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CHAPTER 3. NUTRITIONAL REQUIREMENTS OF GROWING LAMBS: MINERAL SUPPLEMENTATION OF SHEEP IN FEEDLOTS

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Introduction

Minerals added to sheep feedlot rations can be divided into two groups based upon the reason for their use. One group contains the protective minerals and the other group the possible carcase-composition-modifying minerals. The protective minerals include calcium, phosphorus, sodium, selenium, copper and cobalt; and the possible carcase-composition-modifying group include magnesium and chromium. In general the protective minerals do not improve performance of sheep in feedlots, but do prevent production losses and deaths. Often in commercial lot feeding situations the difference between profit and loss can be as little as the cost of a few sheep deaths. It is prudent and simple to minimise these losses by adding some minerals to rations.

The traditional way of classifying minerals is based upon the order of magnitude of their requirements for maintenance of the animal, thus there are macro-minerals (required in the order of grams per kilogram of dry matter intake), trace minerals (milligrams per kilogram of dry matter intake) and ultra-trace minerals (micrograms or less per kilogram) (Underwood and Suttle 1999).

The theory and practice of mineral supplementation can be at odds with each other. Mineral supplements should be used only when requirements cannot be met from the appropriate combination of available feedstuffs. This approach depends on knowing the mineral composition of the feedstuff or having access to a comprehensive database to gain this information. However, it is not sufficient to know the mineral composition of a feedstuff because this does not translate into complete availability of the mineral. The actual intake, the chemical form, the presence of interacting factors and the physiological state of the animal all influence availability to varying degrees that are not always predictable. For instance, inorganic forms of chromium are very poorly absorbed by sheep whereas organic forms have some proven efficacy (Underwood and Suttle 1999). In addition, the animal may have sufficient reserves in tissue storage to sustain the needs for a particular mineral over periods varying from days to over a month. Providing minerals beyond the animal's requirements can be an economic waste because this practice does not lead to any additional benefit and may in fact be harmful in some cases. Nevertheless responsible manufacturers legitimately sell to farmers ready-mixed mineral supplements that are of considerable value to sheep. Notwithstanding this, farmers should be on the alert for exaggerated claims and should seek independent substantiation of these claims in relation to particular benefits to the class of stock under local conditions.

Current usage of minerals

Two major feedlot diet manufacturers in Western Australia were contacted in June 2003 to ascertain what minerals were currently being used in sheep feedlot rations.

For short-term lamb finishing (less than 30-40 days) one manufacturer rarely added limestone, but rather used dicalcium phosphate (DCP) to achieve a pellet with 1.0 per cent calcium and 0.2-0.3 per cent phosphorus (or a Ca:P ratio of 3:1-5:1). Bicarbonate of soda was rarely used by this manufacturer, and salt was not added either, so the pellet had a final sodium content of 0.04-0.05 per cent. A mineral premix was used for two reasons;

commercial expectations that manganese, zinc, iron, iodine, selenium and cobalt would be included in the ration, and historical evidence of deficiencies of selenium and cobalt in Western Australia. For live export pellets (also relatively short-term feeding), no premix or DCP was used by customer request, but lime was added at 1 or 2 per cent to act primarily as a binder to reduce dust rather than as a source of calcium. Other electrolytes (such as potassium) were occasionally included in the feed by this manufacturer (information provided commercial in-confidence).

A second manufacturer also indicated that bicarbonate of soda was not included as a routine, but this depended upon the fibre length of straw in the pellet and the fineness of the milling of the cereal grains. This manufacturer's pellets were made for short-term finishing, often in less than 3 weeks. Magnesium oxide (causmag) and potassium chloride were often included at 0.3-0.5 per cent DM because straw was relatively deficient in magnesium and potassium when compared to hays. DCP was included at the same rate where particular feedstuffs in the pellet were recognised as being low in phosphorus (unlike cereal grains). Depending upon client requirements, gypsum (calcium sulphate) and limestone were added. In addition, sodium chloride was provided proportional to the content already present (i.e. the water salinity) on the feedlot property. The vitamin-mineral premix used by this manufacturer included vitamins A, D, E, and B_1 (with more vitamin E used nowadays compared to a decade ago), and the trace minerals copper (to a final level of 5 mg/kg DM), iron, manganese, zinc, iodine, cobalt, and selenium. Chromium has also been a recent inclusion into the mineral premix (information provided commercial in-confidence).

Protective minerals

Calcium

The main role of calcium (and phosphorus) in the sheep's body is building bone density and strength, and skeletal bone can act as a reservoir during short-term deficiencies of calcium intake. Calcium also has a role in muscle activation. Calcium requirements for growing lambs have been factorially estimated in the range of 2.4-7.0 g/kg DM depending upon body weight, rate of gain, and feed quality (Underwood and Suttle 1999). However, there is no clear definition of calcium requirements for adult sheep mainly because of the lack of agreement over a realistic absorption coefficient for calcium. AFRC (1991) recommend an average absorbability of 68 per cent for all feeds.

Most feedlot rations are based upon cereal grains that are low in calcium. For instance, whole grain barley contains a mean calcium concentration of 0.7 g/kg DM with a range of 0.22-1.46 g/kg DM (AFIC-CSIRO 1987). Whole grain oats contain a mean calcium concentration of 1.17 g/kg DM with a range of 0.44-2.0 g/kg DM (AFIC-CSIRO 1987). Wheat straw contains 1.7 g/kg DM and lupins 2.2 g/kg DM. A typical feedlot ration formulated to 14 per cent crude protein and comprising the following ingredients: 50 per cent straw, 18 per cent barley and 32 per cent lupins would contain approximately 1.68 g Ca/kg DM. As a rule of thumb, Underwood and Suttle (1999) suggest that performance of sheep should not be affected on any diet providing an average of 3 g Ca/kg DM throughout the year. This ration would have a Ca:P ratio of 0.55:1.0 mainly because cereal grains have a poor Ca:P ratio, often of the order of 1:4. Ruminants do not tolerate Ca:P ratios below 1.0:1.0 even though they can tolerate relatively high ratios of 3.0:1.0 even to 7.0:1.0. Therefore calcium is incorporated into feedlot rations in the form of limestone, lime or dicalcium phosphate to produce a Ca:P ratio in the ration in the range 1:1-2:1 (Underwood and Suttle 1999). For short-term feeding, as in finishing lambs, the addition of calcium salts may not be necessary (notwithstanding the risk of urolithiasis), as the homeostatic mechanisms within the body can adjust to a wide range in the Ca:P ratio (see section on phosphorus), and mobilise the large reserves present in bone. Sheep on a cereal grain-based diet for any length of time (for instance, drought feeding) should have a balanced Ca:P ratio to prevent loss of calcium from bone which leads to anorexia, pathologic fractures and predisposes to outbreaks of hypocalcaemia. An inclusion rate of 1.5 per cent limestone (i.e. 0.5% Ca) is commonly recommended in cereal-based diets (Ashby and Morbey 1997).

A poor Ca:P ratio in the diet can also predispose to struvite urinary calculi (magnesium ammonium phosphate) resulting in the condition recognised as 'Water belly' and death of the affected sheep, usually rams or wethers. Urinary calculi have been reported after periods of as little as 3 weeks on a cereal-based diet, although the deaths did not occur until 3 weeks after returning to normal paddock feed (E.G. Taylor 2003, pers. comm.).

Phosphorus

Phosphorus has a role, along with calcium, to maintain bone density and strength, and the bones act as a reservoir during short periods of reduced phosphorus intake. Cereal-based diets usually have an excess of phosphorus, as phosphorus (in the form of superphosphate) is added to soils when growing cereals, thus phosphorus deficiency should never arise when significant amounts of cereal concentrates are fed to sheep (Underwood and Suttle 1999). Dietary requirements for phosphorus are estimated factorially to be in the range of 2.0-2.8 g/kg DM.

Sheep can perform optimally when the Ca:P ratio is within the range of 1:1 to 7:1, due the bone reserves and homeostatic mechanisms. A Ca:P ratio less than this range (< 1:1) results in a severe reduction in performance, as does a ratio greater than this range (> 7:1) but not as severely. These wide ratios are best tolerated when the diet contains at least 2.6 g P/kg DM such as in the ration described above in the calcium section. Severe bone disorders develop when the ration contains only 0.8 g P/kg DM. Excess dietary phosphorus (> 4.6 g/kg DM) can predispose to struvite urinary calculi, but adjustment of the Ca:P ratio can ameliorate this risk (Rogers 2001). Phosphorus present as phytic acid or phytates does not influence the availability of P or other minerals such as calcium or zinc in ruminants because the phytates are degraded in the rumen.

Sodium

Sodium has a major role in maintaining the water balance of the body, in particular in homeostasis of intra- and extra-cellular osmolarity. Regulation of sodium and water homeostasis in the body is performed in the kidneys by altering the concentration of sodium within urine. Cereal grains are low in sodium, and feedlot rations often have salt (sodium chloride) added at the rate of 1.0 per cent. The ARC (1980) estimates that the sodium requirement for growing lambs is 0.6-0.7 g/kg DM, with the lower level applicable to higher growth rates.

The palatability of cereal grain rations can be improved by the addition of salt (Grovum and Chapman 1988). After several weeks on a low salt diet, rapidly growing lambs will develop inappetence and growth retardation (Underwood and Suttle 1999). The addition of salt may not be necessary in short-term finishing systems.

Sodium can also be added to rations in the form of buffers such as sodium bicarbonate (initially 1%, then reducing to 0.5%) or sodium bentonite (initially 2% reducing to 1%). The mechanism of action of these mineral buffers is the subject of much debate, as on a quantitative basis they are included in rations at a rate that would be insufficient to neutralise the lactic acid produced by fermentation of grain (Rowe 2003). It has been proposed that the buffering effect of these sodium salts is by their osmotic action, drawing water into the rumen and increasing rumen outflow rate. This results in an increase in rumen pH (Hutjens 1991). Sodium chloride could work in a similar manner.

Prevention of lactic acidosis due to the rapid fermentation of starch in cereal grains is a major aim of dietary management in feedlots, as this is the most common cause of reduced performance or death in sheep feedlots.

Use of salt will also aid in the prevention of urinary calculi of all compositions by promoting the excretion of dilute urine. In addition to struvite calculi, the other common calculi seen in sheep in feedlots are composed of silicates, a component of the husk of grains (especially oats) and the stems of rangeland grasses (including cereal hays).

When determining the inclusion rate of sodium (and calcium) in rations it is important to consider the content of these minerals in the water supply used within the feedlot, because saline or hard water contains these minerals.

Potassium

Generally diets for sheep are not potassium deficient, although cereal grains are in the range of 3-5 g/kg DM, and alkali-treated straws will have potassium levels lowered by 25 per cent. If non-protein nitrogen sources and leached straws are used in a cereal-based diet, a potential exists for potassium deficiency. Deficiency results in reduced appetite leading to reduced performance.

Dietary requirement for potassium for growing lambs have been estimated at 3-5 g/kg DM, although some reports suggest peak growth occurs at higher levels (up to 7 g/kg DM) (Underwood and Suttle 1999).

Major trace minerals - selenium, copper and cobalt

A deficiency of any of the trace minerals Se, Cu and Co may produce an illthrift syndrome in growing sheep, with a poor growth rate recognised as one sign of deficiency. Deficiencies of each of these minerals have been recognised in lambs and sheep grazing on pastures growing on leached, acidic soils such as in the south-west of Western Australia, Kangaroo Island, and Strathbogie Ranges (Victoria) and are frequently associated with lush springs (i.e. warm and wet with rapid pasture growth). Cereal grains, particularly oats and barley, and lupins can be extremely low in selenium (< 0.02 mg Se/kg DM) (Moir and Masters 1979). Selenium concentrations of pastures and hays are reduced by regular applications of superphosphate and inclusion of a significant proportion of legumes into the sward. A minimum selenium requirement of 0.05 mg/kg DM has been estimated factorially for lambs fed on a highly digestible diet (Grace 1994).

Most farmers now prophylactically treat sheep in selenium-deficient areas either in the short-term by inclusion of selenium in a drench or vaccination at marking, or the long-term by the use of intraruminal pellets or selenium fertilisers. Therefore, unless the sheep entering the feedlot are already suffering depletion of selenium reserves, a short period of feeding is unlikely to result in illthrift. Thus one potential deficiency scenario could be when lambs enter a feedlot after an excellent spring having only received a short-term selenium treatment or no treatment at all. Long-term feeding of deficient rations can deplete body reserves of selenium, so mineral supplementation of sheep in long-term feedlots would be necessary.

Diets based on dry feeds should not be supplemented with copper (Underwood and Suttle 1999). Dry feeds have more available copper than green pastures, so long-term supplementation could result in liver stores of copper approaching critical toxic levels. The estimated dietary requirement for copper is 4-6 mg Cu/kg DM, but this requirement is influenced by available sulphur, molybdenum and iron. Thiomolybdates (reduced complexes of sulphur and molybdenum) and high iron concentrations dramatically decrease the absorption of copper in functional ruminants. Nevertheless care should be taken to sustain the copper level at around 5 mg/kg DM to maintain crimp in wool. Complete diets containing over 15 mg Cu/kg DM can cause toxicity in sheep particularly in breeds such as the Texel and their crosses which are particularly susceptible to copper toxicity. Consumption of plants such as *Heliotropium europaeum* containing hepatotoxic alkaloids predisposes sheep to copper poisoning.

Cereal grains are poor sources of cobalt (Kennedy *et al.* 1992) with levels of 0.01-0.06 mg/kg DM that at best only approach the marginal requirements for growth defined at 0.05-0.08 mg/kg DM (Underwood and Suttle 1999). A single injection of 1 mg of hydroxycobalamin protected lambs for 14 weeks (Hannan *et al.* 1980) and therefore a treatment like this given to lambs prior to feedlot entry for short-term finishing may be all that is required. Diets should not contain greater than 30 mg Co/kg DM in order to avoid cobalt toxicity (ARC 1980).

Care should be taken when supplementing Se, Cu and Co into the diets of sheep. Over-supplementation with parenterally administered treatments would be especially dangerous since selenium toxicity can occur acutely in over-supplemented animals, and copper can also cause an acute toxicity syndrome resulting from an underlying chronic accumulation of copper in the liver (Radostits *et al.* 1994).

Minor trace minerals - manganese, zinc, iron and iodine

Manganese, zinc, iron and iodine may be included in mineral premixes used in Western Australian sheep feedlots. The reason for this is often based upon historical precedent. Both iron and zinc have biological half-lives of about 120 days in sheep, so should not become deficient in short-term finishing systems.

Dietary iodine should be within the range of 0.1-0.3 mg/kg DM for sheep. The main signs of a marginal deficiency are reduced growth rate and with a more severe deficiency, goitre (enlarged thyroid glands). Dietary goitrogens (such as those found in *Brassica* species of plants) and the minerals selenium and iron can increase requirements for iodine (Underwood and Suttle 1999).

Dietary requirements for iron in growing lambs are in the range of 25-40 mg/kg DM. Iron is abundantly available in most forages and grains. Cereal grains typically contain 30-60 mg/kg DM and oilseeds more, and although some grasses on sandy soils contain 'low' iron levels (30 mg/kg DM), southern Australian pastures are reported to have from 70-2300 mg/kg DM (Underwood and Suttle 1999). Iron deficiency results in anaemia, however it is extremely unlikely that deficiency of iron would occur in sheep in an outdoor feedlot.

Manganese requirements have been well defined for growing sheep and 13 mg Mn/kg DM is adequate for growth and wool production and 16 mg/kg DM for testicular growth (Masters *et al.* 1988). Deficiency results in skeletal abnormalities. Cereal grains contain from 8-43 mg/kg DM depending upon grain, but bran and pollard contain higher levels. Diets with manganese in the range of 8-20 mg/kg DM may show a response to supplementation.

Western Australian soils are recognised as zinc deficient, and crop growth rates can be improved with zinc fertilisers. Zinc requirements have been estimated at 8.8-27.0 mg/kg DM depending upon liveweight and growth rate. Autumn and winter pastures in Western Australia typically can contain less than 20 mg Zn/kg DM, and zinc supplementation can have a positive effect on lamb birth rates and weaning weights if administered to ewes in early pregnancy (Masters and Fels 1980). However, this effect is not universal. Masters and Fels (1980) reported that they were unable to repeat the result in the year following the original experiments. Cereal grains typically contain around 40 mg/kg DM depending upon soil zinc status. Cereal straws typically contain around one third of this, often less than 12 mg/kg DM. Zinc deficiency causes a severe and characteristic depression of appetite, which leads to reduced performance.

Possible carcase composition modifiers

Magnesium

The magnesium requirement of sheep varies from 0.7-1.8 g/kg DM (Underwood and Suttle 1999) depending on factors such as the amount of potassium in the diet, the ruminal pH and the presence of ammonium chloride. Magnesium is unusual amongst the minerals in that it is absorbed predominantly across the rumen wall against an electrochemical gradient. Potassium can increase the potential difference and consequently decrease the absorption of magnesium. Increases in ruminal ammonia also decrease magnesium absorption. Acid conditions in the rumen (such as pH 5.5) increase the absorption of magnesium. The extreme variability of magnesium absorption makes it difficult to define magnesium requirements for sheep. Moreover, magnesium is passively mobilised from bone under the influence of calcitrophic hormones such as parathyroid hormone and 1,25 dihydroxycholecalciferol (the active form of vitamin D) during periods of low blood calcium. Excess magnesium will be filtered and excreted from the kidney possibly predisposing to struvite urinary calculi. It is recommended to keep dietary magnesium below 0.23 per cent to prevent this (Rogers 2001).

Magnesium fed at 1.0 per cent DM as the oxide causmag (MgO which is 60% Mg) for 4 days prior to slaughter reduced the loss of muscle glycogen during lairage, and consequently reduced the incidence of dark, firm, dry meat (Gardner *et al.* 2001). This amount of magnesium is more than 3 times the highest requirement specification for magnesium and near the NRC (1985) tolerable limit for magnesium (5 g Mg/kg DM). Mild toxicity was observed at 14 g Mg/kg DM in sheep (Chester-Jones *et al.* 1989). However, the inclusion of 6 g/kg DM was for 4 days in the study by Gardner *et al.* (2001). Moreover, the degree of protection against incidence of dark cutting afforded by supplementing with magnesium was far less than the degree of protection afforded by the provision of a high carbohydrate diet prior to slaughter. Thus the use of magnesium to improve meat-eating quality will be one small part of a suite of management strategies to optimise carcase quality. Further study needs to be done to determine more precisely the optimum timing and rate of supplementation of magnesium to utilise this effect. Nevertheless care should be taken when supplementing with these pharmacological rates of magnesium especially since the feedlot rations are certainly likely to decrease ruminal pH and possibly increase ruminal ammonia.

Chromium

The dietary requirements of sheep for chromium have not been defined but appear to be increased by stress. Transportation, infection and strenuous exercise all increase urinary losses of chromium and can therefore increase requirements (Anderson 1987). Organic sources of chromium in the diet are absorbed 20 to 30 times more efficiently than inorganic sources (Starich and Blincoe 1983). Organic chromium in brewer's yeast has been termed 'glucose tolerance factor' because it can enhance the sensitivity of cells to insulin and similar forms have been reported in wheat. Gardner *et al.* (1998) fed two-year old Merino wethers rations based on barley and lupins at 2.2 times maintenance. The ration was supplemented with 1 mg/kg DM of chromium given as the organic form, chromium chelavite (an amino acid chelate). The sheep were also exercised regularly for 2 hours, 3 times per week to 60 per cent of VO_2 max. Chromium increased the sensitivity of cells to insulin through increases in activity of the enzyme, ATP citrate lyase, a key enzyme in fat synthesis from glucose. Instead of increasing fat synthesis as a result of stimulating this enzyme, the chromium led to a 20 per cent decrease in fat depth over the 12th rib (Gardner *et al.* 1998). The chromium treatment did not affect growth rate, carcase weight or muscle glycogen concentration (Gardner *et al.* 1998). If the sheep meat industry deems the issue to be important, it would be necessary to carry out further experiments to determine the optimum use of chromium to reduce fat deposition over the ribs of sheep.

Conclusions

In relation to mineral supplementation, there appears to be a divergence between what the scientific literature recommends and what is practiced in sheep feedlots. Commercial use of minerals is based upon 'what the customer wants' or commercial expectation, historical precedent, and as yet unproven scientific work. These variations may not have a significant effect on sheep performance in short-term finishing systems, but could prove significant if sheep are left on grain for periods beyond 3 to 4 weeks.

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