A survey of the mineral status of livestock in the Tibet Autonomous Region of China

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Foreword

Livestock production is the predominant industry in Tibet Autonomous Region of China with significant numbers of yaks, cattle, horses, sheep and goats raised under various production systems. Little is known about the mineral and trace element status of these animals although it is suspected that they may be at risk from iodine and selenium deficiency.

This report is the outcome of a cooperative program involving scientists from the Tibet Academy of Agricultural and Animal Sciences, the Institute of Animal Science, Chinese Academy of Agricultural Sciences and Australia. They assessed the mineral and trace element status of yaks, cattle, horses and sheep from different environment and management systems. This assessment involved the collection of blood, milk, urine and dung samples from animals and samples of grazed pasture and feed supplements for chemical analyses.

The investigation has provided a comprehensive assessment of the mineral and trace element status of livestock and identified a number of major and trace minerals that may limit livestock productivity. Marginal deficiencies of these minerals can result in reduced milk production, growth rate, wool production and fertility, and severe deficiencies can result in rapid weight loss and increased mortality. Often the problem encountered in the field is not a severe clinical deficiency but a marginal disorder that is not readily identified. Economically, these marginal disorders can be of considerable significance because productivity is depressed without the problem being detected by the livestock owner.

The researchers suggest that field experiments should be undertaken to assess the magnitude of any responses in milk or wool production or body weight gain to mineral supplements and to evaluate the most cost-effective way of providing these supplements.

The work has increased awareness in the livestock industry about the mineral and trace element needs of farm animals in Tibet Autonomous Region of China and introduced new techniques in the diagnosis of cobalt and iodine deficiency in livestock.

Peter Core
Director
Australian Centre for International Agricultural Research

Photo by John Wilkins, CSIRO

Yaks plough a field in the Lhasa River valley. A range of mineral deficiencies may be limiting productivity of livestock in Tibet.

Photo by Wang Guanglin, ACIAR

Lactating cows are one of the groups most at risk from mineral deficiencies.

Contents

Summary

This study investigated the mineral nutrition of livestock at 40 households in seven important livestock-producing counties in the Tibet Autonomous Region of China. The livestock included in the survey were sheep and yaks in Damxiong, Lizhou and Naqu, sheep in Gangba, yaks in Jiali and cattle in Bailang and Jiangzi. At the time of the investigation—late autumn–early winter and late winter–early spring—livestock available for testing were pregnant ewes and lactating cattle and yaks. Samples collected for laboratory testing were blood and faeces from all species, urine and milk from cattle and yaks, and pasture and feed supplements. Of the wide range of feed supplements offered to livestock, the more common supplements were cereal hay and straw and barley meal.

In general, livestock were in moderate to poor condition and the pastures were of poor quality, as indicated by the low protein content. This study identified a number of major and trace minerals that may limit livestock productivity. The risk from sodium and phosphorus deficiency appears to be widespread, particularly in sheep and yaks, and a number of sheep groups were at risk from calcium deficiency. Sheep in Damxiong and cattle and yaks in all counties were at risk from copper deficiency, and sheep in all counties except in Gangba and yaks in Damxiong, Jiali and Linzhou were at risk from selenium deficiency. There was little evidence of a risk from iodine deficiency, although in sheep the utilisation of iodine may have been impaired by a low selenium status.

In view of the range of mineral deficiencies that may be limiting livestock productivity, it would be of value to the livestock industry if Tibetan scientists undertook a training program in the detection and correction of mineral disorders. Experiments should be undertaken to determine the magnitude of the response in milk or wool production or body weight gain to mineral supplementation and to determine the most cost-effective method of providing these mineral supplements. The assessment of the mineral nutrition of livestock should be extended to include other important livestock-producing counties and to the warmer wetter months when livestock productivity may not be limited by energy and protein intake. With increased levels of production, marginal mineral deficiencies can become more severe and previously unsuspecting mineral deficiencies may occur.

Background

The Tibet Autonomous Region (TAR), which covers an area of 1.2 million km^2, is one of the largest provinces in China, but is also one of the least developed. Administratively, TAR is divided into the six prefectures of Shigatse, Shannon, Naqu, Changdu, Ali and Linzhi and one municipal city of Lhasa. These seven prefectures of almost 900 townships and more than 7000 villages are divided into 74 counties.

Cropping and forestry in TAR are limited to a few areas because of the short growing season and the pastoral system is common. Tashi (2003) has identified four broad livestock-production systems. They are the pastoral production system, the agro-pastoral production system, the crop-based livestock production system and the agro-forestry–pastoral mixed production system (Figure 1). The pastoral production system is in northern Tibet (comprising 17 counties) and is by nomadic management of livestock on rangeland pasture. Livestock usually graze the higher areas in the warmer months (April–September) and the valleys in the colder months. The crop-based livestock production system is in central Tibet (comprising 18 counties) where the animal feed is mostly crop residues such as straw, particularly during winter and spring. In summer, animals may graze upper valley and mountain areas but pasture productivity is often poor due to the dry conditions. Between these two systems is the agro-pastoral production system (comprising 27 counties) where rangelands are the main source of animal feed, with supplementary feeding of crop residues. The rangelands are split into winter grazing, usually the lower areas during the dry winter–spring seasons, and the high mountains in the warmer wetter months (July–September). The agro-pastoral–forestry mixed production system is in southeastern Tibet (comprising 9 counties) and is a mix of livestock, crop and forestry production.

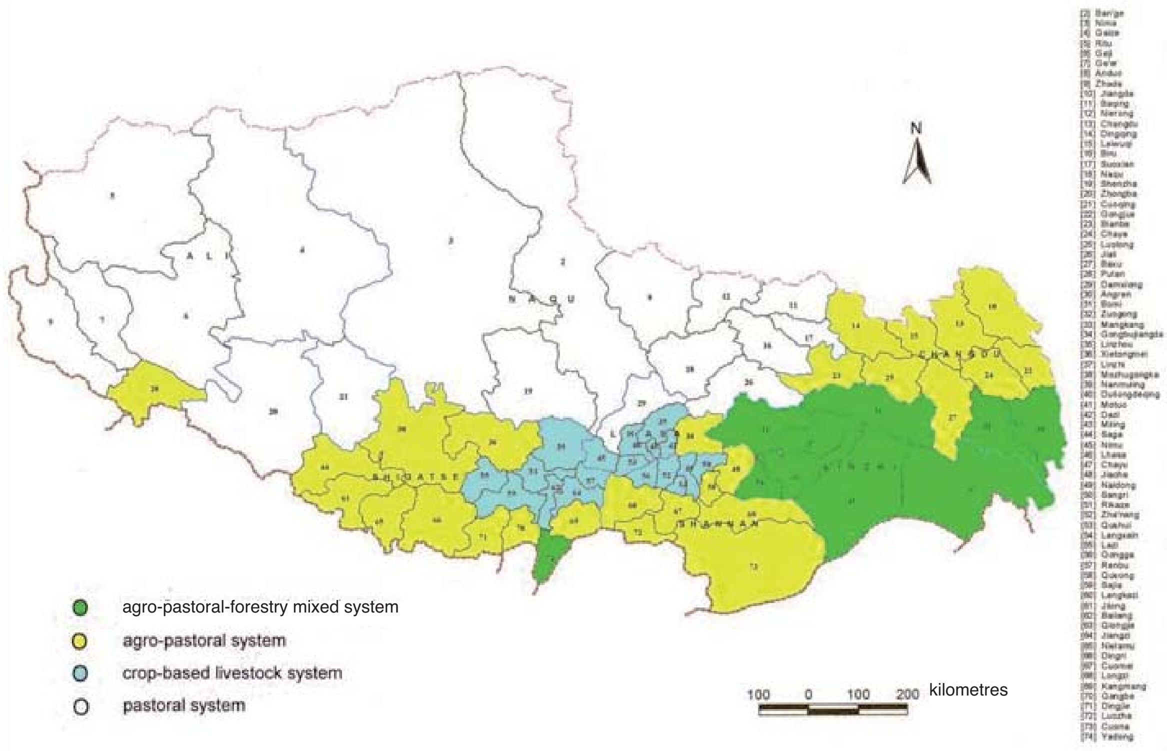

FIGURE 1. The location of the four main livestock production systems in Tibet

In 1999, the livestock in Tibet comprised about 5.5 million large animals (yaks, cattle, zo (yak × cattle crosses), horses and donkeys), 15.6 million sheep and goats, and about 0.2 million pigs. The total number of each species in the major livestock production systems is given in Table 1. Yaks, sheep, goats and horses are common in all livestock-production systems whereas there are few cattle and zo in the pastoral system.

TABLE 1. Approximate number of animals (thousands) in each of the four major livestock production systems in Tibet Autonomous Region (1999)

System	Yaks	Cattle	Zos	Horses	Sheep	Goats
Pastoral	1,780	21	2	111	5,261	2,614
Agro-Pastoral	1,406	369	166	55	2,268	1,190
Crop-Based	422	443	49	43	2,310	1,253
Agro-forestry-pastoral	268	167	102	39	543	134
Total	3,876	1,000	319	248	10,382	5,191

In general, pasture and crop residues for livestock tend to be adequate in late summer and early autumn but are in short supply in late winter and early spring. It is likely that energy and protein intakes are the major nutrients limiting livestock productivity in the latter seasons. Little is known about the mineral and trace-element status of livestock during these seasons. Anecdotal evidence suggests that phosphorus, sodium and iodine deficiency may affect livestock productivity (Tashi 2003; John Chesworth, pers. comm.; Garry Nehl, pers. comm.). It is suspected that iodine deficiency in livestock may be widespread, since it has been reported that residents of the Tibetan plateau were at risk from iodine deficiency (Hetzel 1989). A national survey of selenium content in forages and feed supplements in China (Liu et al. 1987) showed that large areas of Tibet were inadequate in selenium for livestock production (Figure 2): feed levels above 0.05 mg selenium/kg dry matter are required to prevent selenium inadequacy in sheep and cattle (SCA 1990). Of concern is that selenium inadequacy may exacerbate any iodine deficiency since selenium is required for the conversion of tetraiodothyronine (T4) to triiodothyronine (T3), the metabolically active form of thyroxine (Underwood and Suttle 2001).

The objective of this study was to evaluate the mineral nutrition of sheep, cattle and yaks in important livestock-producing counties of TAR.

Materials and methods

Location and livestock

Because of the difficulties of travel, the survey of animals was limited to seven counties which were readily accessible from Lhasa (Figure 3). The counties selected were representative of three of the major livestock production systems: the pastoral system (Damxiong, Jiali and Naqu), the crop-based livestock system (Bailang, Jiangzi and Linzhou) and the agro-pastoral system (Gangba) (Figure 1).

The species identified for sampling in each county were sheep and yaks in Damxiong, Linzhou and Naqu, sheep in Gangba, yaks in Jiali and cattle in Bailang and Jiangzi. For each species, four households were selected to represent the range in management practices in each county. A total of 40 households were selected, 16 with sheep, 8 with cattle and 16 with yaks. The households were given a unique identification number (K1 to K40). The location of these households is given in Figure 4.

Young growing and pregnant/lactating animals are most at risk from mineral deficiencies, but the survey was restricted to the latter group as livestock owners often would not permit the sampling of young animals. At the time of the survey, only pregnant ewes and lactating cows and yaks were available for sampling. A representative group of 10 animals was identified at each household for the collection of blood and faecal samples (all species) and milk and urine samples (cows and yaks).

Samples collected

Blood, urine, milk and faecal samples were collected for chemical analysis in November–December 2003 from households K1 to K20 (late autumn–early winter sampling) and in February–March 2004 from households K21 to K40 (late winter–early spring sampling). At the time of blood collection, samples of pasture grazed by livestock and any feed supplements fed at the time of the visit were also collected for analysis.

Blood was collected by 20 mL syringe from the jugular vein of sheep (3 × 10 mL) and cattle and yaks (2 × 10 mL) and dispensed into 10 mL plastic tubes containing lithium heparin as an anti-coagulant (No. 469924121, Sarstedt Australia Pty Ltd). On the day of sampling, an aliquot of blood (about 3 mL) was kept for selenium assay and the remaining blood sample was centrifuged to remove blood cells and the plasma retained for major and trace-nutrient assays.

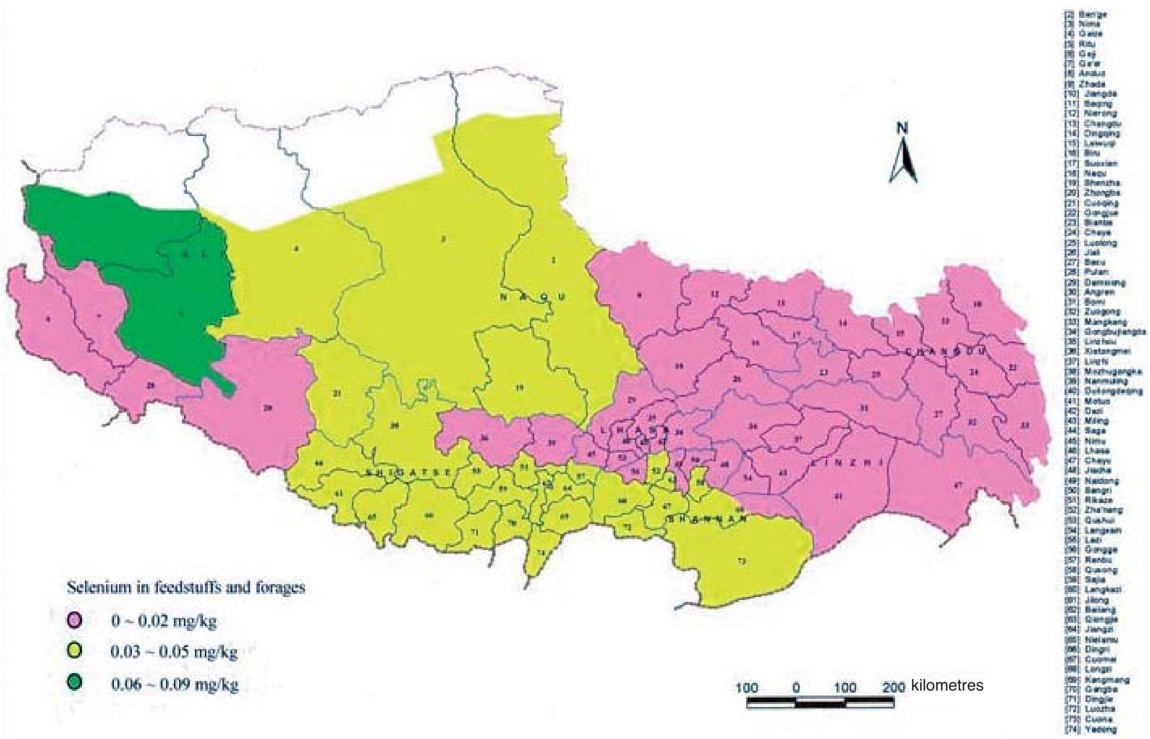

FIGURE 2. Survey of the selenium concentrations in forages and feedstuffs in Tibet

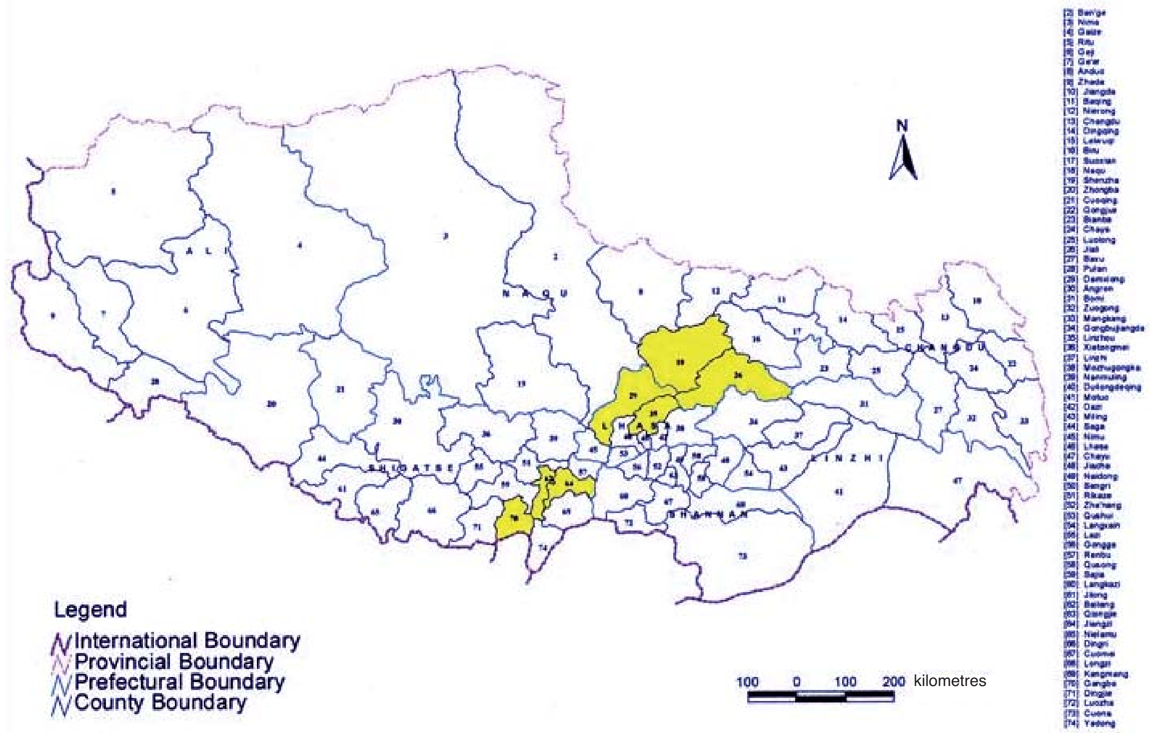

FIGURE 3. Location of counties selected for sampling of livestock

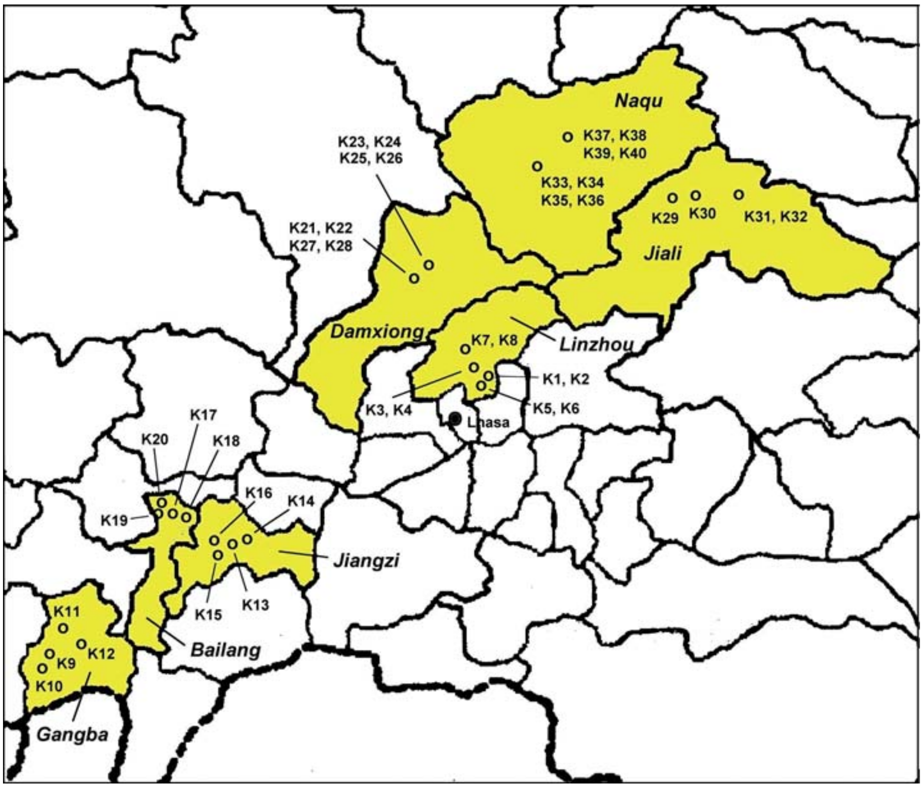

FIGURE 4. The locations of households (household identification code K1–K40) with sheep (K1, K3, K5, K7, K9–K12, K25–K28, K33, K34, K39, K40), cattle (K13–K20) and yaks (K2, K4, K6, K8, K21–K24, K29–K32, K35–K38)

Mid-stream urine samples (about 30 mL) were collected into 70 mL plastic containers, the containers were capped and the samples retained for assay of major minerals, iodine and specific gravity. Milk samples (about 30 mL) were also collected into 70 mL plastic containers and stored cold overnight to allow separation of the cream from the skim milk. The latter was retained for vitamin B_{12} and iodine assay. In the field, all samples were stored cold in iceboxes, and in the laboratory at the Tibet Academy of Agricultural and Animal Sciences (TAAAS) blood, plasma and skim milk samples were stored at –20˚C and urine samples at 4˚C.

Samples of faeces, pasture and feed supplements for major and trace-element assay and nitrogen assay (pasture and feed samples) were collected at the time of blood sampling. Faecal samples (about 25 g) were obtained from the rectum of 5 of the 10 animals selected for blood sampling. Representative samples of grazed pasture (200–300 g) were collected at random from at least eight locations across the grazed area. Care was taken to avoid contamination by soil when cutting the sample from the grazed pasture. Samples (200–300 g) of any supplement fed to livestock were also retained for analysis. In the field, faecal and feed samples were stored at ambient temperature and at the TAAAS laboratory they were dried at 60˚C. All samples were stored cold during airfreight to the Chinese Academy of Agricultural Sciences (CAAS) for chemical analysis.

Chemical analyses

Blood, plasma, urine and skim-milk samples received at CAAS were stored at –20°C. Dried samples of pasture, feed supplements and faeces were ground, using a stainless steel grinder, through a 1 mm screen. Most tests were performed in duplicate. Duplicate results were usually similar (difference < 5%) but if the difference between duplicates exceeded the lowest value of the duplicate then the results were excluded.

Selenium

Whole blood, pasture, feed supplements and faecal samples were acid digested to remove organic matter and the released selenium was reacted with 2,3-diaminonaphthalene (DAN) to form piazselenol, a fluorescent selenium–DAN complex (Watkinson 1979). The piazselenol was extracted into cyclohexane and the selenium quantitated spectrofluorometrically.

Plasma copper and inorganic phosphate

Protein in 1 mL plasma was precipitated by the addition of 2 mL 10% (w/v) trichloroacetic acid (TCA) and the copper in the supernatant (TCA–soluble copper) was measured using an inductively coupled plasma (ICP) emission spectrometer (IRIS Intrepid II, Thermo Electron Corporation, USA). Inorganic phosphate in the supernatant was treated with a molybdate reagent and in the presence of a reducing agent, para aminonaphthol sulfonic acid, the resulting blue colour was measured colorimetrically (Cary 100 Bio UV Visible Spectrophotometer, Varian, USA).

Vitamin B_{12}

Vitamin B_{12} in plasma and skim milk was determined using a radioisotope assay kit (Solid Phase No Boil, Diagnostic Products Corporation, USA). The assay was undertaken according to the manufacturer's instructions except that the denaturation of the plasma and milk proteins was carried out by placing the samples in a boiling water for 10 minutes instead of incubating at 37°C for 30 minutes. Radioactive vitamin B_{12} (^{57}Co-vitamin B_{12}), added to the sample, competed with the sample vitamin B_{12} for binding sites on added intrinsic factor. The intrinsic factor was then isolated and radioisotope counts, measured in a gamma counter (HP Ge r–Spectroscope fitted with a coaxial germanium detector GC 2519, Canberra Industries, USA), were translated into concentration of vitamin B_{12} in the sample by comparison with standard curves of vitamin B_{12} concentration.

Plasma T3 and T4

These iodine-containing hormones were assayed using commercially available kits (Coat-A-Count Total T3 and Coat-A-Count Total T4, Diagnostic Products Corporation, USA). Both kits employed a competitive binding procedure where ^{125}I–T3 and ^{125}I–T4 competed, respectively, with T3 and T4 in the plasma sample for binding sites on an added antibody. Counting the isolated antibody in a gamma counter (FT-609, China) yielded a number which was then converted by way of a calibration curve to a measure of the total T3 and T4 in the sample.

Iodine

Iodine in urine and skim milk was determined electrochemically as iodide, using an ion-specific electrode and meter (TPS Pty Ltd, Brisbane, Australia) as described by Masters et al. (1996).

Plasma albumin

Plasma albumin was measured colorimetrically (Cary 100 Spectrophotometer) using a commercially available kit (Zhongsheng Beikong Bio-Technology & Science Inc.) containing the dye bromcresol green which readily binds to albumin.

Specific gravity

The specific gravity of urine samples was determined as the weight per unit volume of urine.

Major and trace elements

A suite of elements in plasma, urine, faeces, pasture and feed supplements was assayed using the ICP emission spectrometer (IRIS Intrepid II, Thermal Company). The sample organic matter was destroyed before elemental assay by heating 0.5 g feed or faeces in 5 mL nitric acid and 1 mL plasma, or 2 mL urine in 8 mL nitric acid and 0.4 mL perchloric acid in a closed vessel using a microwave digestion system (MARS-5 Microwave Accelerated Reaction System, CEM Corporation). The acid was boiled off the digested sample and the residue made to 10 mL (feed, faeces and urine) or 5 mL (plasma) with 2% (weight/vol) nitric acid.

Protein

Nitrogen in pasture and feed supplements was determined by the Kjeldahl method, which involved the oxidising of the organic matter with sulfuric acid and the measurement of nitrogen as ammonia. The crude protein of the sample was estimated by multiplying the nitrogen value by 6.25.

Quality controls

Samples of whole blood, serum and urine (Seronorm™ Trace Elements, Sero AS, Norway), protein-based control (Anemic Control, Diagnostic Products Corporation, USA), non-fat milk powder (Standard Reference Material 1549, National Institute of Standards & Technology, Gaithersburg, USA), rye grass (Certified Reference Material 281, Community Bureau of Reference, Brussels, Luxembourg) and bovine liver powder (GBW-E 080193, China) were used for quality control. For milk iodine assays, 0.909 g non-fat milk powder (certified iodine content of 3.36–3.40 mg/kg) was made to 10 mL with distilled water to give a calculated iodine value of 305–309 µg/L.

Tables 2 and 3 give details of these external quality controls, with their certified values and the values obtained at CAAS: external quality controls were not used for the assays of plasma inorganic phosphate, albumin, T3 and T4 and nitrogen in pastures and feed supplements. The results obtained with these samples were usually within the certified range (Tables 2 and 3), suggesting that the methods employed at CAAS were accurate and reproducible. However, the vitamin B_{12} values measured in the anemic control were markedly greater than the acceptable values (Table 2). An unresolved problem encountered with the vitamin B_{12} technique was the low radioisotope counts of ^{57}Co in assayed samples (about 10% of the expected counts) relative to the background counts of the gamma counter. In contrast, good recoveries of radioisotope counts were obtained with ^{125}I, which was used in the assays of plasma T3 and T4. Because of the discrepancy between acceptable and obtained values for vitamin B_{12} in the anemic control (Table 2), the measured plasma and skim milk vitamin B_{12} concentrations should be regarded as approximate only.

For the major elements in rye grass, only the measurement of potassium was below the indicative range (Table 3). Certified or indicative values for sodium and sulfur were not available for rye grass. The value obtained by the University of Adelaide for each of these elements was higher than the values obtained by CAAS (Table 3), suggesting that further assays are required by other laboratories in order to determine the true concentration of sodium and sulfur in rye grass. The cobalt and molybdenum values obtained by CAAS were within the certified or indicative values for these elements (Table 3). However, these assays were near the detection limits of the analytical procedures at CAAS and hence their concentrations in feed and faeces should be regarded as only approximate values.

Analysis of data

Blood, plasma, milk and faecal data were subjected to a hierarchical analysis. This statistical test was used to detect, for each species, any differences between counties, between households within counties and between animals within households. Too few urine samples were collected to subject the results to statistical evaluation. The analyses of major and trace constituents in pasture and the more common feed supplements were also subjected to a hierarchical analysis to test for any differences between counties.

TABLE 2. External quality control samples used when assaying nutrients in blood, plasma, urine and skim milk

Quality control sample/test	Units	Certified values[a]	CAAS values
Trace elements whole blood, level 2			
selenium	µmol/L	1.44–1.65	1.47–1.68
Trace elements serum, level 2			
calcium	mmol/L	2.7–3.1	2.72–3.14
magnesium	mmol/L	1.12–1.25	1.09–1.28
phosphorus	mmol/L	1.26–1.42	1.31–1.51
potassium	mmol/L	5.6–6.5	5.4–6.4
sulfur	mmol/L	38–45	38–45
sodium	mmol/L	155–174	154–173
copper	µmol/L	38–43	38–43 (38–44)[b]
iron	µmol/L	32–36	32–39
zinc	µmol/L	13–15	13–15
Trace elements urine			
calcium	mmol/L	2.59–2.79	2.5–2.8
iodine	µg/L	264–300	270–290
magnesium	mmol/L	2.10–2.35	2.2–2.3
phosphorus	mmol/L	17.8–20.3	16–19
potassium	mmol/L	49.0–53.6	49–51
sodium	mmol/L	106–117	106–116
sulfur	mmol/L	16–18	16–18
Anemic control			
vitamin B_{12}	pmol/L	94–134	210–357
Non–fat milk powder iodine	µg/L	305–309[c]	305–320

[a] Usually the mean ± 95% confidence limits.
[b] In parentheses values obtained when assaying TCA–soluble copper.
[c] Calculated values (µg/L) (see text).

TABLE 3. External quality control materials used when assaying minerals in pastures, feed supplements and faeces

Quality control sample/test	Units	Certified values[a]	Experimental[b]		CAAS values[c]
Rye grass					
calcium	g/kg	(7.02–7.38)	6.49–7.01	6.80	6.64–6.99 (6.11–7.12)
potassium	g/kg	(29.8–40.6)	27.2–36.0	32.0	23.8–26.1 (22.2–26.1)
magnesium	g/kg	(1.62–1.70)	1.55–1.63	1.52	1.45–1.57 (1.41–1.63)
phosphorus	g/kg	(2.20–2.40)	1.99–2.31	2.40	2.38–2.61 (2.22–2.61)
sodium	g/kg	n/a	–	3.70	2.83–3.25 (2.75–3.37)
sulfur	g/kg	n/a	–	3.20	3.04–3.13 (2.75–3.15)
cobalt	mg/kg	(0.08–0.16)	–	–	0.08–0.11 (0.08–0.11)
copper	mg/kg	9.3–10.0	9.7–9.9	–	9.8–10.0 (9.4–10.0)
iron	mg/kg	(138–190)	–	148	143–168 (142–170)
manganese	mg/kg	79–84	76–77	–	80–83 (81–83)
molybdenum	mg/kg	0.78–0.90	–	–	0.75–0.85 (0.76–0.86)
selenium	mg/kg	0.024–0.032	–	–	0.025–0.026
zinc	mg/kg	30–33	32–33	–	31–32 (30–33)
Bovine liver powder					
selenium	mg/kg	0.48–0.58	–	–	0.50–0.57

[a] Usually the mean ± 95% confidence limits. Values in brackets are indicative values. n/a – values not available.
[b] Ranges (mean± 95% confidence limits) reported by Madejon et al. (2003) and individual values reported by the University of Adelaide, Waite Analytical Services, South Australia (2004).
[c] Values obtained by CAAS at the time of feed (and faecal) analysis.

Results and discussion

Livestock and feed

At all households, it was noted that animals included in the survey were holding their weight but were in poor to moderate condition. Blood samples were collected from 394 animals (Table 4), comprising 367 females and 27 males. The males were at nine households: K1 (3 males), K3 (2), K6 (1), K9 (6), K10 (2), K11 (5), K12 (6), K19 (1) and K20 (1). The animals were usually at least 2 years old but there was one young animal (< 2 years) from each of four households (K1, K7, K14 and K20). Only a few urine samples were collected because of the difficulties of collecting samples of adequate volume and free of faecal contamination from unrestrained animals in the field. Milk samples were collected from most yaks but only from about one half of the cattle included in the survey (Table 4).

Table 4. Details of the samples collected for chemical analysis

Species/ county	Number of households	Number of samples						
		Blood	Plasma	Milk	Urine	Faeces	Pasture	Feed supplements
Sheep								
Damxiong	4	40	40	–	–	21	–	9
Gangba	4	40	40	–	–	20	3	7
Linzhou	4	40	40	–	3	22	4[a]	7
Naqu	4	40	40	–	–	20	3	12
Cattle								
Bailang	4	34	34	19	2	20	–	15
Jiangzi	4	40	40	25	6	20	–	14
Yaks								
Damxiong	4	40	40	37	20	19	–	11
Jiali	4	40	40	40	15	20	2	13
Linzhou	4	40	40	31	1	20	4[a]	9
Naqu	4	40	40	39	32	21	1	13
Total	40	394	394	191	79	203	13	110

[a] Pasture samples from Linzhou were from areas grazed by both sheep and yaks.

At the time of the survey, sheep and yaks were at pasture but not cattle. Little herbage was available, particularly during February and March, when the grazed areas were under snow. The growth of native herbage on the Tibetan Plateau usually occurs during May to September, when the weather is warm and wet. Long et al. (1999a) identified three phases of herbage availability to the grazing animal: (i) a surplus of green forages from June to September; (ii) a relative surplus of more mature and dry forage from October to January; and (iii) a shortage of dry forages from February to May.

At the time of the survey, livestock at most households were usually given a supplement of hay, straw and barley meal. Samples of pasture and/or feed supplements were collected from all households except household K35 (Table 4). The range of supplements fed was extensive, comprising cereal hay or straw (42 samples), barley meal (32), rape meal (6), pea straw (8), barley brew residues (6), tea dregs (6), peas (3), *Urtica tibetica* hay (3), cheese residues (2), dried radish (1) and rape straw (1). No mineral supplements were offered to livestock during the period of the survey.

The mean protein and mineral concentrations and their ranges in pasture and the more common feed supplements are given in Tables 5 and 7. Also included in Tables 5 and 7 are the Australian recommended dietary mineral requirements of sheep and cattle, and the approximate estimates of dietary protein requirements (Table 5). Little is known about the dietary mineral requirements of yaks and hence, for this survey, it was assumed that their requirements were similar to those of cattle. The recommended mineral requirements should be regarded only as a guide to the mineral needs of livestock on the Tibetan Plateau. Published tables of the mineral requirements of livestock vary between countries and in part reflect differences in the variable safety margin above the minimum requirement (White 1996). The safety margin accounts for the variation in intake, productivity and availability of the nutrient over a range of conditions. Some estimates of the trace mineral requirements of livestock (Table 7) may have to be revised upwards to account for new information that shows effects of trace minerals on the immune function and susceptibility to disease (McDowell 1996a).

TABLE 5. Mean concentrations and ranges of protein and major minerals (g/kg dry matter) in pastures and the more common feed supplements

Sample[a]	Protein	Calcium	Phosphorus	Magnesium	Potassium	Sodium	Sulfur
Requirements[b]: Sheep Cattle	90–130 110–130	1.5–2.6 1.9–4.0	1.3–2.5 1.8–3.2	1.2 2.0	5.0 5.0	0.7–0.9 0.8–1.2	2.0 1.5
Pasture (10–13)	67 19–143	4.9 2.9–9.7	0.8 0.2–1.5	1.1 0.4–1.8	6.3 1.7–11.0	0.2 <0.1–1.3	0.8 0.4–1.1
Cereal hay/straw (41)	78 28–169	7.0 0.8–53.4	1.6 0.4–3.5	1.4 0.4–5.3	13.3 6.1–29.5	0.6 <0.1–3.7	1.3 0.4–3.2
Barley meal (32)	112 87–154	0.9 0.4–3.2	3.4 2.4–6.0	1.3 0.8–2.5	5.1 2.3–8.0	0.2 <0.1–3.1	1.1 0.8–1.8
Barley brew residues (6)	283 230–319	2.1 0.9–6.0	5.3 4.1–9.6	1.6 0.7–4.2	3.2 1.9–8.4	0.2 <0.1–0.6	3.4 2.3–6.4
Pea straw (7–8)	174 149–190	8.4 5.2–9.7	1.9 0.7–4.1	2.0 1.1–2.6	14.1 9.9–20.4	0.1 <0.1–0.1	1.2 0.8–2.3
Rape meal (6)	355 302–393	4.2 1.2–6.2	9.5 3.5–13.0	3.5 0.7–5.6	8.8 1.9–11.8	0.1 <0.1–0.2	9.2 3.3–11.9
Tea dregs (5–6)	180 171–191	10.1 8.2–11.3	1.6 1.4–1.9	1.9 1.6–2.2	3.3 2.5–3.7	0.3 0.3–0.4	1.8 1.5–2.1

[a] The numbers of samples are in parentheses.
[b] Where a range is given, the higher values are for young rapidly growing animals or lactating animals (SCA 1990).

Statistical analysis indicated that pastures from the four counties sampled had similar ($P > 0.05$) concentrations of the major elements, apart from magnesium, but differed ($P < 0.001$) in protein concentrations (Table 6). In general, pastures from Gangba, Linzhou and Naqu had low protein concentrations, suggesting that they were of poor quality and were likely to have a dry-matter digestibility of less than 50% (Lu 1996). The pastures were adequate in calcium and potassium, marginal in phosphorus, magnesium and sulfur and, apart from one pasture, were markedly deficient in sodium in relation to livestock needs (Table 5).

The supplements were low in relation to livestock requirements in a number of minerals, particularly sodium (all supplements), calcium (barley meal and barley meal residues), phosphorus (cereal hay and straw), potassium (barley brew residues and tea dregs), magnesium (cereal hay and straw, barley meal and barley brew residues) and sulfur (cereal hay and straw, barley meal and pea straw). The need for sulfur is closely related to the nitrogen content of the diet, since both are required for the synthesis of sulfur-containing amino acids by the ruminal micro-organisms. In pasture and supplements of lower nitrogen content (cereal hay and straw and barley meal) it appears unlikely that sulfur was limiting nitrogen utilisation since the nitrogen:sulfur ratios in these feeds were near the optimum of about 13:1 for sheep and 14:1 for cattle (SCA 1990).

Statistical analysis showed that the concentrations of protein and a number of minerals in the more common feed supplements differed ($P < 0.05$) between counties. Tea dregs were not included in this analysis because they were obtained from only one county (Naqu). For each supplement, only those constituents that differed ($P < 0.05$) between counties were included in Tables 6 and 8.

TABLE 6. Effect of location on the protein and major mineral concentrations (g/kg dry matter) in pasture and the more common feed supplements. For pasture and each supplement, mean values are given for those constituents that differed ($P < 0.05$) between counties

Sample/ constituent	County[a]							S of D[b]
	Bailang	Damxiong	Gangba	Jiali	Jiangzi	Linzhou	Naqu	
Pasture								
Protein	–	–	25 (3)	125 (2)	–	63 (4)	72 (4)	***
Magnesium	–	–	0.6 (3)	0.8 (1)	–	1.2 (4)	1.6 (4)	*
Cereal hay/straw								
Protein	37 (4)	62 (7)	93 (4)	118 (5)	33 (4)	115 (8)	68 (9)	***
Phosphorus	0.7 (4)	1.0 (7)	0.9 (4)	3.1 (5)	0.6 (4)	2.3 (8)	1.6 (9)	***
Potassium	9.6 (4)	10.8 (7)	8.1 (4)	19.6 (5)	10.3 (4)	15.2 (8)	15.3 (9)	***
Sodium	2.9 (4)	0.1 (7)	0.3 (4)	0.1 (5)	1.8 (4)	0.2 (8)	0.2 (9)	***
Barley meal								
Protein	115 (4)	101 (6)	90 (3)	132 (2)	130 (4)	107 (7)	117 (6)	***
Sulfur	1.1 (4)	0.9 (6)	1.1 (3)	1.2 (2)	1.3 (4)	1.2 (7)	1.1 (6)	*
Pea straw								
Phosphorus	–	1.6 (7)	–	4.1 (1)	–	–	–	*
Potassium	–	13.2 (7)	–	20.4 (1)	–	–	–	*
Sulfur	–	1.1 (7)	–	2.3 (1)	–	–	–	**
Rape meal								
Protein	382 (3)	–	–	153 (1)	329 (3)	–	–	***
Calcium	5.5 (3)	–	–	30.8 (1)	2.9 (3)	–	–	***

[a] The numbers of samples are in parentheses.
[b] S of D: significance of difference; * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Pastures and many supplements were inadequate in copper and selenium and marginal in zinc to meet the trace-element needs of livestock (Table 7). The copper concentrations in pasture, cereal hay and straw and barley meal differed ($P < 0.05$) between counties (Table 8), with samples from Linzhou usually having higher copper concentrations. The availability of copper is reduced by other nutrients, especially molybdenum and to a lesser extent iron and sulfur (see below). In practice, copper:molybdenum ratios (mg/mg) of less than 3 in feed are usually indicative of low available copper (Suttle 1991). This ratio in cereal hay and straw and barley meal supplements differed between counties, with low available copper in supplements from Jiali (Table 8).

Mineral levels in pasture and feed supplements are of use in detecting minerals that may be inadequate for the grazing animal. However, selective grazing, adventitious intake of soil, mineral levels in livestock water, interaction of minerals and mineral reserves of the animal limit the predictability of feed analyses in confirming a mineral deficiency in the animal. Laboratory tests based on animal samples have been developed to assist in identifying mineral disorders in livestock (Puls 1994; Judson and McFarlane 1998). These tests are of importance in helping to identify marginal disorders, since signs of marginal disorders are often non-specific. For most tests, reference ranges have been established for sheep and cattle, but not for yaks, to identify animals at risk from mineral deficiencies. In this study, it was assumed that reference ranges established for cattle were also relevant for yaks.

Major minerals

Phosphorus and calcium

For each species, mean plasma phosphorus concentrations were similar ($P > 0.05$) for all counties but differed ($P < 0.05$) between household groups within counties (Table 9). The risk of phosphorus deficiency appears to be widespread, particularly in sheep and yaks groups (Table 9), as indicated by plasma phosphorus values of less than 1.5 mmol/L (Underwood and Suttle 2001). These findings extend those of Long et al. (1999b), who showed on Tibetan family farms in Tianzhu County, Gansu Province, that yaks in late pregnancy and early lactation were at risk from phosphorus deficiency when on spring pasture and given oaten hay supplements. In the present study, pastures and cereal hay were low in phosphorus but other feed supplements usually had phosphorus levels adequate to meet livestock requirements (Table 5). An indication of the phosphorus adequacy of the diet given to the livestock groups can be obtained from faecal phosphorus concentrations, since faeces is the principal pathway of phosphorus excretion (Whitehead 2000). Mean faecal phosphorus concentrations differed ($P < 0.05$) between groups within counties and there was an indication that sheep groups in Linzhou were on diets of higher phosphorus content than sheep groups in other counties (Table 9). A faecal phosphorus concentration of less than 2.0 g/kg dry matter has been used to identify livestock on diets of low phosphorus content (McCosker and Winks 1994). The low faecal phosphorus concentrations (Table 9) suggest that most sheep and yak groups and half the cattle groups were on diets of inadequate phosphorus content.

Plasma calcium concentrations are hormonally controlled to maintain values greater than 2.2 mmol/L in sheep and greater than 2.0 mmol/L in cattle (Underwood and Suttle 2001). Mean plasma calcium concentrations differed ($P < 0.05$) between sheep and yak groups within counties but not between cattle groups (Table 10). Marginal hypocalcaemia was apparent in a number of the sheep groups and in one yak group. Hypocalcaemia can result from depletion of calcium reserves (chronic calcium deficiency) or an inability of the animal to mobilise calcium reserves to meet the increased demands of late pregnancy or early lactation (acute calcium deficiency).

Pasture calcium levels were usually adequate to meet the needs of livestock, but calcium levels in feed supplements were variable, with low values in some of the grain-based supplements (Table 5). Prolonged feeding of grain with little roughage can result in chronic calcium deficiency (Langlands et al. 1967; Peet et al. 1985). Faecal calcium concentrations provide a guide to the calcium content of the diet, since faeces is the primary pathway for calcium excretion (Whitehead 2000), although milk would also be an important route of calcium egress in lactating cattle and yaks. The high faecal calcium concentrations (Table 10) suggest that, at the time of the survey, all groups, particularly the sheep and yak groups, were on diets of adequate calcium content, assuming a dry-matter digestibility of 50%.

It is suspected that diets high in cations, particularly potassium, can predispose lactating cows and pregnant ewes to acute calcium deficiency. In the present study, pasture and most feed supplements were not high in potassium (Table 5), but high potassium levels were present in cereal hay and straw and pea straw from Jiali (Table 6). Hypocalcaemia can result from low plasma albumin concentrations, since a significant proportion of the plasma calcium is bound to albumin. Mean plasma albumin concentrations differed ($P < 0.05$) between livestock groups within counties (Table 10). It seems that the hypocalcaemia was not due to depressed albumin concentrations since albumin values were normal, being above 24 g/L in sheep and above 27 g/L in cattle and yaks (Puls 1994).

TABLE 7. Mean concentrations and ranges of trace elements (mg/kg dry matter) and the copper:molybdenum ratios (Cu:Mo, mg/mg) in pasture and the more common feed supplements

Sample[a]	Cobalt	Copper	Cu:Mo	Iron	Manganese	Selenium	Zinc
Requirements[b]: Sheep Cattle	0.11 0.11	5 7–10		40 40	15–25 15–25	0.05 0.05	20–30 20–30
Pasture (10–12)	0.71 0.22–1.80	4 2–11	7 <1–18	508 112–1726	66 15–160	0.02 <0.01–0.03	33 5–157
Cereal hay/straw (40–42)	0.34 0.01–1.24	4 <1–8	3 <1–10	438 47–1543	58 13–233	0.03 <0.01–0.29	19 4–65
Barley meal (30–32)	0.19 0.02–0.92	5 2–10	7 1–16	330 80–1176	27 10–54	0.02 0.01–0.11	33 16–208
Barley brew residues (6)	0.24 0.05–0.38	16 9–28	22 <1–2	494 186–774	24 14–59	0.04 0.01–0.06	37 23–86
Pea straw (7–8)	0.31 0.11–0.70	5 4–7	1 <1–1	440 223–805	37 22–53	0.02 0.01–0.05	25 11–44
Rape meal (5–6)	0.16 0.07–0.35	10 6–18	14 9–20	344 210–422	35 13–46	0.05 0.02–0.08	48 25–64
Tea dregs (5–6)	0.51 0.25–0.70	13 9–14	47 41–58	663 310–1259	1256 17–1798	0.13 0.12–0.14	31 21–37

[a] The number of samples are in parentheses.
[b] Where a range is given, the higher values are for young rapidly growing animals or lactating animals (SCA 1990)

TABLE 8. Effect of location on the trace element concentrations (mg/kg dry matter) and the copper:molybdenum ratios (Cu:Mo, mg/mg) in pasture and the more common feed supplements. For pasture and each supplement, mean values are given for the trace elements that differed ($P < 0.05$) between counties

Sample/constituent	County[a]							S of D[b]
	Bailang	Damxiong	Gangba	Jiali	Jiangzi	Linzhou	Naqu	
Pasture								
Cobalt	–	–	0.51 (3)	0.45 (1)	–	1.35 (4)	0.30 (4)	*
Copper	–	–	4 (3)	3 (1)	–	7 (4)	3 (4)	*
Iron	–	–	351 (3)	171 (1)	–	1072 (4)	149 (4)	*
Cereal hay/straw								
Cobalt	0.38 (4)	0.08 (7)	0.24 (4)	0.40 (5)	0.24 (4)	0.30 (8)	0.60 (9)	*
Copper	4 (4)	2 (7)	3 (4)	3 (5)	4 (4)	6 (8)	3 (9)	***
Cu:Mo	6 (4)	3 (7)	3 (4)	2 (5)	6 (4)	3 (8)	2 (8)	**
Manganese	34 (4)	151 (7)	41 (4)	71 (5)	33 (4)	39 (8)	25 (9)	***
Selenium	0.02 (4)	0.02 (7)	0.13 (4)	0.01 (5)	0.02 (4)	0.02 (9)	0.01 (9)	***
Barley meal								
Cobalt	0.44 (4)	0.16 (6)	0.10 (3)	0.03 (1)	0.23 (4)	0.17 (7)	0.13 (6)	*
Copper	6 (4)	5 (6)	3 (3)	6 (2)	5 (4)	7 (7)	5 (6)	*
Cu/Mo	14 (4)	6 (6)	7 (3)	2 (2)	9 (4)	4 (7)	4 (4)	***
Manganese	33 (4)	22 (6)	13 (3)	19 (2)	30 (4)	37 (7)	25 (6)	*
Pea straw								
Cobalt	–	0.25 (7)	–	0.70 (1)	–	–	–	*
Zinc	–	22 (7)	–	44 (1)	–	–	–	*
Rape meal								
Cobalt	0.20 (3)	–	–	0.53 (1)	0.11 (3)	–	–	*

[a] The numbers of samples are in parentheses.
[b] S of D: significance of difference; * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$

TABLE 9. Mean concentrations of inorganic phosphorus in plasma (mmol/L) and phosphorus in faeces (g/kg dry matter)

Species/county	Plasma[a]					Faeces[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep										
Damxiong	1.4	1.7	1.4	1.3	1.3	1.5	1.9	1.7	1.3	1.3
Gangba	1.7	1.2	1.9	1.9	1.7	1.4	1.5	1.2	1.6	1.5
Linzhou	1.7	1.8	1.9	1.4	1.5	2.3	2.9	2.3	1.5	2.3
Naq	1.3	1.1	1.2	1.1	1.5	1.5	1.5	1.4	1.5	1.5
S of D[b]	ns	***				**	***			
Cattle										
Bailang	1.6	1.6	2.2	1.4	1.5	2.3	3.0	2.7	1.6	1.8
Jiangzi	1.6	1.5	1.6	1.6	1.6	2.3	2.7	2.7	1.8	1.8
S of D[b]	ns	*				ns	***			
Yaks										
Damxiong	1.4	1.2	1.4	1.4	1.4	1.6	1.7	1.8	1.6	1.4
Jiali	1.3	1.3	1.5	1.2	1.2	1.9	1.8	2.2	1.8	1.9
Linzhou	1.6	1.7	1.6	1.5	1.5	1.6	1.8	1.7	1.2	1.7
Naqu	1.5	1.5	1.4	1.3	1.8	1.7	1.8	2.1	1.6	1.4
S of D[b]	ns	**				ns	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

TABLE 10. Mean concentrations of calcium (mmol/L) and albumin (g/L) in plasma, and calcium in faeces (g/kg dry matter)

Species/county	Plasma calcium[a]					Plasma albumin[a]					Faeces[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep															
Damxiong	2.2	2.2	2.0	2.3	2.2	28	26	30	22	35	15	15	16	15	15
Gangba	2.2	2.3	2.2	2.1	2.1	33	31	38	37	27	19	32	17	15	14
Linzhou	2.3	2.2	2.2	2.4	2.3	31	31	36	29	28	18	22	14	19	19
Naqu	2.3	2.1	1.9	2.5	2.7	26	27	26	22	31	21	26	22	19	18
S of D[b]	ns	***				ns	***				ns	***			
Cattle															
Bailang	2.6	2.5	2.5	2.6	2.7	33	32	43	32	29	9	12	8	8	9
Jiangzi	2.4	2.5	2.5	2.3	2.4	33	32	29	41	30	10	9	11	11	10
S of D[b]	ns	ns				ns	***				ns	***			
Yaks															
Damxiong	2.4	2.3	2.5	2.2	2.5	28	28	26	27	30	14	17	15	14	13
Jiali	2.3	2.3	2.4	2.4	2.2	30	37	26	28	30	19	21	16	18	19
Linzhou	2.5	2.7	2.3	2.6	2.4	41	46	46	29	44	16	15	16	13	19
Naqu	2.3	2.0	2.5	2.4	2.3	31	29	30	29	38	17	19	17	16	15
S of D[b]	ns	***				*	***				ns	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Sodium and potassium

The sodium concentrations in pastures and feed supplements were usually well below that required by livestock (Table 5). Faecal sodium values of less than 1 g/kg dry matter (Little 1987) indicate that livestock are on diets of low sodium content and at risk from sodium deficiency. A number of sheep and yak groups, particularly sheep and yaks groups in Linzhou and yaks in Jiali, had low faecal sodium concentrations and hence these groups were at risk from sodium deficiency (Table 11). All cattle groups appeared to be on diets of adequate sodium content, although there were significant differences in faecal sodium concentrations between cattle groups within counties (Table 11). Cereal hay and straw fed to cattle in these counties (Bailang and Jiangzi) had a mean sodium level above the dietary requirements of livestock (Table 6).

TABLE 11. Mean sodium concentrations in urine (mmol/L) and faeces (g/kg dry matter)

Species/county	Urine[a] (no. of samples)				Faeces[a]				
	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep									
Damxiong	–	–	–	–	1.62	0.95	0.90	2.54	2.10
Gangba	–	–	–	–	1.95	0.58	2.68	3.09	1.45
Linzhou	–	–	–	–	0.36	0.44	0.56	0.26	0.17
Naqu	–	–	–	–	2.36	2.41	3.42	1.24	2.37
S of D[b]					*	***			
Cattle									
Bailang	–	135 (1)	–	26 (1)	2.74	3.11	3.34	1.16	3.33
Jiangzi	25 (2)	42 (1)	84 (2)	–	2.12	1.40	3.88	1.79	1.39
S of D[b]					ns	***			
Yaks									
Damxiong	3 (8)	1 (1)	117 (6)	2 (5)	1.45	1.34	0.79	2.37	0.86
Jiali	1 (1)	2 (7)	18 (2)	15 (4)	0.50	0.07	0.71	0.81	0.41
Linzhou	–	–	–	–	0.26	0.32	0.44	0.14	0.15
Naqu	65 (8)	16 (7)	41 (9)	37 (8)	1.36	2.00	2.30	0.60	0.67
S of D[b]					*	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Urine is an important route of sodium excretion in livestock on diets of adequate sodium. When dietary sodium intakes are low, little sodium is excreted in urine with values less than 7 mmol/L indicating inadequate sodium intake in cattle (Morris 1980). Because of the variability in excretion of minerals in urine it is usually recommended that at least 10 urine samples be collected for assessment of herd mineral status (Caple and Halpin 1985). In the present study, the number of urine samples collected was inadequate for assessment of most groups, but there was a strong indication that a number of yak groups were at risk from sodium deficiency (Table 11).

Potassium is one of the most abundant minerals in plants, and the potassium concentration in pastures and many feed supplements usually exceeded the level required by livestock (Table 5). Faecal potassium concentrations (Table 12) are not a reliable guide to potassium intake since most of the element is excreted in urine (Whitehead 2000). Potassium concentrations in urine from cattle and yak groups (Table 12) were usually within a 19–120 mmol/L range, indicating adequate but not high potassium intake (Puls 1994).

Magnesium

The magnesium pool in ruminants to meet their metabolic needs is relatively small and can be readily depleted when on diets of low available magnesium or reduced intakes. At the time of the survey, the metabolic pool of magnesium was adequate in most livestock groups (Table 13) as indicated by plasma magnesium values above 0.8 mmol/L (Underwood and Suttle 2001) and urine magnesium values below 5 mmol/L (Puls 1994). Mean plasma magnesium concentrations differed ($P < 0.05$) between groups within counties (Table 13) but these differences are not likely to reflect differences in the magnesium content of the diet, since magnesium concentrations within the normal range are not linearly related to magnesium intake.

TABLE 12. Mean potassium concentrations in urine (mmol/L) and faeces (g/kg dry matter)

Species/county	Urine[a] (no. of samples)				Faeces[a]				
	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep									
Damxiong	–	–	–	–	6.1	8.2	6.9	4.8	4.6
Gangba	–	–	–	–	4.5	6.9	3.9	3.2	3.9
Linzhou	–	–	–	–	8.7	10.7	9.0	5.7	9.4
Naq	–	–	–	–	3.9	4.3	4.1	3.9	3.2
S of D[b]					**	***			
Cattle									
Bailang	–	113 (1)	–	140 (1)	5.2	5.1	5.1	4.9	5.8
Jiangzi	89 (2)	84 (1)	117 (2)	–	5.8	8.0	4.2	6.0	5.0
S of D[b]					ns	*			
Yaks									
Damxiong	114 (8)	122 (1)	61 (6)	85 (5)	5.8	6.3	5.8	5.2	5.2
Jiali	26 (1)	41 (7)	46 (2)	42 (4)	5.4	6.0	5.9	4.8	4.9
Linzhou	–	–	–	–	6.1	6.2	6.7	4.4	7.3
Naqu	67 (8)	67 (7)	19 (9)	15 (8)	4.5	4.4	5.0	4.7	4.1
S of D[b]					ns	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

In general, the magnesium levels in pastures, cereal hay and straw and barley supplements were adequate for sheep but marginal for cattle and yaks (Table 5). Assuming that the principal route of magnesium excretion is in faeces (Whitehead 2000) and that the dry-matter intake had a digestibility of 50%, the faecal magnesium values indicate that the magnesium content of the diet was marginal to adequate in all species. For sheep and yaks, mean faecal magnesium concentrations differed ($P < 0.05$) between counties, with higher values for sheep and yaks in Naqu (Table 13). These findings are consistent with the findings of higher pasture magnesium levels in that county (Table 6). For each species, there were small but significant differences ($P < 0.05$) in faecal magnesium concentrations between groups within counties (Table 13).

Trace elements

Cobalt

The main requirement of livestock for cobalt is for the microbial synthesis of vitamin B_{12} in the rumen. It is the vitamin the animal requires, not the cobalt. Plasma vitamin B_{12} values of greater than 500 pmol/L in sheep and greater than 80 pmol/L in cattle, and milk values above 500 pmol/L in cattle, indicate adequate cobalt intake (Underwood and Suttle 2001). Although difficulties were experienced in measuring vitamin B_{12} (see above), the high vitamin B_{12} values (Table 14) suggest that livestock were not at risk from cobalt deficiency. In lactating cattle, milk vitamin B_{12} is preferred to plasma vitamin B_{12} as a diagnostic indicator, since low plasma vitamin B_{12} values do not exclude the possibility of adequate liver B_{12} reserves (Judson et al. 1997).

TABLE 13. Mean concentrations of magnesium in plasma and urine (mmol/L) and in faeces (g/kg dry matter)

Species/county	Plasma[a]					Urine[a] (no. of samples)				Faeces[a]				
	CM	Ka	Kb	Kc	Kd	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep														
Damxiong	0.94	0.95	0.81	1.01	0.99	–	–	–	–	2.4	2.7	2.6	2.1	2.2
Gangba	0.81	0.90	0.82	0.78	0.74	–	–	–	–	2.3	3.7	2.5	1.5	1.4
Linzhou	0.85	0.76	0.82	0.93	0.90	–	–	–	–	3.2	3.0	3.0	3.9	2.9
Naqu	0.94	0.90	0.74	1.07	1.05	–	–	–	–	4.2	4.0	4.2	4.6	4.0
S of D[b]	ns	***								**	***			
Cattle														
Bailang	0.90	0.91	0.97	0.86	0.91	–	9 (1)	–	9 (1)	3.7	2.8	3.9	5.7	2.4
Jiangzi	0.88	0.85	0.87	0.84	0.96	4 (2)	8 (1)	10 (2)	–	2.3	2.6	2.7	1.9	1.8
S of D[b]	ns	ns								ns	***			
Yaks														
Damxiong	0.86	0.84	0.88	0.73	1.01	58 (8)	54 (1)	31 (6)	72 (5)	2.9	3.2	3.0	2.9	2.7
Jiali	0.95	0.91	1.02	0.92	0.93	79 (1)	60 (7)	75 (2)	60 (4)	2.9	3.0	2.9	2.5	3.2
Linzhou	0.94	1.03	0.83	0.88	1.01	–	–	–	–	2.6	2.6	2.8	2.5	2.8
Naqu	0.86	0.70	0.80	0.96	0.99	54 (8)	47 (7)	64 (9)	59 (8)	3.2	3.1	3.1	3.2	3.6
S of D[b]	ns	***								*	*			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

TABLE 14. Mean concentrations of vitamin B_{12} (pmol/L) in plasma and skim milk

Species/county	Plasma vitamin B_{12}[a]					Skim milk vitamin B_{12}[b]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep										
Damxiong	2218	–	–	2432	1585	–	–	–	–	–
Gangba	1829	–	1742	1919	–	–	–	–	–	–
Linzhou	2568	–	–	2797	2194	–	–	–	–	–
Naqu	2054	–	–	2357	1868	–	–	–	–	–
S of D[b]	ns	**								
Cattle										
Bailang	564	426	574	–	604	2881	2389	2660	3726	3381
Jiangzi	456	273	378	612	–	3637	3561	3262	2962	5477
S of D[b]	ns	**				ns	*			
Yaks										
Damxiong	889	–	769	817	607	3653	3042	3784	3231	4706
Jiali	713	699	511	759	–	–	–	–	–	–
Linzhou	754	397	443	–	1065	3973	5120	3481	3183	4174
Naqu	749	1006	652	344	–	1991	–	1990	–	–
S of D[b]	ns	***				ns	*			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Feed supplements usually had cobalt levels above requirements for sheep and cattle, and pasture cobalt values ranged from about 0.2 to 1.8 mg/kg dry matter (Tables 7 and 8): the higher values may be due in part to soil contamination. For each species, mean faecal cobalt concentrations differed ($P < 0.05$) between groups within counties (Table 15). The high faecal cobalt concentrations (Table 15) support the findings that all livestock groups were on diets of adequate cobalt content, especially since a significant proportion of ingested cobalt can be excreted with urine (Whitehead 2000).

TABLE 15. Mean concentrations of cobalt, copper and molybdenum in faeces (mg/kg dry matter)

Species/ county	Cobalt[a]					Copper[a]					Molybdenum[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep															
Damxiong	1.7	3.1	1.9	0.9	0.9	5	6	5	4	4	2.6	2.0	1.9	3.2	0.6
Gangba	2.1	4.0	1.9	1.1	1.3	6	6	7	5	5	1.0	1.0	1.3	1.0	0.9
Linzhou	3.1	2.2	4.5	3.2	2.5	14	17	11	14	13	2.2	2.5	1.6	1.3	3.3
Naqu	2.5	2.1	2.7	2.4	2.9	6	6	6	5	5	1.6	1.3	1.7	1.9	1.5
S of D[b]	ns	***				***	***				***	***			
Cattle															
Bailang	2.3	1.1	2.4	4.1	1.7	10	10	15	6	8	0.7	0.8	1.0	0.4	0.5
Jiangzi	1.3	1.1	1.7	1.5	0.9	9	10	11	7	8	0.8	0.7	1.0	0.6	0.7
S of D[b]	ns	***				ns	***				ns	***			
Yaks															
Damxiong	2.2	2.3	1.7	2.4	2.0	8	8	7	9	7	3.2	3.6	4.8	2.5	2.8
Jiali	2.5	2.1	2.9	2.2	2.7	9	8	12	7	8	1.4	0.7	2.0	1.6	1.3
Linzhou	3.5	4.1	4.1	3.0	2.9	13	14	12	10	15	2.4	1.6	3.3	1.2	3.4
Naqu	2.6	2.1	2.2	2.9	3.1	7	7	9	7	7	1.2	1.4	1.6	0.9	1.0
S of D[b]	*	***				**	***				*	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Copper

The trichloroacetic acid (TCA)–soluble copper in plasma is a measure of the biologically available copper in livestock. Mean TCA–soluble copper values differed ($P < 0.05$) between counties for sheep and yak groups and between groups within counties for all species (Table 16). Sheep groups in Damxiong and cattle and yak groups in all counties were at risk from copper deficiency with plasma copper values of less than 9 µmol/L (Underwood and Suttle 2001). In ruminants, low plasma-copper values reflect a depleted liver copper reserve but not all animals in a group exposed to the same nutritional regime will have depleted copper reserves at the same time. In a number of the livestock groups (Table 16) with mean values indicating copper adequacy there were individual values above 9 µmol/L suggesting that the group was either entering or recovering from copper inadequacy. Only the sheep groups in Linzhou, three of the four sheep groups in Gangba and one yak group in Naqu were not at risk from copper deficiency (Figure 5). Copper concentrations in pasture and cereal hay and straw tend to be higher in Linzhou than in other counties (Table 8).

Two forms of copper deficiency are seen in the field: a simple deficiency due to the lack of copper in the diet, and an induced deficiency due to a low availability of copper. Other dietary nutrients, especially molybdenum and to a lesser extent iron and sulfur, are the major elements reducing the availability of ingested copper. In the rumen, molybdenum in the presence of adequate sulfur can result in the formation of copper–thiomolybdate complexes that are poorly absorbed. High intakes of sulfur can also reduce the availability of dietary copper with the formation of insoluble copper sulfide. The role of iron in reducing the availability of dietary copper is unclear but it is suspected that the formation of insoluble mixed iron and copper sulfides in the alimentary tract may be involved (Lee et al. 1999).

TABLE 16. Mean concentrations of trichloroacetic acid (TCA)–soluble copper (μmol/L) and the mean percentages of total copper as TCA–soluble copper in plasma of different livestock groups

Species/county	TCA–soluble copper[a]					TCA–soluble copper/total copper[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep										
Damxiong	8	6	10	8	8	84	75	90	85	85
Gangba	11	11	11	12	11	90	84	88	88	97
Linzhou	11	10	11	12	12	85	80	78	93	90
Naqu	10	9	11	10	11	82	78	98	79	74
S of D[b]	**	***				ns	***			
Cattle										
Bailang	8	9	8	7	7	72	77	70	73	68
Jiangzi	6	5	6	6	8	67	63	64	68	74
S of D[b]	ns	*				ns	ns			
Yaks										
Damxiong	9	8	10	11	8	100	77	84	100	85
Jiali	7	7	7	7	6	63	74	70	76	71
Linzhou	9	8	9	8	10	71	64	74	72	73
Naqu	9	9	11	8	8	76	79	81	71	72
S of D[b]	*	***				*	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

In the present study, the relative importance of a low dietary copper or its low availability in causing the copper inadequacy in the livestock is unclear. Copper concentrations in many of the pastures and the more frequently used feed supplements were below requirements of livestock (Table 7). Most pasture samples had copper concentrations below the critical value of 4 mg/kg dry matter for many pasture species (Reuter and Robinson 1997). A low dietary copper intake for many of the livestock groups is also indicated from faecal copper concentrations (Table 15). Mean faecal copper values differed ($P < 0.05$) between counties for sheep and yak groups and between groups within counties for all species (Table 15). Since most of the copper ingested is excreted in the faeces (Whitehead 2000; Underwood and Suttle 2001), faecal copper values (Table 15) indicate dietary copper values from 2 to 9 mg/kg dry matter, assuming a 50% digestibility of ingested dry matter.

The possibility of induced copper inadequacy is indicated from the high concentrations of molybdenum (> 2 mg/kg dry matter), iron and sulfur in selected pastures and feed supplements (Tables 5 and 7). It is suspected that 'shakeback disease' in yaks in the northern region of the Qinghai Plateau, near the border of the Qinghai and Gansu Provinces, was due to a molybdenum-induced copper deficiency (Shen et al. 2005). Signs of the disorder included pica, poor condition, dyskinesia, anaemia and bone fractures. The blood copper values in affected yaks varied from 0.5 to 9.1 μmol/L and the mean copper and molybdenum concentrations in forages grazed by these animals were 6.5 and 5.0 mg/kg dry matter, respectively.

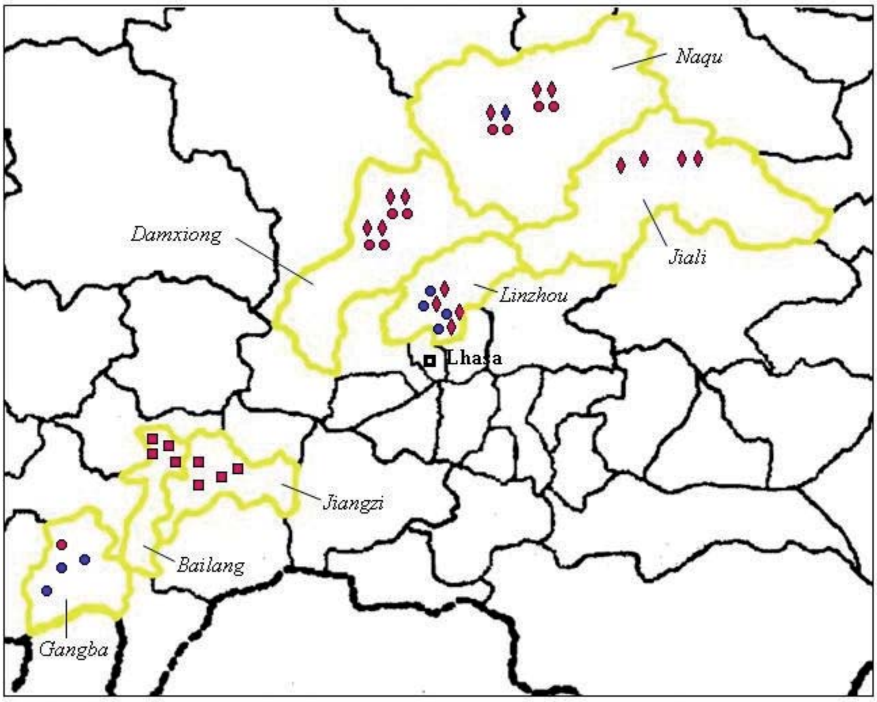

FIGURE 5. Locations of where sheep (●), cattle (■) and yak (◆) groups were of normal (blue symbols) or inadequate (red symbols) copper status

The formation of significant quantities of copper–thiomolybdate complexes in the rumen can result in the appearance of these complexes in circulation. Plasma copper–thiomolybdate complexes are insoluble in TCA (Dick et al. 1975; Smith and Wright 1975), suggesting that the marked difference between total and TCA-soluble copper in plasma of a number of livestock groups (Table 16) was due to the absorption of these complexes. Apart from one sheep group and two yak groups in Damxiong, faecal molybdenum concentrations (Table 15) do not indicate a high dietary intake of molybdenum. However, faecal molybdenum concentrations provide only an approximate guide to the dietary intake since about 50% of the ingested molybdenum can be excreted with urine (Whitehead 2000).

Iodine

Iodine concentrations in urine and milk are responsive to dietary iodine intakes, and iodine concentrations above 100 µg/L urine and above 25 µg/L milk are indicative of an adequate iodine status in cattle (Grace 1994; Puls 1994). The high iodine concentrations in urine and milk in the present study (Table 17) suggest that dietary intake of iodine was adequate in cattle and yak groups in all counties.

Measurements of the iodine-containing hormones T4 and T3 in plasma were also used to assess the iodine status of sheep, cattle and yaks (Table 18). The suggested plasma concentrations (nmol/L) of these hormones indicating adequate iodine status in sheep and cattle are, respectively, above 30 and above 50 for T4 and above 1.7 and above 2.5 for T3 (Underwood and Suttle 2001). Mean plasma T4 values in sheep and cattle groups were variable but normal, whereas they were uniformly low in yak groups (Table 18). Mean plasma T3 values were low in sheep groups in Damxiong and Naqu, in all yak groups and in all but one of the cattle groups (Table 18). Plasma T4 values indicating normal iodine status may be lower in yaks than in cattle since the yaks appeared to be of normal iodine status (Table 17). Apart from iodine status, plasma T4 concentrations can be depressed in livestock exposed to low temperatures or when on reduced feed intake (Lee et al. 1999).

TABLE 17. Mean concentrations of iodine (μg/L) in urine and skim milk from cattle and yak groups

Species/county:	Urine[a] (no. of samples)				Skim milk[a]				
	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Cattle									
Bailang	–	540 (1)	–	880 (1)	253	248	265	240	290
Jiangzi	365 (2)	420 (1)	625 (2)	–	260	278	260	251	238
S of D[b]					ns	ns			
Yaks									
Damxiong	635 (8)	–	980 (6)	795 (4)	244	241	272	244	214
Jiali	220 (1)	299 (7)	170 (1)	688 (4)	–	–	–	–	–
Linzhou	–	–	–	–	223	233	227	200	185
Naqu	744 (8)	737 (7)	474 (9)	523 (8)	200	–	200	–	–
S of D[b]					ns	*			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).
[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

TABLE 18. Mean concentrations of thyroxine (T4) and triiodothyronine (T3) in plasma (nmol/L) of different livestock group

Species/county	Plasma T3[a]					Plasma T4[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep										
Damxiong	1.70	1.41	1.58	1.98	1.84	80	76	87	78	78
Gangba	2.24	2.61	2.15	2.33	1.87	118	141	98	134	100
Linzhou	1.81	2.02	1.75	1.75	1.71	95	102	104	86	87
Naqu	1.30	1.50	1.24	1.37	1.06	72	83	67	64	73
S of D[b]	***	ns				**	***			
Cattle										
Bailang	1.40	0.93	1.15	2.66	0.87	64	50	68	86	58
Jiangzi	1.52	1.60	1.51	0.78	2.21	76	71	105	67	63
S of D[b]	ns	***				ns	**			
Yaks										
Damxiong	1.23	0.84	1.42	1.19	1.45	50	53	48	44	55
Jiali	1.06	0.79	1.17	1.14	1.13	47	41	41	43	62
Linzhou	1.35	0.98	1.53	1.81	1.09	46	55	43	47	40
Naqu	0.79	0.53	0.62	1.04	0.95	46	43	43	49	49
S of D[b]	ns	***				ns	ns			

[a] CM: county mean. Ka–Kd: household identification number (see Table 9 for details).
[b] S of D: significance of difference (see Table 9 for details).

The conversion of T4 to the metabolically active T3 is reduced in selenium-deficient livestock, resulting in a decrease in plasma T3 which may be associated with an increase in plasma T4 (Arthur et al. 1988; Donald et al. 1994). Low plasma T3 values appeared to be associated with low blood selenium values in sheep groups, but this association was not apparent in cattle or yak groups (Figure 6).

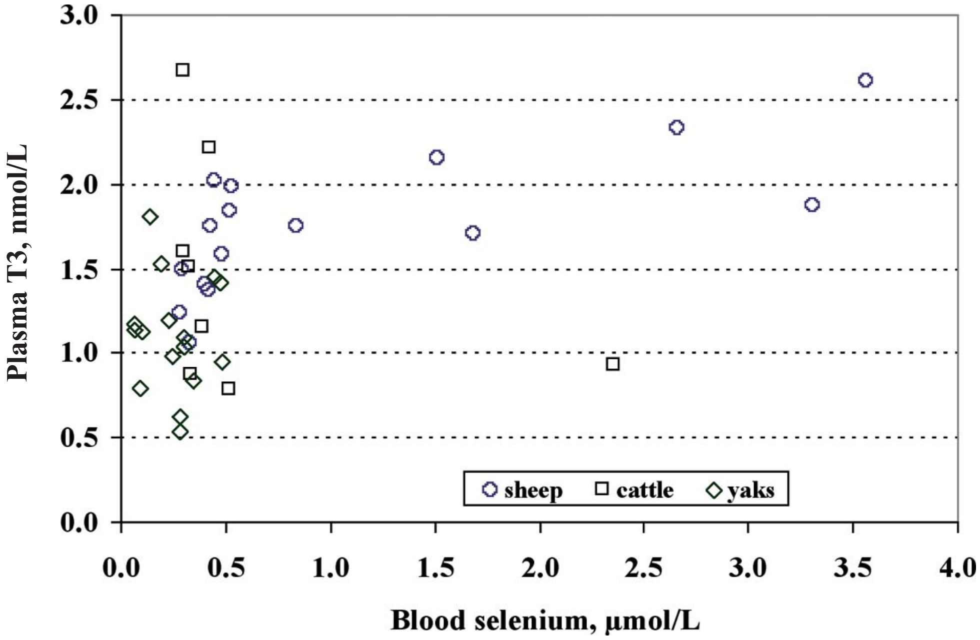

FIGURE 6. Relationship between mean blood selenium concentrations and mean plasma T3 concentrations in sheep, cattle and yak groups

Selenium

All pastures and most feed supplements had selenium concentrations that were less than the selenium requirements of livestock (Table 7). These findings are in agreement with an earlier survey (Figure 2) showing that forages and feedstuffs from the counties included in this survey had selenium concentrations below 0.05 mg/kg dry matter.

The low selenium concentrations in pasture and feed supplements were reflected in the low blood selenium concentrations in many of the livestock groups (Table 19). Mean blood selenium concentrations differed ($P < 0.001$) between counties for sheep and yak groups and between groups within counties for all species. Early studies showed that sheep and cattle at risk from selenium deficiency had blood selenium concentrations of less than 0.5 µmol/L and less than 0.25 µmol/L, respectively (Judson et al. 1987). More recent field studies have shown that sheep with blood selenium concentrations above 0.5 µmol/L were at risk from selenium deficiency (Langlands et al. 1994; Whelan et al. 1994) and hence blood selenium concentrations of less than 0.9 µmol/L have been suggested as indicating selenium inadequacy in sheep (Underwood and Suttle 2001). The critical blood value for cattle has not changed (Underwood and Suttle 2001), although it had been reported that dairy cows (McClure et al. 1986) and beef cows (Awadeh et al. 1998) were at risk from selenium deficiency with blood selenium values above 0.25 µmol/L. Sheep groups in all locations, apart from Gangba and one group in Linzhou, were at risk from selenium deficiency. Cattle were of adequate selenium status, whereas yak groups in Jiali, one group in Damxiong and two groups in Linzhou were at risk from selenium deficiency. The normal selenium status in many of the groups may have been due to the feeding of supplements of high selenium content, since pastures were usually of inadequate selenium content (Table 7). This appears to be so for sheep in Gangba, as the cereal hay and straw supplement in that county had a high selenium content (Table 8).

Zinc

Most pastures and feed supplements had zinc concentrations that were adequate for livestock at maintenance but were generally inadequate for lactating or rapidly growing animals (Table 7). An estimate of the zinc content of the diet can be obtained from faecal zinc concentrations, since faeces is the major excretion route of ingested zinc (Whitehead 2000). Assuming a dry-matter digestibility of 50%, the faecal zinc values indicate that the dietary zinc content was marginal for livestock needs (Table 20). Sheep groups in Linzhou and yak groups in Jiali appear to be on diets of higher zinc content than other groups (Table 20). However, there was no significant difference between counties in the zinc concentrations in pasture and in most supplements (Table 8).

TABLE 19. Mean selenium concentrations in blood (µmol/L) of different livestock groups

Species/county	Blood selenium[a]				
	CM	Ka	Kb	Kc	Kd
Sheep					
Damxiong	0.48	0.40	0.48	0.53	0.52
Gangba	2.70	3.56	1.51	2.66	3.31
Linzhou	0.86	0.45	0.84	0.43	1.69
Naqu	0.33	0.29	0.28	0.42	0.33
S of D[b]	***	***			
Cattle					
Bailang	0.89	2.36	0.39	0.30	0.34
Jiangzi	0.40	0.30	0.33	0.52	0.43
S of D[b]	ns	***			
Yaks					
Damxiong	0.38	0.35	0.47	0.23	0.45
Jiali	0.08	0.09	0.06	0.06	0.10
Linzhou	0.22	0.25	0.19	0.14	0.30
Naqu	0.32	0.28	0.28	0.30	0.48
S of D[b]	***	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

For each species, mean plasma zinc values were similar ($P > 0.05$) for all counties and, apart from sheep, were similar ($P > 0.05$) between groups within counties (Table 20). Despite the suspected marginal intake of zinc, the plasma zinc concentrations were above 9 µmol/L, indicating adequate zinc intake (Underwood and Suttle 2001) at the time of sampling in all livestock apart from one sheep group in Damxiong (Table 20).

Iron and manganese

Iron and manganese concentrations in pastures and feed supplements were usually greater than the levels required by livestock (Table 7). Little ingested iron or manganese is absorbed (Whitehead 2000), hence faecal concentrations of these elements provide an indication of their content in the diet. In general, mean faecal iron concentrations were higher in sheep and yak groups from Linzhou than from livestock groups in other counties (Table 21). Pasture iron concentrations appeared to be higher in Linzhou than in other counties, but iron concentration in supplements did not change with location (Table 8). Mean faecal manganese concentrations differed ($P < 0.05$) between counties for sheep and yak groups, and between groups within counties for all species (Table 21). Assuming a 50% dry-matter digestibility, faecal iron and manganese concentrations indicate adequate to high dietary levels of these elements (Table 21).

For each species, mean plasma iron concentrations were similar ($P > 0.05$) between counties but differed ($P < 0.001$) between groups within counties for sheep and yak groups (Table 21). The mean values were usually within the range of 40–110 µmol/L, indicating high intakes of iron (Puls 1994).

TABLE 20. Mean zinc concentrations in plasma (µmol/L) and faeces (mg/kg dry matter)

Species/county	Plasma[a]					Faeces[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep										
Damxiong	12	17	9	13	11	34	39	35	32	32
Gangba	13	14	14	14	13	21	29	24	15	16
Linzhou	14	13	16	14	14	58	72	52	52	55
Naqu	13	12	10	15	14	45	40	49	47	45
S of D[b]	ns	***				***	***			
Cattle										
Bailang	16	15	19	16	16	22	26	31	15	16
Jiangzi	17	18	16	18	18	25	25	29	23	21
S of D[b]	ns	ns				ns	***			
Yaks										
Damxiong	23	24	23	20	25	36	50	28	34	31
Jiali	24	24	23	26	21	79	68	104	65	81
Linzhou	24	25	25	23	24	54	62	58	43	53
Naqu	21	18	21	24	22	56	46	65	58	57
S of D[b]	ns	ns				**	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

TABLE 20. Mean zinc concentrations in plasma (µmol/L) and faeces (mg/kg dry matter)

Species/county	Plasma[a]					Faeces[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep										
Damxiong	12	17	9	13	11	34	39	35	32	32
Gangba	13	14	14	14	13	21	29	24	15	16
Linzhou	14	13	16	14	14	58	72	52	52	55
Naqu	13	12	10	15	14	45	40	49	47	45
S of D[b]	ns	***				***	***			
Cattle										
Bailang	16	15	19	16	16	22	26	31	15	16
Jiangzi	17	18	16	18	18	25	25	29	23	2
S of D[b]	ns	ns				ns	***			
Yaks										
Damxiong	23	24	23	20	25	36	50	28	34	31
Jiali	24	24	23	26	21	79	68	104	65	81
Linzhou	24	25	25	23	24	54	62	58	43	53
Naqu	21	18	21	24	22	56	46	65	58	57
S of D[b]	ns	ns				**	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

High faecal-iron concentrations have been observed in sheep in northern China (Yu et al. 1995; Masters et al. 1996). It is suspected that the high iron intakes there were due to a lack of pasture and to sodium deficiency, both causing an increase in soil intake. Adventitious or deliberate intake of soil can be a source of more minerals—particularly cobalt, iodine, iron and manganese—than ingested pasture (Reid and Horvath 1980). As soils differ in their chemical and physical properties, it is expected that different soils could have different effects on the mineral status of the grazing animal.

TABLE 21. Mean iron concentrations in plasma (μmol/L) and mean iron and manganese concentrations in faeces (mg/kg dry matter)

Species/ county	Plasma iron[a]					Faecal iron[a]					Faecal manganese[a]				
	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd	CM	Ka	Kb	Kc	Kd
Sheep															
Damxiong	56	94	42	37	53	2786	4008	3183	2030	1921	502	707	602	372	327
Gangba	63	73	61	52	67	4723	9302	4051	2606	2931	106	162	103	80	80
Linzhou	53	45	43	81	41	6640	4486	9168	6857	6051	230	208	268	239	206
Naqu	53	48	45	58	62	3082	3221	3535	2909	2662	497	534	571	445	440
S of D[b]	ns	***				*	***				***	***			
Cattle															
Bailang	71	64	65	84	71	2827	1927	3212	3105	3067	106	100	128	105	91
Jiangzi	64	67	67	60	61	2568	2122	3204	3131	1816	102	97	140	99	74
S of D[b]	ns	ns				ns	*				ns	***			
Yaks															
Damxiong	100	149	101	72	89	4950	5137	4140	5463	4631	373	358	403	381	361
Jiali	63	81	61	91	28	3599	3495	4742	2839	3322	455	336	505	416	562
Linzhou	81	79	91	73	80	6672	7041	6925	5811	6912	226	250	225	176	255
Naqu	91	43	63	129	131	4440	3834	4142	4567	5087	318	366	327	278	303
S of D[b]	ns	***				***	ns				***	***			

[a] CM: county mean value. Ka–Kd household mean values: for each species and for each county, the household identification numbers (K1–K40) are arranged in numerical order, the lowest corresponding to Ka and the highest to Kd (see Figure 4).

[b] S of D: significance of difference. For each constituent, the first value refers to the difference between counties and the second to the difference between households within counties; ns = not significant ($P > 0.05$); * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Conclusions

A survey was undertaken of the mineral nutrition of pregnant sheep and lactating cattle and yaks in seven significant livestock-producing counties in the Tibetan Autonomous Region (TAR) of China. The survey showed that livestock were at risk from a number of mineral deficiencies, particularly of sodium, phosphorus, copper and selenium. The poor to moderate condition of the livestock may have been due in part to a deficiency of one or more of these minerals. Marginal deficiencies of these minerals can result to a varying degree in reduced milk production, growth rate, wool production and fertility, and severe deficiencies can result in rapid weight loss and increased mortality. Of concern is that often the problem encountered in the field is not of a severe mineral deficiency identified by clinical signs but marginal disorders that are not readily identified. Economically, these marginal disorders can be of considerable significance, because productivity is depressed without the problem being detected by the livestock owner.

The correction and prevention of mineral disorders can be achieved with free-choice mineral supplements (McDowell 1996b) or individual treatments (Judson 1996). The choice of treatment will depend on a number of factors, including the mineral(s) to be supplied, the likely duration of the deficiency, additional management procedures required to administer the mineral, whether pasture may respond to the mineral, and the cost–benefit of the treatment. The cost of mineral treatment is often cheap relative to the benefit of improved productivity. However, the provision of additional minerals during late autumn–early spring, when this survey was conducted, may be uneconomical if energy and/or protein intakes are the prime nutrients limiting livestock productivity. It is suggested that field experiments should be undertaken to assess the magnitude of any responses in milk or wool production or body weight gain to mineral supplements and to evaluate the most cost-effective means of providing these mineral supplements.

Mineral inadequacies in livestock are often seasonal, resulting from increased demands of pregnancy, lactation or rapid growth coinciding with reduced mineral content or availability in the pasture. Seasonal trends in mineral concentrations in sheep and pasture have been recorded in northern China (Masters et al. 1993a,b). It is important that this present assessment of the mineral status of livestock in TAR should be extended to include the warmer wetter months when livestock are on abundant pasture, since mineral intake found to be adequate on sparse pastures may not be so on lush pastures (Judson and McFarlane 1998). Consideration should also be given to extending the survey during this period to other important livestock producing prefectures in TAR, such as Ali and Changdu, and to include other species such as goats.

The Tibet Qinghai Plateau is an area where humans are at risk from iodine deficiency (Hetzel 1989; Tashi 2003) and hence it was unexpected to find that the iodine status of livestock in this area was usually normal. A similar finding was made with sheep grazing an area in Shandong Province that was lacking in iodine for human requirements (Yu 1996). In the present study, the adventitious intake and/or deliberate intake of soil as a result of sodium inadequacy may have increased the iodine intake of the animal. Ingested soil can be a source of more minerals than ingested pasture, particularly for iodine, cobalt, iron and manganese, which are usually appreciably higher in soil than in plants (Reid and Horvath 1980). The high faecal iron levels observed in the present study support the view that livestock were ingesting significant quantities of soil. The source of the iodine needs to be resolved in any further survey of the mineral status of livestock. The laboratory facilities at CAAS are excellent and provide a comprehensive range of tests to detect mineral inadequacies in livestock. It would be desirable for the laboratory to develop techniques for measuring iodine concentrations in pasture and feed supplements and in plasma of livestock. Recent studies suggest that plasma inorganic iodine concentrations are more reliable than plasma T3 and T4 values as an indicator of iodine status in sheep and cattle (McCoy et al. 1997; Grace et al. 2001).

Currently, the Tibetan Government is attaching great importance to establishing nutritional standards for livestock in TAR. The conduct of the mineral survey has increased the awareness of TAAAS staff about the importance of meeting the mineral needs of livestock at pasture. With the demands for increased livestock productivity, the staff at TAAAS would benefit greatly from participating in an international training program on mineral nutrition of livestock. Such a program should include a review of current methods for the detection and correction of mineral disorders in the grazing animal, the conduct of field trials to demonstrate the economic and production benefits of correcting mineral deficiencies and appropriate extension programs to extend the findings to livestock owners. The field trials should be undertaken with animals most at risk from a mineral deficiency, such as young, rapidly growing animals or animals during their first pregnancy or lactation.

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Photo by Wang Guanglin, ACIAR

The growth of native herbage on the Tibetan Plateau usually occurs during May to September when the weather is warm and wet.

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