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Role and importance of trace elements in New Zealand livestock. Fact and fiction

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ABSTRACT

In New Zealand as a result of extensive trace element supplementation animal response trials, an excellent database has been established on protocols to detect deficiencies, dietary trace element requirements, and the efficacy of many products to prevent deficiencies. However, situations still arise where the above information is not well evaluated or correctly implemented by some consultants and farmers.

Keywords: sheep; cattle; selenium; cobalt; copper; iodine

INTRODUCTION

The role of trace elements in New Zealand livestock, and particularly the impact of Se, Co, Cu and I deficiencies on animal performance and health, has been well documented (Grace, 1994). Data and information has been collected from many well designed field trials and published in the science literature. Unfortunately, some of this information has not always been accurately disseminated to or used by some consultants and farmers.

There are 3 major areas of concern:

a) Diagnosis of trace element deficiencies
b) Dietary trace element requirements
c) Efficacy of various trace element products or animal remedies

DIAGNOSIS OF TRACE ELEMENTS DEFICIENCIES

A trace element deficiency is unequivocally identified only when the growth or reproduction (or absence of clinical signs) of a group of animals treated with the trace element is significantly better than that of a similar group of untreated animals managed under the same conditions (Sheppard *et al*., 1984; Clark *et al*., 1985). The trial must be well designed with an adequate number of animals per treatment, and the treatments must significantly increase and maintain tissue trace element concentrations for the duration of the trial. Growth responses in lambs of up to 175 g/day due to Co/Vitamin B_{12} supplementation and up to 65 g/day due to Se supplementation have been reported (Sheppard *et al*., 1984; Clark *et al*., 1985). At the present time 10 g/day is an economic response in lambs, that is, returns are sufficient to repay the cost of treatment.

Unfortunately, data from inadequate and poorly designed trace element trials are being published in the popular farmer press. These articles present very little data, can be misleading, and can distort the true situation as regards the extent and magnitude of trace deficiencies.

Well designed trace element dose response trials are time consuming and expensive, and therefore they are not an option for the routine assessment of the trace element status of grazing livestock. However it has been demonstrated that changes in blood (serum) concentrations of Se, Co (Vitamin B_{12}) and I, as well as liver concentrations of Se, Co (Vitamin B_{12}) and Cu, reflect changes in their respective intakes (Somers & Gawthorne, 1969; Woolliams *et al*., 1983). Therefore the Se, Co, Cu and I intakes and status of livestock can be assessed by taking and analysing the appropriate number of blood and liver samples, and then comparing the tissue trace elements concentrations with established reference ranges. These reference ranges have been carefully determined by relating trace element concentrations in tissues to responses in animal performance, such as growth in the case of Se and Co (Sheppard *et al*., 1984; Clark *et al*., 1985), or absence of clinical signs of the deficiency, such as enlarged thyroids in the case of I (Grace *et al*., 2001). The relationships between growth responses and the Se and Vitamin B_{12} status of lambs are illustrated in Figure 1.

FIGURE 1: The relationship between (A, left) blood Se and (B, right) serum Vitamin B_{12} concentrations of untreated lambs and the growth responses to Se supplementation and Vitamin B_{12} supplementation.

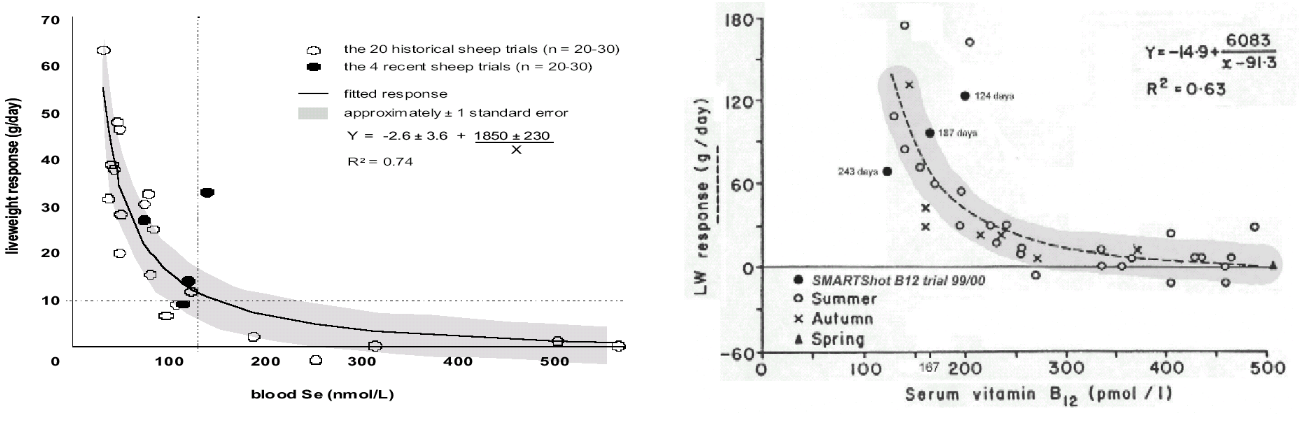

TABLE 1: Tissue reference ranges to diagnose Co and Se deficiency in sheep and cattle.

	Deficient	Marginal	Adequate
		SHEEP	
Cobalt			
Serum Vitamin B_{12} (pmol/L)	<185	185-370	>370
Liver Vitamin B_{12} (nmol/kg fresh tissue)	<110	110-220	>220
Selenium			
Blood Se (nmol/L)	<130	130-250	>250
Liver Se (nmol/kg fresh tissue)	<250	250-450	>450
		CATTLE	
Cobalt			
Serum Vitamin B_{12} (pmol/L)		not recommended	
Liver Vitamin B_{12} (nmol/kg fresh tissue)	<75	75-220	>220
Selenium			
Blood Se (nmol/L)	<130	130-250	>250
Liver Se (nmol/kg fresh tissue)	<600	600-850	>850

From the blood reference ranges shown in Table 1, lambs can then be classified as being deficient, that is they will respond to Se and Co/Vitamin B_{12} supplementation, or adequate, that is they will not respond to supplementation (Grace, 1994; Optigrow, 1997). Data from other tissues, such as liver, has also been used to establish reference ranges for sheep and cattle (Table 1).

The detection of marginal trace element deficiencies can be difficult. The marginal tissue values reflect the probability of obtaining a response to supplementation. The closer the mean flock or herd tissue trace element value is to the deficient reference range values, then the greater is the probability of observing a response.

Reference ranges are always under review and are changed if new data indicates this is necessary to improve the accuracy of the diagnosis (Thompson *et al*., 1998). Blood enzymes, for example glutathionine peroxidases in the case of Se, or ferrioxidase in the case of Cu, can also be used to assess the Se and Cu status of livestock. Reference ranges have been established for these. Animal performance responses to Cu supplementation are few, and therefore the reference ranges for Cu have been based on the appearance or absence of clinical signs such as enzootic ataxia, a nerve disorder, or osteochondrosis, a bone disorder (Grace, 1994).

While tissue trace element concentrations offer a rapid, cost effective and convenient approach to assess the trace element status of livestock, it must be always remembered that they are based on dose animal response trials carried out under New Zealand farm conditions. Overseas criteria are not always applicable to New Zealand. For instance, the blood Se reference ranges for dairy cattle in the USA are <500 nmolSe/L, which is deemed deficient, and >880 nmolSe /L, which is deemed adequate (Maas & Koller, 1985). Using the USA reference ranges it would be concluded that most livestock in New Zealand would respond to Se supplementation, but this is clearly not the case. The difference between the New Zealand and USA recommended reference ranges is related to the different management and feeding systems. Most cows in USA are fed grain/hay diets indoors, while New Zealand dairy cattle are fed pasture or conserved pasture outdoors. Further, Se metabolism is complex, as there is a Se x Vitamin E interaction and low Vitamin E intakes increase the Se requirements. USA diets are usually lower in Vitamin E when compared to New Zealand pastures. Selenium also has an important role in maintaining the integrity of the immune system, and therefore in an indoor management situation where the potential risk of catching various diseases, such as mastitis, is much greater the Se status or tissue Se concentrations of cows may need to be higher in order to maintain their health (Smith *et al*., 1984).

Obviously, using inappropriate reference ranges to evaluate the trace element status of livestock from their blood and liver trace element concentrations leads to an incorrect diagnosis of a trace element deficiency.

DIETARY TRACE ELEMENT REQUIREMENTS

If the dietary requirement of a trace element is known, then the suitability of a pasture, forage or feedstuff to provide an adequate trace element intake to livestock can be readily determined. Dietary trace element requirements are difficult to determine precisely because many factors can influence intake, absorption and utilisation of trace elements in livestock. Two main approaches have been used to determine the dietary trace element requirements in sheep and cattle, as described by Grace (1983); namely (1) practical feeding/supplementation trials, and (2) a factorial model based on data collected from detailed trace element nutrition studies.

In practical feeding studies, large groups of animals (n = about 60) are fed diets of varying, but known, trace element content for 4-6 months. At the start, half the animals in each of the diet groups are supplemented with the trace element under study, and the lowest dietary trace element concentration at which the supplemented animals grow no better than the unsupplemented ones is noted. This dietary trace element concentration is then taken to be the dietary trace element requirement. As an example, when groups of lambs were grazed on pastures containing 0.01 to 0.06 mg Se/kg DM the animals grazing pastures containing greater than or equal to 0.03 mg Se/kg DM showed no response to their Se supplementation (Grant & Sheppard, 1983). The dietary Se requirement is therefore taken to be 0.03 mg Se/kg DM for sheep.

The factorial modelling approach brings together data from nutritional balance studies, isotope kinetic measurements and slaughter trials used to determine the trace element content of various tissues, including the conceptus. The factorial model is outlined in Figure 2. This approach can be used to determine dietary Se and Cu requirements but is not suitable for Co (Vitamin B_{12}) or I because their metabolism is complex, and there are no data on endogenous losses, and the information on tissue concentrations is incomplete.

In this figure faecal endogenous trace element loss is a measure of the inevitable loss from the body in the various digestive tract secretions. Likewise, the urinary trace element excretion is a loss from the body. The sum of the above losses is therefore a measure of the maintenance trace element requirement.

FIGURE 2. The factorial model to determine dietary trace element requirements.

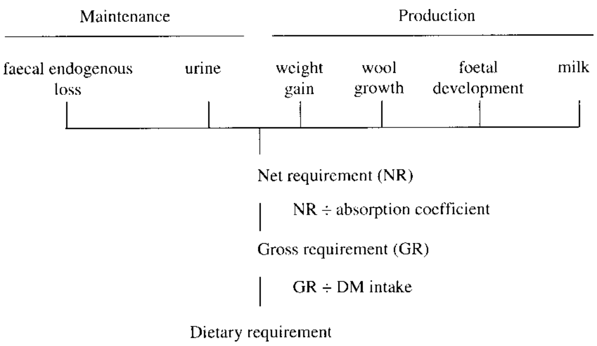

TABLE 2. Amounts of Se associated with the endogenous loss, growth, gestation and lactation in sheep and the calculated dietary Se requirement for lambs.

Endogenous loss (µg/kg LW)	0.25
Liveweight gains (µg/kg LWG)	51.0
Accumulation in conceptus during late pregnancy (µg/day)	10.0
Secreted in milk (µg/kg)	6.0
Dietary Se requirement for a lamb	
Maintenance (25 kg LW x 0.25 µg/kg LW)	6.25
Growth (0.2 kg/day x 51 µg/kg LWG)	10.20
Net Se requirement	16.45 µg/ day
Coefficient of absorption	40%
Gross Se requirement	41.12 µg/ day
Dietary Se requirement	
(41.1 µg ÷ 1.4 kg DM/day)	29 µg Se/kg DM

An example of the use of the factorial model to determine the dietary Se requirements of a growing lamb is given in Table 2 (Grace, 1994).

There is a high degree of confidence in the determined dietary Se requirement for the growing lamb because the values (i.e. 0.029 and 0.03 mg/kg DM) determined by the factorial model and the Se supplementation/ feeding studies are similar.

Many factors can influence the absorption of a trace element and therefore its dietary requirement. This is the situation for Cu, as dietary antagonists Mo, Fe and Zn impair Cu absorption and reduce liver Cu stores. Increasing pasture Mo concentrations from 1 to 4 mg Mo/ kg DM has been found to reduce the Cu absorption coefficient by about 50% in sheep (4.6% vs. 2.2%), (Knowles *et al*., 1999), and this results in the dietary Cu requirements being increased about 2-fold (i.e. 5.9 to 11.8 mg Cu/kg DM). Cattle are more sensitive than sheep to changes in Mo intakes, while their dietary Cu requirements are about double those of sheep (Knowles *et al*., 2000).

In most overseas intensive livestock enterprises grain/ hay diets are fed, and therefore in contrast to New Zealand, the addition of trace elements as dietary supplements are a very cost effective and easy way of preventing trace element deficiencies. The recommended dietary trace element requirements from overseas authorities also usually have built in a greater "insurance factor", and therefore are higher than those recommended in New Zealand based on our field trials. For example, in the USA the recommended dietary Se requirement for dairy cattle is 0.3 mg Se/kg DM (National Research Council, 2001), while in New Zealand the recommended dietary Se requirement is 0.03 mg/kg DM (Grace 1994). Dietary trace element requirements are always under review and are revised as new data becomes available.

EFFICACY OF TRACE ELEMENT PRODUCTS

Another area of misunderstanding is the efficacy of various trace element supplements. Some of the confusion can be related to commercial pressure to sell competing products, and to the lack of suitable experimental data (i.e. sufficient animals in an appropriate design) to support the effectiveness of the treatment.

Generally the efficacy of orally administered trace elements such as Co, Cu and I is short, about 2-4 weeks depending on the dose rate (Andrews, 1954; Cunningham, 1948; Sinclair & Andrews, 1954), although the efficacy of oral Se is 6-12 weeks (Grace *et al*., 1994). New developments, based on controlled released technologies have given rise to new long acting injectable Vitamin B_{12} and Se products (Grace & Lewis, 1999; Ankenbauer-Perkins *et al*., 2000). For example, 3 mg of Vitamin B_{12} given as a long acting injection has an efficacy of 245 days, whereas 2 mg of the water soluble Vitamin B_{12} given as an injection has an efficacy of 28-40 days (Grace *et al*., 1998).

Further, the expanding practice of adding trace elements to unrelated drenches and vaccines means that the timing of the administration of the trace element is constrained by the optimum time for drenching and vaccinating the animal, which may not be related to the onset of the trace element deficiency. For example, on properties where Co and Se deficiency occurs in flocks, there are sound biological advantages to treating lambs at docking rather than at weaning, when most drenching programmes are implemented.

When implementing a strategy to prevent trace element deficiencies it is important to know the best time to supplement and the efficacy of the product used. In a Se deficient flock ewes can be treated 4 weeks premating and 4 weeks prelambing with 5 mg Se, and their lambs with 2 mg Se at docking as sodium selenate, or injected once with 50 mg Se as barium selenate 4 weeks premating to ensure good lambing percentages, reduce lamb mortality and to prevent white muscle disease.

Similarly the use of Se, Co and Cu amended fertilisers ("topdressing") can be beneficial to prevent trace element deficiencies in grazing livestock (Grace, 1994), but the timing of their application is critical because plant uptake of Se, Co and Cu occurs only during a 2-4 month period. To prevent Co deficiency in lambs, the Co must be applied in early spring, not autumn. In contrast, Se and Cu are best applied in autumn to increase the Se status of ewes premating, and to increase liver Cu stores in cattle and deer sufficiently to counter the winter/early spring decrease in their Cu status. Controlled release systems are also being developed for trace element amended fertilisers to give more flexibility in their use.

CONCLUSION

New Zealand has an excellent database founded on many well designed trials, which describes the metabolism, dietary requirements and protocols used to diagnose trace element deficiencies, as well as the efficacy of many commercial trace element remedies. Unfortunately, situations still arise where some consultants and farmers do not access or use all the scientific-based information that is available. Too often the reporting on trace elements published in the popular farmer media is inaccurate, and is usually incomplete. The interaction between scientists, media, animal health companies, consultants and farmers needs to improve to assist the livestock industry.

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