RECENT ADVANCES IN COPPER AND SELENIUM SUPPLEMENTATION OF GRAZING RUMINANTS

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SUMMARY

Procedures for providing supplementary copper and selenium were classified into methods which involve direct application to pasture, free access methods, drenches, parenteral injections and slow release techniques; the advantages and disadvantages of each are examined with emphasis on procedures which have recently become available. A major problem is the subclinical deficiency which is often transient and difficult to identify but has a significant effect on productivity; alleviation can often be achieved at low cost once the problem is identified giving a favourable cost-benefit relationship.

INTRODUCTION

In recent years the number of trace elements known to be essential for the optimal health and growth of higher animals has increased to 15 (As, Co, Cr, Cu, F, Fe, I, Mn, Mo, Ni, Pb, Se, Si, V and Zn; Mills, 1983) but only five (Co, Cu, I, Se and Zn) have been shown conclusively to impair the productivity of grazing ruminants in Australia. Co, Cu and Se insufficiencies are more widely distributed than I and Zn insufficiencies; the latter appear to be restricted to the Eastern States and Western Australia respectively.

Clinical effects associated with frank deficiencies are well defined (Underwood, 1977), and are frequently identified by producers in regions in which they occur. In contrast subclinical effects are not recognized, are often transient, are associated with depressed production possibly with an impaired ability to mount an immune response, and cost-benefit analysis frequently indicates that supplementation procedures should be implemented. For example wool production on the New England Tablelands can be depressed by 10-15% by Se insufficiency which could be corrected at a cost of less than 30¢/sheep/year. Areas of marginal insufficiencies are widespread, frequently occurring as halos around areas of severe deficiency and their boundaries fluctuate between years with seasonal and other factors. As a result it is difficult to know if a particular herd or flock should be supplemented and there appears to be a need for low cost, safe, long term supplementation strategies which will correct transient deficiencies as and when they occur. Some progress in developing such strategies for Cu and Se

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supplementation have been achieved in recent years, and are the subject of this report.

Supplementation strategies can be classified into three groups: (1) application of the nutrient to the pasture possibly in conjunction with a regular fertilizer application, (2) free choice supplementation (e.g. salt blocks) and (3) techniques of direct administration to the animal. The need for supplementation and the advantages and disadvantages of the various strategies vary with the nature, incidence and ease of identification of the insufficiency, and these are briefly described before different supplementation strategies are considered.

COPPER

Nature of the problem

Cu insufficiency arises from inadequate concentrations of Cu in the forage, from its generally low availability in pasture (<8%) and from excessive concentrations of Mo and S and other dietary components (e.g. Fe) which form Cu complexes (e.g. Cu-thiomolybdate; Dick, 1975) primarily in the rumen; these complexes are unavailable to the animal. Cu is required for many enzyme systems, and clinical manifestations of insufficiency are correspondingly variable ranging from defective melanin synthesis (depigmentation of wool and hair) and keratinization (steely wool) to connective tissue defects and ataxia (swayback). Growth and possibly fertility may be reduced, cattle are more sensitive than sheep, and MO-induced deficiencies may be associated with severe scouring and appear to be a major cause of depressed productivity. Hypocuprosis and depressed growth in calves with an absence of overt manifestations of Cu deficiency has been reported in Victoria (Bingley and Anderson, 1972) where '60% of Cu supplements marketed for animals in Australia are sold' (Hosking et al., 1986). The incidence of the problem in southern Australia is seasonal with Cu status being at a minimum in winter and spring when pastures are green. Deficient areas have also been identified in QLD, NSW, TAS, SA and WA. Early signs of insufficiency in sheep include fleece defects, and since sheep are sensitive to Cu toxicity and growth responses are generally small, it may be prudent to delay supplementation until fleece defects or other clinical signs can be identified. Growth of cattle is more sensitive to deficiency. Cattle also show coat depigmentation although this is not specific for Cu deficiency; supplementation is sometimes justified by the improved appearance of the coat particularly in cattle ready for market. Cu status can be assessed from hepatic Cu concentration but sample collection may present problems. Cu concentrations in TCA-precipitated plasma declines when Cu-status is low while concentrations in the erythrocyte is determined by Cu status at erythropoiesis and declines more slowly than plasma Cu as an animal moves into deficiency.

Direct Application to Pasture

Copper has been applied directly to soil in Australia since 1879 (Gilkes, 1981). Plant as well as animal deficiencies may be corrected, and a single application of c. 2 kg Cu/ha may last for up to 10 years on some soils. All animals receive the supplementary Cu and handling is not necessary. Disadvantages are cost particularly if extensive areas require treatment, toxicity if animals graze pastures while the fertilizer remains on the foliage, and its limited effectiveness against MO-induced deficiencies. Dietary Mo and ruminal sulphide react in the rumen to form thiomolybdates which complex with dietary Cu and reduce the availability of the Cu. Relationships between Cu availability and dietary S and Mo concentrations have been derived but the coefficients are probably diet-specific. Increased intakes of dietary Cu must be sufficient to overcome this reduction in availability. Factors which increase S and Mo concentrations include the application of S-containing fertilizers and the availability of immature green forage which are sources of ruminal sulphide; plant Mo concentrations also increase with soil pH and on poorly drained soils, and the application of MO-containing fertilizers or lime increases the likelihood of induced Cu deficiency. Since MO-induced deficiencies are both common, and the form of Cu deficiency most likely to reduce the growth rate of young cattle (Phillippo, 1983), recent emphasis has been given to supplementing the animal.

Free Access Methods

The provision of Cu in salt blocks and more recently in drinking water from metered troughs (MacPherson, 1981) has the advantage that handling of animals is avoided but other sources of drinking water must not be available and the intake of individual animals is variable. Variability in supplement intake is a particular problem because excessive intakes of Cu are toxic particularly for sheep, and lesser intakes may result in unacceptable increases in liver Cu concentration. Regulatory authorities in Australia impose limits on tissue Cu concentrations in order to protect export markets. A major problem for the producer contemplating supplementation is that he is usually unaware of the Cu status of his stock, and free choice supplementation as a precautionary measure may result in some animals being unsupplemented while others have unacceptable hepatic Cu concentrations. The problem is reduced but not eliminated if each animal is given a known dose of Cu.

Parenteral Injection

Organic Cu compounds such as Cu glycinate (cattle), diethylamine cupro-oxyquinoline sulphonate (sheep) and copper calcium edetate (both species) can be administered sub-cutaneously, and have the advantage of avoiding the gastro-intestinal tract and therefore the main site of thiomolybdate complexing. They are easily administered to cattle without locking their head into a bailgate, but unfortunately have a long history of causing swelling, abscesses, reduced productivity and, in severe cases, anaphylaxis and death; copper calcium edetate appears to cause the least reaction but this may be attributable to the carrier in some preparations rather than to the chemical form of the supplement (Boila et al., 1984). Parenteral injections may also cause discoloration necessitating the excision of meat surrounding the injection site.

Slow Release Techniques

Two forms of Cu supplementation have been developed in recent years. Dewey (1977) proposed the use of oxidised copper wire particles, and workers at the University of Leeds (Telfer et al., 1984) developed soluble glass pellets which are intended to reside in the rumen. Both forms are administered by mouth, are suitable for sheep and cattle and are intended to protect against Cu insufficiency for 6-12 months. Oxidised particles are unreactive in the rumen but some particles are trapped in the mucosal folds of the abomasum, and release Cu over several weeks in the acid environment; this is readily absorbed and stored in the liver. The rod-like characteristics of the particles and the degree of oxidation are critical; copper oxide powder and elemental Cu are ineffective. Disadvantages of the particles include the difficulty of varying dose size in relation to liveweight (and thence liver weight), and the need to individually dose each animal by mouth which in the case of cattle necessitates locking the head into a bailgate. This increases labour costs. Similar problems exist with soluble glass pellets which are intended to lodge in the rumen where they dissolve over several months releasing a payload of Cu, Co and Se. The incorporation of Cu into a multi-element dose does not appear to be desirable because the pellets may be used in areas of Co or Se insufficiency where Cu status is adequate; this increases the likelihood of excessive Cu concentrations in tissues. There has been some criticism of the use of the glass pellets in Britain for correcting Cu insufficiencies. The release rate of Cu in commercial pellets was inadequate to prevent hypocupraemia (MacPherson, 1985), presumably becausethe pellet was formulated to prevent excessive tissue Cu concentrations, and as a result released insufficient Cu in situations where Cu availability was reduced by excessive intakes of Mo, S and/or Fe. In the Author's opinion, Cu supplements should only be used in areas where there is reason to suspect Cu insufficiency and at times when Cu reserves are likely to be low. In such situations release rates can be formulated to deliver adequate payloads without undue risk of excessive tissue Cu concentrations. The soluble glass pellet and oxidised Cu particles are not yet available commercially in Australia. Both forms of supplementation have been available overseas for several years.

SELENIUM

Nature of the Problem

Se insufficiency is observed in sheep and cattle in all southern states and is associated with higher rainfall regions; most plants do not have a requirement for Se. In NSW, Se insufficiency is located along the Great Dividing Range, frequently on acid soils and usually on improved pastures. The productivity of both sheep and cattle can be impaired without obvious clinical symptoms but sheep appear to be the more sensitive possibly because the fleece acts as a Se sink. Vitamin E and Se have similar functions of protecting membranes from damage by peroxide and other active radicals, but most problems in Australia are Se-responsive. Subclinical Se insufficiencies occur in years of above average rainfall, and reduce growth, wool production and fertility; lambs in particular may show clinical characteristics and in particular stiffness in the limbs and in extreme cases white muscle disease. Se passes across the placenta and supplementation of the ewe is an effective means of supplementing lambs in early life, but the protection diminishes rapidly as the lamb grows and consumes increasing quantities of grass. Se reserves are usually assessed by analysing whole blood for Se or assessing the activity of the Se-enzyme, glutathione peroxidase. Both Se and the enzyme are concentrated in the red blood cell and are incorporated at erythropoiesis; this estimate of Se status is therefore an estimate of Se intake over several months. Plasma Se concentration may provide a better estimate of contemporary Se intake.

Direct Application to Pasture

The application of sodium selenate to pastures at the rate of 10 g Se per ha has recently been pioneered in New Zealand, and is now registered for use in some Australian states (e.g. Victoria). Selenate is extremely toxic and the product is usually sold encapsulated in a water soluble prill. The material is effective for about a year and the material cost is generally higher than treating individual animals, but savings in labour costs may offset this disadvantage. The selenate induces a rapid increase in forage Se concentration which also falls rapidly, and the procedure relies on the grazing animal storing Se in its tissues. The material may not need to be spread uniformly across the property, and it may be possible to treat limited areas through which animals are rotated at appropriate intervals, thus reducing material costs.

Free Access Methods

There are several reports in the literature of the incorporation of sodium selenite into compressed salt blocks but the procedure cannot be recommended (see Money *et al.*, 1986) because of the failure of some animals to take the supplement and of others to consume excessive quantities. In a study at Armidale in which ewes and their lambs were given access to selenized salt, 54, 9 and 10% of the lambs did not show increased blood Se levels at birth, 55 and 79 days of age respectively.

Drenches

The oral administration of Se salts has a number of advantages. The material is of tow cost, and the Se can sometimes be combined with anthelmintic thus minimising labour costs. The dose for either sheep or cattle is 0.1 mg Se/kg liveweight, and is a safer route of administration than injection. A major disadvantage is the ill-defined life of the supplement. Repeated drenching is necessary and the dosing strategy is most frequently used to maximise the growth and survival of lambs. The elevations in blood Se concentrations in lambs born to ewes receiving a single dose of oral selenate are presented in Table 1. The adequacy of the response in blood Se concentration depends on the severity of the deficiency, and a working rule is that lambs will respond to Se supplementation if blood concentrations are <0.02 ug Se/ml. Timing of supplementation in relation to the stage of pregnancy is critical and dosing in the last trimester of pregnancy is necessary. It is also desirable to dose prior to mating because Se insufficiency can induce early embryo mortality and hence infertility.

Table 1 The increase in blood Se concentrations (ug Se/ml) in lambs whose dams were given 5 mg Se as a drench at various stages of pregnancy and lactation. The increase was calculated as the difference between concentrations in lambs whose dams did and did not receive any supplement

	AGE OF LAMBS (DAYS)		
	Birth	44 days	80 days
20 days pregnant	0.004	0.004	-0.004
60 days pregnant	0.014	0.013	0.007
100 days pregnant	0.028	0.010	0.011
140 days pregnant	0.016	0.022	0.018
10 days lactation	-	0.012	0.015

Parenteral Injection

Subcutaneous and intra-muscular injections of selenites and selenates are widely used; in comparison with oral dosing, the procedure has the advantage that the salts are not exposed to the rumen where they may be reduced to elemental Se and thus rendered partially unavailable. It may also be easier to inject than to orally dose cattle, and the costs are reduced if livestock are to be mustered and injected for other purposes (e.g. clostridial vaccination). Disadvantages are toxicity and the short period of effectiveness of sodium salts. The range between safe and toxic doses is narrow and as a result some commercial preparations contain relatively little Se; the LD50 of sodium selenite given intra-muscularly to sheep is 0.45 mg Se/kg liveweight. In an attempt to slow the rate of release of Se from the injection site, Kuttler et al. (1961) suspended barium selenate in an oil-beeswax mixture. More recently Cawley and MacPhee (1984) described the use of a barium selenate suspension in a 'viscous incipient' marketed in Britain as 'Deposel'; an injection of 1 mg/kg liveweight was reported to be safe and to provide Se for 6 to 12 months. Carcass residues pose a possible problem with slow release forms of Se given parenterally (see Allen and Mallinson, 1984) and the gastro-intestinal tract is perhaps a safer site in which to locate depots of slow release supplements.

Slow Release Techniques

Intra-ruminal pellets containing cobalt oxide were introduced in the late fifties, and the concept was extended to the provision of Se by Kuchel and Buckley (1969). This pellet contained 5% elemental Se and 95% iron, and was retained in the reticulo-rumen because of its density; it was believed to be effective for four or more years. Several million sheep pellets are sold in Australia each year, the pellet costs about 25¢ and potentially provides a low cost and long lasting method of combating sub-clinical Se insufficiencies, which is particularly suitable for wool production because Se is released continuously. Unfortunately some commercial pellets have been shown to be less satisfactory, and two years appears to be the upper limit of the effective life of pellets presently available commercially. Hudson et al. (1981) suggested that the pellet functioned as a voltaic cell and that effective life was positively correlated with the particle size of the elemental Se. Other factors which limit the longevity of the pellet include ruminal encrustat ion with calcium phosphates (especially brushite) and regurgitation. Uncertainty as to the effective life of the pellet creates problems for stockowners because marginal Se insufficiencies may reduce production without obvious clinical symptoms, and the stockowner may incorrectly believe that Se status is adequate because a Se pellet has been administered. Some authorities (e.g. Hosking et al., 1986) do not recommend the use of the pellets because of these uncertainties, and the method is seldom used outside Australia; a cattle Se pellet is about to be launched on the Australian market.

The soluble glass pellet described earlier also releases Se and appears to be as effective as the Fe:Se pellet during its prescribed year of life. This is less than the 2 year period presently achieved by most commercial Fe:Se pellets; in addition the glass pellet is more expensive in Britain where it is commercially available, and it is as likely to be regurgitated as the Fe:Se pellet because its specific gravity is lower and the glass pellet becomes smaller with time as its payload is released.

Most of the strategies described here were developed for combating outbreaks of frank deficiency, and may be less appropriate for overcoming subclinical, transient deficiencies which are believed to be widespread in Australia. Such conditions are difficult to identify, and if supplementation is to be undertaken as a precautionary measure, then the strategy must be effective, low cost, safe and long acting. On intensively grazed pastures containing insufficient Cu for optimal plant or animal production, direct application of fertilizers has many advantages; other strategies are necessary when dietary deficiencies are induced by excessive Mo intakes, and it may not be possible to provide supplements which are effective for more than a year. The provision of Cu supplements directly to the animal as a precautionary measure can be criticised because of the risk of excessive tissue residues; this may not be a problem in animals not intended for immediate human consumption and copper oxide particles or parenteral injections which do not cause tissue lesions, would appear to be the methods of choice.

Se-containing fertilizers have to be applied more frequently than Cu-fertilizers, and may not be justified on cost grounds as a precautionary measure. The inclusion of Se in drench or vaccine costs little, and may provide sufficient Se for optimal lamb production if given frequently. The Author prefers Fe:Se pellets because of the extended period for which Se is (or should be) provided at comparatively low cost. A continuous supply of Se is probably desirable for continuous processes such as wool production, which is very sensitive to Se insufficiency, and studies are in progress in an attempt to overcome some of the problems associated with the Fe:Se pellet.

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