saline and alkaline soils are often distributed at low altitudes. The soils are rich in carbonate (around 10–20%), so that the calcium-accumulating horizon appears in certain depth of profiles. In the region, the soils are also rich in both total and available potassium and boron, and while rich in total phosphorus are poor in available phosphorus. Deficiencies may be apparent in up to 60% of the total area. Soils are also rich in water-soluble fluorine, especially the soda alkaline soils in depressions, so that fluorosis of humans and animals is common. Likely deficiencies of these soils are zinc, manganese, iron, molybdenum, iodine and selenium.

Siallitic soil region

The region covers around 30% of the total land area of China. The soils in the region are neutral or weakly acid. Textures are clay loam and the secondary minerals are principally 2:1 type layer silicate, such as montmorillonite, illite and vermiculite. The soluble salts and carbonates have mostly been lost through leaching from the soil, and this has led, in particular, to potassium deficiency in 47% of the region. Phosphorus availability in the soil is reduced due to a decrease of free calcium and an increase in active iron and aluminium. By comparison with the carbonate soil region, there are fewer areas deficient in available zinc, manganese, iron and iodine and more areas deficient in boron, molybdenum, fluorine and selenium.

Ferrallitic soil region

This region is in the tropical area south to the Changjiang River and covers about 18% of the total land area of China. The soils are acid, clay in texture and the secondary minerals are mainly iron and aluminium sesquioxides, kaolinite, goethite, and gibbsite.

The principal soil geochemical types are: ferrallitic soils; siallitic soils that are distributed in the local area; and ferrolysed (paddy) soils that have been affected by human activity. The soils are high in aluminium as well as free iron. Total iron is up to 40%. Cation exchange capacity (pH 7) in the soils is less than 24cmol(+)/kg clay (Gong 1986).

Under conditions of abundant moisture and heat, the mobile elements such as potassium, boron and fluorine are strongly leached, resulting in a deficiency of these elements in soils of the region, especially ferrolysed soils. The soils are not poor in total molybdenum and selenium, but availability of the elements is low. Phosphorus is the compounded form of iron or aluminium, so that its availability is low and the deficient area covers 46% of the region. Trace elements such as zinc, copper, manganese and iron are richer in the soils of this region than other regions, and iodine is abundant.

Zonal distribution of elements

From the above discussion of the characteristics of the soil geochemical regions combined with other information (Liu et al. 1978; 1982; Xie 1994) it is apparent that:

- availability of phosphorus and boron is in the order of the saline >carbonate >siallitic >ferrallitic soil regions;
- availability of zinc, iron and manganese is in the order of the ferrallitic >siallitic >carbonate >saline soil regions;
- availability of fluorine and molybdenum is in the order of the saline >carbonate >siallitic >ferrallitic regions.

Phosphorus availability is affected by combination with calcium in the saline and carbonate soil regions, and with iron and aluminium in the siallitic and ferrallitic soil regions. Based on the present data, the phosphorus-deficient areas in soil regions of northwest China are greater than those of southeast China due to fertilisation. Copper is not obvious in the zonal distribution due to local soil-forming factors. For abundance and proportions of copper, zinc, molybdenum, manganese, boron and selenium, see Figure 2.

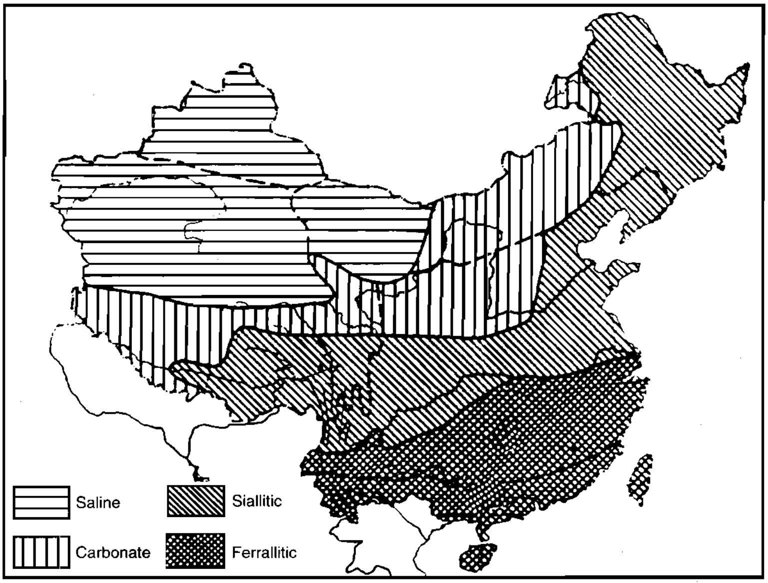

Figure 1. Pedogeochemical regions of China.

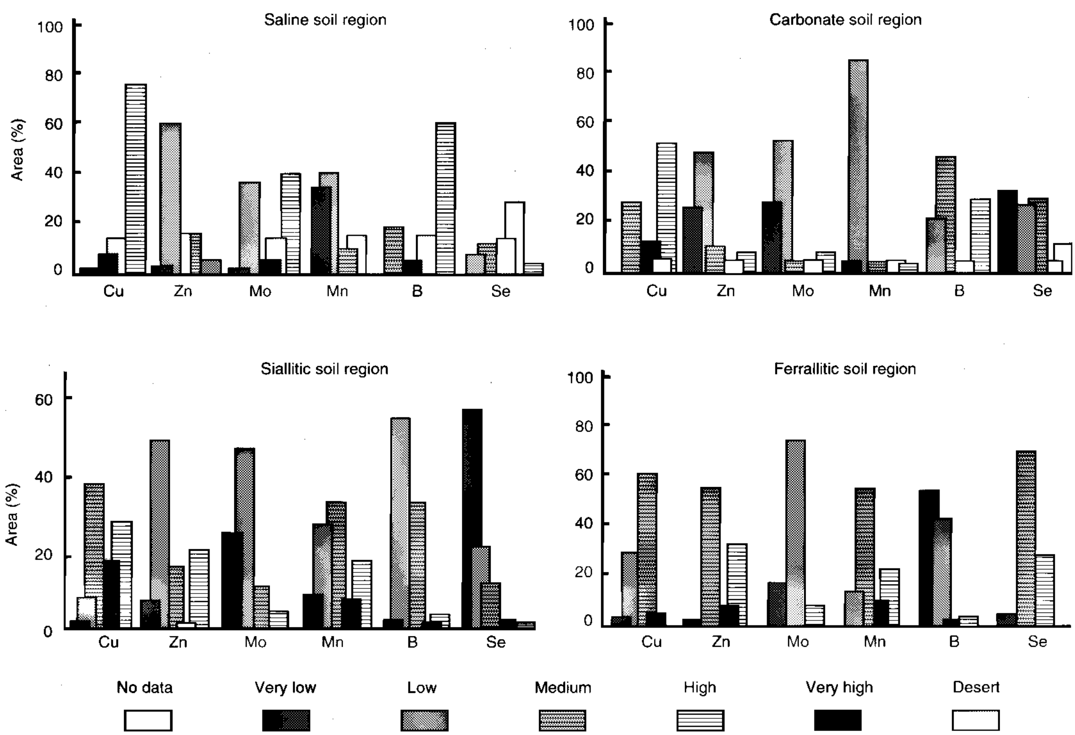

Figure 2. The abundance and proportions of some trace elements in different soil regions.

Pedogeochemistry and Human and Animal Health

There is evidence that there is an intimate relationship between the pedogeochemical environment and human and animal health (Lin 1991; Gong and Luo 1992; Gong and Huang 1994). At present, some endemic diseases have been studied in depth and are clearly understood. For example, excess fluorine in the soil may result in fluorosis of humans and animals, while deficiency of iodine may result in endemic goitre of young animals and humans, contributing to hair loss, slowly developing bones and fewer brain cells. Deficiency of sulfur and selenium may cause the Keshan and Kashin-Beck diseases of humans and white muscle diseases of animals. In addition, deficiency of cobalt may lead to anaemia in ruminants. Of course, causes of some endemic diseases are not clearly understood. For example, investigating endemic diseases in Xinjiang revealed that the goats in Qiemo county frequently abort their lambs, or they are paralysed in spring. Camels are also susceptible. In Yutian county, fractures to horses occur easily and their manes are weak. Distribution of elements in the soil must be studied further to find out what environmental factors cause these diseases.

Distribution of endemic diseases and soil zonation

There are close relationships between geochemical endemic diseases and some elements, leading to a relationship between the distribution of endemic diseases and the zonal distribution of elements. There is a need for further study into reasons why endemic diseases occur. The soils of northern China appear alkaline due to the arid soil-forming environment, resulting in enrichment of fluorine. So, in the pastoral areas in arid and semi-arid areas of northern China the content of fluorine is relatively high in soils and herbage, especially in the areas where alkalinisation is strong, resulting in fluorosis of livestock. In the northern region, domestic animals do not appear potassium-deficient because potassium in soils of the region is abundant. The trace element zinc has lower levels in soils and forage grasses, possibly leading to zinc deficiency in livestock. The trace element iodine is also low in soils and herbage of arid regions. This leads to iodine deficiency diseases of humans and domestic animals. Some elements, such as available copper, molybdenum and selenium, are present in relatively high levels in alkaline soils, so that animals do not show obvious deficiency diseases. In moist siallitic and ferrallitic soil regions the soils are poor in fluorine, potassium and molybdenum, and rich in boron and iodine.

Distribution of endemic diseases and soil non-zonation

Distribution of soils and elements are also affected by non-zonal factors such as parent material and topography, which influence distribution of endemic diseases. Parent material is the main origin of elements in soil, having an obvious influence on the distribution of elements and thus endemic diseases. In China, the cause of selenosis in certain locations (Enshi, Hubei Province and Ziyang, Shan'xi Province) results from the distribution of coal-series strata which is selenium-rich, reaching up to100 ppm as well as producing soils which have high selenium levels leading to selenosis of humans and animals (Li et al. 1986; Zhao et al. 1993). The fluorosis which develops in local areas of the Guizhou Plateau results from distribution of fluorine-rich parent rocks. The soils are often low in copper on parent material of sandstone, generally deficient in zinc on lime purple sandstones and are poor in selenium on loess.

Distribution of soils and elements is influenced by undulating topography which may lead to changes in the bio-climatic conditions in the local area. Elements such as fluorine, boron, iodine, and selenium leach toward the lowest point while elements such as zinc, copper, iron, and manganese often accumulate in situ. As a result, certain elements may concentrate in some areas and be depleted in others, causing disease.

Endemic diseases and element interactions

Evidence indicates that endemic diseases of humans and animals may also be caused by interactions between elements. An excess or deficiency of an element can reduce or increase absorption of other elements by humans and animals. For instance, concentrations may be the same in drinking water of two different areas, but one area may have iodine deficiency diseases and the other may not. In the Himalaya region of China, iodine levels in drinking water and food are not deficient, but iodine deficiency diseases of humans and livestock are still common. Analysis of drinking water found high levels of calcium and fluorine which hinders iodine absorption in humans and animals resulting in iodine deficiency (Lin 1991). Copper deficiency may result from high molybdenum and sulfur or iron in the environment as well as a simple lack of copper (Ren et al. 1992). Consideration must be given to the relationship of endemic diseases and element interactions as well as single element deficiencies when studying livestock nutrition.

Protection and Treatment of Endemic Diseases with Soil Biogeochemical Methods

Fertilizer applications

One method is to fertilise with elements deficient in soils to increase the level in crop and forage grass. For instance, selenium fertilizer may be used on soils, or sprayed onto leaves to increase selenium levels in feed and cereal. Successful applications have been recorded in the USA, Denmark, New Zealand and the Loess Plateau of China (Lin 1991; Tian and Peng 1994). Besides fertilising with deficient elements the other goal is to balance soils based on the interaction between elements in order to stimulate and control availabilities of related elements. An acidic organic fertilizer may be used on alkaline soils to change the pH of soils and improve the bio-availability of the elements such as zinc, iron and manganese. Gypsum is used on alkaline soils to reduce fluorine availability.

Improving water quality

Some endemic diseases may be lessened by adding deficient elements to water sources, or by lowering the level of the elements in excess to protect human and animal health. For example, fluorine is put into drinking water in fluorine-deficient areas, or is reduced with chemical and physical methods if in excess. In recent years in Hetian Xinjiang, iodine deficiency diseases (IDD) were treated by putting liquid iodine into irrigated water. The iodine levels increased fivefold in drinking water, fourfold in soils and twofold in crops, improving the environment of the deficient disease area. IDD was controlled and the breeding rate of livestock increased by 50% (De Long et al., these proceedings).

Feed composition and protection from endemic diseases

Different levels of elements exist in various crops and herbages due to their absorption by the plants. Humans may adjust the selection and composition of food to replenish some deficient elements in the environment and to protect against endemic diseases. In fact, the composition of food and drinking water has been changed in some affected areas, improving living standards and lowering the incidence of endemic diseases. For example, farmers in a Keshan disease area used maize and root potato, which have low selenium and molybdenum levels, as their staple foods. The drinking water was poor. Now with improved living standards their main foods are wheat and rice and the drinking water is groundwater. Moreover, exchange of goods and materials between affected and non-affected areas has led to a more varied diet in areas where deficiencies exist. Consequently, the number of affected areas has been reduced in recent years (Li et al. 1993).

References

Fortescue, J.A.C. 1980. Environmental Geochemistry. New York, Heidelberg and Berlin, Springer-Verlag.

Gong, Z.T. 1982. Origin and development of soil geochemistry. Progress in Soil Science. 10(1), 1–17 (in Chinese).

Gong, Z.T. 1986. Soil geochemical environment of China. In: Committee of Environmental Geochemistry, Chinese Society of Geology, ed., Environmental Geochemistry and Health. Guiyang, Guizhou People's Publishing House, 86–94 (in Chinese).

Gong, Z.T. and Luo, G.B. 1992. Pedogeochemical environments and people's health in China. Pedosphere. 2(1), 71–77.

Gong, Z.T. and Huang, B. 1994. Spatial differentiation of Se, F, and I in soils and human health. In: Zhao, Q.G., ed., Pedosphere, Nanjing, Nanjing University Press, 188–203.

Huang, B., Gong, Z.T., Gu, G.A. and Shi, C.H. 1994. Geochemistry of water soluble fluorine in aridisols with different landscapes and relation to endemic diseases in the Tianshan mount region. In: Zhao, Q.G., ed., Pedosphere, Nanjing, Nanjing University Press, 544–550.

IANRR-CAAS (Institute of Agriculture Natural Resources and Regionisation, Chinese Academy of Agricultural Science) 1986. Resources and Utilisation of Arable Land of China. Beijing, Surveying and Mapping Publishing House (in Chinese).

ISSAS (Institute of Soil Science, Academia Sinica) 1986. Soil Atlas of China. Beijing, Cartographic Publishing House (in Chinese with English abstract).

Li, R.B., Tan, J.A., Wang, W.Y., Zhao, N.Q. and Li, D.Z. 1986. Study on selenosis of animal and its geographical environment in western Hubei province, China. In: Edition Committee of Physical Geography and Environment, ed., Study on Physical Geography and Environment. Guangzhou, Zhongshan University Press, 220–225 (in Chinese).

Li, R.B., Yuan, P.Y., Wang, W.Y., Tan, J.A. and Ju, S.J. 1993. Study on dynamic monitoring of Keshan diseases and environment in Hulunber, Inner Mongolia. Geography Science, 13(4), 368–374 (in Chinese with English abstract).

Lin, N.F. 1991. Medical Environmental Geochemistry. Changchun, Jilin Science and Technology Press (in Chinese with English abstract).

Liu, Z., Tang, L.H., Zhu, Q.Q., Han, Y.Q. and Ouyang, T. 1978. Preliminary summary on content and distribution of trace elements in soils of China. Acta Pedologica Sinica, 15(2), 138–150 (in Chinese with English abstract).

Liu, Z., Zhu, Q.Q., Tang, L.H., Xu, J.Q. and Yin, C.L. 1982. Geographic distribution of trace-element-deficient soils in China. Acta Pedologica Sinica, 19(3), 209–223 (in Chinese with English abstract).

Ren, J.K., Li, G.H., Lu, D.X., Wu, L.H., Wang, Q.J., Rong, W.H., Yu, S.X., Gao, F.S., Li, J.F. and Dai, F.Q. 1992. Determination of mineral nutrients of grazing sheep in Aohan, Inner Mongolia. Part II: Trace Elements. Nei Mongol Animal Science, (3), 10–15 (in Chinese).

Tian, J.L. and Peng, X.L. 1994. Soil Geochemistry in Loess Plateau of China. Beijing, Science Press (in Chinese).

Xie, J.C. 1994. Change of K nutrient in agriculturally sustainable development and its management. In: Chinese Society of Soil Science, ed., Soil Science and Agriculturally Sustainable Development. Beijing, China Science and Technology Press. 211–215 (in Chinese).

Xiong, Y. and Li, Q.K. 1991. Soils of China (2nd edition) Beijing, Science Press (in Chinese).

Zhao, C.Y., Ren, J.H. and Xue, C.Z. 1993. Selenium in soils of an Se-rich area in Ziyang County, China. Acta Pedologica Sinica, 30(3), 253–259 (in Chinese with English abstract).

Identification of Mineral Elements Limiting Sheep Production in Northern China

David Masters[1], Yu Shunxiang[2], Gao Fusen[2], Liu Bin[2], Jiao Suxian[2], Lu De-Xun[3], Shao Kai[3], Xu Guimei[3], Rong Weihong[3], Ren Jiakong[4], Kang Chenglun[5], Kong Qinglei[5], Kong Fanjiang[5], Harali Shabuer[6], Nuernisha[6], Liu Ning[6], Bai Fuben[6] and John Lindsay[1]

Abstract

Changes in the mineral status of grazing sheep were measured on 15 farms and four times during the year. The farms were selected to represent the major fine-wool sheep growing areas in northern China. Five farms were used in each of the Inner Mongolia Autonomous Region and the Xinjiang Uygur Autonomous Region, three in Gansu Province and two in Qinghai Province. Samples of blood, faeces and saliva were collected from 2-year-old reproducing ewes, in summer, autumn, winter and spring. Collection of some animal tissue samples and milk were made less often. Samples were analysed for a range of mineral elements. Low levels of sodium (Na:K<10:1), magnesium (plasma <0.4 mmol/L), selenium (plasma <0.5 μmol/L), iodine (milk <0.6 μmol/L) and copper (plasma <6 μmol/L) on some farms indicated that these elements will need to be provided as supplements if animal productivity is to be increased. Responses to mineral supplements during one year gave smaller responses than expected and further experimentation is required to quantify the benefits of using mineral supplements.

NORTHERN China contains vast areas of grassland in both arid and alpine environments. These are used for grazing animals and support 25–30 million fine-wool sheep as well as meat sheep, goats, horses, yaks, and cattle. A comprehensive examination of the mineral status of sheep at three sites in northern China (Yu et al. 1995; Lu et al. 1995) provided evidence of low concentrations of minerals in the pasture plants growing on these grasslands and inadequate mineral intakes in grazing sheep. Specifically, the analysis of tissues and pasture samples, together with the measurement of responses to supplements, indicated that sodium, selenium, sulfur, copper and zinc deficiencies may occur over large areas of northern China.

Mineral deficiencies and particularly micro-mineral deficiencies are inconsistently expressed and dependent on factors such as soil type, pasture type (age and species), physiological state of the animal (growth, lactation), amounts and type of supplementary feed, and stocking rate. Therefore, caution is essential when extrapolating results from three farms to other regions or even to other farms in the same region. Consequently, the aim of the current study was to provide more extensive data by evaluating the mineral status of sheep on 15 farms in four provinces in northern China.

Production of both wool and sheep meat are major priorities in China. A new initiative to emphasise

[1] CSIRO Division of Animal Production, Private Bag, PO, Wembley, WA Australia 6014
[2] Institute of Animal Science, Chinese Academy of Agricultural Sciences, 2 Yuanmingyuanxi Road, Haidian, Beijing, China 100094
[3] Inner Mongolia Academy of Animal Science, Western Suburbs of Huhehot City, Huhehot, Inner Mongolia Autonomous Region, China 010030
[4] Institute of Animal and Veterinary Sciences, Chifeng, Inner Mongolia Autonomous Region, China 024031
[5] Lanzhou Institute of Traditional Veterinary Medicine, Chinese Academy of Agricultural Sciences, Xiaoxihu, Lanzhou, Gansu, China 730050
[6] Xinjiang Academy of Animal Science, 21 Youhao Donglu, Urumqi, Xinjiang Uygur Autonomous Region, China 830000

work with grazing ruminants in northern China was announced by the Chinese Government in August 1989. Clearly then, China places considerable importance on improved practices for sheep production. While much emphasis has been placed on genetic improvement of flocks it is well documented that poor nutrition is the primary constraint on production of fine wool sheep (Yu et al. 1988, Masters et al. 1990).

The major nutritional problems are protein, energy and mineral deficiencies. While correction of protein and energy deficiencies may be complicated, expensive and long-term, the correction of mineral deficiencies by the provision of mineral supplements is inexpensive and usually cost-effective. Even under conditions where protein and energy sources are limited the provision of mineral supplements can result in significant increases in productivity.

The objectives of the on-farm activities of this research were to provide:

- a description of the mineral status of grazing sheep to identify deficiencies and toxicities for correction and avoidance;
- a description of seasonal changes in mineral status to identify when it is necessary to provide supplements;
- a comparison of different geographical regions and soil types to identify where it is necessary to provide supplements;
- identification of interactions between minerals in the Chinese environment and consequently establish the causes of deficiencies and/or toxicities and the most effective measures for correction;
- development and testing of mineral supplements for the correction of mineral deficiencies in grazing sheep;
- measurement of responses to minerals on selected farms;
- evaluation of different methods of supplementation.

There were an additional number of off-farm activities, including:

- establishment of methods of analysis for iodine, cobalt, inorganic sulfate and phosphate, and vitamin B_{12} in Beijing (in the previous project methods of analysis of calcium, potassium, phosphorus, magnesium, sulfur, sodium, molybdenum, manganese, iron, copper and zinc were established);
- establishment of a new set of sampling protocols to ensure collection of the most appropriate samples, from sheep, for the diagnosis of mineral problems;
- provision of research experience for junior Chinese researchers in Australia, to establish a high level of expertise in the regional academies and increase the awareness of potential production losses due to mineral deficiencies;
- publication of workshop proceedings, in Chinese and English, to be used as a standard reference for all ruminant nutritionists in China.

Only results from on-farm activities are included in this report.

Experimental Program

The program for the first year of the project was as follows:

1. identification and selection of five farms in Inner Mongolia Autonomous Region and Xinjiang Uygur Autonomous Region, three farms in Gansu Province and two in Qinghai Province;
2. collection of samples from 20 two-year-old ewes on each farm on four occasions (sampling once in each of summer, autumn, winter and spring; samples collected included blood, faeces, milk and saliva; samples of liver, kidney, bone and muscle were collected from some of the sheep slaughtered on the farm, usually in autumn);
3. transfer of most samples to Beijing, with some analysis at regional academies;
4. collection of data on farms, including: sheep numbers, management systems, feeding strategies and productivity.

During the second year, samples were analysed and data collated. From this information, a number of farms were selected for the evaluation of responses to supplements in year three.

Locations, Environment and Management

Most of the fine wool sheep in China are found in the northern provinces and in particular in the Inner Mongolia Autonomous Region, the Xinjiang Uygur Autonomous Region, Qinghai Province, Gansu Province and the Tibetan Autonomous Region. Farms for this project were selected from all of these provinces with the exception of Tibet (Figure 1). The farms were selected to provide a range of environments, locations and management systems in each province or region (Table 1). The areas used to rear grazing animals are usually unsuitable for crops, and consequently tend to be characterised by low rainfall (mostly in summer), short growing season, extreme cold in winter and often strong winds. Most, although not all, of the farms were large and state-run and many provided stud sheep to smaller farms. Because the flocks used were from larger farms, they were probably better fed and cared for than those kept by smaller households.

Sheep were not the only livestock of these farms. Other animals included goats, cattle, horses, camels

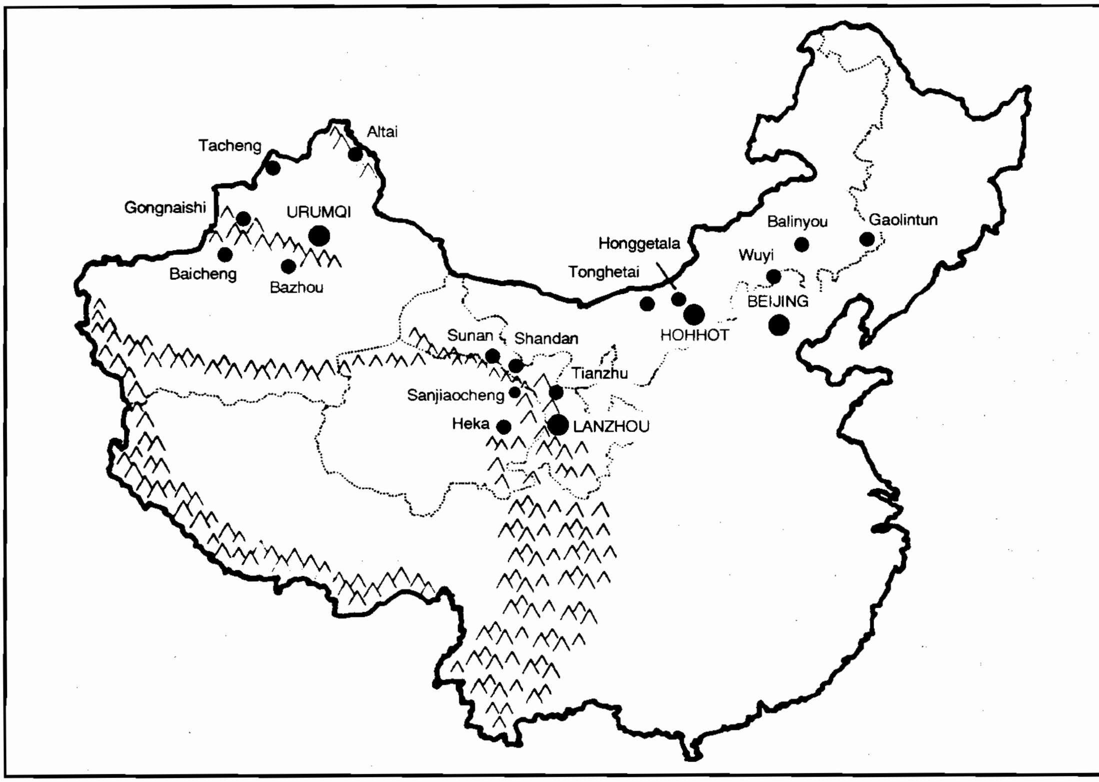

Figure 1. Locations of the farms used as experimental sites during the project.

Table 1. Climate and altitude of the 15 farms used in the first year of the project.

Province	Farm	Average temp.[a] °C	Average rainfall mm	Annual evap. mm	Sunlight hours	Frost-free days	Altitude (m) autumn–spring (summer) pasture
Xinjiang	Altai	4.4	95	1795	3116	150	800 (1500–3000)
	Tacheng	6	292	1605	2947	136	520 (2000–2900)
	Gongnaisi	9.1	250–280	2144	2659	165	800 (2500–3400)
	Baicheng	7	80–150	1640	2300	204–210	1050 (2600–3300)
	Bazhou	7.9	65	1950	3138	167	1500 (2500–3500)
Gansu	Sunan	3.5	200–300	not avail.	2800–2900	100–120	2580 (3500–4000)
	Shandan	2.7	150–230	2245	2995	102	1700 (2800)
	Tianzhu	1.2	230	1700	2800–2900	90	2600–3100
Qinghai	Sanjiaocheng	−1.1	327	1535	2850	108	3200 (4000–4800)
	Heka	1.0	361	1490	2810	52	3250 (4200)
Inner Mongolia	Tonghetai	4.3	180	2644	3213	120	1280
	Honggetala	3.4	256	2752	3172	105	1400
	Wuyi	1.4	300–400	1936	3154	104	1280
	Balinyou	6.3	355	2100	3050	120–130	700
	Gaolintun	6.0	350	1800	not avail.	142	160

[a] Average temperatures are calculated from the full year. On all farms temperature extremes are wide and usually range from −30°C to +30°C during the year.

and yak. Sheep are grown for both wool and meat production. While the grazing areas on the farms were often large, pastures were native species and were grown without applications of inorganic fertilizer. The low rainfall and short growing season result in fluctuations in the quantity and quality of pasture available and low levels of production of wool and meat (Masters et al. 1990). The pastures and sheep were managed traditionally, with the small flocks of sheep accompanied by a herdsman at all times and allowed to graze over unfenced rangeland. In the alpine regions of Gansu, Xinjiang and Qinghai, sheep graze the higher elevations in summer and gradually return to the lower slopes or desert pasture in autumn, spring and winter. In winter the sheep were often housed for much of the day and fed supplements. In Inner Mongolia, sheep farms were located on the grasslands or edge of the desert. Flocks were still accompanied by a herdsman during the day but grazed in the same area for most of the year. Details of sheep numbers, management and feeding are shown on Table 2.

Sampling and Analytical Methods

In the first year of the project (1992–93) blood, parotid saliva, faeces and pasture samples were collected in summer, autumn, winter and spring. In addition, milk was collected during lactation in spring/summer, and liver, muscle and bone samples were collected at slaughter in late autumn. Sheep sampled were young ewes during their second pregnancy and lactation.

Table 2. Sheep numbers, management and feeding on the 15 farms used during the first year of the project.

Province	Farm	Pasture area (ha)	Sheep[a]	Mating	Weaning	Supplements	When fed
Xinjiang	Altai	71000	52000	Aug or Oct/Nov	July	Maize, wheat bran, oilseed, silage, straw 120–150 g/hd/day	Oct–Apr
	Tacheng	83000	38000	Aug or Oct/Nov	July	Maize, wheat bran, oilseed, straw 130–150 g/hd/day	Dec–Apr
	Gongnaisi	33000	20000	Aug or Oct/Nov	July	Maize, wheat bran, oilseed, straw 110–150 g/hd/day	Dec–Apr
	Baicheng	27000	28000	Aug or Oct/Nov	July	Maize, wheat bran, oilseed, straw, bagasse, alfalfa 100–150 g/hd/day	late Dec
	Bazhou	11000	10000	Aug or Oct/Nov	July	Maize, wheat bran, oilseed,straw hay, beet 100–150 g/hd/day	Nov–Apr
Gansu	Sunan	4100	2800	Nov	Sept	Hay 200 g/hd/d., concentrates (corn, barley) 100 g/hd/day	Dec–Mar
	Shandan	13300	3700	July	May	Hay 900 g/hd/d., concentrates (corn, barley) 60 g/hd/day	Nov–Apr
	Tianzhu	130000	7600	Nov	July/Aug	Hay 800 g/hd/d., concentrates (corn, barley, peas) 120 g/hd/day	Dec–Apr
Qinghai	Sanjiaocheng	32200	38000	Nov	Sept	Hay 700 g/hd/d., concentrates (barley, oats, oilseed meal) 250 g/hd/day	Dec–Apr
	Heka	13300	21000	Nov	Aug	Hay 650 g/hd/d., concentrates (barley, oats, oilseed meal) 450 g/hd/day	Nov–Apr
Inner Mongolia	Tonghetai	29000	8000	Sept/Oct	July	Hay 25 kg/hd/yr., concentrates (oats, corn, barley) 12.5 kg/hd/yr	Jan–Apr
	Honggetala	38000	35100	Sept/Oct	July	Hay and other fodder 150 kg/hd/yr, concentrates (oats, corn other cereals) 80 kg/hd/yr	Dec–Apr
	Wuyi	53300	49300	Oct/Nov	Aug	Hay and oats stubble 100 kg/hd/yr, concentrates (corn, oats) 50 kg/hd/yr	Jan–Apr
	Balinyou	84000	8000	Aug/Sept	May/June	Hay 100 kg/hd/yr, concentrates 30 kg/hd/yr	Dec–Apr
	Gaolintun	13300	5000	Aug/Oct	June	Hay 100 kg/hd/yr, concentrates (corn, soybean meal) 70 kg/hd/yr	Nov–Apr

[a] On all farms other livestock are also raised; these may include goats, cattle, horses and yaks. Sheep may include both fine-wool and meat sheep.

Blood samples

Twenty-two millilitres of blood were collected from each animal by jugular venipuncture into heparinised tubes (125 international units Li heparin/10 mL tube). The samples were processed as indicated in Figure 2. Plasma obtained in the field was stored refrigerated until return to the laboratory, where sub-sampling and deproteinisation were carried out.

Deproteinisation was carried out by adding 3 mL of 10% trichloroacetic acid (TCA) to 3 mL of plasma. The mixture was chilled, then shaken and centrifuged at 1500 × gravity for 10 min. The supernatant and the plasma samples were stored frozen prior to analysis.

Saliva samples

A stainless steel sample probe, connected to a 50 mL syringe by silastic tubing (Figure 3), was used to aspirate parotid saliva from a site in the mouth between the cheek and the molar teeth. The syringe plunger was slowly withdrawn to assist the serous saliva to drain into the silastic tubing.

The saliva was drained from the silastic tubing into a small storage vessel and further samples of saliva taken until a total of 2–3 mL had been collected. The total sample was stored cold and, after returning to the laboratory, was frozen prior to analysis for sodium and potassium.

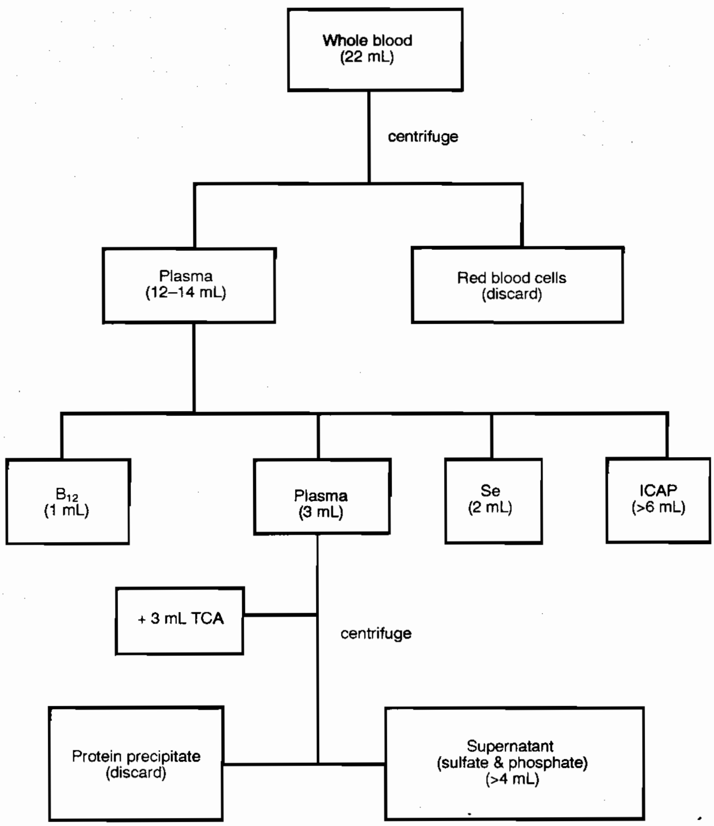

Figure 2. Flow chart for collection and processing of blood samples prior to analysis.

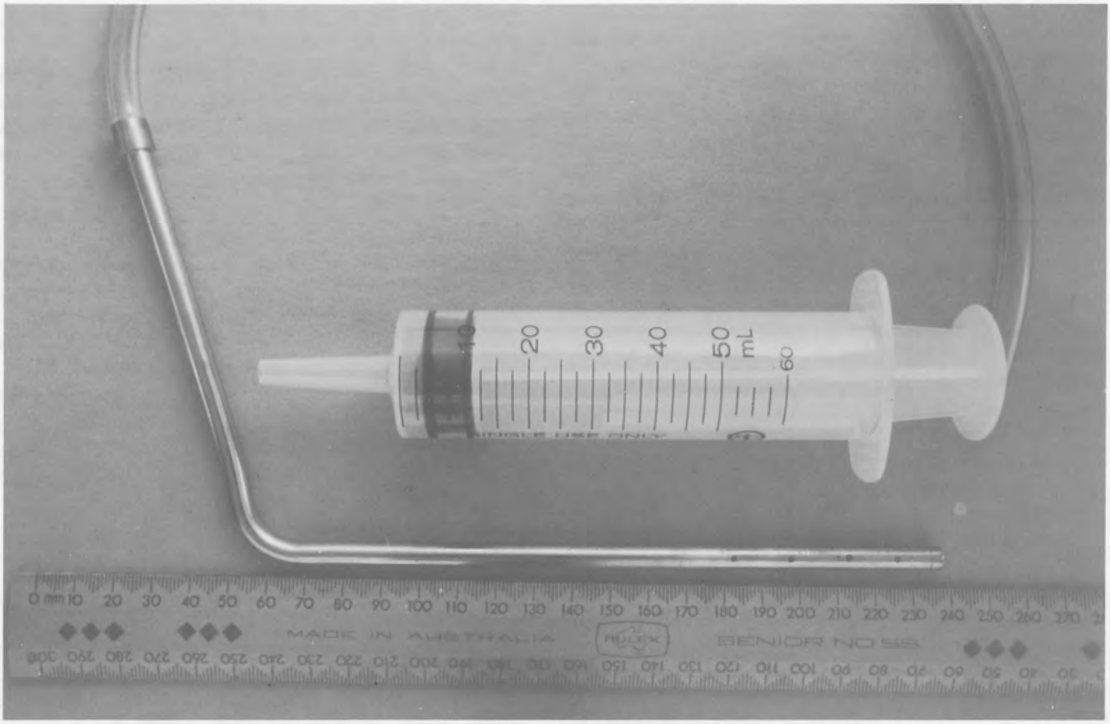

Figure 3. Apparatus used to collect parotid saliva from sheep.

Faeces

Samples (5–10 g) of fresh faeces were collected directly from the rectum at the time of blood sampling and stored cold. On return to the laboratory, samples were oven-dried and ground through a 1-mm screen.

Tissue samples

Tissues were collected from freshly slaughtered sheep in late autumn (October–November) and stored frozen as above.

Analytical Methods

Mineral elements

Plasma, tissue and faeces samples were wet-digested using a mixture of nitric and perchloric acids (8:0.6 mL) prior to mineral analysis.

Copper in diluted plasma, and sodium and potassium in diluted saliva samples were analysed by atomic absorption spectrometry (AAS model 3030B, Perkin Elmer).

Calcium, magnesium, iron, sodium, potassium and phosphorus in all digests, and molybdenum, copper and zinc in tissues and faeces were analysed using an Inductively Coupled Argon Plasma analyser (ICAP 9000, Jarrell-Ash Division of Fisher Scientific Co.).

Selenium was estimated using a spectrofluorimetric method described by Watkinson (1979).

Iodine in milk was estimated electrochemically as iodide, using an ion-specific electrode and meter (TPS Pty Ltd, Brisbane, Australia). Both milk samples and aqueous potassium iodide standard solutions were diluted with an equal volume of 2 g/L potassium nitrate solution to ensure that the ionic strength of the solutions measured was constant. The instrument was standardised using solutions containing 0.4 and 4 μmol/L of iodide; the logarithmic circuitry of the instrument ensured that the response to iodide ion was linear from 0.4 to 8 μmol/L.

Inorganic sulfur (sulfate-S) in plasma was estimated using an auto-analyser method developed by the University of Missouri (Technicon 1980). Plasma, deproteinised with an equal volume of 10% TCA, was mixed with an acidic gum arabic solution containing barium chloride. The resulting barium sulfate was held in suspension by the viscous gum arabic solution and the turbidity measured at 420 nm wavelength. The analytical system was washed with an alkaline EDTA solution between samples to prevent a build-up of barium sulfate precipitate. The concentration of sulfate-S in plasma was estimated by reference to a set of potassium sulfate standards in the range 0–1.25 mmol S/L, and results calculated using a computer program with a logarithmic transformation of the absorbance data.

Inorganic phosphorus (phosphate, Pi) in plasma was estimated with an auto-analyser method using a solution of ammonium molybdate and antimony potassium tartrate (Mo/Sb reagent) (Technicon 1978). Deproteinised plasma, as described above, was mixed with the Mo/Sb reagent, reduced with ascorbic acid, and the intense blue colour developed in a heating coil at 37°C. The colour intensity was read in the colorimeter unit at 660 nm. The concentration of Pi in the plasma was estimated with reference to a set of standards in the range 0.05–2.4 mmol P/L. The colour response of the standards was linear over this range.

Vitamin B_{12} analysis

Vitamin B_{12} in plasma was estimated using a microbial assay with *Euglena gracilis*. *E. gracilis*, Z strain was grown in a synthetic medium with added plasma as the sole vitamin B_{12} source. At the end of a 5-day incubation period the turbidity of the solutions was measured and the B_{12} concentration in the plasma estimated by reference to turbidity of a set of standards containing 0–1000 pmol/L cyanocobalamin.

The inoculates were incubated in a controlled temperature environment with bright white light (approx. 160 w/m^2) supplied by white fluorescent tubes. A white translucent cover was fitted over the fluorescent tube to ensure an even distribution of light intensity throughout the box.

The standard curve obtained was adequately described by a quadratic equation, and a limited extrapolation (up to about 1500 pmol/L) of the data was used. It should be noted that these values between 1000 and 1500 pmol/L are less reliable than estimates in the range 45–1000 pmol/L.

Sheep having vitamin B_{12} levels in plasma of less than 200 pmol/L are considered to be cobalt-deficient; levels in the range of 200–400 pmol/L are marginal while those above 400 pmol/L are considered normal.

Validation of methods

Assayed multi-sera-low (Random Laboratories, Ardmore, UK) and bovine liver (NBS certified standard reference material #1577a) were used as quality control samples for ICAP analysis and the results are shown in Figure 4.

In general, the results of analysis were within ±10% of the expected values, although the discrepancy for molybdenum in liver was +19%. These results indicate that the methodology used is adequate for detecting gross deficiencies from biological samples.

The performance of the iodide electrode and meter was checked by preparing sets of iodide standards prepared either in water or in a sample of ewe's milk. The results are shown in Figure 5. The concentration lines for iodide in water and milk were linear and parallel over the measurement range. Extrapolation of the standard curve, generated from standard additions to milk, indicated a concentration of iodine in milk of 1.7 µmol/L (Figure 5). This was in good agreement with the independently measured value of the bulk milk sample of 1.8 µmol/L.

Stability of samples

Because most of the farms used in this study were in remote areas and thus distant from both regional laboratories and the main laboratory in Beijing, it was necessary to check that samples did not deteriorate during transport or storage and that the measured values were an accurate indication of the actual values at the time of sampling.

The stability of these samples was investigated by analysing milk and plasma stored in the refrigerator (4°C) or at ambient temperature (approx. 20°C) for periods of 1–7 days. Deproteinisation of plasma samples with 10% TCA for Pi and sulfate-S analysis were carried out after the indicated storage time.

The iodide content of milk increased from an initial value of 1.84 µmol/L to 2.25 µmol/L after 4 days storage and had a value of 2.16 µmol/L at day 7 (Figure 6). However, this change was not statistically significant and as the level indicating an iodine deficiency is around 0.6 µmol/L, the 20% variation observed is unlikely to be important in distinguishing between adequate and deficient levels of iodine in milk samples.

There was no change in the vitamin B_{12} content of plasma (Figure 7) stored at 4°C for up to 7 days, and even at room temperature (approx. 20°C) the change from 2680 to 2930 pmol/L was only 9% over 7 days.

Both Pi (Figure 8) and sulfate-S (Figure 9) levels remained constant with time on storage over 7 days and had measured coefficients of variation of 4% and 9% respectively.

For all of the analytical techniques used in these studies, results obtained after sample storage for a period of up to 7 days would accurately reflect the actual concentration of analytes.

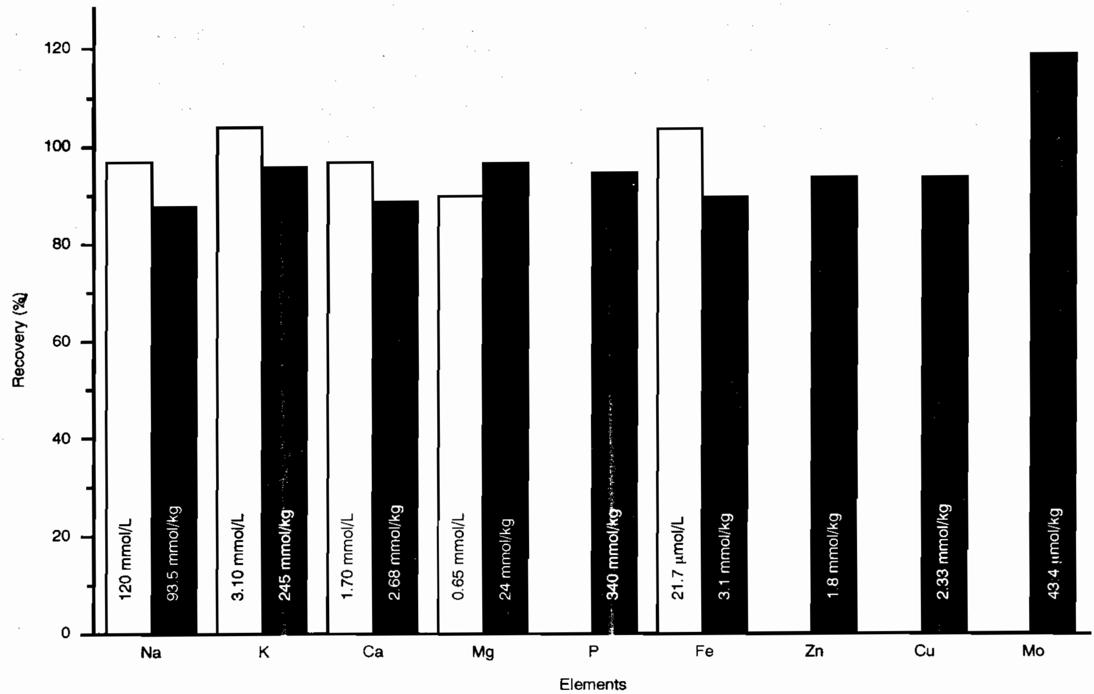

Figure 4. Recovery of elements, analysed using Inductively Coupled Argon Plasma Analyser, from plasma (open bars) and liver (solid bars) of known concentration. Observed concentrations are shown within the bars.

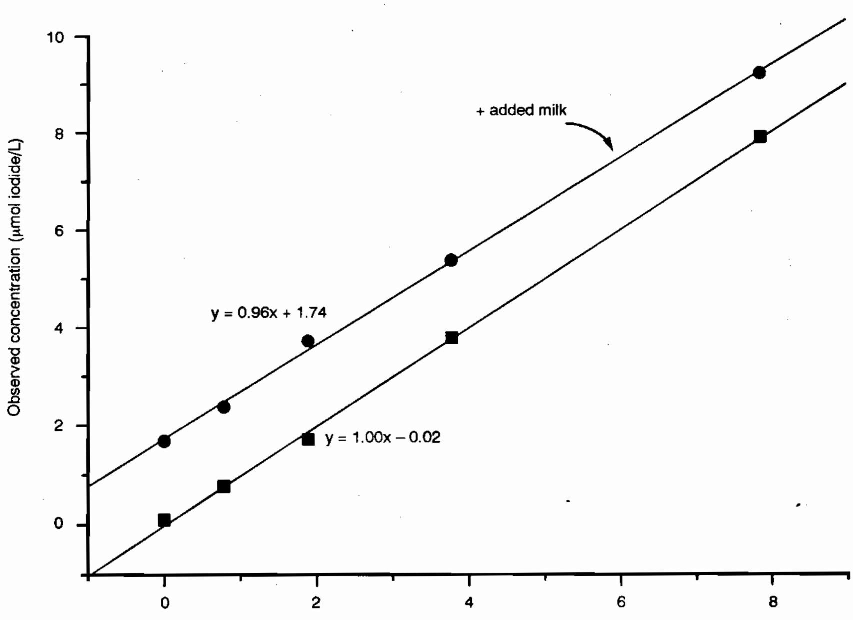

Figure 5. Concentrations of iodide standards prepared in milk (●) or in water (■).

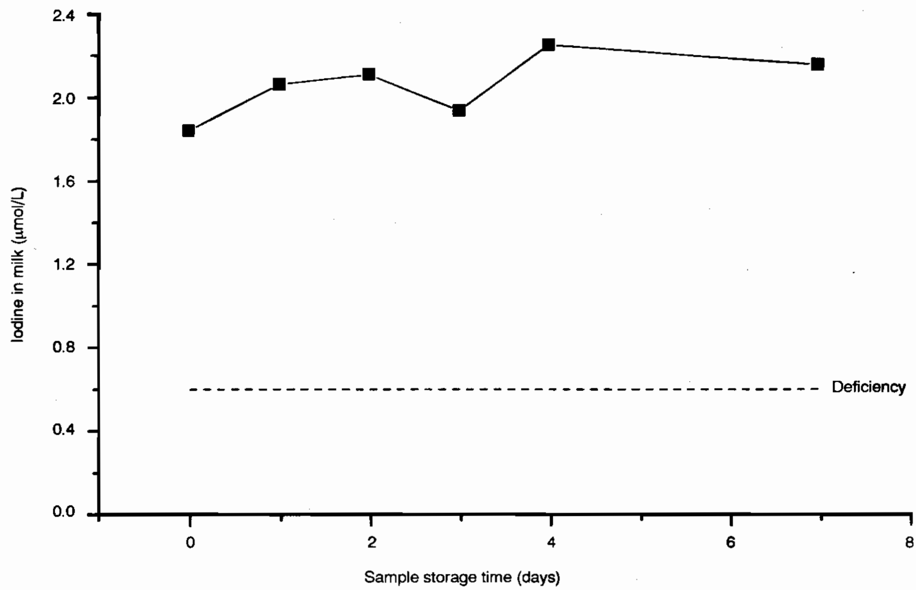

Figure 6. Concentration of iodide in a milk sample after storage in the refrigerator for 1–7 days. Values less than 0.6 µmol/L indicate iodine deficiency.

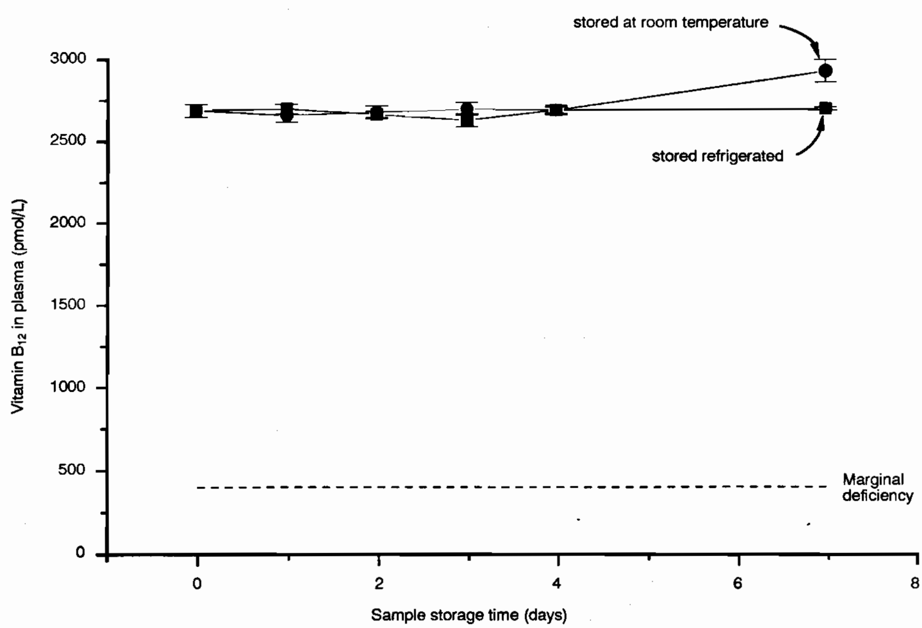

Figure 7. Concentration of vitamin B_{12} in plasma after storage in the refrigerator (■) or at room temperature (●) for 1–7 days. Values less than 400 pmol/L indicate cobalt deficiency.

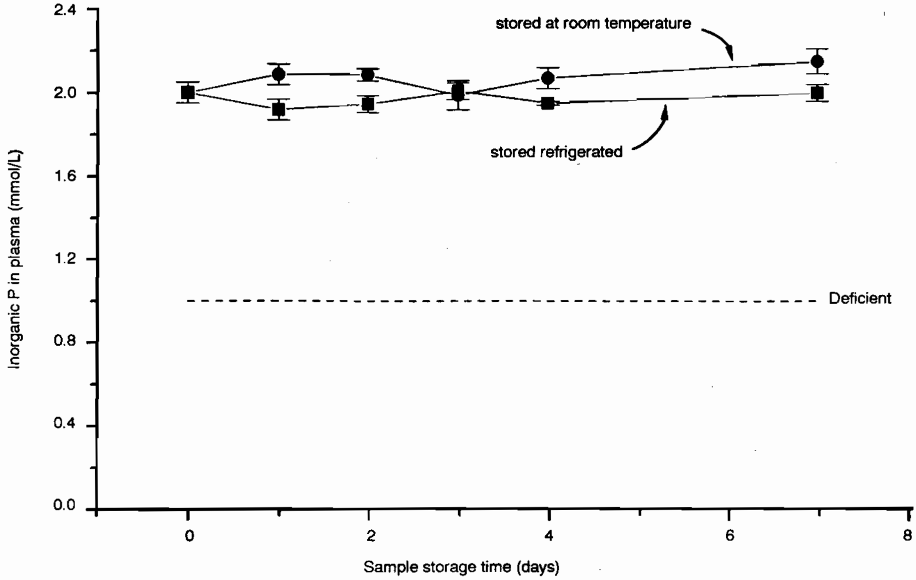

Figure 8. Concentration of inorganic phosphorus in plasma after storage in the refrigerator (■) or at room temperature (●) for 1–7 days. Values less than 0.9 mmol/L indicate phosphorus deficiency.

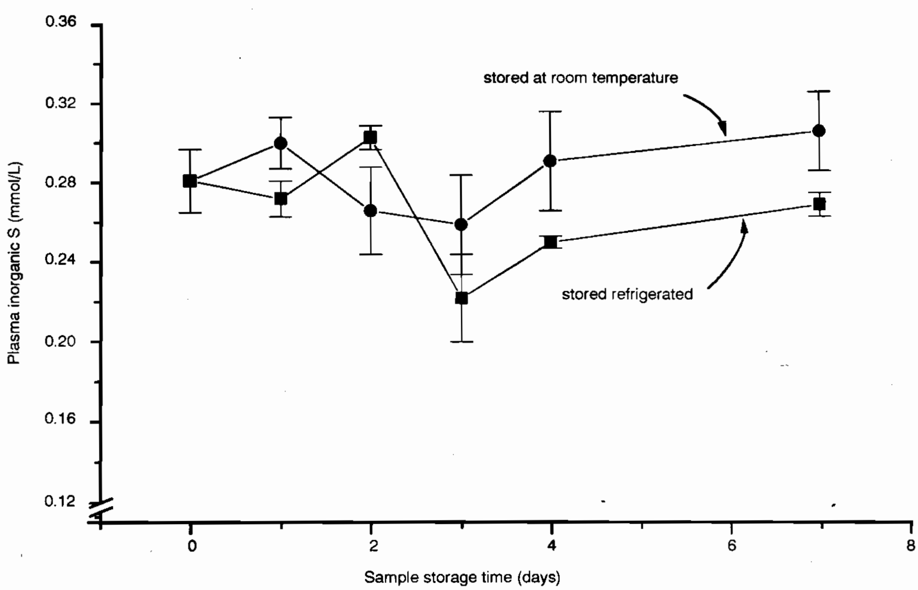

Figure 9. Concentration of inorganic sulfur in plasma after storage in the refrigerator (■) or at room temperature (●) for 1–7 days. Values less than 0.6 mmol/L indicate sulfur deficiency.

Mineral Status of Grazing Sheep and Supplementation Experiments

Sodium, potassium and magnesium

The most reliable indicator of sodium status of ruminants is the ratio of sodium to potassium in parotid saliva. A ratio of less than 10:1, on a molar equivalent basis, is an indication of potential responsiveness to sodium supplementation (Langlands 1987), although others have suggested that a ratio of 4:1 is needed to indicate an incipient sodium deficiency (McSweeney et al. 1988). Morris and Peterson (1975) suggested that a ratio of over 30:1 is needed to indicate sodium adequacy in reproducing ewes. Sodium:potassium was at or below 10:1 for part of the year in Balinyou and Honggetala farms in Inner Mongolia, Tianzhu farm in Gansu, Sanjiaocheng and Heka farms in Qinghai and Bazhou and Tacheng farms in Xinjiang (Table 3). However, only at Balinyou and Tianzhu, in summer, did the ratio fall below 4:1.

The concentration of sodium in faeces was below that reported in sodium-deficient cattle (1400 mg/kg, Murphy and Gartner 1974) at a number of farms for all or part of the year (Table 3). Consistent with the results for saliva, sheep from Balinyou were the lowest in faecal sodium with a concentration of 264 mg/kg dry matter (DM) in summer.

A lack of sodium will result in reduced feed intake, weight loss and abnormal appetite. Deficiencies of sodium have been recognised in China and some salt supplements are usually provided to grazing sheep. These supplements are often not fed during summer because of the difficulty with transport to the elevated summer pastures and the perception that the lush green pastures available at this time supply all necessary nutrients. The results indicate that a lack of sodium may be a problem, even though some salt is fed. However, responses in sheep remain to be established under grazing conditions. Masters et al. (1993) described habitual soil consumption, a sign of sodium deficiency, on one farm in northern China. However, in pen studies, Vincent et al. (1986) reported that milk production and lamb growth were unaffected by sodium deficiency even after 2 years of sodium depletion. Similarly, Morris and Peterson (1975) reported that even when ewes were fed only 10% (200 mg/kg DM) of the NRC recommended level for sodium, and at sodium: potassium ratios below 10:1, there was no effect on feed intake, lamb growth or milk production. It may be that a prolonged period of sodium depletion is required before responses are seen and that the poor overall nutrition and production of Chinese sheep, together with intermittent salt supplements, will mask responses to supplementation. This hypothesis needs to be tested under grazing conditions. Secondary effects of low sodium intake such as soil consumption and increased susceptibility to magnesium deficiency, however, may affect productivity indirectly by causing excessive intake of iron or other elements contained in soil or by an increased incidence of grass tetany.

The normal range of magnesium in plasma is 0.8–1.3 mmol/L (Suttle and Field 1969; Langlands 1987). Concentrations of magnesium in plasma on a number of farms were between 0.6 and 0.8 mmol/L during spring, and a mean concentration of 0.25 mmol/L was measured in sheep from Gaolintun farm in winter (Table 4). Clinical signs of magnesium deficiency (grass tetany) have been observed when magnesium in plasma falls below 0.4 mmol/L (Suttle and Field 1969). Winter and spring coincide with lactation and at this time demand for magnesium and the expected incidence of grass tetany are increased.

Magnesium in faeces ranged from 2700 mg/kg DM to over 10 000 mg/kg DM (Table 4). In previous research in China, the concentration of magnesium in faeces was approximately 2–3 times higher than the concentrations in pasture (Lu et al. 1995). Therefore the lowest concentrations of magnesium in faeces were consistent with intakes of 1000–1500 mg/kg DM. The dietary magnesium requirement for lactating ewes is 1200 mg/kg DM (Minson 1990). However, it is the total amount of magnesium that is consumed and absorbed that is important (Grace 1983). In China during winter and spring, pasture and feed availability are inadequate to maintain liveweight (Masters et al. 1990) and this may result in insufficient intakes of magnesium during late pregnancy and lactation. In addition, a number of other factors are involved in magnesium absorption — in particular, high intakes of potassium together with low sodium (Suttle and Field 1969) depress absorption of magnesium from the rumen and increase the risk of grass tetany. High concentration of potassium in the rumen may result from high potassium in the diet and/or a low dietary sodium intake causing increased potassium secretion in saliva.

Potassium concentrations in plasma were always above the range reported for deficient sheep (2.5–4.1 mmol/L), (Telle et al. 1964; Campbell and Roberts 1965) (Table 3), indicating that pasture and supplementary feeds were providing sufficient potassium at all times. High intakes of potassium may present more of a problem. High potassium intakes depress sodium (Campbell and Roberts 1965) and magnesium (Suttle and Field 1969) absorption from the rumen.

Table 3. The ratio of sodium to potassium in saliva, sodium in faeces and potassium in plasma during spring, summer, autumn and winter, on 15 farms in northern China.

Province/Farm	Sodium:potassium ratio in saliva (mM/mM)				Sodium in faeces (mg/kg DM)				Potassium in plasma (mmol/L)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gansu												
Sunan	14.1	14.3	14.2	17.4	1589	1381	1500	1013	5.4	5.5	5.9	5.6
Tianzhu	28.9	3.9	13.6	20.0	3335	914	2539	1241	5.4	5.5	6.0	210
Shandan	18.8	14.3	19.8	16.5	4653	1651	2892	2123	5.7	5.5	5.9	5.8
Qinghai												
Sanjioacheng	18.5	4.4	33.1	24.1	1264	510	1768	930	6.1	5.9	6.0	6.4
Heka	12.9	5.7	27.6	13.6	669	670	932	562	5.0	5.9	5.9	5.9
Xinjiang												
Altai	73.7	14.7	19.1	42.4	2536	1054	1655	3007	5.2	5.4	6.2	5.8
Baicheng	12.9	16.1	13.0	20.8	1651	3753	1068	2563	5.7	6.4	5.5	6.9
Bazhou	14.3	15.3	12.4	9.5	660	2899	4344	1734	5.6	5.8	5.8	4.5
Gongnaishi	18.2	12.7	15.6	14.8	1673	1228	3004	1585	5.3	5.9	5.7	5.1
Tacheng	84.4	10.2	11.5	34.1	1222	2184	5312	1257	5.1	5.7	6.1	5.3
Inner Mongolia												
Balinyou	35.7	1.7	4.8	7.6	1671	264	434	441	5.3	5.1	6.0	4.8
Tonghetai	23.0	29.7	77.1	24.7	2586	2460	1459	1512	5.3	5.7	6.3	5.7
Honggetala	31.2	6.2	34.3	31.0	1938	389	1992	1253	5.6	5.6	5.5	5.6
Wuyi	16.1	38.6	19.2	26.2	526	1225	1734	770	5.4	4.8	6.1	5.7
Gaolintun	48.0	34.5	57.0	17.1	2336	1905	1203	2152	4.4	5.4	4.6	5.4

Table 4. Magnesium in plasma and faeces of sheep from 15 farms in northern China.

Province/Farm	Magnesium in plasma (mmol/L)				Magnesium in faeces (mg/kg DM)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gansu								
Sunan	0.71	0.92	1.15	1.03	7238	8118	8344	7297
Tianzhu	0.79	1.0	1.05	0.88	8608	8778	5997	5418
Shandan	0.84	0.97	0.87	0.93	8579	14900	7900	11232
Qinghai								
Sanjioacheng	0.85	0.94	0.88	1.19	6561	3294	6510	9724
Heka	0.63	0.95	0.89	0.86	7093	6850	3980	4780
Xinjiang								
Altai	1.18	1.05	1.02	0.99	9371	10606	12040	3215
Baicheng	0.73	1.02	0.81	0.72	11449	4630	9451	6446
Bazhou	0.96	0.78	1.0	1.2	12650	6784	2352	8658
Gongnaishi	0.85	1.12	0.84	0.65	7733	7593	7733	8462
Tacheng	0.94	1.0	0.92	0.88	4876	6048	6131	3518
Inner Mongolia								
Balinyou	0.70	1.04	1.07	0.95	2728	5516	3755	3540
Tonghetai	0.63	0.87	1.05	0.83	3057	3661	7595	6494
Honggetala	0.91	0.92	0.95	0.92	5166	7326	7102	7374
Wuyi	0.85	0.99	1.2	1.06	4601	6056	3099	2982
Gaolintun	0.52	0.94	0.65	0.26	3560	9204	5706	4462

In summary, although salt supplements are fed routinely on many farms, sodium status is still low. Some improvements in productivity may occur with increased salt consumption, although further research is necessary to determine if the current strategies are adequate. Most importantly, any decrease in salt supplementation would result in prolonged sodium depletion and a severe sodium deficiency. Salt supplements should therefore be maintained or increased on the farms studied and introduced where they are not currently used. In the flat, semi-arid grazing regions in Inner Mongolia and possibly other farms, inclusion of magnesium in the salt during winter and spring may be necessary to avoid grass tetany.

Selenium

Langlands et al. (1991a,b,c) reported that concentrations of selenium in plasma of between 0.06 and 0.24 µmol/L were associated with deficiencies in reproducing ewes, and supplementation resulted in increased wool growth and fibre diameter, more lambs weaned and better liveweight gain of lambs. Langlands et al. (1991b) also observed some lamb deaths from muscular dystrophy at these plasma selenium levels. Concentrations within this range were observed at Heka farm in Qinghai Province (Table 5).

Recently it has been suggested that the critical concentration of selenium in plasma, necessary to support wool growth, is 0.5 µmol Se/L for breeding ewes and 0.25 µmol Se/L for non-breeding sheep (Langlands et al. 1994, Whelan et al. 1994). Based on these revised estimates of selenium requirements, sheep on all farms in Gansu (Sunan, Tianzhu and Shandan) and on Gongnaishi farm in Xinjiang also had inadequate selenium supply for part of the year. Selenium in plasma also approached the critical minimum concentration on a number of other farms in all provinces. Using the equations derived by Langlands et al. (1994) to describe the relationship between plasma selenium and wool growth on the data from Heka farm, a lack of selenium would have depressed clean wool growth by 100–200 g/year. In addition, a reduction in lamb growth and survival would be expected on this farm.

Concentrations of selenium in faeces supported the results of plasma analysis. More than half the selenium in the diet is excreted in the faeces (White and Somers 1977) and usually less than half of the dry matter ingested by the sheep is excreted. Therefore the concentration of selenium in faeces should be higher than the concentration in the ingested feed. Dietary requirements for selenium are estimated at between 0.03 and 0.05 mg/kg DM and on three farms the concentration of selenium in faeces was

Table 5. Selenium in plasma and faeces during spring, summer, autumn and winter, on 15 farms in northern China.

Province/Farm	Selenium in plasma (µmol/L)				Selenium in faeces (mg/kg)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gansu								
Sunan	0.37	0.24	0.36	0.47	0.106	0.061	0.072	0.075
Tianzhu	0.49	0.42	0.52	0.59	0.151	0.094	0.100	0.099
Shandan	0.59	0.38	0.62	0.85	—	—	—	—
Qinghai								
Sanjioacheng	0.62	0.57	0.82	0.72	0.092	0.043	0.081	0.076
Heka	0.11	0.14	0.10	0.61	0.033	0.034	0.024	0.045
Xinjiang								
Altai	1.29	0.71	1.38	0.62	0.222	0.051	0.152	0.084
Baicheng	0.95	0.82	1.19	1.06	0.296	0.072	0.139	0.133
Bazhou	1.83	0.62	1.87	1.77	0.604	0.037	0.476	0.316
Gongnaishi	1.33	0.39	0.62	1.14	0.127	0.067	0.205	0.152
Tacheng	0.89	0.68	1.82	1.06	0.141	0.104	0.250	0.123
Inner Mongolia								
Balinyou	0.61	0.94	1.13	0.77	0.080	0.084	0.310	0.070
Tonghetai	1.39	1.05	0.97	0.95	0.164	0.169	0.156	0.123
Honggetala	1.23	2.25	1.13	1.99	0.176	0.256	0.107	0.193
Wuyi	0.85	0.95	0.76	0.85	0.099	0.058	0.050	0.069
Gaolintun	1.39	1.06	1.40	1.01	0.105	0.228	0.300	0.140

below 0.05 mg/kg, indicating an inadequate intake of this element (Table 5). Also on 10 of the 15 farms the concentration of selenium in faeces was below 0.1 mg/kg for at least part of the year. These levels may also be consistent with a dietary selenium concentration of below 0.05 mg/kg.

As in previous studies in China and elsewhere, concentrations of selenium in plasma were usually lowest in summer and autumn, when pasture and animal growth are at their highest.

There have been previous reports of selenium deficiency in domestic animals and humans in China (Liu et al. 1987; Yu, these proceedings). Despite these reports there is not a widespread system for supplementation with selenium and only a limited awareness on farms by the animal managers that selenium deficiency may significantly depress productivity. The results indicate that regular supplementation with selenium in many parts of China, but particularly in the alpine regions of Gansu and Qinghai, will improve productivity of grazing sheep. Selenium should be provided routinely to ewes as a low-cost component of feed concentrates and salt supplements.

The selenium requirement for young growing sheep is higher than for adults and, where measurements of selenium status have been made on young sheep and adults on the same farm, young sheep are lower in selenium and more likely to have depressed liveweight gain and wool growth (Masters et al. 1995, Yu et al. 1995). For this reason, lambs should be provided with selenium, prior to grazing summer pastures, on all farms studied in Gansu, Qinghai and Xinjiang.

Iodine in milk

Lactating ewes secrete a significant amount of ingested iodine in milk. When lambs have been born with iodine deficiency, the concentration of iodine in milk is usually less than 0.6 μmol/L (Hosking et al. 1986). There was a wide range of iodine concentrations in the milk samples collected in China (Figure 10). The lowest concentration, at Wuyi farm in Inner Mongolia (0.55 μmol/L), indicates an iodine deficiency. At two other farms, Tonghetai in Inner Mongolia (0.71 μmol/L) and Sanjiaocheng in Qinghai (0.76 μmol/L) the concentrations in milk approached the deficient level. On these farms a lack of iodine may depress wool production, milk production, reproductive performance and lamb survival. Addition of iodine to feed or salt supplements is inexpensive and should be carried out routinely on the farms with low concentrations of iodine in milk, or where there is evidence of iodine deficiency in the human population.

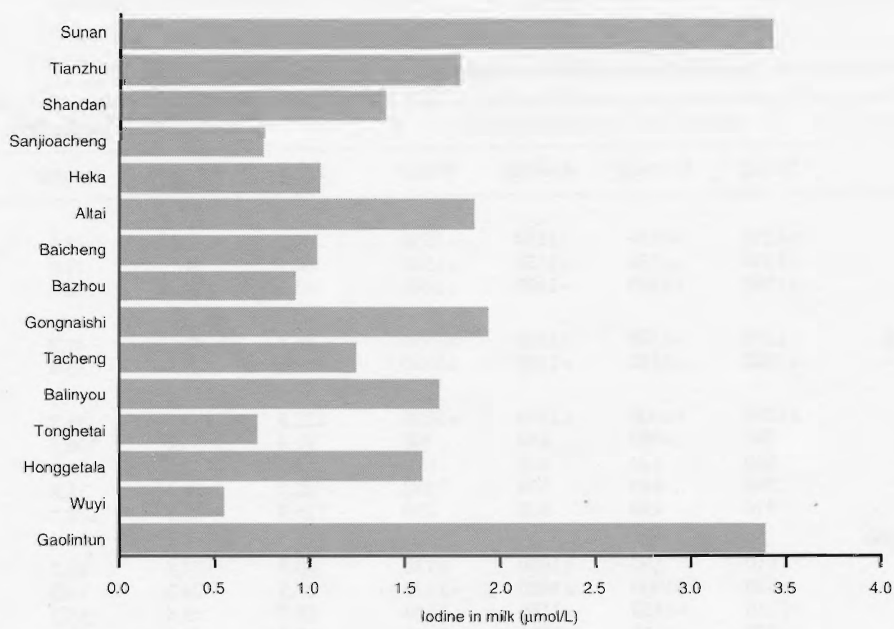

Figure 10. Iodine in ewe's milk from 15 farms in northern China.

The identification of a biological interaction between selenium and iodine (Arthur et al. 1990) is of relevance to this project. A lack of selenium depresses the conversion of T_4 (thyroxine) to T_3 (3,5,3'-tri-iodothyronine) and results in a significant depression in plasma T_3 and an increase in plasma T_4, even in ewes and lambs consuming adequate iodine (Donald et al. 1993). Selenium deficiency may therefore exacerbate an iodine deficiency. On Wuyi, Heka, Sanjiaocheng and possibly Tonghetai farms, both selenium and iodine statuses were low. Sanjioacheng farm is of particular interest. On this farm even though some selenium is provided to ewes, mixed with feed concentrates, selenium status was low. Young growing sheep are not given selenium supplements and would be expected to have selenium levels similar to those observed at Heka farm. As iodine was also low on Sanjioacheng the possibility of an interaction between the two elements affecting lamb growth and survival is high.

Vitamin B_{12} in plasma

Cobalt deficiency results in a depression in production of vitamin B_{12} in the rumen. Measurement of vitamin B_{12} in plasma and liver is used as an indicator of cobalt status. Concentrations of vitamin B_{12} in plasma of below 200 pmol/L indicate a deficiency of cobalt in feedstuffs, while concentrations above 400 pmol/L are considered normal. Concentrations between 200 and 400 pmol/L are marginal and some responses may be expected (Judson et al. 1987). In the analysis of samples collected at the 15 farms in China, plasma from 5 of the 20 experimental sheep, at each sampling time, were analysed for vitamin B_{12}. Subject to these results, further analysis was to be carried out if deficiencies appeared likely. In addition, the assay used was established to measure concentrations accurately up to approximately 1100 pmol/L. As this is well above deficiency levels, no attempt was made to dilute samples and re-analyse to obtain accurate concentrations where initial concentrations were above 740 pmol/L.

On most farms the concentrations of vitamin B_{12} in plasma were above the range measured by the assay and therefore well in excess of the deficient level (Table 6). On Bazhou, Gongnaishi and Tacheng in Xinjiang the lowest seasonal means approached the lower level of the normal range (400 pmol/L) and some individual sheep were below this concentration. These high vitamin B_{12} concentrations may be due to high levels of cobalt in pastures or to soil consumption. Lack of sodium and low pasture availability both cause an increase in soil intake. Others have shown that soil consumption increases cobalt status of sheep. Some further research in Xinjiang may be justified to determine if there are responses to cobalt. In addition, the possibility of cobalt deficiency would be increased if pasture productivity and sheep growth were increased by improved sheep husbandry techniques.

Table 6. Vitamin B_{12} in plasma and zinc in faeces of sheep from 15 farms in northern China.

Province/Farm	Vitamin B_{12} in plasma (pmol/L)				Zinc in faeces (mg/kg DM)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gansu								
Sunan	>1250	>1310	>1550	>1550	64.7	65.4	43.4	34.3
Tianzhu	>1550	>1550	>1550	>1550	84.7	86.5	71.0	56.4
Shandan	>1300	>1360	>1490	>1440	63.8	61.0	36.4	46.0
Qinghai								
Sanjioacheng	>1550	>1200	>1550	>1550	56.4	80.2	41.7	48.3
Heka	>1400	>1450	>1370	>1350	65.8	79.8	33.6	40.6
Xinjiang								
Altai	>1190	>1000	>1310	>1150	122.8	115.7	35.8	47.9
Baicheng	760	>980	660	700	91.4	54.0	106.5	61.9
Bazhou	660	520	830	610	88.3	57.4	39.7	34.7
Gongnaishi	590	440	570	780	82.1	88.6	32.8	61.2
Tacheng	470	450	930	490	126.9	81.0	108.3	72.9
Inner Mongolia								
Balinyou	810	560	>1080	>930	40.9	77.4	42.7	38.3
Tonghetai	>880	>1000	>1090	>1120	27.8	24.3	18.0	25.8
Honggetala	>1110	>1150	>1150	>1120	33.7	48.4	33.2	38.1
Wuyi	>1070	>1110	>1080	>1080	65.0	62.3	56.0	48.9
Gaolintun	>1150	>1150	>1150	>1150	55.9	60.7	58.8	43.5

Phosphorus and sulfur

The normal range for inorganic sulfur (sulfate-S) in plasma is 0.6–1.25 mmol/L (Jones et al. 1982) and for inorganic phosphorus (Pi) in plasma is 1–2 mmol/L. Jones et al. (1982) reported that sulfate-S in blood was related to sulfate-S in forage and average daily gain in sheep. Daily gain was depressed at sulfate-S concentrations below 0.9 mmol/L. In these experiments however, sulfur intakes were increased by fertilizer application to pastures. Under such circumstances other characteristics of pasture, such as the content of sulfur amino acids, may also have changed and affected liveweight gain. Responses to inorganic sulfur supplements, provided directly to the sheep, have been inconsistent. Peter et al. (1987) reported that providing sulfur to sheep grazing low quality dry pasture increased liveweight gain and wool growth. Doyle et al. (1992) did not detect any response to sulfur in young grazing sheep, even when sulfate-S declined to 0.25 mmol/L. Provision of sulfur will increase digestibility of feed and protein production by microorganisms in the rumen, but only if the sulfur concentration in the feed is very low (probably <1 g/kg) and a source of soluble nitrogen is available (Hume and Bird 1970).

In China, the sulfate-S concentration in plasma fell below 0.6 mmol/L at Sunan in Gansu, Bazhou in Xinjiang and Balinyou, Honggetala and Wuyi in Inner Mongolia. This usually occurred in autumn or winter when pastures were drying off or dead. Under such conditions supplements of sulfur may improve the utilisation of the pasture consumed, particularly if supplied with a source of soluble nitrogen such as urea. Sheep at Sunan and Shandan in Gansu, Heka in Qinghai, Altai and Bazhou in Xinjiang and Balinyou, Wuyi and Gaolintun in Inner Mongolia all had sulfate-S in plasma below 0.9 mmol/L in summer and/or autumn (Table 7). This indicates that even green pasture contained low concentrations of sulfur and a possible sulfur deficiency for plant growth. Further research is needed to establish if sheep would respond to inorganic sulfur or if the use of sulfur-containing fertilizer would be a more profitable option.

Pi in plasma in the Chinese farms studied ranged from 0.55 to 1.77 mmol/L (Table 7). There was no clear pattern relating Pi either to location or season. However, Pi tended to be higher in summer when sheep were consuming green feed. Little et al. (1978) reported that a concentration of Pi below 0.6 mmol/L is accompanied by a depletion of phosphorus reserves in bone, without causing any affect on reproductive performance. Read et al. (1986) reported that concentrations of Pi of less than 0.65 mmol/L were associated with depressed liveweight and feed intake in grazing sheep. Of relevance to the

Table 7. Sulfur (as sulfate) and phosphorus (as phosphate) in plasma of sheep from 15 farms in northern China.

Province/Farm	Sulfur as sulfate in plasma (mmol/L)				Phosphorus as phosphate in plasma (mmol/L)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gansu								
Sunan	1.0	—	0.47	0.47	1.42	—	0.90	0.84
Tianzhu	1.50	1.48	0.94	1.13	1.22	1.48	1.48	1.74
Shandan	1.41	0.69	1.16	1.66	1.29	1.45	1.22	1.29
Qinghai								
Sanjioacheng	2.09	1.50	1.19	1.56	0.94	1.16	0.81	1.94
Heka	1.13	1.75	0.69	0.91	1.10	1.41	1.16	1.10
Xinjiang								
Altai	1.84	0.72	1.28	1.03	1.45	1.55	0.58	1.45
Baicheng	2.0	2.06	1.09	1.47	1.16	1.45	0.96	1.06
Bazhou	1.59	0.43	1.50	1.09	1.03	1.68	0.77	1.16
Gongnaishi	1.47	—	1.62	0.84	0.96	—	1.26	1.10
Tacheng	2.65	3.03	3.25	2.53	0.74	0.87	0.94	1.00
Inner Mongolia								
Balinyou	0.75	1.50	0.38	0.25	0.55	1.00	1.19	0.84
Tonghetai	0.72	1.41	1.00	0.78	1.48	1.35	1.74	1.77
Honggetala	1.13	1.63	0.53	0.94	1.32	1.55	1.45	1.29
Wuyi	1.13	0.65	0.31	0.44	1.29	1.74	1.65	1.52
Gaolintun	1.09	1.03	1.00	0.41	1.19	1.41	1.35	1.35

current results, McMeniman and Little (1974) reported that, in reproducing ewes with a Pi concentration of between 0.65 and 1.0 mmol/L, wool and liveweight responses to phosphorus supplements only resulted when an additional energy supplement (molasses) was fed at the same time.

The reproducing ewes on a number of Chinese farms would have been depleting phosphorus stores at some times of the year; however, it is likely these stores were replenished during the summer when phosphorus status was increased. Given the low intakes of protein and digestible organic matter for much of the year in China (Lu, these proceedings) responses to phosphorus alone would not be expected. Where additional sources of crude protein or energy are supplied to sheep these usually also contain phosphorus (as occurs with cereal grain supplements); if they do not, a phosphorus supplement may be needed.

Copper, molybdenum and iron

Copper deficiency is indicated by a copper concentration in plasma of <4.7 µmol/L, adequate concentrations are >7.9 µmol/L and values in between are marginal (Judson et al. 1987). At Sanjioacheng in summer values approached the deficiency level (Table 8). The low copper status of sheep on this farm was supported by low copper levels in the liver. The mean (±sem) concentration in the liver of five non-experimental sheep slaughtered on the farm was 102 (±0.5) µmol/kg fresh weight. The deficient concentration is below 80 µmol/kg (Paynter 1987), although clinical signs of copper deficiency have been observed at concentrations between 125 and 220 (Hogan et al. 1971). Sheep on other farms did not have low copper concentrations in plasma although copper in liver at Heka (236 µmol/kg wet weight) and Tacheng (126 µmol/kg wet weight) indicated a marginal copper status on these farms. On other farms copper in the liver ranged from 315 to 2900 µmol/kg wet weight.

The cause of low copper status of sheep on some farms is likely to be due to a reduction in copper absorption caused by high intakes of molybdenum and/or iron, rather than a low copper intake. In ruminants, the major route of excretion of copper and molybdenum is via the faeces (see Davis and Mertz 1987; Mills and Davis 1987), therefore the ratio of copper to molybdenum in faeces reflects the concentrations and ratios of these two elements in feed. The variability in copper absorption means that the copper:molybdenum ratio in faeces is likely to be higher than the actual ratio in pasture and therefore may underestimate the extent of the interaction between the elements. Suttle (1981) reported that increasing molybdenum in forage from 1 to 4 mg/kg

Table 8. Copper in plasma, copper:molybdenum in faeces and iron in faeces of sheep from 15 farms in northern China.

Province/Farm	Copper in plasma (µmol/L)				Copper:molybdenum in faeces (mg:mg)				Iron in faeces (mg/kg DM)			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
Gansu												
Sunan	15.9	22.0	19.4	14.5	2.02	2.26	2.05	1.64	9173	3785	7053	6265
Tianzhu	10.7	20.3	17.5	17.0	1.94	2.11	2.82	1.73	10617	9763	5458	8318
Shandan	11.2	17.5	20.0	16.1	2.88	2.65	3.20	2.90	6726	7775	6547	5967
Qinghai												
Sanjioacheng	8.5	5.8	11.2	9.8	1.55	2.96	1.38	1.31	8331	1187	6503	3205
Heka	17.6	20.3	17.2	16.7	2.82	2.48	1.37	1.28	6868	3969	4759	6808
Xinjiang												
Altai	16.7	17.6	20.8	12.9	3.03	10.40	2.50	3.26	4876	838	2941	3486
Baicheng	15.1	16.2	18.6	13.9	4.91	3.22	3.28	2.48	5117	2148	3687	4179
Bazhou	13.2	17.0	15.6	14.8	3.52	2.95	4.48	6.22	3695	2589	1235	1961
Gongnaishi	17.8	18.4	19.1	11.7	4.17	5.32	3.18	1.45	3772	1782	3474	14057
Tacheng	16.5	17.6	13.9	24.4	7.47	2.71	9.82	4.08	1351	1014	481	2476
Inner Mongolia												
Balinyou	15.7	20.0	17.2	12.9	1.59	3.71	4.22	2.19	4683	2421	1315	2127
Tonghetai	15.0	16.5	20.8	17.2	4.77	2.30	2.08	3.18	599	2017	3214	1290
Honggetala	15.7	20.0	20.2	18.7	2.88	2.41	1.37	2.30	4039	8182	8301	5071
Wuyi	16.9	20.0	17.2	15.7	2.57	4.36	4.44	2.94	526	1225	2785	4949
Gaolintun	14.5	12.1	20.5	17.0	4.66	4.46	2.24	1.79	491	217	3056	3155

DM decreases copper availability by approximately 60% and that copper:molybdenum ratios of less than 2:1 were associated with a decline in copper absorption and in some cases copper depletion. The ratio of copper:molybdenum in faeces was higher than 2:1 on most farms in most seasons. Lowest concentrations were at Sanjioacheng and Heka farms where copper:molybdenum was below 2:1 more frequently than any other farms (Table 8).

The high concentrations of iron in faeces result from high iron in pasture and/or consumption of soil and are consistent with iron intakes of 100 times requirement (Yu et al. 1995). A lack of pasture and a deficiency of sodium both cause increases in soil intake. Consumption of high iron in pasture or soil has been shown to reduce the copper status of sheep (Suttle et al. 1984). High intakes of iron not only increase the susceptibility of sheep to copper deficiency but may depress production directly. Intakes of iron of 40 times requirement depress rate of liveweight gain and efficiency of feed conversion (Wang 1995).

As with selenium, copper supplements should be provided as a component of any feed concentrate or salt supplement used on the farms in Qinghai. There was no clear evidence that copper was required on other farms. However, results from previous research (Yu et al. 1995) show that copper deficiency is a potential problem in Gansu.

Other elements

Under grazing conditions, with a range of pasture zinc concentrations, the concentration of zinc in faeces is 2–4 times the concentration in pasture (Masters 1982). Zinc requirements of grazing sheep are 20–30 mg/kg DM. In China the concentration of zinc in faeces ranged from 18 to 127 mg/kg DM. The lowest concentrations were measured at Balinyou, Tonghetai and Honggetala in Inner Mongolia (Table 6). The lowest concentrations are indicative of low zinc intakes and probable zinc deficiency in pasture plants. Under such conditions, increased reproductive performance has been reported in sheep supplemented with zinc (Masters and Fels 1980, 1985).

Most calcium is excreted in the faeces and, like zinc, faecal calcium can provide a simple guide to calcium intake. The calcium requirement of sheep is up to 3.2 g/d (1.5–2.6 mg/kg DM, SCA 1990). Calcium in faeces ranged from 11 to 34 g/kg DM — these levels of excretion indicate calcium intake was above requirements at all times.

Response trials

Based on the results of the survey of all farms, six farms were selected for further experimentation. Details of the farms, animals used and treatments for three of the farms are shown in Table 9.

Table 9. Farms, sheep and treatments of experiments in 1994–95.

Province/ Farm	Sheep classes	Treatments*		
		1	2	3
Qinghai				
Heka	Weaners	±Na, Zn, Co	±Se	±I
	Ewes	±Na, Mg, Zn, Co	±Se	±I
Inner Mongolia				
Balinyou	Ewes	±Na, Ca, S, Zn, Se, Co		
Wuyi	Ewes		±I	

* For treatment 1 all components were included in a loose mineral mix and fed to sheep once or twice per week. Comparisons made between similar flocks. Treatments 2 and 3 were given as pellets (Se) or injections (I); treatments were compared within flocks.

Heka farm

Experiments with ewes commenced in July 1994 and continued to July 1995. The flock of ewes receiving the loose mineral supplement (containing sodium (1.0 g/day), magnesium (0.6 g/day), zinc (30 mg/day) and cobalt (0.1 mg/day)) were significantly heavier than ewes receiving the standard farm supplements in September (36.5 vs 39.0 kg), December (37.8 vs 39.7 kg) but not July (30.8 vs 31.1 kg). By July, however, approximately 30% of the unsupplemented ewes were missing from the flock and may have died or been removed due to poor condition. Only 13% of the flock receiving the loose mineral supplement were missing. Ewes receiving selenium (intra-ruminal pellet) were significantly ($P<0.01$) heavier at the end of the experiment (July) than non-supplemented ewes, but the difference between the groups was only 0.9 kg (30.5 vs 31.4 kg). By July 1995 the ewes receiving only the farm supplements weighed 30.3 kg, while those receiving the loose mix together with selenium and iodine weighed 31.5 kg. The treatments had no effect on lamb birthweight or weaning weight, and birthweights (overall mean 2.9 kg) and weaning weights (overall mean 14.3 kg) were very low in all groups.

Weaner sheep given a loose mineral supplement (containing sodium (0.8 g/day), zinc (24 mg/day) and cobalt (0.08 mg/day)) were significantly lighter in December than weaners given farm supplement

(19.1 vs 18.2 kg, P<0.001) but significantly heavier by April (15.9 vs 16.5 kg, P<0.01). Weaners provided with iodine injections (1 mL iodised oil i.m., 475 mg I/mL) were heavier than untreated sheep in April (16.0 vs 16.4 kg, P<0.05). In April, the weaners receiving only the farm supplements weighed 16 kg while those receiving the loose mix together with selenium and iodine weighed 17 kg.

Early results from this farm indicated very low concentrations of a number of minerals and more clear-cut responses were expected. However, during the experimental period, the farm was affected by a severe drought. Liveweights of ewes and weaners and reproductive rates of all sheep were low and significant numbers of sheep died. Given the low status of a number of minerals in the sheep on this farm, continued research over a 3–5 year period is required to evaluate the benefits of mineral supplements.

Wuyi farm

Provision of iodine to ewes on Wuyi farm (1 mL iodised oil i.m., 475 mg I/mL) had no effect on ewe liveweight at any stage during the experiment. The pre-experimental liveweights (September 1994) of the groups were: iodine supplemented 52.6 kg and control 53.7, by the end of the experiment in June 1995, the corresponding weights were 55.7 kg and 55.4 kg. There was a trend towards more lambs born from the iodine-supplemented ewes (83 vs 78 lambs per 100 ewes mated). Lamb birthweights from the iodine-supplemented ewes were 4.56 (singles) and 3.37 (twins) kg and from the control flock were 4.54 (singles) and 3.35 (twins) kg. Accurate survival rates of lambs in the two groups could not be determined due to a policy of cross-fostering a twin with ewes that had lost a lamb.

Others have reported that in other seasonal environments, only the lambs born when green feed is available are susceptible to iodine deficiency (Hosking et al. 1986). Lambing at Wuyi farm is in March/April during the period when pasture is dead and no green feed is available. This may be why no effect of iodine was observed in the current experiment and why iodine deficiency is not commonly reported in livestock in China, even though it is a problem in the human population.

Balinyou farm

The sheep used in the experiment at Balinyou were maintained within one flock throughout the experiment. Twice each week the flock was split into the two separate experimental groups. A supplement containing sodium (1 g/day), calcium (1.4 g/day), sulfur (0.9 g/day), zinc (29 mg/day), selenium (0.16 mg/day) and cobalt (0.11 mg/day) was given to the treatment group. The experiment commenced in September 1994. At this time the treatment group weighed 52.2 kg and the control group 53 kg; by March the treatment group was slightly heavier than the control group (53.5 vs 51.5 kg, P<0.07) and significantly heavier at the end of the experiment in June (50.3 vs 49.0 kg, P<0.02). The treated sheep grew more greasy wool (7.4 vs 6.6 kg, P<0.01) and weaned a heavier group of lambs (23.5 vs 18.8 kg, P<0.01).

Conclusions

Analysis of a range of animal samples has indicated that sheep in some parts of China have low intakes of a number of essential minerals during the year. Based on experiences with mineral supplements in other areas of the world, the low mineral status would be expected to limit production of meat and wool. The responses to mineral supplements were smaller than expected, but these results were obtained from experiments in only one year. Further experiments are required over a number of years to quantify the benefits of using mineral supplements. These experiments will require close supervision, where they are conducted on commercial farms, to ensure adequate collection of data and reliable implementation of experimental programs.

Importantly, the low productivity on some of the farms in China would mask or depress the responses to minerals. Therefore any increase in production would exacerbate the effects of mineral deficiencies.

References

Arthur, J.R., Nicol, F. and Beckett, G.J. 1990. Hepatic iodothyronine 5'-deiodinase. The role of selenium. Biochemical Journal, 272, 537–540.

Campbell, L.D. and Roberts, W.K. 1965. The requirement and role of potassium in ovine nutrition. Canadian Journal of Animal Science, 45, 147–156.

Davis, G.K. and Mertz, W. 1987. Copper. In: Mertz, W., ed., Trace Elements in Human and Animal Nutrition, 5th edn, San Diego, Academic Press, 301–364.

Donald, G.E., Langlands, J.P., Bowles, J.E. and Smith, A.J. 1993. Subclinical selenium insufficiency 4. Effects of selenium, iodine, and thiocyanate supplementation of grazing ewes on their selenium and iodine status, and on the status and growth of their lambs. Australian Journal of Experimental Agriculture, 33, 411–416.

Doyle, P.T., Love, R.A., Dunlop, R.H. and White, C.L. 1992. Supplementation of young sheep with lupins plus sulfur and a complete mineral mix. Australian Journal of Experimental Agriculture, 32, 267–271.

Grace N.D. 1983. Magnesium. In: Grace N.D., ed., The Mineral Requirements of Grazing Ruminants. Occasional Publication No. 9, New Zealand Society of Animal Production, 92–99.

Hogan, K.G., Money, D.F.L., White, D.A. and Walker, R. 1971. Weight responses of young sheep to copper and connective tissue lesions associated with grazing of pastures of high molybdenum content. New Zealand Journal of Agricultural Research, 14, 687–701.

Hosking, W.J., Caple, I.W., Halpin, C.G., Brown, A.J., Paynter, D.I., Conley, D.N. and North-Coombes, P.L. 1986. Trace Elements for Pasture and Animals in Victoria. Melbourne, Department of Agriculture and Rural Affairs.

Hume, I.D. and Bird, P.R. 1970. Synthesis of microbial protein in the rumen. IV. The influence of the level and form of dietary sulphur. Australian Journal of Agricultural Research, 21, 315–322.

Jones, M.B., Rendig, V.V., Torell, D.T. and Inouye, T.S. 1982. Forage quality for sheep and chemical composition associated with sulfur fertilisation on a sulfur deficient site. Agronomy Journal, 74, 775–780.

Judson, G.J., Caple, I.W., Langlands, J.P. and Peter, D.W. 1987. Mineral nutrition of grazing ruminants in southern Australia. In: Wheeler J.L., Pearson C.J. and Robards G.E., ed., Temperate Pastures—their Production, Use and Management. Melbourne, Australian Wool Corporation/CSIRO, 377–384.

Langlands, J.P. 1987. Assessing the nutrient status of herbivores. In: Hacker, J.B. and Ternouth, J., ed., The Nutrition of Herbivores. Sydney, Academic Press, 363–390.

Langlands, J.P. Donald, G.E., Bowles, J.E. and Smith, A.J. 1991a. Subclinical selenium insufficiency. 1. Selenium status and the response in liveweight and wool production of grazing ewes supplemented with selenium. Australian Journal of Experimental Agriculture, 31, 25–31.

—1991b. Subclinical selenium insufficiency. 2. The response in reproductive performance of grazing ewes supplemented with selenium. Australian Journal of Experimental Agriculture, 31, 33–35.

—1991c. Subclinical selenium insufficiency. 3. The selenium status and productivity of lambs born to ewes supplemented with selenium. Australian Journal of Experimental Agriculture, 31, 37–43.

— 1994. Selenium concentrations in the blood of ruminants grazing in northern New South Wales. IV. Relationship with tissue concentrations and wool production of Merino sheep. Australian Journal of Agricultural Research, 45, 1701–1714.

Little, D.A., Siemon, N.J. and Moodie, E.W. 1978. Effects of varying phosphorus intake and requirement on measures of skeletal mineralisation in the ewe. Australian Journal of Experimental Agriculture and Animal Husbandry, 18, 514–519.

Liu, C.H., Duan, Y.Q, Lu, Z.H., Jin, Y.Y. and Su, Q. 1987. Regional selenium deficiency of feedstuffs in China. In: Combs, G.R., ed., Selenium in Biology and Medicine, 3rd international symposium. New York, Van Nostrand Reinhold, 47–52.

Lu, D.X., Yu, S.X., Yang, R.Z., Shao, K. and Masters, D.G. 1995. Some aspects of macromineral nutrition of grazing sheep in northern China. In: Anderson, N., Peter, D.W., Masters, D.G. and Petch, D.A., ed., Production of Fine Wool in Northern China: Effect of Nutrition and Helminth Infections. ACIAR Technical Report No. 32, Canberra, Australian Centre for International Agricultural Research, 40-44.

Masters, D.G. 1982. Zinc and reproduction in the ewe. PhD thesis, University of Western Australia.

Masters, D.G. and Fels, H.E. 1980. Effect of zinc supplementation on the reproductive performance of grazing merino ewes. Biological Trace Element Research, 2, 281–290.

—1985. Zinc supplements and reproduction in grazing ewes. Biological Trace Element Research, 7, 89–93.

Masters, D.G., Purser, D.B., Yu, S.X., Wang, Z.S., Yang, R.Z., Liu, N., Wang, X.L., Lu, D.X., Wu, L.H., Rong, W.H., Ren, J.K., and Li, G.H. 1990. Production from fine wool sheep in three areas in Northern China. Asian-Australasian Journal of Animal Science, 3, 305–312.

Masters, D.G., Purser D.B., Yu S.X., Wang Z.S., Yang R.Z., Liu N., Lu D.X., Wu L.H., Ren J.K. and Li G.H. 1993. Mineral nutrition of grazing sheep in northern China. I. Macro-minerals in pasture, feed supplements and sheep. Asian-Australasian Journal of Animal Science, 6, 99–105.

Masters, D.G.,Yu, S.X., Wang, Z.S., Lu, D.X., Wu, L.H., Ren, J.K., Li, G.H. and Purser, D.B. 1995. Consequences of mineral deficiencies in sheep in northern China. In: Anderson, N., Peter, D.W., Masters, D.G. and Petch, D.A. ed., Production of Fine Wool in Northern China: Effect of Nutrition and Helminth Infections. ACIAR Technical Report No. 32, Canberra, Australian Centre for International Agricultural Research, 45–50.

McMeniman, N.P. and Little, D.A. 1974. Studies on the supplementary feeding of sheep consuming mulga (*Acacia aneura*) I. The provision of phosphorus and molasses supplements under grazing conditions. Australian Journal of Experimental Agriculture and Animal Husbandry, 14, 317–321.

McSweeney, C.S., Cross, R.B., Wholohan, B.T. and Murphy, M.R. 1988. Diagnosis of sodium status in small ruminants. Australian Journal of Agricultural Research, 39, 915–942.

Mills, C.F. and Davis, G.K. 1987. Molybdenum. In: Mertz, W., ed., Trace Elements in Human and Animal Nutrition, 5th ed., San Diego, Academic Press, 429–465.

Minson, D.J. 1990. Forage in Ruminant Nutrition. San Diego, Academic Press.

Morris J.G. and Peterson R.G. 1975. Sodium requirements of lactating ewes. Journal of Nutrition, 105, 595–598.

Murphy, G.M. and Gartner, R.J.W. 1974. Sodium levels in the saliva and faeces of cattle on normal and sodium deficient diets. Australian Veterinary Journal, 50, 280–281.

Paynter, D.I. 1987. The diagnosis of copper insufficiency. In: Howell, J. McC. and Gawthorne J.M., ed., Copper in Animals and Man, Vol. 1, Boca Raton, CRC Press Inc., 101–116.

Peter, D.W., Buscall, D.J. and Young, P. 1987. Effects of sulphur and/or lupin supplements on the productivity of weaner sheep. In: Rose, M., ed., Herbivore Nutrition Research. Occasional Publication of the Australian Society of Animal Production, 203–204.

Read, M.V.P., Engels, E.A.N. and Smith, W.A. 1986. Phosphorus and the grazing ruminant. 1. The effect of supplementary P on sheep at Armoedsvlakte. South African Journal of Animal Science, 16, 1–6.

SCA (Standing Committee on Agriculture) 1990. Feeding Standards for Australian Livestock: Ruminants. Melbourne, CSIRO Australia.

Suttle, N.F. 1981. Predicting the effects of molybdenum and sulphur concentrations on the absorbability of copper in grass and forage crops to ruminants. In: Howell, J.McC., Gawthorne, J.M. and White, C.L., ed., Trace Element Metabolism in Man and Animals 4. Canberra, Australian Academy of Science, 545–548.

Suttle, N.F. and Field A.C. 1969. Studies on magnesium in ruminant nutrition. 9. Effect of potassium and magnesium intakes on development of hypomagnesemia in sheep. British Journal of Nutrition, 23, 81–91.

Suttle, N.F., Abrahams, P. and Thornton, I. 1984. The role of a soil × sulfur interaction in the impairment of copper absorption by ingested soil in sheep. Journal of Agricultural Science, Cambridge, 103, 81–86.

Technicon 1978. Individual/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Industrial method no. 329-74W/B. Technicon Industrial Systems, Tarrytown, New York.

—1980. Sulfate-sulfur in soil extracts. Industrial method no. 590-80SA. Technicon Industrial Systems, Tarrytown, New York.

Telle, P.P., Preston, R.L., Kintner, L.D. and Pfander, W.H. 1964. Definition of the ovine potassium requirement. Journal of Animal Science, 23, 59–66.

Vincent, I.C. Williams H.L. and Hill R. 1986. Effects of sodium intake on lactation and Na levels in body fluids of Blackface ewes. British Journal of Nutrition, 56, 193–198.

Wang Z.S. 1995. Adverse effect of high intakes of iron in sheep. PhD thesis, University of Western Australia.

Watkinson, J.H. 1979. Semi-automated fluorimetric determination of selenium in biological materials. Analytica Chimica Acta, 105, 319–325.

Whelan, B.R., Peter, D.W. and Barrow, N.J. 1994. Selenium fertilisers for pastures grazed by sheep. II. Wool and liveweight responses to selenium. Australian Journal of Agricultural Research, 45, 877–887.

White, C.L. and Somers, M. 1977. Sulphur–selenium studies in sheep. I. The effects of varying dietary sulphate and selenomethionine on sulphur, nitrogen and selenium metabolism in sheep. Australian Journal of Biological Science, 30, 47–56.

Yu, S.X., Masters, D.G., Su, Q., Wang, Z.S., Duang, Y.Q. and Purser, D.B. 1988. Mineral and trace element nutrition of sheep in Gansu Province, Northern China. In: Hurley, L.S., Keen, C.L., Lonnerdal B. and Rucker R.B., ed., Trace Elements in Man and Animals. 6. New York, Plenum Publishing Corporation, 171–172.

Yu, S.X., Masters, D.G., Purser, D.B., Wang, Z.S., Yang, R.Z., Liu, N., Lu, D.X., Wu, L.H., Ren, J.K. and Li, G.H. 1995. Description of the trace element status of sheep in three areas of northern China. In: Anderson, N., Peter, D.W., Masters, D.G. and Petch, D.A., ed., Production of Fine Wool in Northern China: Effect of Nutrition and Helminth Infections. ACIAR Technical Report No. 32. Canberra, Australian Centre for International Agricultural Research, 35–39.

Effects of Selenium Supplementation on the Productivity of Xinjiang Finewool Ewes in Northwest China

H. Ding, X.M. Jiang, D.M. Yang, Mayila, J.F. Wilkins and I.C. Fletcher[1]

Abstract

Xinjiang Finewool ewes were supplemented with selenium, administered as a single subcutaneous injection of barium selenate one month before joining. Supplemented ewes showed increased plasma selenium concentrations that were still evident at the end of lambing, seven months after selenium administration. Supplementation had no significant effect on reproductive rate, but supplemented ewes produced more wool and were heavier when their lambs were weaned than unsupplemented ewes. These responses to supplementation confirm the suggestion from an earlier study of micro-nutrient status that sheep in the region are at risk from subclinical selenium deficiency.

SELENIUM, although required in only small amounts in the animal, has an essential metabolic role as part of the enzyme glutathione peroxidase that protects cell membranes against oxidative damage (Hoekstra 1975). Severe deficiency in sheep is characterised by clinical symptoms of white muscle disease (muscular dystrophy) and mortality in lambs, but milder deficiency may affect sheep productivity even when no clinical symptoms are evident. Supplementation with selenium in the latter situation can increase wool production, body weight gain and reproductive rate (Wilkins et al. 1982; Langlands et al. 1991a,b,c, 1994; Whelan et al. 1994).

Subclinical selenium deficiency may be predicted from tissue analysis, but can be confirmed only by production responses to supplementation. This investigation was carried out to measure productivity responses to selenium supplementation in finewool sheep on a farm where earlier studies of micro-mineral status (Masters et al. 1993) indicated that sheep were at risk from subclinical selenium deficiency.

[1] China–Australia Sheep Research Project, Xinjiang Academy of Animal Science, 21 Youhao Dong Lu, Urumqi 830000, Xinjiang, People's Republic of China

Materials and Methods

The investigation was carried out at Nanshan Stud Farm, located 75 km southwest of Urumqi in the Xinjiang Uygur Autonomous Region of northwest China. The environment and sheep production system have been described by Masters et al. (1990).

One hundred and eighty mixed age Xinjiang Finewool breeding ewes from one of the 16 farm flocks were allocated by stratified random sampling based on offshears body weight to two groups, each of 90 ewes. One group was kept as an untreated control and the other treated with a single subcutaneous injection of barium selenate (Deposel, 1 mL/50 kg body weight) in mid-September 1992, 4 weeks before joining. The experimental procedure was repeated in 1993 with 240 mixed-age breeding ewes from each of another two farm flocks.

In both years ewes were weighed at the beginning of mating, approximately 4 weeks before lambing and at weaning. The numbers of lambs born to each ewe and their survival to tagging at 4–6 weeks of age were recorded. Ewe greasy fleece weights were recorded at shearing in June, and midside wool samples were taken for measurement of clean yield, staple length and fibre diameter. In the second year blood samples were taken from a random sample of 20 control and 20 selenium-treated ewes from each of the two flocks immediately before selenium injection in mid-September 1993, at the end of mating in early December 1993 and at the end of lambing in late April 1994. Plasma selenium concentrations in these samples were measured, using the vapour generation method, by atomic absorption spectrometry.

Data were analysed using the SYSTAT multivariate general linear hypothesis model (Wilkinson 1990). Plasma selenium concentrations were assessed by analysis of variance for a completely random experimental design with three repeated measurements in a factorial arrangement of two selenium treatment groups and two flocks. Ewe reproductive data were assessed by analyses of variance for a completely random experimental design with factorial arrangement of two selenium treatments and three flocks. Analyses of ewe body weights and wool production included a third factor, reproductive performance, to compare ewes that failed to lamb, had lambs that died before tagging, or reared lambs to tagging.

Results

Results were not obtained from all ewes initially allocated to the experiment because of lost ewe identity and other difficulties experienced in collecting data from seasonally migrating flocks. The number of observations recorded for each measurement is included in the tabulation of results.

Mean selenium concentrations in blood plasma are summarised in Table 1. Results from both flocks have been pooled for presentation since there were no significant differences between flocks, and no significant selenium × flock interactions. Control ewes showed no significant variation in plasma selenium between sampling times. Plasma selenium concentration increased significantly after supplementation, and remained significantly higher than in untreated animals at the end of lambing.

Ewe productivity measurements are summarised in Table 2. All traits except lambs born per ewe joined and clean wool yield showed significant variation between flocks, but there were no significant interactions to suggest that responses to selenium differed over the range of flock/year variation encountered in the experiment. The tabulated effects of selenium supplementation therefore have been pooled across flocks to simplify presentation. Ewes treated with selenium had significantly higher fleece weights, and significantly higher body weights when their lambs were weaned, than untreated ewes.

There were no significant effects of selenium on any other measurements. Greasy and clean fleece weights varied significantly with ewe reproductive performance, but there also was significant interaction between selenium and reproduction in the latter. Least squares mean clean fleece weights for untreated and selenium supplemented ewes respectively were 2.4 kg and 2.6 kg for ewes that failed to lamb, 2.1 kg and 2.6 kg for ewes that lost lambs, and 2.3 kg and 2.3 kg for ewes that reared lambs.

Discussion

Plasma selenium concentrations recorded in untreated ewes during this investigation were similar to those previously recorded by Masters et al. (1993) in ewes grazing the spring, autumn and winter seasonal pastures on the same farm. They were higher than the level of 0.25 μmol/L below which Langlands et al. (1991a,b,c) found reductions in ewe wool growth and weaning rate, but lower than the level of 0.51 μmol/L subsequently recommended as a minimum requirement for breeding ewes (Langlands et al. 1994). Plasma concentrations in selenium supplemented ewes, on the other hand, remained at or above 0.51 μmol/L throughout the investigation.

Table 1. Selenium concentrations (least squares means in (μmol/L ± standard errors) in blood plasma. Numbers of observations contributing to each mean are shown in parentheses.

	Time of sampling		
	Before injection	End of mating	End of lambing
No treatment	0.38 ± 0.03[ab] (37)	0.42 ± 0.03[ab] (36)	0.31 ± 0.04[a] (32)
Selenium injection	0.41 ± 0.03[ab] (40)	0.61 ± 0.03[c] (37)	0.50 ± 0.03[bc] (34)

Means with different superscripts are significantly ($P<0.05$) different.

Table 2. Effects of selenium supplementation and reproductive performance on ewe productivity traits (least squares means ± standard errors). Numbers of observations contributing to each mean are shown in parentheses.

Productivity trait	Selenium		Reproductive performance		
	Control	Supplemented	No lambs	Lost lambs	Weaned lambs
Body weight (kg)					
Pre-mating	55.2 ± 0.5 (191)	55.6 ± 0.4 (192)	55.7 ± 0.9 (37)	55.2 ± 0.5 (108)	55.2 ± 0.3 (238)
Pre-lambing	54.3 ± 0.9 (211)	54.5 ± 0.6 (218)	55.1 ± 1.2 (43)	52.9 ± 1.0 (116)	55.3 ± 0.4 (270)
Weaning	57.2 ± 0.7 [a] (164)	59.4 ± 0.6 [b] (173)	59.1 ± 1.0 (42)	58.4 ± 0.9 (88)	57.4 ± 0.4 (207)
No. ewes mated *	99 ± 1 (290)	99 ± 1 (295)	n a	n a	n a
No. ewes lambed *	91 ± 2	90 ± 2	n a	n a	n a
No. lambs born *	117 ± 4	126 ± 4	n a	n a	n a
No. lambs tagged *	76 ± 4	78 ± 3	n a	n a	n a
Greasy fleece wt (kg)	5.0 ± 0.08 [a] (229)	5.2 ± 0.08 [b] (225)	5.3 ± 0.12 [a] (50)	5.0 ± 0.10 [ab] (107)	5.0 ± 0.05 [b] (297)
Clean yield (%)	47 ± 0.7 (182)	48 ± 0.8 (182)	48 ± 1.1 (41)	48 ± 1.0 (84)	47 ± 0.4 (239)
Clean fleece wt (kg) **	2.3 ± 0.06 [a] (159)	2.5 ± 0.06 [b] (164)	2.5 ± 0.09 [a] (37)	2.3 ± 0.09 [ab] (75)	2.3 ± 0.04 [b] (211)
Staple length (cm)	7.9 ± 0.1 (179)	8.1 ± 0.1 (182)	8.0 ± 0.2 (41)	8.1 ± 0.2 (82)	7.8 ± 0.1 (238)
Fibre diameter (μm)	20.6 ± 0.2 (184)	20.9 ± 0.2 (189)	20.9 ± 0.3 (43)	20.8 ± 0.3 (86)	20.8 ± 0.1 (244)

Means within main effects with different superscripts are significantly ($P<0.05$) different.
na, not applicable.
*Per 100 ewes joined.
**Significant interaction between selenium and reproductive performance is described in the text.

In this context the results of the present investigation showing significant responses to selenium supplementation in ewe wool production and ewe body weight at weaning, but not in any other productivity traits, are consistent with the situation for subclinical deficiency described by other authors (Wilkins et al. 1982; Langlands et al. 1991a,b,c; Whelan et al. 1994).

Langlands et al. (1994) reported responses in wool production to selenium supplementation in ewes that reared lambs, but not in ewes that failed to lamb. In contrast, ewes in the present investigation that failed to lamb or lost their lambs showed responses in wool production to selenium supplementation, but ewes that reared lambs showed no response despite their lower average fleece weight. This suggests that limited feed availability around lambing time in the Nanshan environment may be insufficient to satisfy the large increase in nutrient demand for lactation, and in this situation limited energy and/or protein availability may become a primary constraint on wool production that precludes a response to selenium supplementation in lactating ewes.

References

Hoekstra, W.G. 1975. Biochemical function of selenium and its relation to Vitamin E. Federation Proceedings, 34, 2083–2089.

Langlands, J.P., Donald, G.E., Bowles, J.E. and Smith, A.J. 1991a. Subclinical selenium insufficiency 1. Selenium status and the response in liveweight and wool production of grazing ewes supplemented with selenium. Australian Journal of Experimental Agriculture, 31, 25–31.

— 1991b. Subclinical selenium insufficiency 2. The response in reproductive performance of grazing ewes supplemented with selenium. Australian Journal of Experimental Agriculture, 31, 33–35.

— 1991c. Subclinical selenium insufficiency 3. The selenium status and productivity of lambs born to ewes supplemented with selenium. Australian Journal of Experimental Agriculture, 31, 37–43.

— 1994. Selenium concentration in the blood of ruminants grazing in New South Wales. 4. Relationship with tissue concentrations and wool production of Merino sheep. Australian Journal of Agricultural Research, 45, 1701–1714.

Masters, D.G., Purser, D.B., Yu, S.X., Wang, Z.S., Yang, R.Z., Liu, N., Lu, D.X., Wu, L.H., Ren, J.K. and Li, G.H. 1990. Production from fine wool sheep in three areas in northern China. Asian Australasian Journal of Animal Science, 3, 305–312.

— 1993. Mineral nutrition of grazing sheep in northern China 2. Selenium, copper, molybdenum, iron and zinc in pasture, feed supplements and sheep. Asian Australasian Journal of Animal Science, 6, 107–113.

Whelan, B.R., Barrow, N.J. and Peter, D.W. 1994. Selenium fertilizers for pastures grazed by sheep 2. Wool and liveweight responses to selenium. Australian Journal of Agricultural Research, 45, 877–887.

Wilkins, J.F., Kilgour, R.J., Gleeson, A.C., Cox, R.J., Geddes, S.K. and Simpson, I.H. 1982. Production responses in selenium supplemented sheep in northern New South Wales. 2. Liveweight gain, wool production and reproductive performance in young Merino ewes given selenium and copper supplements. Australian Journal of Experimental Agriculture and Animal Husbandry, 22, 24–28.

Wilkinson, L. 1990. 'SYSTAT: The System for Statistics.' (SYSTAT, Inc.: Evanston, Illinois).

Effect of Iodination of Irrigation Water on Crop and Animal Production in Long Ru, Hotien County, Xinjiang

G. Robert DeLong[1], Jiang Xin-Min[2], Murdon Abdul Rakeman[3] Zhang Ming-Li[2], Ma Tai[4], Mahamet Karem, Dou Zhi-Hong[3], Nancy DeLong and Cao Xue-Yi[3]

Abstract

Iodination of irrigation water for the control of severe iodine deficiency was begun in June 1992, in a contiguous area of Long Ru township containing four rural villages, with a combined population of 5600 people. In March 1983 iodine dripping was extended to Bakechi township (population 15 600) and in June 1994 to Tusala (population 24 000). This paper describes measurements of agricultural production before and after iodination over a 3-year period, as well as comparisons with neighbouring villages.

The results indicate that increased availability of iodine resulted in increased fertility of ewes and/or increased survival of newborn lambs. As a consequence, sales of animal products in the test villages increased by 31–43% relative to the control villages.

Provision of iodine to the livestock population in this severely iodine-deficient area may have significant economic benefits to the population, apart from its effect on human health and development.

IODINATION of irrigation water for control of severe iodine deficiency was begun in a contiguous area of Long Ru township containing four rural villages, with a combined population of 5600 people, in June 1992. In March 1993, similar dripping was begun in another township, Bakechi, about 30 km downstream from Long Ru, in an area with a population of 15 600. In June 1994, similar dripping was extended to another township, Tusala, covering an area of population 24 000. Data have been collected and partly reported on the ensuing change in iodine concentrations in soil, grain crops and their straw, vegetables, meat, milk and eggs, sheep and chicken thyroid glands, and urinary iodine excretion of young children (ages 2–6 years) and women of child-bearing age. This paper describes measurements of agricultural and livestock production before and after this iodination. Controls for the observations in Long Ru consist of the five nearest villages (two upstream and three downstream, as all are strung out along the Karakax River) belonging to the same township (Long Ru) as the test villages, with virtually identical patterns of agriculture and society, and similar iodine deficiency. The control villages received no iodination or other intervention.

The entire township, surrounded by desert or mountains, comprises 14 villages; the other five are further upstream, and differ in character in being primarily nomadic (two) or pastoral (three). They were not included as controls except in data reporting total number of animals. In Bakechi, only data on animal production were obtained; there are eight test villages and six control villages. The latter are adjacent to the test villages and virtually identical except that they were not iodinated. Early data only have been obtained in Tusala, and are not reported here.

This society keeps careful records at the village level of production of all major agricultural products.

[1]Duke University Medical Center, Durham, USA
[2]The Institute of Endemic Diseases Research, Urumqi, People's Republic of China
[3]The Xinjiang Anti-Epidemic and Health Station, Urumqi, People's Republic of China
[4]Tianjin Medical College, Tianjin, People's Republic of China

We accessed and utilised these records retrospectively for the present report; neither we nor the villagers had any idea prospectively that the records would be so used.

Effect on Major Grain Crops

In summary, no effect was detectable. In both test and control villages, mean wheat productivity, in kg/mu (mu is the usual Chinese agricultural measure of land area, equalling 1/15 hectare or 667 m^2) was level over the years 1990–94. Rice productivity was level during 1990–93 (mean 215 kg/mu) but increased markedly in 1994 to 386 kg/mu in the test villages only, for unknown reasons. Corn productivity steadily rose each year from 1990 to 1994 (from 260 kg/mu to 358 kg/mu), paralleling similar steady increases in the five control villages. Notably, corn yields in the four test villages averaged about 25 kg/mu less than the yields in the five control villages each year (before and after iodination).

Changes in Indicators

The number of animals in the test villages was unchanged during the period 1990–94, while decreasing in the other villages. The total number of animals in eight villages (no data are available for the two nomadic villages) decreased 6.3% in this period; the number of sheep (comprising about 80% of animals) decreased by 12.3% during the same period. In the five primary control villages, sheep numbers decreased by 10.6%. In the four test villages during the same period, the total number of animals (+0.6%) and the number of sheep (–0.3%) both remained essentially stable. Thus the relative number of sheep increased by 10.3% in the test villages, and the total number of animals by 6.9%, compared to the controls.

A similar result was obtained in Bakechi. In the eight test villages, the number of sheep increased by 9.5% during 1993–94 compared with the number during the three previous years. The number in the six control villages fell by 0.6%, a relative difference of 10.1% favouring the test villages.

Increase in sheep born alive

In the four test villages, we compared the number of sheep born alive (the 'born alive' refers to viable sheep who survive to the time of counting at the end of the calendar year) in 1992–94 with the same figure for the previous two years. The number born alive increased by 20% in 1992, by 42% in 1993, and by 63% in 1994, as compared to the mean value for the two pre-treatment years. By comparison, in the five control villages, the number decreased by 4.2% in 1992, 1.2% in 1993, and increased by 20% in 1994, compared to the two pre-dripping years 1990–91. The increases in the test villages were significantly greater than those of the control villages for each year at the $P<0.02$ level.

In the eight test villages in Bakechi, sheep born alive increased 24% in 1993 (the first year of dripping) compared to the mean of the previous three years, and decreased by 4.7% in 1994. In the control villages, sheep born alive decreased by 12.3% in 1993 and by 21.3% in 1994, as compared to the mean of 1990–92. The increase in the test villages in 1993 is significant ($P<0.05$) compared to the control villages; the change in 1994 is not significant.

Increase in value of animal products sold

Each village records the total value of animals and animal-derived products sold each year; the value, in yuan, includes sales of sheep, mutton, wool, fleeces, cattle and their products, eggs and poultry products. Sheep and their products make up the bulk of this figure, which we estimate amounts to about 25% of total village income. For this calculation in Long Ru, we used 1990, 1991, and 1992 as base years, since sales of sheep born in 1992, the first year of dripping, would only be reflected the next year.

In the four test villages combined, the average value per year for 1993–94 was 62% greater ($P=0.001$) than the average value of the three base years. The value of animal product sales in 1994 was 82% greater ($P<0.02$) than the average value of the three base years 1990–92. In the five control villages, the annual average for 1993–94 was 31% greater ($t=1.59$, $n=20$, $P>0.10$) than the average for the base years; the value of sales in 1994 was 39% greater ($t=1.79$, $n=20$, $P>0.05$) than the average in the three base years; both these increases were not significant. Inflation of prices, a significant factor during 1993–94, applied to both groups equally. The results indicate that sales of animal products increased 31–43% more in the test villages than in the control villages.

The two measurements, the number of sheep born alive and the annual sales of animal products, show parallel results, sheep born alive increasing markedly and significantly in the test villages during 1992–94 and sales of animal products increasing similarly in 1993–94, compared to the control villages. It is expected that the two indices should be linked, since sale of sheep is a major component of animal product sales. Even so, it strengthens the observations to find that both measurements, which are derived and calculated independently in the villages, yield similar results.

These results strongly support an hypothesis that the increased availability of iodine after mid-1992 resulted in increased fertility of ewes and/or increased survival of newborn sheep (and perhaps other animals). Increased availability of iodine was demonstrated directly (Table 1).

The data suggest that animals increase their iodine content more during the second year after dripping than during the first year, perhaps because most of the crops and plant matter they eat was grown the previous year.

Provision of iodine to the livestock population in this severely iodine-deficient area may have significant economic benefits to the population, apart from its effects on human health and child development. An increase of 40% in sales of animal products in the four Long Ru test villages amounts to about 75 000 Y (US $9000) per year. The cost of all potassium iodate used during the two years of dripping in these four villages (80 kg) was 6400 Y if the iodate could be bought at the UNICEF price, or about 12 800 Y if bought, as was the case, at Chinese commercial prices. The fact that dripping was not necessary in 1994, and apparently is not necessary again in 1995 (because iodine remains in the soil, crops, and animals; 1995 retesting of urine iodine levels in the people is not yet complete) makes economic benefit, and the benefit:cost ratio, that much greater. The increase in sheep production in Bakechi portends similar economic benefits.

These results, if maintained and replicated, argue strongly that iodine repletion in the soil, or at least in domestic animals, has an important economic benefit, and may yield a seven-fold or greater return on its cost every year for several years. It may be considered as fertiliser for animals. This should be an important argument for extending the iodine dripping method in the conditions of southern Xinjiang, but also has significance for other rural areas of severe iodine deficiency where the people may be provided with adequate iodine through use of iodised salt, but where important economic benefits could be realised by iodination of animals, or possibly of soil. Such situations may be widespread in China as well as in other areas of severe iodine deficiency worldwide. This is especially true since poverty and protein-energy malnutrition often accompany and complicate iodine deficiency. Environmental repletion may prove to be the most natural and favourable way to provide iodine in some iodine-deficient areas and communities.

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Table 1. Changes in concentration of iodine in tissues after iodine dripping (mean ± SD).

Tissues	Iodine concentrations (μmol/kg)	
	Before dripping	After dripping
Sheep thyroid glands[a]	364 ± 177 (n = 7)	745 ± 213 (n = 4) ($P < 0.05$)
Mutton[b]	0.45 ± 0.09 (n = 7)	3.0 ± 0.15 (n = 5) ($P \le 0.01$)
Chicken thyroid glands[b]	194 ± 72 (n = 4)	574 ± 158 (n = 4) ($P \le 0.01$)
Chicken meat[b]	0.40 ± 0.04 (n = 7)	1.7 ± 0.43 (n = 4) ($P \le 0.01$)
Eggs[b]	0.21 ± 0.04 (n = 70)	1.74 ± 0.03 (n = 4) ($P \le 0.01$)

[a] Before dripping in June 1992; after dripping in November 1993.
[b] Before dripping in June 1992. After dripping in December 1994, 30 months after beginning dripping and 16 months after last dripping.

Selenium, Iodine and Thyroid Hormone Metabolism

Guo Yuming, Li Zhiwei and Zhou Yuping[1]

Abstract

The type I and type II 5'-iodothyronine deiodinases are seleno-enzymes. Selenium deficiency depresses the activities of type I and type II, 5'-iodothyronine deiodinase in animal tissues, and impairs the conversion of thyroxine (T_4) to 3,3',5-triiodothyronine (T_3) and thus the rat plasma T_4 level is elevated and the T_3 level declines. The magnitude of change of plasma thyroid hormone levels in broiler chicks is influenced by iodine nutritional status, i.e. the effect is amplified by iodine deficiency. The activities of 5'-iodothyronine deiodinases are not affected by iodine deficiency. Selenium deficiency exaggerates the iodine deficiency, i.e. T_3 levels are further lowered, and plasma thyrotropin level and the ratio of thyroid weight over bodyweight are elevated by selenium deficiency. The iodine deficiency lowers the selenium concentrations in chick's tissues, and the activities of glutathione peroxidases are also depressed, but the underlying mechanism(s) is unknown. The nutritional interactions between selenium and iodine need thorough research. Local active 5'-iodothyronine deiodinase and T_3 levels are essential for brown adipose tissue to oxidise fat to produce heat. Selenium deficiency may impair the non-shivering thermogenic function of brown adipose tissue and the capacity of anti-cold-stress of newborn ruminants.

PREVIOUS reports of the effects of selenium nutrition on thyroid hormone metabolism of animals are inconsistent — for instance, plasma thyroxine and thyronine levels decreased in selenium-deficient chicks (Jensen et al. 1986) while the two hormone levels were elevated in selenium-deficient rats (Golstein et al. 1988); however, Beckett et al. (1987) and Arthur et al. (1988) reported that selenium deficiency elevated plasma thyroxine (T_4) and lowered plasma 3,3',5-triiodothyronine (T_3) levels in rats and cattle. Research on the underlying biochemical mechanism, whereby the selenium and thyroid hormone metabolism are interrelated, showed that selenium deficiency caused activity loss of 5'-iodothyronine deiodinases (5'-IDI) in rat tissue such as thyroid, liver, kidney, muscle, brain, pituitary and brown adipose tissue (Beckett et al. 1989, 1990; Arthur et al. 1990a and Guo 1991).

Since Arthur et al. (1990b) and Behne et al. (1990) identified that 5'-IDI in rat liver was a selenium-containing enzyme with a molecular weight of 27 000 daltons, and Berry et al. (1991) showed, using molecular cloning techniques, that the mRNA for the 5'-IDI of 27 000 daltons has the UGA code for selenocysteine, the type I 5'-IDI was confirmed to be a seleno-enzyme. T_3 is produced by deiodination of T_4 catalysed by 5'-IDI, thus selenium deficiency could inhibit the production of T_3 through lowering the activities of 5'-IDI in some tissues, and the plasma T_3 levels might be changed.

A study showed that after 6 weeks of selenium depletion, the activities of 5'-IDI in rat liver, kidney, brown adipose tissues, brain and pituitary tissues decreased 91, 68, 57, 59 and 40% respectively, and plasma T_4 increased and T_3 decreased respectively (Table 1). Research was also conducted on broiler chicks. The results of a previous experiment showed selenium deficiency caused 5'-IDI activities in the liver and the T_3 in plasma to be lowered significantly, but T_4 levels in plasma did not change (Table 2).

In a third experiment that used a 2 × 2 factorial design, the basal diet contained 0.009 mg selenium/kg and 0.056 mg iodine/kg, the supplementation levels of selenium and iodine were 0.30 mg/kg and 0.35 mg/kg respectively. The four groups were

[1] Department of Animal Nutrition and Feed Science, Beijing Agricultural University, Beijing 100094, People's Republic of China

Table 1. Effect of selenium deficiency and cold exposure on rat body weight and intrascapular brown adipose tissue (IBAT) weight, plasma thyroxine (T_3) and thyronine levels (T_4), and GSHPx and 5'-IDI activities in liver, kidney, pituitary and intrascapular brown adipose tissue (mean ± s.e.).

		Cold-unexposed		Cold-exposed	
		Se-sufficient	Se-deficient	Se-sufficient	Se-deficient
Bodyweight (g)		257 ± 4.9	260 ± 4.5	254 ± 9.0	260 ± 10.5
IBAT weight (mg)		502 ± 10.3[a#]	489 ± 10.7[a]	419 ± 15.6[b]	448 ± 46.9[a]
Plasma thyroid hormone levels:					
T_3(nmol/L)		1.33 ± 0.13[a]	1.00 ± 0.07[b]	2.13 ± 0.13[c]	1.57 ± 0.10[ac]
T_4(nmol/L)		73.6 ± 6.42[a]	94.4 ± 2.29[b]	80.0 ± 4.16[a]	107.0 ± 5.81[b]
Activities of GSHPx (μmol NADPH oxidised/mg protein/minute) and 5'-IDI in tissue (^{125}I%/mg protein/minute):					
Liver	GSHPx	1.25 ± 0.328[a]	0.001 ± 0.000[b]	1.05 ± 0.20[a]	0.001 ± 0.000[b]
	5'-IDI	12.7 ± 1.22[a]	1.2 ± 0.48[b]	13.5 ± 0.90[a]	1.66 ± 0.28[b]
Kidney	GSHPx	0.60 ± 0.28[a]	0.016 ± 0.001[b]	0.51 ± 0.059[a]	0.016 ± 0.001[b]
	5'-IDI	12.4 ± 0.59[a]	3.92 ± 0.58[b]	12.7 ± 0.70[a]	3.86 ± 0.38[b]
Pituitary	GSHPx	0.036 ± 0.006[a]	0.013 ± 0.000[b]	0.028 ± 0.003[a]	0.015 ± 0.003[b]
	5'-IDI	18.0 ± 2.37[a]	10.8 ± 3.39[b]	20.8 ± 1.19[a]	13.9 ± 1.83[b]
IBAT	GSHPx	0.14 ± 0.010[a]	0.004 ± 0.000[b]	0.14 ± 0.013[a]	0.007 ± 0.001[b]
	5'-IDI	2.39 ± 0.77[a]	1.03 ± 0.21[b]	112.2 ± 13.04[c]	4.54 ± 0.77[c]

#: Means with different superscripts in the same row differ significantly ($P < 0.05$) (Guo 1991).

control (+Se+I), selenium deficient (–Se+I), iodine deficient (+Se–I) and the combined deficiency (–Se–I). The data showed that iodine deficiency reduced growth by 9.6% and the combined deficiency reduced it to 29.6%. The relative weights of thyroid gland increased 2.2 times in the iodine-deficient chicks ($P < 0.01$). Selenium deficiency decreased the activities of glutathione peroxidase (GSHPx) and 5'-IDI in livers and kidneys of 4-week-old chicks. Under iodine sufficiency, selenium deficiency did not significantly affect plasma T_4 or T_3 levels, while under iodine deficiency, plasma T_4 levels were elevated slightly (6.9%) ($P>0.05$) and T_3 levels decreased by 49.8% ($P<0.05$) by selenium deficiency. This suggests that the effect of selenium on nutritional status of thyroid hormone metabolism of chicks may be influenced by iodine nutritional status.

Table 2. The influence of selenium deficiency on 5'-IDI activity of liver and the plasma thyroid hormone levels (mean ± s.e.).

Dietary Se (mg/kg)	T_4 (μg/mL)	T_3 (μg/mL)	5' IDI activity (^{125}I%/mg protein/minute)
0.022	11.3 ± 1.63	1.1 ± 0.12[a]	18.7 ± 5.32[a]
0.300	11.7 ± 3.11	1.9 ± 0.5[b]	64.4 ± 3.29[b]

#: Means with different superscripts in the same column differ significantly ($P<0.05$) (Li 1995).

The 5'-IDI in pituitary, brain and brown adipose tissues is type II 5'-IDI with a molecular weight of 29 000 daltons and differs from that in the liver and kidney tissues (Safran and Lenard 1991). It has recently been shown that the type II enzyme of 5'-IDI also contains selenium. The activities of type II 5'-IDI can be regulated by thyroid hormones (Silva and Larsen 1986; St. Germain 1988), so it is unclear to what extent selenium deficiency may influence it.

Selenium and Non-shivering Thermogenesis

Brown adipose tissues play the most important role in non-shivering thermogenesis in rodents and newborn ruminants under cold stress. The brown adipose tissue accounts for 1–5% of the liveweight of the newborn mammals and atrophies in a few weeks to be replaced by white fat. The non-shivering thermogenic capacity is determined by the concentration of the tissue-specific uncoupling protein, located in the inner mitochondrial membrane, regulated by T_3 in the tissue (Danforth and Burger 1989). Noradrenaline from the sympathetic nerves (which extensively innervate brown adipose tissue) is the main acute stimulus for thermogenesis.

Following noradrenergic stimulation, adenylcyclase is activated and cAMP formed. The cAMP activates a hormone-sensitive lipase. Fatty acids mobilised from the stored triacyglycerol are then transported to the mitochondria and oxidised

(Nicholls and Locke 1984). In the presence of uncoupling protein, the fatty acid oxidation is uncoupled from the synthesis of ATP, and the potential energy is dissipated as heat. The enzyme 5'-IDI has a high activity in brown adipose tissue, and is stimulated by noradrenaline. The presence of this enzyme provides a local supply of T_3 to brown adipose tissue.

Reiter et al. (1990) showed that after rats were exposed to cold for 12 hours, the activities of 5'-IDI and lipoprotein lipase and the mRNA of uncoupling protein elevated markedly. The enhanced 5'-IDI activity stimulated local T_3 production and its conjugation with the receptor and the production of uncoupling protein increased (Bianco and de Silva 1988), thus increasing the oxidation of brown adipose and thermogenesis. The study showed that after six weeks of selenium depletion postweaning, acute cold exposure elevated the 5'-IDI activity threefold, but in the selenium-sufficient rats the elevation magnitude was 46-fold. In order to maintain the body temperature under cold stress, the brown adipose was oxidised and then the tissue weight decreased. The decrease of intrascapular brown adipose tissue in the selenium-deficient rats was about half that of selenium-sufficient ones (Table 1). This suggests that selenium deficiency impaired the non-shivering thermogenic function of brown adipose tissues, and the survival capacity of newborn ruminants under cold exposure may be decreased by selenium deficiency.

Nutritional Interrelationships of Selenium and Iodine

Iodine is a component of thyroid hormones. Iodine deficiency may cause thyroid hormone levels to decrease resulting in goitre and other iodine deficiency disorders. Gelön et al. (1990) showed that the concentration of uncoupling protein of brown adipose tissues in selenium- and iodine-deficient rats was much lower than in the selenium-deficient or iodine-deficient and control rats. So selenium deficiency may exaggerate the iodine deficiency through impairing the conversion of T_4 to T_3. In a previous study with rats the authors showed that the concentrations of T_4 and T_3 and iodine in the thyroid tissues, and T_3 concentrations in liver and plasma of combined deficient rats were lower than in tissues from rats deficient in iodine only, whereas the plasma thyrotropin levels and thyroid weights were higher. The iodine nutritional status did not influence the activity of type I 5'-IDI, but the activity of type II 5'-IDI in the brain was significantly higher in the combined deficient rats than in those only deficient in iodine, whereas the activity of type II 5'-IDI in the pituitary was lowered (Beckett et al. 1993).

The results (Table 3) of our study on chicks showed that the effects of selenium deficiency on thyroid hormone metabolism seemed to be influenced by iodine nutritional status. Iodine deficiency also lowered significantly the selenium concentration in the tissues of broiler chicks of 4 weeks of age

Table 3. The influences of dietary selenium and iodine levels on selenium concentration, activities of GSHPx and 5'-IDI in the heart, liver, kidney and pancreas (mean ± s.e.).

	Treatment			
	+Se+I	+Se−I	−Se+I	−Se−I
Selenium concentrations in tissues (μmol/kg):				
Heart	3.3 ± 0.52[a]	2.9 ± 0.14[a]	0.5 ± 0.09[b]	0.5 ± 0.05[b]
Liver	7.5 ± 0.64[a]	6.9 ± 0.58[a]	1.4 ± 0.11[b]	0.8 ± 0.14[c]
Kidney	8.2 ± 0.51[a]	7.6 ± 0.72[a]	3.0 ± 0.53[b]	1.6 ± 0.25[b]
Pancreas	2.5 ± 0.10[a]	2.2 ± 0.21[a]	1.2 ± 0.14[b]	0.7 ± 0.09[c]
Activities of GSHPx in tissues (μmol NADPH oxidised/mg protein/minute):				
Liver	0.229 ± 0.026[a]	0.217 ± 0.043[a]	0.018 ± 0.005[b]	0.009 ± 0.004[c]
Kidney	0.142 ± 0.010[a]	0.094 ± 0.024[b]	0.018 ± 0.004[c]	0.011 ± 0.002[c]
Plasma T_4, T_3 levels (μg/mL):				
T_3	0.51 ± 0.09[a]	0.76 ± 0.01[a]	0.78 ± 0.09[a]	0.38 ± 0.09[b]
T_4	15.42 ± 0.68[a]	11.00 ± 3.37[b]	16.22 ± 7.43[a]	11.75 ± 0.35[b]
Activities of 5'-IDI in tissues (^{125}I%/mg protein/minute):				
Liver	107.8 ± 15.5[a]	106.1 ± 23.4[a]	58.7 ± 20.9[b]	20.8 ± 22.9[c]
Kidney	135.2 ± 10.3[a]	121.2 ± 25.2[a]	73.8 ± 29.5[b]	55.0 ± 29.9[c]

#: Means with different superscripts in the same row differ significantly (P<0.05 or P<0.01) (Li 1995).

(P<0.05). Compared to the control, the tissue concentration of selenium in iodine-deficient, selenium-deficient and combined deficient rat heart tissues was 11.5, 71.3 and 83.9% respectively, that in the liver decreased 9.1, 81.5 and 89.2%, that in the kidney decreased 7.7, 63.6 and 80.5%, and in the pancreas decreased 12.4, 53.1 and 69.3% respectively. The iodine contents in the selenium-deficient rat thyroids decreased, but were not influenced by selenium nutritional status. Iodine did not influence the activities of 5'-IDI in all the tissues, but decreased the activities of liver GSHPx by up to 47.5% (P<0.05), and the activities of kidney GSHPx by up to 30% (P<0.05). The inhibition of GSHPx might be ascribed to lower selenium retention in the tissues. All the research results showed that the nutritional interrelationships of selenium and iodine are complex, and more thorough research is needed.

References

Arthur, J.R., Morrice, P.C. and Beckett, G.J. 1988. Thyroid hormone concentrations in selenium deficient and selenium sufficient cattle. Research in Veterinary Science 45, 122–123.

Arthur, J.R., Nichol, F., Hutchinson, A.R. and Beckett, G.J. 1990a. The effect of selenium depletion and repletion on the metabolism of thyroid hormones in the rat. Journal of Inorganic Biochemistry, 39, 101–108.

Arthur, R.J., Nichol, F., and Beckett, G.J. 1990b. Hepatic iodothyronine 5'-deiodinase — the role of selenium. Biochemistry Journal, 272, 537–540.

Beckett, G.J., Beddows, S.E., Morrice, P.C., Nicol, F. and Arthur, J.R. 1987. Inhibition of hepatic deiodination of thyroxine is caused by selenium deficiency in rats. Biochemistry Journal 248, 443–447.

Beckett, G.J., MacDougall, D.A., Nicol, F. and Arthur, J.R. 1989. Inhibition of type I and type II iodothyroxine is caused by selenium deficiency in rats. Biochemistry Journal, 259, 889–892.

Beckett, G.J., Nicol, F., Rae, W.H.P., Beech, S., Guo, Y. and Arthur, R.J. 1993. Effect of combined iodine and selenium deficiency on thyroid hormone metabolism in rats. American Journal of Clinical Nutrition Supplement, 57, 240s–243s.

Behne, D., Kyriakopoulous, A., Meinhold, H. and Koehrle, J. 1990. Identification of type I iodothyronine 5'-deiodinase as a selenoenzyme. Biochemical and Bio-hysical Research Communication, 73, 1143–1149.

Berry, M.J., Banu, L. and Larsen, P.R. 1991. Type I iodothyronine deiodinase is a selenocysteine-containing enzyme. Nature, 349, 438–440.

Bianco, A.C. and de Silva, J.E. 1988. Cold exposure rapidly induces virtual saturation of brown adipose tissue nuclear T3 receptors. American Journal of Physiology, 255, 496–503.

Danforth, Jr., E. and Burger, A.G. 1989. The impact of nutrition on thyroid hormone physiology action. Annual Review of Nutrition, 9, 201–207.

Gelön, A., Arthur, J.R., Beckett, G.J. and Trayburn, P. 1990. Effect of selenium and iodine deficiency on the level of uncoupling protein in brown adipose tissue of rats. Biochemistry Society Transactions, 18, 1269–1270.

Golstein, J., Corvilain, B., Lamy, F., Paquer, D. and Dumont, J.E. 1988. Effects of selenium deficient diet on thyroid function of normal and perchlorate treated rats. Acta Endocrinologica (Copehn) 118, 495–502.

Guo Yuming 1991. The necessity of selenium to the normal thyroid hormone metabolism of rats. PhD dissertation, Beijing Agricultural University.

Jensen, J.S., Colnago, G.L., Takahashi, K. and Akiba, Y. 1986. Dietary selenium status and plasma thyroid hormones in the chick. Biological Trace Element Research, 10, 11–18.

Li Zhiwei 1995. The effect of selenium on the thyroid hormone metabolism of broiler chicks and the nutritional interrelationships between selenium and iodine. PhD dissertation, Beijing Agricultural University.

Nicholls, D.G. and Locke, R.M. 1984. Thermogenic mechanism in brown adipose tissue. Physiology Review, 64, 1–64.

Reiter, R.J., Klaus, S., Ebbinghaus, C., Heldmaier, G., Redlin, U., Ricquier, D., Vaughan, M.K. and Steinlechner, S. 1990. Inhibition of 5'-deiodination of thyroxine suppresses the cold-induced increase in brown adipose tissue messenger ribonucleic acid for mitochondrial uncoupling protein without influencing lipoprotein lipase activity. Endocrinology 126, 2550–2554.

Safran, M. and Lenard, J.L. 1991. Comparison of the physico-chemical properties of type I and type II iodothyronine 5'-deiodinase. Journal Biological Chemistry, 266, 3233–3238.

Silva, J.E. and Larsen, P.R. 1986. Interrelationships among thyroxine, growth hormone, and the sympathetic nervous system in the regulation of 5'-iodothyronine deiodinase in rat brown adipose tissue. Journal of Clinical Investigation, 77, 1214–1223.

St Germain, D.L. 1988. The effects and interactions of substrates, inhibitors, and the cellular thiodisulfide balance on the regulation of type II iodothyronine 5'-deiodinase. Endocrinology, 122, 1860–1868.

An Investigation of Fluorosis of Cattle and Goats in Western Inner Mongolia

Xu Guimei[1]

Abstract

The relationship between fluorine intake and tooth lesions in cattle and goats grazing near Baotou city in Inner Mongolia was investigated. There was a direct relationship between tooth damage and fluoride in pasture and bone. Strategies such as transferring animals to safe pasture, housing animals and planting trees around pasture plots were introduced to minimise the problems.

SINCE 1970, a disease characterised by tooth lesions (Figure 1a,b) has been observed at Shadegai Commune 10 kilometres west of Baotou City in western Inner Mongolia. Affected animals had difficulty chewing and eating, resulting in malnutrition and retarded growth. According to statistics from Biketi, in 1978 animal numbers in that area had dropped 66% compared to 1965. The output value of animal husbandry in the area dropped substantially and pastoralists suffered financially from the effects of this disease.

Aetiology and Epidemiology

An investigation (Wang and Shan 1985) showed that air fluoride was higher than normal whereas well-water fluoride was lower (Figure 2). Soluble fluoride concentration in 67 samples collected from surface soil was 8 times that of deep soil. Levels of fluoride in bone, serum and urine measured from affected animals (Li et al. 1985a; Li et al. 1985c) were significantly higher than controls (Figure 3). Figure 4 shows the fluoride content of grass from safe pasture

Figure 1a,b. Tooth lesions characteristic of chronic fluorosis.

[1] Inner Mongolian Academy of Animal Science, Hohhot 010030, People's Republic of China

and bone fluoride concentrations from animals grazing on it, and the changes of bone fluoride content from affected sheep introduced into safe pasture one year later. The nearer the pasture to Baotou city, the higher the grass and bone fluoride (Figure 5). Measures of tooth length (Dong et al. 1985) were inverse to concentrations of fluoride in grass and bone while the incidence of fluorosis was positively related to grass and bone fluoride. The investigation suggested that high grass fluoride concentrations, originating from air pollution emanating from enterprises nearby, was the direct reason for chronic fluorosis of sheep.

Mechanism

The susceptibility of tooth enamel to high levels of fluorine resulted in a decrease in tooth hardness. The excessive fluoride caused abnormal changes of other minerals, such as a decrease in the amount of calcium in the body (Xu 1989). The differences in pathological changes of a sheep's teeth are determined by seasons and individual tolerance.

Treatment

Three treatments — $MgCl_2.6H_2O$, $NaB_4O_7.10H_2O$ and $KAl(SO_4.12H_2O)$ — were used (Li et al. 1985b) and the efficacies are given in Figure 6. Only the boride preparation had a small effect in reducing blood fluoride and increasing urine fluoride; the others had no significant effect.

Prevention

In the absence of effective drugs and without the possibility of eliminating the fluoride pollution, a strategy for prevention was implemented. The strategy included transferring livestock to safe pasture, introducing healthy livestock, improving grazing and managing conditions, such as building animal houses and planting trees around pasture plots, changing husbandry structures or raising fluorine-tolerant animals (pigs and poultry). Better results were achieved after these strategies came into effect.

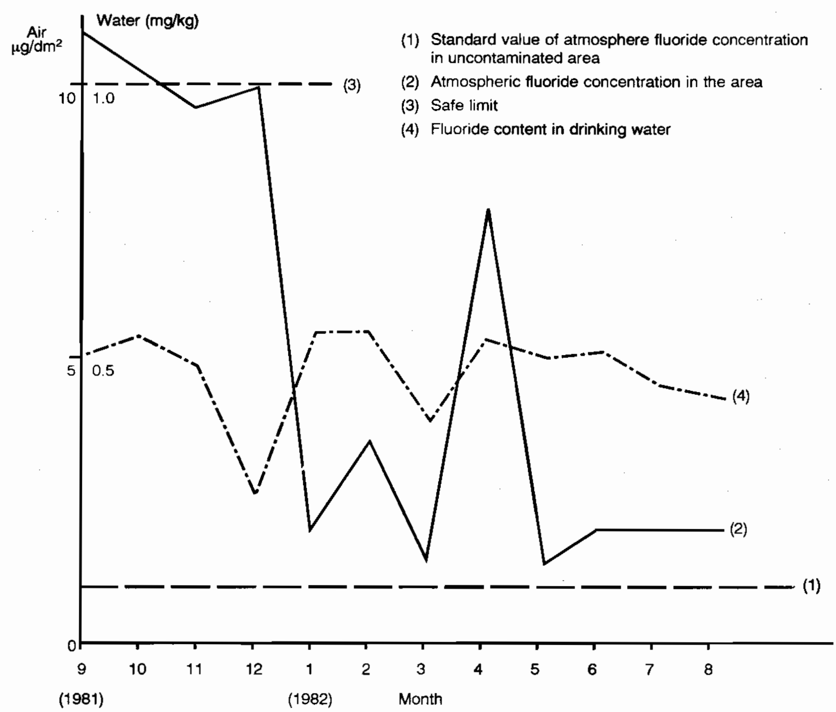

Figure 2. Changing patterns of fluoride concentration in the drinking water and atmosphere in the Shadegai area studied.

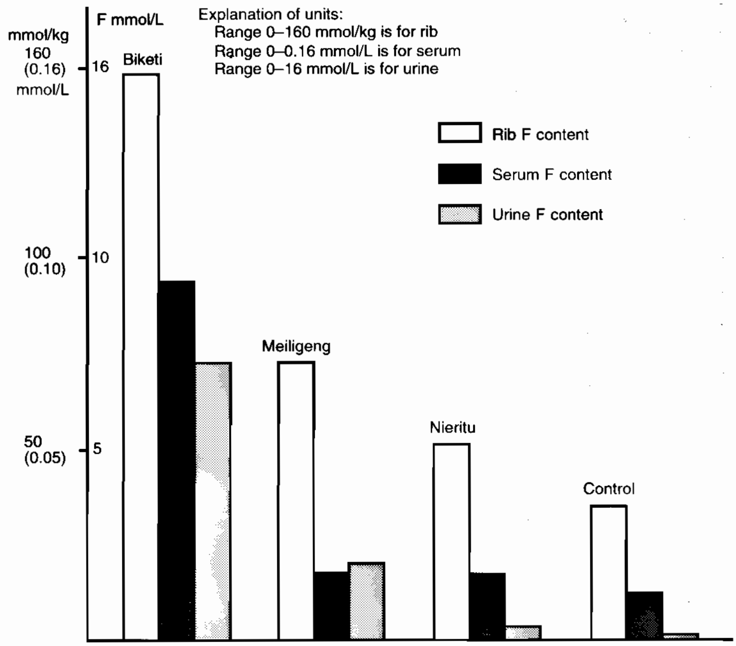

Figure 3. Fluoride values in the rib, serum and urine of goats grazing in areas with different levels of the disease.

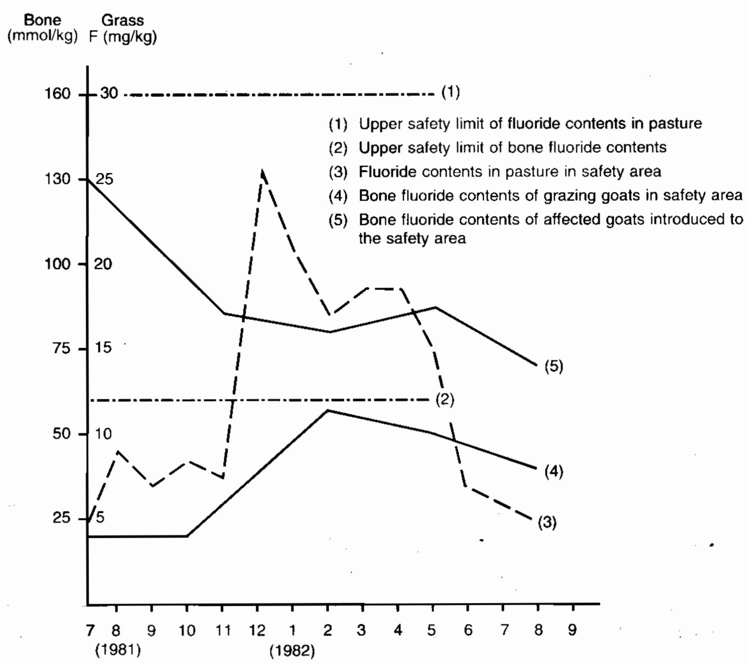

Figure 4. Changing patterns of fluoride concentration in pasture and goat bone in an uncontaminated area.

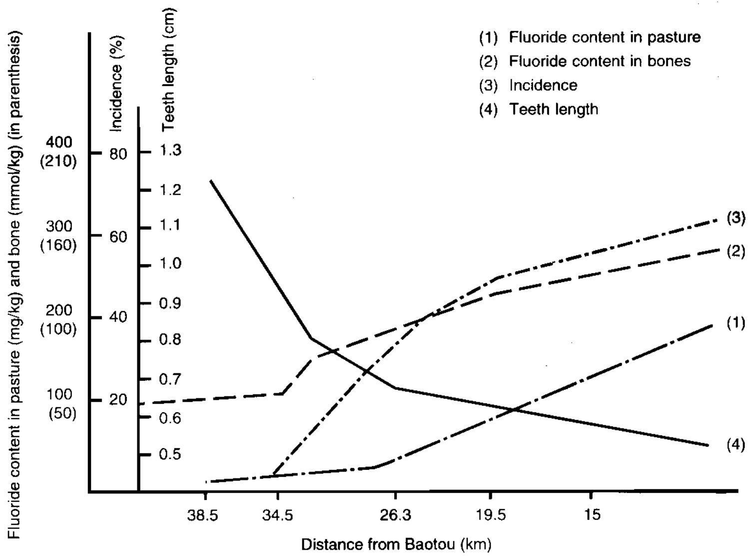

Figure 5. Measures of fluoride content in affected goats at locations of varying distance from Baotou.

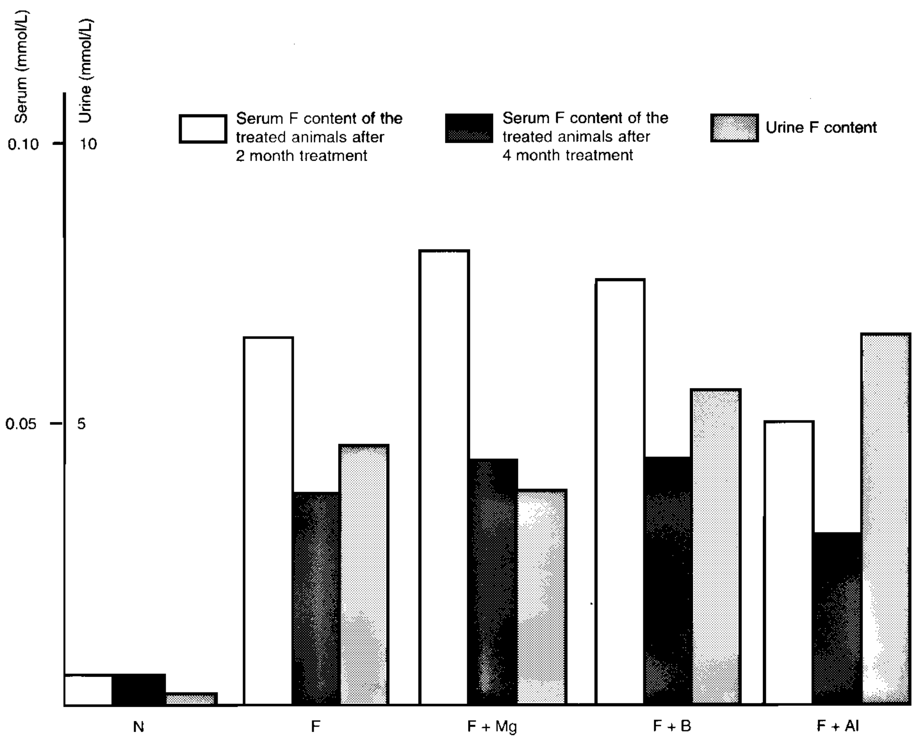

Figure 6. Effects of the treatment on serum and urine fluoride contents of the experimental animals.

Conclusion

Chronic fluorosis of animals in Shadegai Region was caused by fluoride pollution from enterprises near Baotou city. Effective strategies were put forward to ensure the development of animal husbandry in fluoride-contaminated areas.

References

Dong Baoshan, Li Guolin, Zhao Guiyan, Xu Guimei, Liu Xiaosong, Zhan Shubai, Li Jingyu and He Ping 1985. Changing patterns of teeth of goats suffering from chronic fluorosis at Shadegai. Inner Mongolian Veterinary Journal, 2, 45.

Li Guolin, Zhao Guiyuan, Dong Baoshan, Xu Guimei, Liu Xiaosong, Zhan Shubai, He Ping and Li Jingyu 1985a. Investigation of goat fluorosis at Shadegai Region. Inner Mongolian Veterinary Journal, 2, 28.

—1985b. The study on alleviation of chronic fluorosis by means of pharmaceuticals. Inner Mongolian Veterinary Journal, 2, 81.

Li Zouhuang, Zhao Guiyuan, Wang Hongzhong, E. Haixing, Ren Bingliang and Dong Baoshan 1985c. Report of chronic fluorosis of domestic animal in Inner Mongolia (1st report) Inner Mongolian Veterinary Journal, 2, 3–5.

Wang Shoudao and Shang Huashan 1985. Investigation of fluoride pollution at Shadegai, Wulate, Qian County. Inner Mongolian Veterinary Journal, 2, 20.

Xu Guimei 1989. Analysis of ten trace elements of cashmere and serum from chronic fluorosis goats. Inner Mongolian Animal Science, 4, 28.

Mineral and Vitamin Status of Sheep in Syria, Jordan and Turkey

C.L. White[1], T. Treacher[2] and F.A. Bahhady[2]

Abstract

There is little information on the incidence of micronutrient deficiencies of sheep in the west Asian and north African regions. This paper reports on a preliminary survey of the micronutrient and macronutrient status of sheep in parts of Syria, Jordan and Turkey. Blood samples were taken from (mainly) Awassi sheep at 18 sites during the winter lambing period of 1994. Feed samples were also collected from each site, and both blood and feed were analysed for a range of micro- and macronutrients.

There were marked differences between sites in terms of blood concentrations of vitamins and minerals. On the basis of published critical values, sheep from five sites could be classified as being low or deficient in vitamin E, two in selenium, two in copper and four in zinc. Vitamin A and vitamin B_{12} concentrations were above the deficient range at all sites.

Cereal grains contained amounts of sodium that were below published estimates of requirements. At two sites, lambs fattened indoors and fed on cereal-based diets showed pica. This was manifest as chewing the walls of the hut.

The results show that sheep are at risk from mineral and vitamin deficiencies in Syria, Jordan and Turkey. There is a need for further studies in the region and extending into North Africa and Eastern Asia. This is particularly important in view of the fact that animal products have the potential to play an important role in alleviating deficiencies of micronutrients in the human population.

THERE are 355 million sheep and goats and 120 million cattle and buffalo in west Asia and north Africa (FAO 1987). In west Asia the majority of sheep are raised as an adjunct to crop production and are fed on crop residues and grain (Thompson et al. 1988). Sheep products in the form of milk, cheese and meat constitute the main sources of high quality protein, minerals and vitamins for humans, and therefore play an important role in determining the health of the human populations of the region.

Despite some reports of deficiencies of selenium/vitamin E and copper in lambs in parts of Turkey (FAO 1986, 1992), and despite knowledge of the impact of such deficiencies on animal health and production (Underwood 1981; McDowell 1992), there are no published data on the incidence or severity of deficiencies of minerals or vitamins in sheep in the west Asian or north African regions.

[1]CSIRO Division of Animal Production, Private Bag, PO Wembley, Western Australia, 6014, Australia
[2]International Centre for Agricultural Research in Dry Areas, Aleppo, Syria

The aim of this project was to provide preliminary quantitative information on the mineral (macro and micro) and vitamin (A, E and B_{12}) status of sheep flocks in some of the major sheep-producing areas of Syria, Jordan and Turkey.

Sampling

Selection of sites and flocks

Samples were collected at a total of 18 sites in Syria, Jordan and Turkey (Table 1, Figure 1). Sites were chosen to represent the main sheep-producing regions and systems in the three countries. Unless indicated otherwise, as far as we were aware the sheep had received no mineral or vitamin supplements. The deliberate exclusion of farms using mineral supplements was to establish a baseline value for the natural level of minerals and vitamins. In fact, few farmers used vitamin or mineral supplements, and so selection of sheep at the village level was not a time-consuming task.

Table 1. Details of sampling sites.

Sample No.	Sheep type and sample size	Village/town	Farming system
Syria			
1	Lactating Awassi ewes; n=10	Tarheem/Al bab	Sheep were grazing a barley crop (early vegetative stage) and grass. They were supplemented with barley grain, barley straw, cottonseed cake and bread or bran.
2	Lactating Awassi ewes, n=10	Taybet-El Emam/Hama	Sheep were penned indoors and fed barley grain, barley straw, wheat bran and cottonseed cake.
3	Lactating Awassi ewes n=10	Gammari/Aleppo	Sheep were grazing a barley crop (early vegetative stage) and supplemented with lentil straw, barley grain, wheat bran and cottonseed cake.
4	Lactating Awassi ewes n=10	Maragha/Wadi Al Azib	Sheep were grazing sparse vegetation containing *Atriplex* species and natural grasses. They were supplemented with barley grain, cottonseed meal and barley straw (not locally produced).
5	Lactating Awassi ewes n=10	Adam/Wadi Al Azib	Sheep were raised under similar conditions to Wadi-Al-Azib, except that the barley straw and grain was locally grown.
6	Awassi lamb n=1	Deir Ez Zor	This was a lamb brought in from a nearby farm for investigation. Signs of ataxia were evident (staggers, lolling head movements).
7	Awassi lambs aged 1 month n=5	Souar/Deir Ez Zor	Ewes were grazing irrigated wheat (young vegetative stage) and dry unimproved pastures (sparse), and supplemented with barley grain and straw. Lambs were scouring badly and had a high mortality (30%).
8	Awassi lambs aged 3 months n=5	Souar/Deir Ez Zor	This flock was a few km away from the first at Souar. The farmer reported no disease signs. The diets were the same as for the first Souar flock.
12	Pregnant Cham female goats n=10	Karahta Research Station	There was a high mortality in dams with signs that resembled hypomagnesaemia or hypocalcaemia. Goats were grazing a vegetative barley crop and were fed 1 kg/day of concentrates.
18	Lactating Cypriot × Awassi ewes n=5	Research Station/ Hama	Sheep were kept indoors and fed pelleted diets and barley straw. They exhibited severe wool shedding without any apparent skin lesions. There was a high incidence of mastitis and pneumonia in the ewes and a high incidence of scouring in lambs.
Jordan			
9	Lactating Awassi ewes n=10	Madaba/Amman	Ewes were grazing unimproved grass with supplements of barley grain and bran with some barley or wheaten straw.
10	Lactating Awassi ewes n=10	Karak	Ewes were grazing green unimproved and unfertilised herbage and supplemented with barley grain.
11	Lactating Awassi ewes n=10	Kanasri/Aman	The ewes were grazing unimproved grass and supplemented with barley grain.
Turkey			
13	Lactating white Karaman ewes n=10	Ortakonak/Konya	Ewes and lambs were kept indoors. Lambs were fattened on barley grain and cottonseed cake. They showed signs of salt deficiency (pica, licking of walls).
14	Pregnant white Karaman ewes n=10	Haymaren Research Institute/Konya	Pregnant ewes were fed indoors on lucerne hay and concentrates containing a mineral mixture (including trace elements). No reported health problems.
15	Lactating white Karaman ewes n=10	Sakyatan/Konya	Ewes and lambs were kept indoors and fed a diet comprised mainly of barley grain and hay with cottonseed cake. This farmer had coated the walls with concrete to stop lambs licking it. Lambs had been given Se/vit E injections at birth.
16	Pregnant Daglic ewes n=10	Ardigli/Konya	The ewes were housed over winter and fed barley grain, barley straw and cottonseed cake. This area was elevated and snow-covered.
17	Lactating Turkish Awassi ewes	Garkipare/Adana	The ewes were grazing green grass shoots. They appeared undernourished and all had skin lesions resembling zinc deficiency. A low haematocrit was observed. The farmer fed citrus pulp and cracked grain when available.

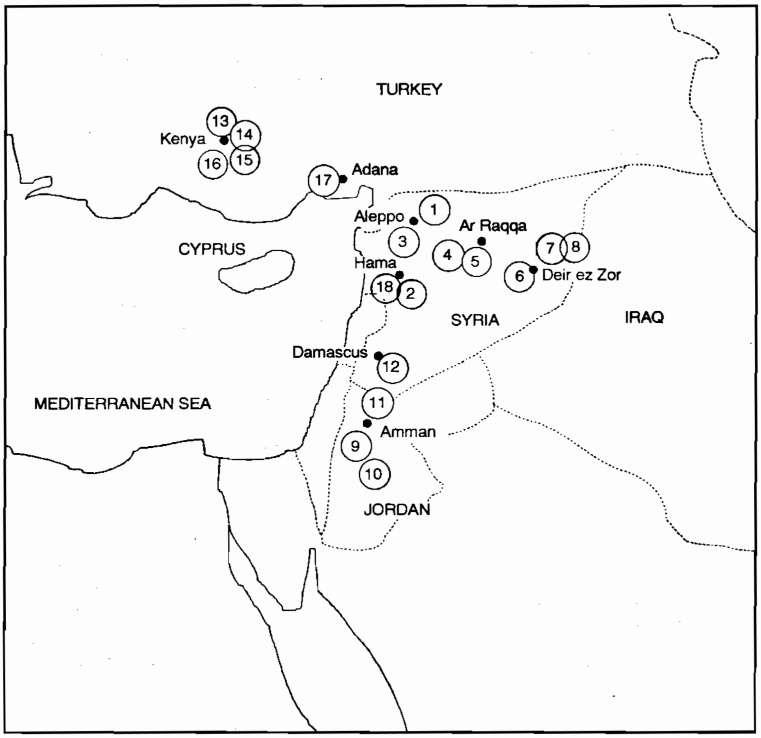

Figure 1. Sampling sites.

Procedures

Sampling was carried out during February–March 1994. Details of the sheep are provided in Table 1. The choice of an individual flock within a region was made after consultation with local livestock advisers, farmers and veterinarians. At most sites 10 ewes aged between 2 and 4 years and in early lactation were sampled. At two sites lambs were sampled in preference to ewes because of signs of copper deficiency in a lamb.

Blood was collected into syringes containing heparin and processed as described by White et al. 1992. Plasma and whole blood samples were frozen and stored at −18°C or colder until analysis. They were transported with dry ice to Australia, irradiated (6 Mrads) and analysed for the range of minerals and vitamins shown in Table 2. Analysis of vitamins A (retinol), E (α-tocopherol) and B_{12} were carried out by the Western Australian Department of Agriculture laboratories. An HPLC method was used for vitamins A and E, and a microbiological assay for vitamin B_{12}. Radiation destroyed some vitamin activity and the results were adjusted on the basis of two samples that had been taken locally and split into two before being irradiated. Copper and zinc were analysed using atomic absorption spectroscopy on supernatant from plasma treated with trichloro-acetic-acid (White et al. 1992). Selenium was analysed using whole blood (White et al. 1992)

Samples of the most commonly used feedstuffs and herbage were collected at each property. Not all feedstuffs are represented at each site because of unavailability of the sample or because not all feed types were used. The samples were dried at 60°C for 24 hours and ground in a cast iron mill before analysis by a registered laboratory (CSBP Australia Ltd) for nitrogen, sodium, potassium, phosphorus, calcium, sulfur, magnesium, manganese, zinc, copper, iron and molybdenum, using a variety of standard chemical procedures. Results are expressed on a dry weight basis.

Table 2. Mean concentrations of micronutrients in plasma and blood of sheep. Flocks containing deficient sheep (as defined in Table 3) are underlined. Note that results for sites 6 (single lamb) and 12 (goats) have been omitted. Sheep at site 14 were receiving a multi-mineral and vitamin supplement.

Country	Site No.	Sheep[1]	Vitamin A (μmol/L)	Vitamin E (μmol/L)	Vitamin B_{12} (nmol/L)	Se (WB[2]) (μmol/L)	Cu (μmol/L)	Zn (μmol/L)
Syria								
	1	LE	2.39	<u>2.90</u>	2.71	0.9	19.1	<u>9.9</u>
	2	LE	2.39	3.04	1.98	1.4	20.3	11.9
	3	LE	2.95	4.43	2.08	1.4	16.2	13.3
	4	LE	2.07	6.99	1.36	1.6	12.5	15.3
	5	LE	2.43	<u>1.88</u>	2.38	2.1	17.2	11.5
	7	L	2.32	<u>1.09</u>	0.46	3.3	<u>3.0</u>	13.0
	8	L	1.90	<u>1.72</u>	0.59	4.3	5.0	13.8
	18	LE	2.07	<u>2.11</u>	3.02	4.2	13.5	<u>9.9</u>
Jordan								
	9	LE	2.92	3.06	1.36	2.6	17.8	13.6
	10	LE	3.06	<u>2.90</u>	1.06	3.4	16.7	11.0
	11	LE	2.81	3.00	1.53	3.6	19.1	11.8
Turkey								
	13	LE	1.62	3.46	2.89	0.6	13.2	<u>9.0</u>
	14	LE	1.77	<u>1.35</u>	1.64	3.5	19.5	12.1
	15	LE	1.55	4.30	1.01	1.3	14.2	<u>8.5</u>
	16	PE	1.62	3.41	1.97	0.4	13.8	11.5
	17	LE	1.86	6.62	2.25	5.2	16.4	11.3
SEM			0.07	0.16	0.07	0.13	0.47	0.31

[1]LE = lactating ewe, L = lamb, PE = pregnant ewe.
[2]Whole blood.

Results and Discussion

There were marked differences between sites in terms of concentrations of vitamins and minerals in blood (Table 2). On the basis of the critical values shown in Table 3, seven sites could be classified as low or deficient in vitamin E, two marginally deficient in selenium, one deficient in copper and four marginally deficient in zinc (Table 2). Vitamin A and vitamin B_{12} concentrations were above the deficient range at all sites.

Table 3. The normal range and deficient concentrations of micronutrients in plasma and whole blood of adult sheep.

Nutrient	Deficient concentration	Normal range
Plasma:		
Vitamin A (Retinol) (μmol/L)	<0.5[1]	0.7–2.8
Vitamin E (α-tocopherol) (μmol/L)	<3.0[2]	4.6–11.6
Vitamin B_{12} (nmol/L)	<0.22[2]	0.44–2.95
Zn (μmol/L)	<6.0[2]	10.7–13.8
Cu (μmol/L)	<4.7[3]	10.7–23.6
Se (whole blood) (μmol/L)	<0.25[4]	>0.76

[1]Pierce (1945; 1954). [3]Paynter (1986).
[2]Hosking et al. (1986). [4]Paynter (1996).

Low vitamin E values were associated mainly with grain feeding and absence of green feed. Low copper values occurred only in lambs in the Euphrates valley. Copper levels were normal in the feed but the ewes were grazing green barley shoots that contained levels of sulfur up to 0.6%. This high level of sulfur would almost certainly have contributed to the copper deficiency through the formation of insoluble copper sulfides in the rumen (Suttle and McLaughlin 1976).

The lowest selenium values were seen in sheep in Turkey in the highlands near Konya. Sheep in the lower rainfall inland Steppe areas of Syria and Jordan had normal selenium status, but those closer to the coast in the higher rainfall areas were low to marginal. A seasonal variation exists in Australia for blood selenium concentration in sheep, so further work is required to determine the severity of the deficiency in these marginal areas at times of the year when growth rate is maximal.

The low plasma zinc values at four sites do not necessarily indicate a deficiency because plasma zinc concentration can be reduced by infection. One of these four low-zinc flocks had signs of mastitis and respiratory infections. The low-zinc flocks in Turkey were kept indoors and fed grain and hay — neither of which were low in zinc. These conflicting indicators do not make it possible to draw any firm conclusions about the incidence of zinc deficiency.

Table 4. The nutrient content of the different feedstuffs combined across sites (mean ± sem).

		N	P	K	Ca	Mg	Na	S	Cu	Zn	Mn	Fe	Mo
Feed type	n[1]	%	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Alfalfa hay	2	2.7 ± 0.1	0.46 ± 0.09	1.52 ± 0.90	1.32 ± 0.85	0.36 ± 0.05	0.20 ± 0.07	0.24 ± 0.05	11 ± 1	50 ± 14	68 ± 17	1220 ± 943	0.52 ± 0.21
Barley grain	13	2.3 ± 0.1	0.35 ± 0.02	0.56 ± 0.05	0.23 ± 0.06	0.20 ± 0.01	0.04 ± 0.01	0.19 ± 0.01	8 ± 1	34 ± 3	40 ± 5	406 ± 73	0.57 ± 0.12
Barley straw	8	0.6 ± 0	0.07 ± 0	1.35 ± 0.07	1.70 ± 0.38	0.25 ± 0.04	0.19 ± 0.14	0.35 ± 0.09	5 ± 1	16 ± 3	100 ± 30	2027 ± 677	0.22 ± 0.06
Barley whole green tops	3	4.5 ± 1.0	0.52 ± 0.08	4.38 ± 0.30	1.01 ± 0.3	0.25 ± 0.04	0.26 ± 0.12	0.50 ± 0.07	12 ± 3	37 ± 13	76 ± 18	398 ± 95	0.81 ± 0.37
Bread	1	2.2	0.26	0.26	0.36	0.12	0.50	0.20	6	26	28	539	0.32
Concentrate	3	3.1 ± 0.1	0.40 ± 0.04	2.02 ± 1.04	1.44 ± 0.62	0.51 ± 0.19	0.26 ± 0.15	0.26 ± 0.07	14 ± 3	54 ± 21	146 ± 86	4056 ± 3267	0.57 ± 0.06
Cotton seed	3	3.3 ± 0.1	0.45 ± 0.01	1.07 ± 0.07	0.24 ± 0.10	0.37 ± 0.02	0.01 ± 0	0.24 ± 0.01	11 ± 1	32 ± 3	24 ± 6	313 ± 202	0.34 ± 0.01
Cotton seed cake	3	5.3 ± 0.2	0.77 ± 0.05	1.60 ± 0.08	0.29 ± 0.03	0.57 ± 0.03	0.01 ± 0	0.44 ± 0.08	16 ± 1	49 ± 2	29 ± 3	301 ± 64	0.84 ± 0.11
Cotton seed hulls	1	1.1	0.16	1.25	0.21	0.21	0.01	0.12	6	14	27	143	0.29
Goat pellets	1	3.5	0.61	1.05	0.72	0.38	0.47	0.24	14	56	60	354	0.43
Irrigated grass	1	4.0	0.47	3.00	3.14	0.52	0.50	0.39	11	63	88	1502	0.68
Lentil straw	1	0.8	0.04	1.14	3.20	0.52	0.02	0.10	10	24	258	7632	0.89
Pasture	3	3.7 ± 0.8	0.40 ± 0.1	2.52 ± 0.62	2.42 ± 1.25	0.43 ± 0.08	0.22 ± 0.14	0.32 ± 0.04	10 ± 2	49 ± 11	108 ± 36	2855 ± 1305	0.45 ± 0.12
Pelleted feed	1	3.2	0.65	0.95	1.29	0.44	0.27	0.24	19	75	129	2344	0.48
Sugar beet pulp	3	1.6 ± 0.1	0.12 ± 0.04	0.28 ± 0.13	0.89 ± 0.05	0.34 ± 0.02	0.21 ± 0.04	0.14 ± 0.01	7 ± 1	16 ± 1	93 ± 7	1227 ± 114	0.17 ± 0.05
Wheat bran	8	2.9 ± 0.1	0.94 ± 0.09	1.12 ± 0.08	0.43 ± 0.18	0.49 ± 0.03	0.02 ± 0	0.23 ± 0.01	15 ± 1	85 ± 3	176 ± 13	1060 ± 684	0.42 ± 0.05
Wheat straw	5	0.8 ± 0.2	0.13 ± 0.03	1.41 ± 0.27	0.66 ± 0.16	0.22 ± 0.03	0.35 ± 0.08	0.25 ± 0.04	4 ± 1	19 ± 4	63 ± 14	1457 ± 353	0.75 ± 0.21
Wheat tops	2	4.9 ± 0.4	0.31 ± 0.03	3.45 ± 0.11	0.72 ± 0.20	0.16 ± 0.01	0.32 ± 0.06	0.45 ± 0.05	9 ± 3	31 ± 9	102 ± 20	297 ± 87	0.31 ± 0.09

[1] n = number of samples contributing to each mean.

A summary of mean values for nutrient levels for different feed types is shown in Table 4. An estimate was made of the intake relative to requirement of each nutrient at 13 of the sites. This was done by multiplying the concentration of nutrients by published levels of consumption of different feed types at the different locations (Thomson et al. 1988; ICARDA 1992). The results are shown in Table 6, expressed as a percentage of the nutrient requirements of sheep (ARC 1980; Table 5). Although these are estimates they indicate the likelihood of various deficiencies.

On this basis, sodium was the most common deficit — only three out of 13 flocks met requirements. Sodium deficiency causes growth retardation and reduces feed intake and milk production. Clinical manifestations include pica (Underwood 1981; ARC 1980). Observations of licking and chewing walls by housed grain-fed lambs in Turkey provides supporting evidence for sodium deficiency. However, in the absence of concentrations of sodium in urine or saliva, or any response data, the evidence for sodium deficiency remains largely inferential.

Table 5. Requirement levels of micro- and macronutrients in feed. Estimates are derived from ARC (1980) with modifications based on more recent data (e.g. Minson 1990, SCA 1990) and are for lactating ewes producing 2 L of milk/day or 20 kg lambs growing at 200 g/day (whichever is the higher).

Nutrient	Concentration (%)	Nutrient	Concentration (mg/kg)
N	2.5	Cu	5
P	0.25	Zn	25
K	0.45	Mn	25
Ca	0.37	Mo	0.05
Mg	0.18	Fe	40
Na	0.15		
S	0.18		

The estimated intake of nitrogen was below requirement in eight out of 13 flocks (Table 6). Since energy intake could not be estimated, it is difficult to know if protein deficiency was occurring independently of simple undernutrition.

Intakes of phosphorus, potassium, calcium, magnesium and sulfur were generally adequate, although low estimated intakes were detected at some sites. These were usually associated with low intakes of grain. It was notable that barley grain and straw from the region contained levels of calcium that were 3–5 times greater than comparable feed from the USA and Australia (NRC 1985; AFIC 1987).

The dietary requirements for copper, zinc, manganese, iron and molybdenum were estimated to be met at most sites (Table 6). The high concentrations and intakes of zinc were surprising, considering the evidence of low plasma zinc concentrations at several sites. The most likely explanation for a zinc deficiency, if it is occurring, is an interaction between zinc and some other element. High iron contamination of some feedstuffs combined with high calcium intakes may be reducing zinc availability, but this has not been clearly established under field conditions. Iron concentrations were exceptionally high in several feed sources, suggesting contamination with soil or some other source. Levels of soluble iron above 500 mg/kg will cause copper deficiency in ruminant calves and cause depressed milk yield, weight loss and diarrhoea in lactating cows (Grace 1983).

Table 6. Estimated nutrient supply of diets expressed as a percentage of requirements (ARC 1980).

Country	Site No	N	P	K	Ca	Mg	Na	S	Cu	Zn	Mn	Fe	Mo
Jordan													
	10	74	177	225	129	161	65	94	151	178	385	2656	885
	9	81	199	243	103	163	31	102	143	178	381	2243	205
Syria													
	5	66	103	203	419	189	105	213	297	163	758	8472	1039
	1	70	146	246	81	139	31	89	155	133	284	881	279
	3	78	131	224	293	170	60	107	165	184	517	7522	1703
	2	89	166	195	81	122	86	104	158	176	242	1082	459
	18	100	143	335	476	192	168	116	259	248	538	9239	639
	7	101	84	322	148	130	335	201	116	121	269	2027	785
	8	109	128	61	134	103	21	100	158	137	144	1241	906
	4	62	111	232	320	159	83	243	148	139	352	3797	488
Turkey													
	16	59	83	173	131	94	23	74	153	64	199	1452	946
	14	113	192	443	189	303	55	138	190	117	166	911	1404
	13	124	200	212	62	190	56	127	197	117	142	1701	2008

The effect of iron as soil contamination is largely unknown, but since many dietary ingredients in this survey had iron levels above 1000 mg/kg there is a need to determine the possible effects this might be having. For example, the concentrate feed used at Hama Animal Research Institute contained over 10 000 mg Fe/kg and the sheep were all shedding wool and had low plasma zinc concentrations. Whether the two facts are related needs investigating.

In summary, this survey suggests that deficiencies of several minerals and vitamin E may be occurring in sheep flocks in parts of west Asia. However, the results need to be interpreted with caution. Firstly, we do not know whether the critical values derived from Australian and European sheep breeds apply also to Awassis, and secondly, the preliminary nature of the survey can give only a very crude guide as to the seasonal incidence and geographical distribution of deficiency. Nonetheless, the results do show that at a number of sites the concentrations of several micro and macro-nutrients are below the range necessary for normal health and production, and suggest that a more systematic survey of animals together with experiments involving supplementary treatments is warranted.

References

AFIC (Australian Feeds Information Centre) 1987. In: Ostrowski-Meissner, H.T., ed., Australian Feed Composition Tables, National Collection. Sydney, AFIC–CSIRO.

ARC (Agricultural Research Council) 1980. The nutrient requirements of ruminant livestock. Slough, Commonwealth Agricultural Bureaux.

FAO (Food and Agriculture Organization) 1986. Sheep and Goats in Turkey, by B.C. Yalcin. Animal Production and Health Paper 60. Rome, Food and Agriculture Organization of the United Nations.

—1987. Agriculture: Towards 2000 (Revised version 1987). Rome, Food and Agriculture Organisation of the United Nations, C87/27.

—1992. Epidemiological Research on sheep abortion in Central Anatolia — nutritional and other non-infectious causes. Project No. TUR/90/015. Interim Consultant's Report by J. McDonald.

Grace, N.D. 1983. The Mineral Requirements of Grazing Ruminants. New Zealand Society of Animal Production, Occasional Publication No. 9. Palmerston North, Keeling and Mundy Ltd.

Hosking W.J., Caple, I.W., Halpin, C.G., Brown, A.J., Paynter, D.I., Conley, D.N. and North-Coombes, P.L. 1986. Trace Elements for Pastures and Animals in Victoria. Melbourne, Victorian Government Printing Office.

ICARDA (International Centre for Agricultural Research in the Dry Areas) 1992. Pasture, forage and livestock program. Annual Report.

Masters D.G. and Fels, H. G. 1980. Effect of zinc supplementation on the reproductive performance of grazing Merino ewes. Biological Trace Element Research, 2, 281–291.

McDowell, L.R. 1992. Minerals in Animal and Human Nutrition. New York, Academic Press Inc.

Minson, D.J. 1990. Forage in Ruminant Nutrition. San Diego, Academic Press Inc.

NRC (National Research Council). 1985. Nutrient Requirements of Sheep. Washington DC, National Academy Press.

Paynter, D.I. 1986. The diagnosis of copper insufficiency. In: Howell, J.McC. and Gawthorne, J.M., ed., The Metabolism of Copper in Man and Animals, Vol.1, CRC Press, Florida, 101–119.

—1996. Diagnosis of mineral deficiencies. In: Masters, D.G. and White, C.L., ed., Detection and Treatment of Mineral Nutrition Problems in Grazing Sheep, ACIAR Monograph No. 37, ACIAR, Canberra, 45–56.

Pierce, A.W. 1945. The effect of intake of carotene on the general health and on the concentration of carotene and vitamin A in the blood and liver of sheep. Australian Journal of Experimental Biology and Medical Science, 23, 295–303.

—1954. The effect of intake of carotene on reproduction in sheep. Australian Journal of Agricultural Research, 5, 470–483

SCA (Standing Committee on Agriculture). 1990. Feeding Standards for Australian Livestock — Ruminants. Melbourne, CSIRO Publications.

Suttle, N.F. and McLaughlin, M. 1976. Predicting the effects of dietary molybdenum and sulfur on the availability of copper to sheep. Proceedings of the Nutrition Society, 35, 22A-23A.

Thompson, E.F., Bahhady, F.A. and Martin, A. 1988. Sheep husbandry at the cultivated margin of the northwest Syrian steppe. Aleppo, International Centre for Agricultural Research in the Dry Areas (ICARDA).

Underwood, E.J. 1981. The Mineral Nutrition of Livestock. Slough, Commonwealth Agricultural Bureaux.

Whelan, B.R., Barrow, N.J. and Peter, D.W. 1994. Selenium fertilisers for pastures grazed by sheep. II. Wool and liveweight responses to selenium. Australian Journal of Agricultural Research, 45, 877–887.

White, C.L., Martin, G.B., Hynd, P.I. and Chapman, R.E. 1994. The effect of zinc deficiency on wool growth and skin and wool follicle histology of male Merino lambs. British Journal of Nutrition, 71, 425–435.

White, C.L.,Masters, D.G., Peter, D.W., Purser, D.B., Roe, S.P. and Barnes, M.J. 1992. A multi element supplement for grazing sheep. I. Intake, mineral status and production response. Australian Journal of Agricultural Research, 43, 795–808.

Mineral Deficiencies in Grazing Sheep in Pakistan

Sadaqat Hayat Hanjra[1], Arshad Iqbal[2] and Muhammed Jaffer Hayat[2]

Abstract

Pakistan's sheep population (28.3 million) is scattered throughout the country in 32 000 flocks. These animals are raised in either small sedentary household units (1–5 animals) or larger transhumant and nomadic flocks (200 and above). Over 70% of the sheep population draws feed from grazing. Feed is extremely scarce both in winter (November–January) and summer (May–July) periods.

Soil deficiencies of some minerals, particularly zinc, copper, iron and iodine, have been observed in several regions of the country. Animals grazed on fodder and other crops grown on such soils manifest nutritional disorders.

Occasionally pronounced stunted growth, low wool production, low fertility and emaciation have been noticed. Rickets and ataxia are commonly observed in kids. Goitre and steely wool have also been reported.

PAKISTAN is divided into several agroclimatic regions. In the north there are snow clad mountains and high alpine pastures. The Indus valley has one of the largest canal irrigation systems in the world; the Thal and Cholistan deserts are very arid. Baluchistan, the largest land area, is mostly barren. In the south there are semi-arid to subhumid expanses. Of the 88 million hectares land area, 82% is unfit for arable agriculture. These vast tracts are used by grazing livestock, particularly sheep and goats. The rangelands have inherently low productivity due to environmental constraints and chronic overgrazing that has depleted the natural vegetation. In the irrigated tracts of Punjab and Sindh, livestock graze marginal grazing strips, canal and river banks, roadsides and community grazing strips and may also be fed crop residues. Seventy per cent of sheep draw their feed requirements from grazing.

The availability of feed from all sources is inadequate considering the total livestock population of the country. The deficit is variously estimated at 30–40% of the requirements in terms of nutrients (Hanjra and Rasool 1993). The sheep population estimated at 28.3 million (Government of Pakistan 1995) is distributed throughout the country (Figure 1).

These animals provide annually over 230 000 tonnes of meat (18.4% of the total meat) and 60 000 t of wool. There are an estimated 32 000 flocks (43% Punjab; 22% Baluchistan; 16% Azad Jammu and Kashmir; 13% Sindh; and 6% North Western Frontier Province). The flock size ranges between five and 200 head with only 10% above 200. The production systems are divided into: nomadic, 44%; transhumant, 38%; and household and sedentary, 18%.

Mineral Deficient Areas

Khattak and Parveen (1987) reviewed work on mineral-deficient soils and reported that information was patchy.

It was observed that 85% of soils have insufficient zinc to meet the needs of crops. Boron is high in Punjab and Sindh. Copper and iron are deficient to marginal. A severe deficiency of copper and iodine was observed in soil and plants of the Thal Desert. The northern areas show severe deficiency in iodine. Excessive selenium has been reported in certain parts of Punjab and North Western Frontier Province. Cobalt is deficient in hilly tracts of Punjab and North Western Frontier Province.

[1]FAO, PO Box 1476, Islamabad, Pakistan

[2]Department of Livestock Management, University of Agriculture, Faisalabad, Pakistan

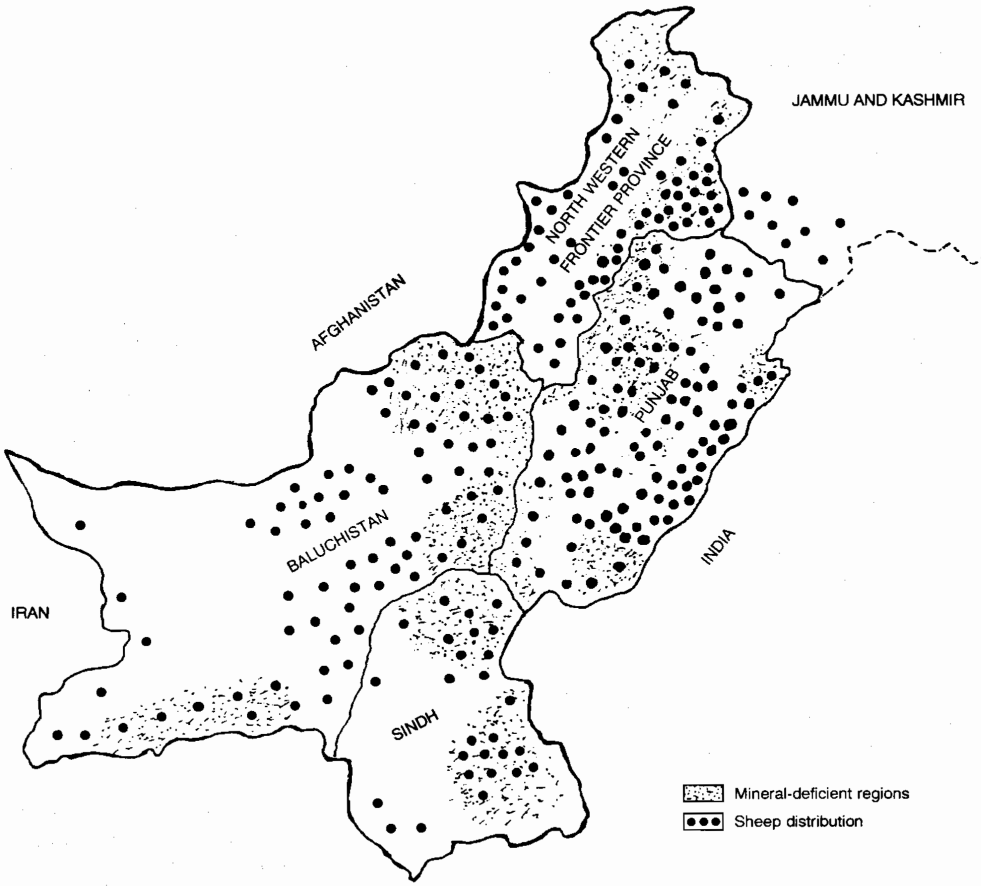

Figure 1. Sheep distribution and mineral-deficient regions in Pakistan.

Ali and Malik (1993) have reported a severe deficiency of phosphorus in the desert area of Sindh. The mineral-deficient areas have been shown in Figure 1.

Plant Composition

Low levels of calcium, phosphorus and copper were reported in summer fodders (Anon. 1972). It was reported that the high ambient temperature and plant growth reduced the level of micronutrients in plants. Chemical analyses of 60 different grasses, weeds and tree leaves generally eaten by livestock (sheep and goats) were conducted to determine levels of iron, phosphorus, calcium, sodium and potassium. It was revealed that most of the range grasses contained low levels of calcium (0.02–0.2%), sodium (0.002–0.062%), potassium (0.48–1.72%), phosphorus (0.02–0.137%) and iron (0.003–0.065%).

The mineral composition of various grasses dropped drastically in summer. The tree leaves mostly showed adequate quantities of all the micro- and macronutrients except phosphorus. The weeds had adequate concentrations of iron, sodium and calcium but were deficient in phosphorus and potassium.

Nutritional disorders are commonly observed in the grazing animals. Since there are severe deficiencies of other nutrients (protein, carbohydrates and fats), the situation becomes more complex. Furthermore, grazing sheep also harbour parasitic infestations, so the symptoms of mineral deficiencies are further aggravated.

Various minerals also interact, e.g., the absorption and retention of copper are greatly influenced by the amounts of molybdenum and sulfur present in the feed. Other factors contributing to micronutrient levels are stage of growth and water composition of the plant, and climate.

Table 1. Mineral deficiency in grazing sheep.

Survey No.	Age group	% Affected	Symptoms	Possible cause
1	Suckling lambs/orphan kids	2	Rickets	Ca/P deficiency
	(lambs dropped=527)	17	Mortality	Ca, P, I, deficiency, poor feed
2	Suckling to one year	20	Stunted growth	Ca/P, I deficiency
		<1	Goitre	I deficiency
3	Suckling to one year	2	Ataxia	Cu deficiency
4	Adult female (600)	5	Low wool yield Poor mothering ability Long kidding interval	Poor feed availability and mineral deficiencies

Hanjra and Dawson (1988) conducted three field surveys. In survey 1, data were collected from grazing flocks in Thal (desert area of Punjab). The observations made are listed in Table 1.

Incidence of disease symptoms was pronounced in orphan lambs, which suffered high mortality (17%) till the age of 6 months. The reason apparently was very low calcium, phosphorus and iodine intake through milk and feed.

The seasonal changes in the availability of grazing biomass also influenced the disease incidence. Stunted growth and poor wool growth were more pronounced in the summer season than the winter season. Khan and Hanjra (1970) reported a significant difference in the weight gain in summer (low daily weight gain) and winter seasons (summer av. daily weight gain 0.07 kg; winter av. daily weight gain 0.13 kg).

In survey 2, a study was conducted where four sedentary flocks (No. 635) were raised on small community grazing strips, tree leaves and crop residues. The results are presented in Table 2.

The data indicate a low wool growth (0.76 kg per annum) with steely wool. The wool fibres were also more brittle in the summer than the winter clip. Other parameters did not show abnormalities. The daily weight gain of adult male lambs was 0.12 kg, which is almost equal to 0.14 kg weight gain in a well fed flock. The data indicate that sheep relying on different sources of feed could meet their requirements easily by comparison to a single feed source.

Anon. (1972) and Ranjhan (1981) observed anaemia, reduced growth rate, wool shedding and production of stringy wool in the grazing sheep. The physiological parameters of blood showed a very low level of copper. Weak lambs in Lohi sheep were dropped (birth weight 2.62 kg grazing flock vs 3.6 kg at Government farms). However, the growth was static in May and June when the temperature went up beyond 40° C and most of the grasses died.

Table 2. Some production parameters of sedentary flocks.

Fertility (%)	76.00
Mortality in adult sheep (%)	3.50
Mortality in lambs (%)	5.00
Magnesium tetany (adult female over 4 years age (%))	0.30
Wool growth (kg/adult)	0.76
Average daily weight gain (kg)	0.12

In survey 3 the feeding and management of three village flocks (No. 176) in the hilly tract of Punjab was studied. It was observed that during feed shortage the lambs licked earth. The pregnant sheep in the same flock chewed bones, pieces of cloth and shoes. Lambs showed loss of appetite, low wool growth, loss of weight and emaciation. The most plausible explanation was deficiency of minerals. Data collected on the incidence of swayback showed 14% of lambs with symptoms. It was also observed that the overall feed availability was quite poor in the area. The soils of the hilly tract showed deficiency of cobalt and copper.

Zafar and Awan (1990) reported a high mortality in the grazing flocks (16%) which was attributed to poor nutrition (mineral deficiencies) and disease (high parasitic infestation).

References

Ali, A. and Malik, M.Y. 1993. Nutrition. In: Mackintosh, J.B., ed., Sheep Production in Pakistan. Islamabad, Pakistan Agricultural Research Council, 117–120.

Anonymous 1972. Mineral deficiency and mineral estimation of fodder, grasses and shrubs. 10th Annual report. Directorate of Livestock Farms, Punjab, Pakistan. 68–75.

Government of Pakistan 1995. Ministry of Food and Agriculture, Islamabad, Pakistan.

Hanjra, S.H. and Dawson, M.D. 1988. Raising small ruminants on grazing and crop residues. Farming Systems Research Programme. Internal report. RARC. Pakistan. 23–28.

Hanjra, S.H. and Rasool, S. 1993. Potential of *Atriplex* as a forage for livestock in Pakistan. In: Davidson, N. and Galloway, R., ed., Productive Use of Saline Land. ACIAR Proceedings No. 42, Canberra, Australian Centre for International Agricultural Research, 68–70.

Khan, A.H. and Hanjra, S.H. 1970. Effect of grazing and grazing-plus-supplement feeding on body weight, wool quality and carcass quality in sheep. Pakistan Journal of Agricultural Science. 7:3. 65–68.

Khattak, J.K. and Parveen, S. 1987. Micronutrient status of NWFP soils. In: Khattak, J.K., Perveen, S. and Farmanullah, ed., Proceedings of the national seminar on micronutrients in soil and crops in Pakistan. NWFP. Agricultural University, Peshawar, Pakistan. 62–74.

Ranjhan, S.K. 1981. Mineral nutrition and metabolism. In: Ranjhan, S.K., ed., Animal Nutrition in the Tropics. New Delhi, Vikas Publishing House, 115–118.

Zafar, A.H. and Awan, M.A. 1990. Production performance and economics of small ruminants in district Okara. 11th annual report. Livestock Production Research Institute, Bahadarnagar, Okara, Pakistan, 105–109.

Trace Element Research in Sheep in Malaysia

M.M. Noordin[1]

Abstract

Although the Malaysian livestock industry, particularly that part pertaining to sheep, has increased tremendously, research towards improving productivity has been focused on the production systems and nutrition. This includes integrated farming systems with crop plantations and the use of agricultural by-products as sources of feed.

Investigation into trace element nutrition or nutritional pathology has however been insignificant and this is the most neglected field of research in sheep. This is reflected by an increase in unsolved cases of ill thrift, infertility, abortion and pica nationwide. It is believed that trace mineral imbalances are major constraints contributing to these problems.

A critical integrated review of previous findings, including geographical and socioeconomic factors, is presented, and a strategic model for conducting and improving the research in trace element nutrition in Malaysia is discussed.

Malaysia's Sheep Industry

THE indigenous sheep of Malaysia (Malin) originated from sheep of Tibet via the Yunnan province (Davendra and McLeroy 1982). Whatever their origin, the local sheep have evolved under an environment of low nutrition with little or no human intervention. This small hardy animal weighs approximately 23–28 kg with a daily weight gain ranging between 28 and 45 g (Rajion et al. 1993).

The total population of sheep has increased from 39 000 head in 1980 to an estimated 350 000 head in 1993. The number is expected to grow further, reaching 1 million in the next decade. The growth in sheep numbers is due to liberalisation of imports of various breeds for cross-breeding with the Malin (Mahyuddin 1993).

Traditionally, the sheep industry has been in the hands of the smallholder and is not as developed as the pig or poultry industries. The production systems may be extensive, semi-intensive or intensive. Under all these production systems, wasting diseases, depressed growth, pica and anorexia are often seen and are believed to relate to trace element deficiencies, toxicities or imbalances (Howell 1991). The above conditions, being either marginal or acute, have inhibited productivity in ruminants (Wan Zahari and Davendra 1985), a similar scenario to many other parts of the world (McDowell 1976).

Research in Sheep

Although the Malaysian livestock industry, particularly that part pertaining to sheep, has increased tremendously, research towards improving productivity has been focused on the production systems and nutrition. Research in sheep has improved productivity but not to a significant and acceptable commercial level (Babjee 1994). This includes integrated farming with crop plantations (Chong et al. 1991) and the use of agricultural by-products (Chooi et al. 1988) as sources of feed.

Trace element research

Research into trace elements, either from the production or pathology point of view, is insignificant, and in fact is the most neglected field of research in sheep in this country. This may be due to the absence of expertise or the lack of comprehensive mineral research conducted nationwide. The accumulated

[1] Faculty of Veterinary Medicine and Animal Science, Universiti Pertanian Malaysia, 43400 UPM Selangor Darul Ehsan, Malaysia

data on feed, especially in relation to trace elements, need to be analysed at some central point.

Although the Malaysian Agricultural Research and Development Institute (MARDI) has recognised the paucity of knowledge concerning mineral nutrition, investigative programs were mounted on a small scale and were largely concentrated on large ruminants (Mannetje et al. 1975; Wan Zahari and Davendra 1985). Thus, a problem exists but the basic information is lacking.

The following are the findings and the major problems encountered in mineral research in this country and the probable solutions to rectify them.

There are a few approaches used in assessing the trace element status of sheep. The most widely used approach was to test serum/plasma (Noordin and Zuki 1995) or tissues (Wan Zahari et al. 1983), and the other is by assessing productive performance (Wan Zahari et al. 1983). The use of serum may not reflect the actual status of trace elements except in overt toxicities or deficiencies. So far, no-one has employed biopsy as a method of serial sampling and assessing the status of trace elements. The paracostal technique (Donald et al. 1984) was found to be an effective and safe biopsy method for sheep, (Noordin 1992). The use of biopsy will not only reduce cost but will also allow sequential studies of tissue changes in a spatial manner.

Similarly, the digestion of samples also varies with the single acid digestion being widely used (Chooi et al. 1988; Wan Zahari et al. 1983). However, the double acid method is currently gaining popularity, due to its better yield and standardisation (Noordin and Zuki 1995). Nevertheless, the triple acid method (Ishmael et al. 1971) is the best method of wet ashing of tissues for the determination of trace elements (Galgan and Frank 1993).

An estimation of the extent of selected mineral deficiencies is shown in Figure 1 and some features are highlighted in the following discussion. The estimation was based on published reports in plants/soils (Kanapathy 1976; Arulandoo and Mohamad 1987; Mutalib et al. 1991), sheep (Wan Zahari et al. 1983; Noordin and Zuki 1995) and other ruminants (Mannetje et al 1975; Wan Zahari and Davendra 1985; Muniandy and Najamuddin 1989).

Experiments conducted in sheep have shown deficiencies in cobalt (Wan Zahari et al. 1983) and also in iron (Noordin and Zuki 1995). Wan Zahari et al. (1983) successfully treated cobalt deficiency (by giving 600 μg vitamin B_{12} intramuscularly but not with any oral cobalt treatment) during the early stages, but the problem recurred or continued to progress by the 14th week. The response was measured by increases in body weight gain (approximately 3.5 kg) and in plasma vitamin B_{12} over the period of 20 weeks. The ineffectiveness of oral cobalt treatment could have resulted from the use of cobalt bullets which, when administered orally, may have been regurgitated or been coated with calcium phosphate, hence reducing bioavailability of cobalt (Anon. 1980). Furthermore, in that experiment, tissue studies were not done to assess the morphology of tissues with respect to their response to therapy.

A low iron status (average concentration in plasma of 12.5 μmol/L or less) was found to coincide with the incidence of haemonchosis (Noordin and Zuki 1995), a disease which is endemic throughout the country (Amin-Babjee et al. 1990). Almost every sheep is at risk of the disease, especially in relation to management practices (overcrowding, grazing during early morning and resistance to anthelmintics). It is well known that this parasite causes blood loss, leading to anaemia which will deplete iron storage (Dargie and Allonby 1975). Thus, careful interpretation of data has to be done in areas endemic for a particular disease, especially those that might alter the metabolism of trace elements.

A major problem in trace element research in Malaysia is the absence of a map showing trace element deficient or toxic areas. There are about 200 soil series in Malaysia (Shamshuddin 1981) of which only 168 have been well studied. In general, Malaysian soils are mostly acidic and have high levels of iron and aluminium (Kanapathy 1976; Shamshuddin 1981). The high levels of these two elements have rendered phosphates unavailable. Phosphorus deficiency appears to be the most prevalent and economically important mineral problem affecting grazing ruminants in tropical areas (McDowell 1976). Thus, phosphorus deficiency is commonly seen in plants (Kanapathy 1976; Arulandoo and Mohamad 1987) and has been reported in cattle (Eng et al. 1978; Wan Zahari and Davendra 1985) and buffaloes (Wan Zahari and Davendra 1984). Although no study has been carried out, a similar scenario of phosphorus deficiency is believed to occur in sheep (Figure 1).

Again, owing to the acidic nature of the soils (pH<5.5), deficiencies in potassium have been reported in a variety of crops (Kanapathy 1976). This condition is more pronounced during the dry season and sudden drought. In a country like Malaysia where almost half the year is dry, deficiency of potassium is probably second to phosphorus and is most likely to occur in about 30% of the total sheep population (Figure 1).

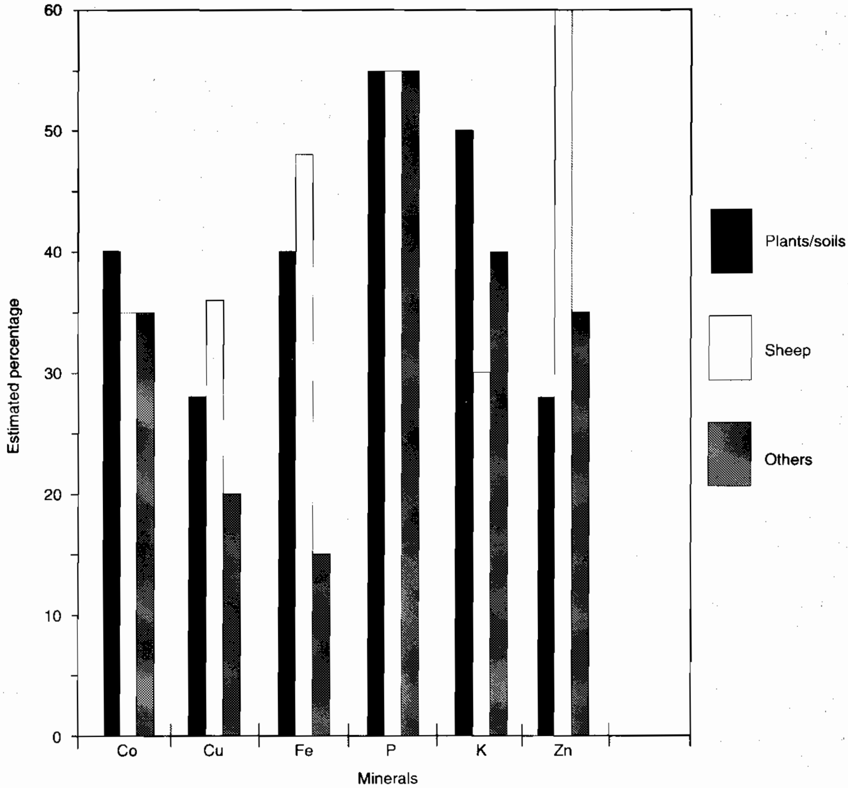

Figure 1. An estimation of mineral deficiencies (plant/soils, sheep and other ruminants).

Peat soil is well documented for being deficient in copper and zinc (Mutalib et al. 1991). Although reports on copper and zinc deficiencies in sheep have not been documented, it is anticipated that sheep reared on such soils are at risk of being copper or zinc deficient.

Sodium deficiency has been reported in cattle (Wan Zahari and Davendra 1983) but did not appear to be a problem in sheep (Wan Zahari and Abdul Wahid 1985). It appears that salt supplementation by farmers in the form of blocks or mineral licks may have prevented or minimised the occurrence of sodium deficiency in sheep.

A rather erroneous assumption based on map areas is to assume that the status of trace elements in other species is similar to that found in sheep. Separate studies should be done in sheep before such an assumption can be drawn or verified. For example, copper deficiency in cattle (Muniandy and Najamuddin 1989) may differ from that of sheep, due to differences in metabolism and consequent susceptibility to deficiencies or toxicities (Weber et al. 1980).

Another problem associated with trace element work is exact definition of the management system employed in sheep rearing. Basically, there are three systems — extensive, semi-intensive and intensive — but there is no clear demarcation between each system. The tendency of farmers not to follow any strict management system or to merge all systems in a single period of production have made investigation into trace element nutrition even more difficult. Thus, mineral formulation data for one particular system may vary.

Furthermore, sheep reared in different parts of the country under one management system may differ in response to a particular therapy simply due to a difference in soil series. The pH, chemical composition of soils, rainfall and type of vegetation may affect the bioavailability of trace elements (Roberts 1976). This alteration in bioavailability may enhance deficiencies or toxicities in a particular area. For example, cattle of similar breed reared under the same management system had different copper status due to geographical location (Muniandy and Najamuddin 1989).

Work on copper toxicity, usually synonymous with palm kernel cake (PKC) toxicity, has been intensively carried out. The annual production of PKC is estimated to be between 270 000 and 350 000 t. Generally, 50% of raw fruit will be converted into PKC during processing. Since PKC is readily available and rather cheap compared to conventional feedstuffs, farmers have used it as a popular source of feed. Earlier reports on PKC toxicity (Chooi et al. 1988; Zamri-Saad et al. 1989) have implicated PKC as the primary source of this toxicity, due to its high copper content (25–40 μg/g). In animals that died of PKC toxicity the concentrations of copper (dry weight basis) in the liver and kidneys were 15.7–63 mmol/kg and 3.3–3.8 mmol/kg respectively. Prophylactic studies using copper antagonists such as zinc and molybdate have been carried out (Abd Rahman et al. 1992). Cases of osteodystrophic fibrosa (ODF) were observed in PKC-fed goats receiving 15 g Mo/head/day for 3 months (Noordin and Nutman 1995, unpubl.). Although ODF has not been reported in sheep in this country, the case in goats demonstrated the importance of extreme care in view of the usage of antagonists. However, as a preventive measure, total feeding of PKC in the absence of an antagonist is discouraged. Sporadically, urolithiasis is seen in PKC-fed rams due to its high phosphorus: calcium ratio (>2.5:1) (Zamri-Saad et al. 1989).

As mentioned earlier, infectious agents can modify the overall status of trace elements in sheep (Noordin and Zuki 1995). Thus, in mounting an investigative program in trace element research, the role of infectious and non-infectious agents should be considered.

The role of non-dietary influences such as pyrrolizidine alkaloid has been known to interfere with the metabolism of iron and copper (Howell et al. 1993; Noordin et al. 1993). Similarly, in Malaysia, a steroidal compound found in *Brachiaria decumbens* (Nordin et al. 1993), has been shown to suppress the zinc status to as low as 6 μmol/L (Salam, pers comm.). This plant, which is grown in almost all government farms, was shown to be toxic to sheep (Noordin et al. 1987) but not to cattle (Noordin et al. 1989) in Malaysia. Thus, zinc deficiency could be a major problem in sheep if they continue to graze this pasture (Figure 1). Zinc deficiency could be exacerbated if the area where the plant is cultivated is peat in nature (Mutalib et al. 1991).

Strategies to Improve Trace Element Research in Malaysia

This is a modified strategy based on a program proposed by Howell (1991) on trace element research in ruminants in Malaysia.

Baseline data

Baseline data are needed and these have to be streamlined by the use of standard methods throughout the country. The cooperation between farmers, Department of Veterinary Services and research institutions would greatly facilitate the program. It is hoped that with this cooperation, areas of study including the management systems and prevalence of diseases can be identified.

Assessment of important elements such as calcium, cobalt, copper, iron, magnesium, manganese, sodium, sulfur, selenium and zinc in tissues, soils and pastures should be carried out. The use of biopsy, abattoir and necropsy specimens from a healthy and productive flock would provide the baseline information. Similar samples should be taken from areas where sheep form an important part of the agricultural economy. The management system employed in that area should also be exactly defined. Simultaneously, investigations into infectious diseases and malnutrition should be mounted.

Map areas

Results obtained from the test areas should be compared to baseline data and figures published for reference values. By using this information, locations in Malaysia can be mapped out to designate marginal, overtly deficient or toxic areas. This will assist in the formulation of feed or treatment regimens for particular areas.

Production and tissue response

The next step is to design experimental trials to assess the production and possibly the tissue response to minerals in areas that have been identified. This will include regular weighing, collection of samples and performing necropsies on sick and dead animals.

Guidelines for mineral supplementation

Positive results in terms of responsiveness to treatment in the trials will be taken as the recommended guidelines for that particular area (taking into account the management system/s). This will be followed by the most practical method of supplementation to improve the farmers' livelihood without disrupting their lifestyle. The cost–benefit analysis and the information will be disseminated to farmers.

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References

Abd Rahman, M.Y., Wong, H.K. and Sharif, H. 1992. Copper toxicity in sheep fed palm kernel cake. In: Proceedings of the National IRPA Seminar. Kuala Lumpur, Ministry of Education, Malaysia, 510–511.

Amin-Babjee, S.M., Lee, C.C., Sheikh-Omar, A.R. and Mohna, S.S. 1990. An abattoir study of gastrointestinal parasites of adult indigenous goats. Jurnal Veterinar Malaysia, 2, 103–108.

Anonymous 1980. Mineral Tolerance of Domestic Animals. Washington, National Academy of Sciences, 577 p.

Arulandoo, X. And Mohamad, A.M. 1987. The need for phosphorus application in Muda project areas. Teknologi Padi, 3, 13–18.

Babjee, A.M. 1994. The direction of the sheep industry in Malaysia. In: Davis, M.P., Sheikh-Omar, A.R. and Rajion, M.A., ed., Proceedings of the Second Sheep Symposium in Malaysia. Serdang, Universiti Pertanian Malaysia, 1–4.

Chong, D.T., Tajuddin, I. and Abd Samat, M.S. 1991. Stocking rate effect on sheep and forage productivity under rubber in Malaysia. In: Shelton, H.M. and Stür, W.W., ed., Forages for Plantation Crops, ACIAR Proceedings 32, Canberra, Australian Centre for International Agricultural Research, 102–106.

Chooi, K.F., Hutagalung, R.I. and Wan Mohamed, W.E. 1988. Copper toxicity in sheep fed oil palm by-products. Australian Veterinary Journal, 66, 156–157.

Dargie, J.M. and Allonby, E.W. 1975. Pathophysiology of single and challenge infection of *Haemonchus contortus* in Merino sheep: Studies on red cell kinetics and the 'self-cure' phenomenon. International Journal of Parasitology, 5, 147–157.

Davendra, C. and McLeroy, G.B. 1982. Goat and Sheep Production in the Tropics. London, New York, Longman, 271 p.

Donald, G.E., Paull, D.R. and Langlands, J.P. 1984. Liver biopsy technique for assessing copper status of sheep. Australian Veterinary Journal, 61, 121–123.

Eng, P.K., Manetje, L.t. and Chen, C.P. 1978. Effects of phosphorus and stocking rate on pasture and animal production in Johore, Malaysia. 2. Animal liveweight changes. Tropical Grassland, 12, 198–207.

Galgan, V. and Frank, A. 1993. Notes and comments on the determination of selenium in biological materials. Norwegian Journal of Agricultural Sciences, Supplement, 11, 57–74.

Howell, J. McC. 1991. Trace element research in ruminants in Malaysia. In: Momcilovic, B., ed. Proceedings of the 7th International Symposium on Trace Elements in Man and Animals. Institute of Medical Research and Occupational Health, University of Zagreb, (15) 4–5.

Howell, J. McC., Deol, H.S., Noordin, M.M. and Dorling, P.R. 1993. Trace element interactions with special reference to the interaction of copper and heliotrope in sheep. In: Anke, M., Meissner, D. and Mills, C.F. ed. Proceedings of the Eighth International Symposium on Trace Elements in Man and Animals. Gerdstof, Verlag Media Touristik, 271–278.

Ishmael, J., Gopinath, C. and Howell, J. McC. 1971. Experimental chronic copper poisoning in sheep. Histological and histochemical change during the development of lesions in the liver. Research in Veterinary Science, 12, 358–366.

Kanapathy, K. 1976. Guide to Fertilizer Use in Peninsular Malaysia. Kuala Lumpur, Ministry of Agriculture, 141 p.

Mahyuddin, M.D. 1993. A review of the Malaysian livestock industry. In: Fatimah, C.T.N.I., Ramlah, A.H. and Bahaman, A.R., ed. The Animal Industry in Malaysia, Serdang, Universiti Pertanian Malaysia, 1–6.

Mannetje, L.t., Sidhu, A.S. and Murugaiyah, M. 1975. Cobalt deficiency in cattle in Johore: Liveweight changes and response to treatment. MARDI Research Bulletin, 4, 90–98.

McDowell, L.R. 1976. Mineral deficiencies and toxicities and their effect on beef production in developing countries. In:Smith, E.J., ed., Proceedings Beef Cattle Production in Developing Countries, Edinburgh, 216–241.

Muniandy, N. and Najamuddin, M.Y. 1989. Serum copper concentrations of crossbred cattle in Peninsular Malaysia. Jurnal Veterinar Malaysia, 1, 75–78.

Mutalib, A.A., Lim, J.S., Wong, M.H. and Koonvai, L. 1991. Characterisation, distribution and ultilisation of peat soil in Malaysia. In: Aminuddin, B.Y., Tan, S.L., Aziz, B., Samy, J., Salmah, Z., Siti Petimah, H. and Choo, S.T., ed., Proceedings of the International Symposium on Tropical Peatland, Kucing, Sarawak, MARDI, Ministry of Agriculture Malaysia, 7–16.

Noordin, M.M. 1992. The pathogenesis and treatment of chronic copper, heliotrope and hepatogenous chronic copper poisoning in sheep. PhD thesis, Murdoch University, Western Australia, 284 p.

Noordin, M.M., Zamri-Saad, M., Salam Abdullah, A. and Rajion, M.A. 1987. Effects of grazing *Brachiaria decumbens* on the ultrastructure of liver and kidney of sheep. Jurnal Veterinar Malaysia, 19, 215–218.

Noordin, M.M., Salam Abdullah, A. and Rajion, M.A. 1989. Experimental *Brachiaria decumbens* toxicity in cattle. Veterinary Research Communications, 13, 491–494.

Noordin, M.M., Howell, J. McC. and Dorling, P.R. 1993. The effects of zinc on copper and heliotrope poisoning in sheep. In: Anke, M., Meisner, D. and Mills, C.F., ed., Proceedings of the Eighth International Symposium on Trace Elements in Man and Animals. Gerdstof, Verlag Media Touristik, 279–282.

Noordin, M.M. and Zuki, A.B. 1995. The status of copper, iron and zinc of sheep under different management systems. Submitted to Jurnal Veterinar Malaysia.

Nordin Lajis, H., Salam Abdullah, A., Jalaludin, S. Bremmer, J.B. and Khan, M.N. 1993. Epi-sarsapogenin and episimilagenin: two saponenins isolated from the rumen content of sheep intoxicated by *Brachiaria decumbens*. Veterinary and Human Toxicology, 58, 387–389.

Rajion, M.A., Alimon, A.R. and Davis, M.P. 1993. Goat and sheep production. In: Fatimah, C.N.I., Ramlah, A.H. and Bahaman, A.R., ed., The Animal Industry in Malaysia. Serdang, Universiti Pertanian Malaysia, 51–68.

Roberts, H.E. 1976. Bovine cuprosis. Veterinary Record, 99, 496–498.

Shamsuddin, J. 1981. Sains Tanah, Kuala Lumpur, Dewan Bahasa Pustaka, 273 p.

Wan Zahari, M. and Davendra, C. 1983. Effect of cobalt on appetite and mineral plasma concentration in Kedah Kelantan cross Braham cattle. MARDI Research Bulletin, 11, 71–78.

—1984. The effects of four feeding levels of dietary diammonium phosphate and phosphorus requirement by swamp buffaloes. MARDI Research Bulletin, 12, 6–20.

—1985. The mineral profile of indigenous swamp buffaloes at Kedah-Kelantan in Malaysia. MARDI Report, 101, 1–88.

Wan Zahari, M., Davendra, C. and Ali, J. 1983. The effect of dietary cobalt and vitamin B_{12} on the performance of indigenous sheep. MARDI Research Bulletin, 11, 366–377.

Wan Zanari, M. and Abdul Wahid, S. 1985. Mineral composition of blood and various tissues of crossbred goats. MARDI Research Bulletin, 13, 333–340.

Weber, K.M., Boston, R.C. and Leaver, D.D. 1980. A kinetic model of copper metabolism in sheep. Australian Journal of Agricultural Research, 31, 773–790.

Zamri-Saad, M., Sharif, H. and Rahman, M.Y.A. 1989. Preliminary observation on the disease pattern in fattening sheep fed with oil palm by-products. Pertanika, 12, 187–188.

Some Issues of Mineral Nutrition in Mongolian Sheep Herds

G. Sambuu[1]

Abstract

Mongolia currently has 14 million sheep that are dependent on pasture for nutrient supply. While the sheep are well adapted to the harsh climatic conditions, pastures are natural and grown without the use of fertiliser, and therefore productivity is limited. Deficiencies of iodine, selenium, zinc and cobalt have been described along with toxicities of fluorine.

MONGOLIA remains one of the few countries in the world where extensive pastoralism of sheep still plays an important role in the national economy.

There are currently 14 million sheep of 10 breeds in Mongolia. Of these 90% are Mongolian breeds. Mongolian sheep breeds are well adapted to harsh climatic conditions from –35° to –70°C and snow depth of 20–70 cm in winter and +35° to +40°C in summer. They are raised on the open range throughout the year.

In Mongolia 85% of pastures are considered natural, growing more than 500 plant types. These pastures are truly natural and no fertilisers are used. However, depending on chemical composition of pastures, grasses, water and soil in some areas there can be a deficiency or excess of microelements in sheep.

Sheep living at an altitude of 3200–3500 m in Khangar mountains are small in stature and their productivity is very low (for example, they are 2–3 kg lighter than sheep living in Gobi or the steppe zones) because some pastures have insufficient iodine, cobalt and zinc. Some lambs may have white muscle disease, and to prevent it selenium injections are given to pregnant sheep, or to lambs in the 20 days after birth. The mortality of lambs increases 20–30% if such preventative measures are not taken.

Near the Achit lake region sheep have soft bones, an endemic disease due to shortage of iodine and cobalt and excess fluorine and magnesium. As well, research shows that the content of fluorine in the water of lakes near the Inner Mongolian border is 3.6 times higher (3.4–3.7 mg/L) than normal and as a result sheep living in this region have teeth problems. Local herdsmen call it 'black teeth' disease. This condition (fluorosis) was revealed in 1980.

According to these examples Mongolian sheep in some areas have comparatively low concentrations of some mineral elements. As Mongolia is rich in natural salted water resources containing microelements such as sodium and sulfur, and as, traditionally, Mongolian herdsmen have accumulated much experience in facing shortages of mineral elements, Mongolian sheep generally have low rates of mineral deficiency.

Mongolians move their sheep herds from one place to another, changing to pastures not only rich in wormwood (*Artemesia*) and grasses of the onion family, but also to sources of natural salts. In summer and autumn herdsmen move sheep 50 to 200 km to alleviate shortages of feed and mineral elements. In winter and spring they give the sheep natural salts every two weeks.

Mongolian native sheep have an excellent ability to adapt to local environmental conditions to utilise cheap feed all year round, and to resist difficult weather and diseases. Excellent physiological characters of Mongolian sheep, such as fertility, long life cycle, good hair coat and hardiness make them especially suitable for outdoor life. Since they are genetically distinct it is important to protect them, and to distribute and breed them in other countries.

Crosses between highly productive Australian and New Zealand merino sheep and Mongolian fine and semi-fine wool breeds — Kuangai, Orkhou and Yoroo — have scientific importance and may have great potential to increase wool production.

[1] National Agricultural University of Mongolia, Ulaanbaatar, Mongolia