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# The Soil-Plant-Animal Phenomena: Serum Mineral Status of Fiji Fantastic Sheep Grazing Batiki Grass (*Ischaemum aristatum* Var. *indicum*) and Pangola Grass (*Digitaria decumbens*) in Samoa

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**Abstract:** A study was carried out during the dry season period to determine the mineral status of soil/forages (batiki and pangola grasses) grazed by the Fiji Fantastic Sheep (FFS) at four government owned livestock farms located at Avele, Togitogiga, Lemafa and Tanumalala within Upolu Island, Samoa. Also blood serum mineral content was examined. Soils and forages were sampled in June and August from the four farms. Among the four farms, soil at Togitogiga was comparatively low in Ca, Mg, K and Zn; while P and K were deficient in the soil at Avele. Ca content in the batiki grass at Avele was 2.7 g kg$^{-1}$ DM while at Togitogiga and Lemafa it ranged between 1.8-2.1 g kg$^{-1}$ DM. Ca content in the pangola grass (Tanumalala farm) ranged between 1.7-2.3 g kg$^{-1}$ DM. Phosphorus (P), Mg, Na and K contents in the forages were 2.1 g kg$^{-1}$ DM; 2.5 g kg$^{-1}$ DM, 0.5 g kg$^{-1}$ DM and 8.5 g kg$^{-1}$ DM, respectively. Ca;P ratio in the forages was 1:1. Na content in batiki and pangola grasses was below the critical level an indication of deficiency. The content of micro-minerals in the forages was Fe (97.9 mg kg$^{-1}$ DM), Mn (172.9 mg kg$^{-1}$ DM); Cu (3.3 mg kg$^{-1}$ DM) and Zn (36.9 mg kg$^{-1}$ DM). Micro-minerals were adequate in the forages and above the requirements of an adult sheep. Mean concentration of serum macro-minerals was Ca (25.2 mg 100 mL$^{-1}$); P (3.2 mg 100 mL$^{-1}$); Mg (0.9 mg 100 mL$^{-1}$): Na 51.9 mg 100 mL$^{-1}$) and K (2.4 mg 100 mL$^{-1}$), while serum micro minerals were Fe (372.4 mg 100 mL$^{-1}$); Mn (1.1 mg 100 mL$^{-1}$); Cu 3.3 mg 100 mL$^{-1}$ and Zn (7.6 mg 100 mL$^{-1}$). Except for Ca and Fe, the serum content of other macro and micro minerals were below the ovine reference range. In this report we tested the soil, forage and carried out direct veterinary evidence for deficiency through blood analysis to validate the mineral status of the Fiji Fantastic sheep grazing batiki and pangola grasses in Samoa and compared the values obtained with appropriate standards of adequacy or safety. In conclusion, it appears that the critical levels proposed for most macro and micro minerals elements are higher than may apply to the FFS grazing low potential grasses in the dry season in Samoa. Supplementation of the sheep with mineral lick block during grazing would alleviate the problems of the deficiencies of some of the macro and micro minerals observed in the forages and in the serum of the sheep.

**Key words:** Marco and micro minerals, soil, forage, serum, deficiency, supplementation

## INTRODUCTION

Soil is the source of all mineral elements found in plants. Most naturally occurring mineral deficiencies in livestock are associated with specific seasons and are directly related to both soil mineral concentration and soil characteristics. Of all the mineral concentrations in soils, only a fraction is taken up by plants. The bioavailability of minerals in soils depends upon their effective concentration in soil solution (Reid and Horvath, 1980).

The concentration of minerals in forages are dependent upon the interactions of a number of factors including soil, plant species, stage of maturity, yield, pasture management and climate (McDowell, 1985) interactions among minerals (Gomide, 1978; Reid and Horvath, 1980) and season of the year (Aregheore and Singh 2003). Grazing livestock under these conditions are easily exposed to the danger of deficiency of some minerals (McDowell, 1985).

The quantity, quality and continuity of feed supply throughout the year promote the level of animal production in any environment. Among the 5 nutrients required by ruminant livestock minerals [macro or micro (trace)] are vital for the survival and productivity of grazing animals. The nutritional importance of minerals in ruminant nutrition has been stressed (Underwood, 1981; McDowell, 1985; Aregheore and Singh, 2003) and a number of publications have well documented the

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inadequacy of tropical forages in meeting the mineral requirements of grazing ruminants (Little *et al*., 1989; Fujihara *et al*., 1992a,b; McDowell *et al*., 1993; Serra *et al*., 1995; Srivastava and Sharma, 1998; Aregheore and Hunter, 1999).

Livestock producers in the tropics do not supplement their grazing animals with minerals with the possible exception of salt (McDowell, 1985) and therefore rely exclusively on forages to meet their mineral requirements (Perdomo *et al*., 1977). There is wide spread deficiencies of macro and micro nutrients elements in grazing ruminants in the tropics including Samoa because grazing livestock have to depend largely upon forage to fulfill their mineral requirements. Forages rarely satisfy all of the needed mineral requirements of grazing livestock (McDowell, 1977).

Amongst the grass species found in Samoa, batiki grass is the most prominent. It is a moisture loving grass and grows virtually in all areas except in the western districts of Upolu where it tends to form weak sward incapable of competing with weeds. It is very tolerant to low fertility situations, being able to grow even in very poor highland soils. Although it is the most abundant grass grazed by ruminant livestock, animals grazed on it alone if not given adequate dietary supplements have poor breeding and growth performance (Lee, 1999; Aregheore *et al*., 2004). In the western district of Upolu, pangola grass is dominant.

Sheep meat (mutton) is highly cherished in Samoa. In order to reduce the importation of mutton from overseas the Government of Samoa in August 2004 through the assistance of FAO brought 44 Fiji Fantastic sheep (40 ewes and 4 rams) from Fiji for breeding, multiplication and distribution to smallholder farmers. The project aims to enhance the supply of quality meat in rural areas through the incorporation of sheep in the traditional farming system. The origin of the Fiji Fantastic sheep has been described (Manuel, 1997) and since August 2004 to date, new additions through lambing had increase the current sheep herd in Samoa to about 120 sheep. At present the sheep are located in four government farms namely, Togitogiga, Lemafa, Tanumalala and Avele within Upolu Island and also at the University of the South Pacific, School of Agriculture and Food Technology Livestock Farm.

The challenges before ruminant nutritionists and pasture agronomists in using a single grass specie as a sole source of forage for animals is to determine whether or not the pasture can supply adequate nutrients for maintenance, growth and production (Aregheore *et al*., 2004). Mineral concentrations in both soils and herbage affect the mineral status of grazing livestock (Towers and Clark, 1983). Therefore the amount of minerals in forages and biological availability of minerals need to be considered in the formulation of rations for grazing livestock (Aregheore and Hunter, 1999). The relationship between mineral contents of forage and mineral nutrition of the Fiji Fantastic sheep is scant. Also information on soil-forage (batiki and pangola grasses)-sheep interaction is not available in the South Pacific region. This study therefore aims to report on the mineral status of soil/forages in four government farms located at Avele, Togitogiga, Lemafa and Tanumalala, and serum mineral concentrations of the Fiji Fantastic sheep grazing batiki or pangola grasses in the four farms within Upolu Island , Samoa.

## MATERIALS AND METHODS

**Site:** Four farms that belong to the Livestock Division, Ministry of Agriculture and Fisheries Apia, Samoa were selected for the study. The farms are:-

- Avele Government Livestock Farm,
- Togitogiga Government Livestock Farm,
- Lemafa Government Livestock Farm and
- Tanumalala Government Livestock Farm,

The first three farms have batiki grass as the sole forage while at Tanumalala Farm has Pangola grass (*Digitaria decumbens*). These are the two grass species grazed by the Fiji Fantastic sheep in Samoa. The trial covered the dry season period (April-September) and the climatic temperature is 30-27°C, while the humidity averages 80%.

**Collection of soils and grass samples and preparation for analysis:** Soils and forages (batiki and pangola grasses) were sampled from the four farms. The samples were randomly collected from each site at the beginning, middle and towards the end of the dry season. Soil samples were obtained using a stainless sampling auger to a depth of 15 cm. The forage were cut to a length of 4-6 cm from the ground to stimulate grazing height. Forage samples were cut using a stainless bush knife and placed in clean bags on the site. The forage samples were obtained from the same sites where the soil samples were taken. Both the soil and forages were dried at 60°C for 36 h and ground using a simple laboratory mill to pass through 1 mm sieve (forage) and 2 mm sieve for (soil).

The ground samples were stored in air-tight containers until required for analysis. Both the soil and forage samples were later dry ashed at 600°C for 4 h, followed by wet digestion of 0.5 g in 15 mL of 2:1 (v $v^{-1}$) mixture of-($HNO_3$/$HClO_4$), diluted with distilled water and made up to 50 mL. To detect Ca, Mg, P, Mn, Zn, Cu and Fe, an atomic absorption spectrophotometer (GBC 908 AA, Scientific Equipment Pty Ltd, Dandenog, Victoria, Australia) was used, while K was determined using a flame photometer (Ciba-Corning Flame Photometer 410) (Daly and Wainiqolo, 1993).

**Blood samples and preparation for analysis:** Blood samples were collected from eight mature sheep (4 ewes and 4 rams) that were randomly selected from the farms located at Avele, Togitogiga and Tanumalala by jugular vein puncture in the morning. The blood samples with a drop of EDTA in tubes were sealed quickly with a rubber stopper and kept at 40°C in a cooler box containing ice and brought to the laboratory for centrifugation in the laboratory.

The blood samples were centrifuged at a speed of 3000 rpm for 20 min. The supernatant plasma was decanted into crucibles and first dried in a forced draught oven at 60°C for 6 h and then dry ashed in a muffle furnace at 550° C and analyzed as above.

## RESULTS AND DISCUSSION

There are three options for nutrient testing, the soil may be tested for deficiencies; herbage may be tested (either fresh or conserved) or direct veterinary evidence for deficiency may be sought through blood analysis. In this report we have used these three options to validate the mineral status of the Fiji Fantastic sheep grazing batiki grass at Avele, Togitogiga and Lemafa and Pangola grass at Tanumalala in Samoa.

Table 1 and 2 present mineral concentrations in the soils at Avele, Togitogiga, Lemafa and Tanumalala Government Livestock Farms where the sheep are grazed. Among the four farms, soil at Togitogiga was comparatively low in Ca, Mg, K and Zn; while P and K were deficient in the soil at Avele. The mineral contents in the four farms indicate their level of concentration in available soil solution. The high level of Fe in the soil is consistent with Cox (1973) that Fe deficiency cannot be expected due to sufficient content of Fe in soils and adequate pasture conditions. Reid and Horvath (1980) observed that the bioavailability of minerals in soils depends upon their effective concentration in soil solution. However, soils in the four farms had macro and micro mineral concentrations above soil critical levels (McDowell, 1985).

The availability of minerals to animals depends on the age and species of the animal, the intake of the mineral and its needs, the chemical form in which the mineral is ingested; the amounts and proportions of other dietary components with which its interacts metabolically and environmental factors such as accessibility and intensity of sunlight.

Since the detection and diagnosis of mineral disabilities of dietary origin based on mineral analysis of feed can be misleading in this report we have therefore carried out assessment of the actual or likely occurrence of a dietary mineral deficiency or excess in the forage grazed by the Fiji Fantastic Ssheep (FFS) in the four government farms by comparing the values obtained with appropriate standards of adequacy or safety or deficiency. Under grazing condition, ruminant livestock ingest minerals from the forage and soil ingestion and Table 3 presents the mean of macro mineral concentrations in the forages-batiki grass at Avele, Togitogiga and Lemafa; and Pangola grass at Tanumalala

Table 1: Macro and micro mineral elements in soils at the four farms

| | Ca g kg$^{-1}$ | | Olsen P mg kg$^{-1}$ | | Mg meq/100g | | K meq/100g | |
|---|---|---|---|---|---|---|---|---|
| Farms | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Avele | 2.3-2.6 | 2.4 | 44-45 | 45.0 | 84-143 | 113.5 | 72-73 | 72.5 |
| Togitogiga | 0.3-0.6 | 0.5 | 32-33 | 32.5 | 106-109 | 107.5 | 83 | 83 |
| Lemafa | 11.5-13.1 | 12.3 | 37 | 37 | 99-142 | 120.5 | 46-84 | 65 |
| Tanumalala | 2.3-2.1 | 2.2 | 34-35 | 34.5 | 82-84 | 83 | 18-21 | 19.5 |
| Mean | 4.3 | | 37.3 | | 106.1 | | 21.3 | |
| Critical level[1] | 0.35 | | 10 | | 0.07 | | 0.15 | |

[1]Soil critical levels (McDowell, 1985)

Table 2: Micro mineral elements in soils at the four farms

| | Fe mg kg$^{-1}$ | | Mn mg kg$^{-1}$ | | Cu mg kg$^{-1}$ | | Zn mg kg$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|
| Farms | Range | Mean | Range | Mean | Range | Mean | Range | mean |
| Avele | 84-143 | 113.5 | 72-73 | 72.5 | 5.6-7.0 | 6.3 | 2.8-8.4 | 5.6 |
| Togitogiga | 106-109 | 107.5 | 83 | 83 | 5.4-6.3 | 5.9 | 1.5-1.9 | 1.7 |
| Lemafa | 99-142 | 120.5 | 46-84 | 65 | 1.4-3.6 | 2.5 | 1.3-3.6 | 2.5 |
| Tanumalala | 82-84 | 83 | 18-21 | 19.5 | 3.5-3.7 | 3.6 | 3.5-3.7 | 3.6 |
| Mean | | 106.1 | | 60 | | 4.6 | | 3.4 |
| Critical level[1] | | 4.3 | | 19 | | 0.6 | | 2 |

[1]Soil critical levels (McDowell, 1985)

Table 3: Macro mineral elements in forage at the four farms

| | Ca g kg$^{-1}$ | | P g kg$^{-1}$ | | Mg g kg$^{-1}$ | | Na g kg$^{-1}$ | | K g kg$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| Farms | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | mean |
| Avele | 2.5-3.0 | 2.7 | 1.6-1.8 | 1.7 | 2.2-2.7 | 2.4 | 0.8-1.0 | 0.9 | 3.2-3.2 | 3.2 |
| Togitogiga | 1.9-2.4 | 2.1 | 2.3- 2.5 | 2.4 | 2.7-3.0 | 2.9 | 0.3-0.4 | 0.4 | 8.3-9.9 | 9.1 |
| Lemafa | 1.3 - 2.4 | 1.8 | 1.7-2.4 | 2.0 | 2.1-2.5 | 2.3 | 0.3-0.4 | 0.4 | 10.4-15.9 | 13.2 |
| Tanumalala | 1.7 - 2.3 | 2.0 | 2.5-2.5 | 2.5 | 2.0-2.7 | 2.4 | 0.2-0.3 | 0.3 | 7.4-9.6 | 8.5 |
| Mean | | 2.2 | | 2.1 | | 2.5 | | 0.5 | | 8.5 |
| Adult sheep requirements* | | 2.5 -5.0 | | 1.5-2.7 | | 1.0-2.0 | | 0.8-1.0 | | 7.0-8.0 |

*Adult Sheep requirements (Underwood, 1981; McDowell *et al*., 1993; Charry *et al*., 1992)

grazed by the FFS. The content of the macro minerals in the grasses are similar to values reported earlier by Aregheore (2004) in the South Pacific region (Youssef and Brathwaite, 1987) in West Indies and Little *et al*. (1989) in Indonesia. However, supplementation of the FFS with mineral lick block during grazing would alleviate the problems of the deficiencies of some of the macro and micro minerals observed in the forages and this is consistent with Prabowo *et al*. (1984a, b).

The batiki grass at Avele had Ca content of 2.7 g kg$^{-1}$ DM while at Togitogiga and Lemafa Ca content ranged between 1.8-2.1 g kg$^{-1}$ DM. Pangola grass (Tanumalala farm) had Ca concentration that ranged between 1.7-2.3 g kg$^{-1}$ DM (mean 2.0 g kg$^{-1}$ DM). The batiki grass at Togitogiga and Lemafa and pangola grass at Tanumalala had Ca content lower than 2.6-5 g kg$^{-1}$ DM recommended as being adequate to meet the requirement of adult sheep (NRC, 1985) and 2.5 g kg$^{-1}$ DM for adult tropical sheep (Charry *et al*., 1992). However, the Ca content of the grasses are above the 1.15 g kg$^{-1}$ DM recommended as ideal for adult sheep weighing 50 kg live-weight (ARC Working Party, 1980; McDowell *et al*., 1993).

Phosphorus (P) is probably the most protean of all minerals elements. In addition to its other functions, it is further involved in the control of appetite, in a manner not yet fully understood and in the efficiency of feed utilization. The mean P content in the forages was 2.1 g kg$^{-1}$ DM a level within 1.6-2.7 g kg$^{-1}$ DM recommended for adult sheep (McDowell *et al*., 1995). This was also within 1.6-3.8 g kg$^{-1}$ DM (NRC, 1984). Dietary Ca:P ratio of between 1:1 is assumed to be ideal for growth and bone formation, since this is approximately the ratio of the two minerals in the bone (Underwood, 1981). Ca;P ratio in the forage was 1:1, however, ruminant livestock can tolerate a wide range of Ca:P ratios, especially when their vitamin D status is high.

Magnesium is virtually involved in the metabolism of carbohydrates and lipids as a catalyst of a wide range array of enzymes which require this element for optimum activity (Wacker, 1969). The minimum Mg needs of sheep for growth can generally be met by pastures or rations containing 0.7 g kg$^{-1}$ DM. Mean Mg concentration of the forages in the four farms was 2.5 g kg$^{-1}$ DM and this was higher than the critical Mg requirement for adult sheep at 1.0 g kg$^{-1}$ DM (McDowell *et al*., 1993).

Potassium (K) is an important mineral and many enzymes have specific requirement for it. It acts with other ions such as sodium, magnesium, calcium in influencing enzyme activities. Underwood (1981) observed that the clinical and biochemical manifestation of K deficiency in farm animals are not well documented, presumably a reflection of the ample supply of the mineral in most forages, however, reduced appetite is one of the first signs of inadequate K deficiency. Mean K concentration of the forages was 8.5 g kg$^{-1}$ DM and this was slightly above than the critical K level of 7 - 8 g kg$^{-1}$ DM for adult sheep (McDowell *et al*., 1993; Renner, 2001).

Sodium (Na) serves in many regulatory functions in the body and stimulates the appetite. Extensive areas of Na deficiency in livestock occurs in many parts of the world, especially in tropical countries where grass pastures have been reported to contain between 0.8-1.0 g kg$^{-1}$ Na on DM basis (Underwood, 1981). Mean Na concentration in the forage was 0.5 g kg$^{-1}$, a level below the recommended dietary level of 0.8-1.0 g kg$^{-1}$ DM for satisfactory growth of lambs and lactating ewes (Hagsten *et al*., 1975; Morris and Peterson, 1975). Adult sheep that weighs 50 kg requires 1.3 g kg$^{-1}$ Na on DM basis while, a 40 kg castrate growing at 0.15 kg requires 1.4 g kg$^{-1}$ DM, (McDowell *et al*., 1995). The concentration of Na in the forages (batiki and pangola grasses) was below the critical level an indication that deficiency can occur. The sheep on the four farms therefore should be supplemented with NaCl (salt) in the form of mineral lick block to cater for low value in the forage during the dry season.

Micro minerals are required in small amounts, or traces. Of all the mineral concentrations in soils, only a fraction is taken up by plants. As mentioned earlier, the concentration of minerals in forages are dependent upon the interactions of a number of factors including soil, plant species, stage of maturity, yield, pasture management and climate (McDowell, 1985) interactions among minerals (Gomide, 1978; Reid and Horvath, 1980) and season of the year (Aregheore and Singh, 2003) and field location especially soil (Rogers, 2003).

Table 4: Micro mineral elements in forage at the four farms

| Farms | Fe mg kg$^{-1}$ Range | Fe Mean | Mn mg kg$^{-1}$ Range | Mn Mean | Cu mg kg$^{-1}$ Range | Cu Mean | Zn mg kg$^{-1}$ Range | Zn Mean |
|---|---|---|---|---|---|---|---|---|
| Avele | 44.9-62.5 | 53.7 | 160-239 | 199.5 | 3.3-3.4 | 3.3 | 41.0-45.8 | 43.4 |
| Togitogiga | 95.1-268 | 181.6 | 215-240 | 227.5 | 3.3-3.7 | 3.5 | 29.5-30.0 | 29.8 |
| Lemafa | 58.1-81.3 | 69.7 | 148-164 | 156.0 | 2.4-4.7 | 3.5 | 27.9-43.7 | 35.8 |
| Tanumalala | 75.6-97.8 | 86.7 | 85.9-131 | 108.5 | 2.6-3.2 | 2.9 | 34.7-43.2 | 38.9 |
| Mean | | 97.9 | | 172.9 | | 3.3 | | 36.9 |
| Adult sheep requirements* | | 25-40 | | 40 | | 1.5-6.0 | | 15-33 |

*Adult Sheep requirements (Underwood, 1981; Charry *et al*., 1992; McDowell *et al*., 1993)

Table 4 presents the mean of micro (trace) mineral contents in the forages. Iron (Fe) content in the forage was above requirement of adult sheep for optimal performance (McDowell, 1985). The high Fe content in the forage is consistent with the high soil Fe value and this coincides with zero incidence of deficiency in the soil samples (Khan *et al*., 2006). It has been observed that changing conditions of soil and climate as well as physiological state of plant affects the Fe concentration and absorption in plants (Kabat-Pendias, 1992; Khan *et al*., 2006). Fe concentration in the soil and the forage showed a positive association with each other and this is consistent with Khan *et al*. (2006). However, the high Fe content of the grasses may be detrimental to the sheep because very high levels of Fe might interfere with Cu metabolism (Youssef and Brathwaite, 1985). Pasture and forage vary markedly in Mn content as a reflection of species differences and soil effects. Concentration of Mn in the forages was higher than the critical level of 40 mg kg$^{-1}$ DM suggested for adult sheep (McDowell *et al*., 1993).

Mean Cu content in the forage was 3.30 mg kg$^{-1}$ DM; a value lower than the dietary Cu requirement of 7.0 mg kg$^{-1}$ DM reported by NRC (1985) for sheep. However, the mean value 3.30 mg kg$^{-1}$ DM Cu falls within the range of 1.5-6.0 mg kg$^{-1}$ DM suggested as adequate for adult sheep (Beck, 1951; Underwood, 1981; McDowell, 1985). Cu of the grasses had no relationship with the soil Cu content in all the farms and Cu values reported in this study were within the range reported by Tiffany *et al*. (2001) in north Florida and Khan *et al*. (2006) in Punjab-Pakistan.

According to NRC standard (1985), the requirement for Zn in the diet of sheep is in a range of 20-33 mg kg$^{-1}$ DM and the maximum tolerable level being 750 mg kg$^{-1}$ DM. The overall mean Zn content of in the forage was 36.9 mg kg$^{-1}$ DM and it was within the normal level tolerated by sheep (Underwood, 1981; NRC 1985; McDowell *et al*., 1993).

The significance of overall dietary balance for absorption and utilization of mineral nutrient by sheep cannot be overemphasized. Consequently, it was observed that with the exception of Ca and Na, the concentrations of other macro and micro minerals in the forages grazed by Fiji Fantastic sheep in the four government farms did not indicate any potential risk of deficiencies based on the recommended critical levels for ruminant livestock (Underwood, 1981; McDowell, 1985; NRC, 1985; McDowell *et al*., 1993; McDowell and Valle, 2000). Also it was significant interest to note that the macro and micro minerals of the pangola grass were within the values reported by Perdomo *et al*. (1977) in Venezuela and Florida for pangola grass.

Many different tissues can be used to provide index of availability of minerals. The choice of the tissue for analysis varies with the minerals under investigation, however, whole blood or blood serum or plasma is more widely employed for studies of mineral nutrition because it invariably reflects in some aspects of its composition and the mineral status of the animal. Diagnosis based on blood plasma/serum analysis clearly confirms responses to specific nutrient supplementation. However, there is no documentary evidence of the use of diagnosis based on blood serum analysis to clearly confirm responses to specific mineral requirements of the Fiji Fantastic sheep that grazed either batiki or Pangola grasses. Therefore in this study we have analyzed for the concentration of minerals from blood serum of FFS and compare values obtained with appropriate standards of adequacy or safety or deficiency.

This study therefore attempts to present information on the status of mineral concentration in the blood serum of FFS grazing batiki or pangola grasses in Samoa. Table 5 and 6 present concentration of macro and micro minerals in the blood serum of the Fiji Fantastic sheep in 3 farms.

Ca deficiency symptoms owing to low Ca intake are slow to develop, because the bone calcium may be drawn on as a reserve supply. Forage that contains between 2.4-3.2 g kg$^{-1}$ DM Ca is considered adequate to meet the requirements of grazing sheep (NRC 1985). Although the concentration of Ca in the forage was 2.1 g kg$^{-1}$ DM and the concentration of serum Ca in the sheep was within the critical level. Normal blood serum Ca lies between 9-12 mg 100 mL$^{-1}$ and the mean serum Ca of the FFS in the three

Table 5: Macro mineral elements in blood serum of Fiji Fantastic sheep

| | Ca mg 100 mL$^{-1}$ | | P mg 100 mL$^{-1}$ | | Mg mg 100 mL$^{-1}$ | | Na mg 100 mL$^{-1}$ | | K mg 100 mL$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| Farms | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Avele | | | | | | | | | | |
| Ewe (4) | 14.0-21.0 | 17.5 | 2.8-3.1 | 2.98 | 0.5-1.2 | 0.9 | 48.3-58.8 | 53.6 | 1.9-3.4 | 2.7 |
| Ram (4) | 9.0-12.0 | 10.5 | 2.4-3.6 | 2.9 | 0.3-0.5 | 0.4 | 34.6-51.5 | 43.1 | 2.1-2.5 | 2.3 |
| Mean | | 14.0 | | 2.9 | | 0.7 | | 48.3 | | 2.5 |
| Togitogiga | | | | | | | | | | |
| Ewe (4) | 32.0-37.0 | 34.5 | 3.1-3.4 | 3.3 | 0.7-1.2 | 0.9 | 27.9-61.9 | 44.9 | 1.8-2.7 | 2.3 |
| Ram (4) | 26.0-33.0 | 29.5 | 3.1-3.9 | 3.5 | 0.6-1.3 | 0.9 | 48.3-83.5 | 65.9 | 1.8-2.4 | 2.1 |
| Mean | | 32.0 | | 3.4 | | 0.9 | | 55.4 | | 2.2 |
| Lemafa | | | | | | | | | | |
| Ewe (4) | 17.0-27.0 | 22.0 | 2.59-3.79 | 3.2 | 0.5-1.1 | 0.8 | 46.3-52.7 | 49.5 | 1.6-2.9 | 2.3 |
| Ram (4) | 21.0-38.0 | 29.5 | 2.89-3.49 | 3.2 | 0.6-1.9 | 1.3 | 49.5-60.3 | 54.9 | 2.1-2.7 | 2.4 |
| Mean | | 25.8 | | 3.2 | | 1.0 | | 52.2 | | 2.4 |
| Typical normal levels for adult sheep (mg dL$^{-1}$)* | | 9.3-11 | | 4.0-7.3 | | 2.0-2.7 | | 141-159.6 | | 43-63 |

* Typical normal levels for adult sheep (mg 100 mL$^{-1}$) (Underwood, 198; Boyd 1984; Renner, 2001)

Table 6: Micro mineral elements in blood serum of Fiji fantastic sheep

| | Fe mg 100 mL$^{-1}$ | | Mn mg 100 mL$^{-1}$ | | Cu mg 100 mL$^{-1}$ | | Zn mg 100 mL$^{-1}$ | |
|---|---|---|---|---|---|---|---|---|
| Farms | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Avele | | | | | | | | |
| Ewe (4) | 305-495 | 262.5 | 0.4-3.5 | 1.9 | 0.4-7.1 | 3.7 | 5.2-12.4 | 8.8 |
| Ram (4) | 294-466 | 380 | 0.2-0.4 | 0.3 | 0.2-1.9 | 1.0 | 6.2-7.8 | 6.9 |
| Mean | | 321.4 | | 1.1 | | 2.4 | | 7.9 |
| Togitogiga | | | | | | | | |
| Ewe (4) | 459-547 | 503 | 0.6-1.9 | 1.2 | 1.4-5.7 | 3.6 | 6.4-10.9 | 8.7 |
| Ram (4) | 288-479 | 383.5 | 0.1-1.8 | 0.9 | 2.3-5.1 | 3.7 | 3.6-9.8 | 6.7 |
| Mean | | 443.3 | | 1.1 | | 3.7 | | 7.7 |
| Lemafa | | | | | | | | |
| Ewe (4) | 275-389 | 332 | 0.3-1.2 | 0.8 | 1.7-6.3 | 4.0 | 6.5-8.2 | 7.4 |
| Ram (4) | 340-406 | 372 | 0.3-2.3 | 1.3 | 1.8-5.9 | 3.9 | 3.8-10.4 | 7.1 |
| Mean | | 352.5 | | 1.1 | | 3.9 | | 7.2 |
| Typical normal levels for adult sheep* | | 182 (ewe) | | | | | | |
| | | 152 (rams) | | 20 | | 7-12 | | 10-14 |

* Typical normal levels for adult sheep (mg 100 mL$^{-1}$) (Underwood, 1981; Boyd 1984; Renner, 2001)

farms was between 9-38 mg 100 mL$^{-1}$. and this indicated that the grasses contained adequate dietary Ca that meet the requirements of the FFS in Samoa.

Serum Phosphorus (P) among the sheep ranged between 2.1-3.9 mg 100 mL$^{-1}$. Serum P level lower than 4.0-4.7 mg 100 mL$^{-1}$ is regarded as normal for adult sheep (Underwood, 1981). The forage grazed by the sheep had a mean P content of 2.1 mg 100 mL$^{-1}$, a level higher than 1.6 mg 100 mL$^{-1}$ and 2 .0 mg 100 mL$^{-1}$ considered deficient for ewes during gestation and lactation, respectively. Although the serum P value was below 4 mg 100 mL$^{-1}$, sheep in the four farms did not exhibit any unthrifty appearance nor did they exhibit any symptom of listlessness, the development of a knocked-kneed conformation, with general lack of body conformation (NRC, 1985). This seems to indicate that the sheep were able to absorb and efficiently utilized the available P in the forage during the dry season.

Serum magnesium (Mg) did not differ among the sheep (rams and ewes) at Avele, Togitogiga and Lemefa farms with a range of 0.3-1.9 mg 100 mL$^{-1}$. Serum Mg concentration was within values of 1.8-3.2 mg 100 mL$^{-1}$ and 1.0-1.7 mg 100 mL$^{-1}$, adult sheep and growing sheep, respectively and 0.7-1.2 Mmol L$^{-1}$ reported for adult sheep by Renner, (2001).

Serum sodium (Na) concentration was 48.30, 55.4 and 52.2 mg 100 L$^{-1}$ (mean 51.9 mg 100 mL$^{-1}$) for Avele, Togitogiga and Lemefa farms, respectively. Mean serum Na was relatively low compared to value of 141-159.6 Mmol L$^{-1}$ reported for adult sheep (Renner, 2001). Sodium occurs largely in body fluids and bones and sodium in the blood makes up over 90 % of the bases of the serum but is not present in blood cells. It could therefore be assumed that most of the available Na in the sheep was concentrated in the bones and hence the low value obtained in the serum. The concentration of Na in the forage was low (Table 3) and this might have contributed to the low serum Na content in the sheep. However, the sheep did not show any sign of growth retardation, reduce appetite or increased water consumption, which are typical signs of Na deficiency. The low serum Na content therefore support further our earlier recommendation of the need for supplementation of the sheep with mineral lick block to overcome any deficiency.

Serum potassium (K) was 2.5; 2.2 and 2.3 mg 100 $L^{-1}$ (Mean 2.3 mg 100 $mL^{-1}$) for Avele, Togitogiga and Lemefa farms, respectively. Serum K is lower than 3.4 -5.6 Mmol $L^{-1}$ (Renner, 2001) and 4.3-6.3 Mmol $L^{-1}$ (Boyd, 1984) reported for adult sheep. The forage K content was slightly above the critical K level for adult sheep. The low serum K observed may not be unconnected with K availability and its concentration in the erythrocytes which is 25 % times that of plasma and serum (Underwood, 1981).

Animals have limited capacity to excrete iron (Fe) therefore retention in the body is largely controlled by absorption. Generally the Fe content of soils is many times that of the plants they support. reported that Fe deficiency is rare in grazing livestock due to a generally adequate content in soils and forages together with contamination of plant by soil. Mean serum Fe concentration of the sheep was 352.5 mg 100 $mL^{-1}$ and this was highly above the critical level for normal ewes and rams at 182 mg $dL^{-1}$ and 152 mg $dL^{-1}$, respectively (Underwood and Morgan, 1963). The sheep had sufficient level of Fe in the serum and this indicates that they were not afflicted with blood-sucking parasites or had worm burden which tends to lower serum Fe concentration depending on the level of infestation. The high serum Fe might have been caused by the comparatively high Fe content of the forage grazed and also probably due to high Fe absorption by the sheep. Generally, Besides, Fe metabolism is interrelated with that of other metal ions (Haenlein, 1980).

Manganese (Mn) concentrations in the blood, bones and liver decline in animals deprived of Mn. Blood Mn values are extremely variable, reflecting both individual variability and whole blood concentration below 20 mg $dL^{-1}$ suggest the possibility of deficiency in sheep (Underwood, 1981). Mean serum Mn concentration was 1.1; 1.1 and 1.0 mg 100 $mL^{-1}$ (mean 1.1 mg 100 $mL^{-1}$) for sheep at Avele, Togitogiga and Lamefa, respectively. This level is extremely lower than the critical level of 20-40 mg $dL^{-1}$ for growing and adult sheep (Underwood, 1981; McDowell, 1985; NRC, 1985; McDowell *et al.*, 1993). The low serum Mn concentration seems to indicate that there was interference from the concentration of Ca and P in the forage and excess supply of P which worsened the utilization of Mn. Manganese metabolism is affected by Ca and P supplie (Anke *et al.*, 1972) and an excess supply of P would worsen the utilization of Mn (Haenlein, 1980).

Mean serum copper (Cu) of the sheep at Avele, Togitogiga and Lamefa farms was 2.4, 3.6 and 3.9 mg 100 $mL^{-1}$ (mean 3.3 mg 100 $mL^{-1}$), respectively. However, serum Cu in the sheep ranged between 0.2-6.3 mg 100 $mL^{-1}$. In sheep, serum Cu may range from 0.6-1.5 mg 100 $mL^{-1}$ with a high proportion lying between 0.8-1.2 mg $mL^{-1}$ (Underwood, 1981). Values of 0.2-0.3 mg 100 $mL^{-1}$ are common in sheep that grazed deficient pastures however, serum Cu below 0.5 mg 100 $mL^{-1}$ is indicative of deficiency (Underwood, 1981). The sheep at Avele farm showed lower serum Cu than critical level (below 0.5 mg 100 $mL^{-1}$). Cu deficiency is wide throughout the world and it is likely to occur when dietary Cu content in the pasture is lower than requirements for sheep at 7.0 mg $kg^{-1}$ DM (NRC, 1985). The low Cu content of the forage is indicative of likely deficiency and may be implicated for the low serum Cu concentration. Serum Cu concentrations reflects the dietary status, however the normal range is high (Underwood, 1981). Generally, there is a decline in Cu concentration in animal tissues or fluid when Cu intakes are low (Beck, 1941).

Mean serum Zn concentrations was 7.9; 7.7 and 7.2 mg 100 $mL^{-1}$ (mean 7.6 mg 100 $mL^{-1}$) for sheep at Avele, Togitogiga and Lamefa farms. Serum Zn of the FFS is higher than the normal range reported by Conchran *et al.* (1991), Underwood (1981) for sheep, therefore Zn deficiency is unlikely to occur. The serum Zn concentrations indicated that Zn requirements of the sheep were met through grazing of the forage at Avele, Togitogiga and Lamefa farms. Zn is has been observed to be essential for sheep growth and the forage grazed by the sheep had mean Zn content of 36.9 mg $kg^{-1}$ a value within the range of 15 -50 suggested as adequate for adult sheep (Renner, 2001).

Serum mineral concentrations of the sheep were variable and were not within normal range reported for sheep (Underwood, 1981; Cochran *et al.*, 1991; Renner, 2001). Mineral imbalances exert a significant effect on the health and productivity of livestock through out the tropics. The relationship between mineral contents of soil and forage in relation to serum mineral concentration of the Fiji Fantastic sheep was exhaustively examined in this report. It appears that the critical levels proposed for most elements are higher than may apply to the FFS grazing low potential grasses in Samoa during the dry season. It is hereby concluded that supplementation of the FFS with mineral lick block during grazing would alleviate the problems of the deficiencies of some of the macro and micro minerals observed in the forages (Prabowo *et al.*, 1984a, b) and in the blood serum of the sheep.

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