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MINERAL IMBALANCES OF RUMINANTS IN SOUTHERN AFRICA

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Historical

The significance of minerals in livestock nutrition was recorded in South Africa in 1912 (Theiler, 1912) with simultaneous reference to a commission's observations made in 1805 describing "lamziekte" in cattle, as affecting principally the loins and the hindquarters, noting also measurable increases in incidence during drought periods. It was also observed that animals were affected as far north as Bechuanaland, and east to the Eastern Cape. A close correlation was recognized between "stijfziekte", "lamziekte" and the chewing of bones by all classes of stock, but in particular growing animals, cows in calf and lactating. Hutcheon is quoted by Theiler in the above publication as having conducted an experiment in which cattle fed bone meal did not contract either disease. A correlation was also noted between disease incidence and low phosphate content of soils.

Attention was given to calcium by 1931 (Du Toit, Malan & Groenewald, 1931) as a possible limiting factor in sheep nutrition but no response to calcium supplementation was noted on hay diets. First reference to the possible significance of trace elements in nutrition is noted in 1932 as quoted in 1935 experimental series on the iodine requirements of sheep. In this case no beneficial response could be found as a result of iodine supplementation, although a simultaneous suspected vitamin A deficiency was noted during the experimental period. (Malan, Du Toit & Groenewald, 1935).

Plant Survey

A far reaching analytical plant survey was commenced in 1930 (Du Toit, Louw & Malan, 1940), to define the areas deficient in phosphorus in South Africa and calcium, magnesium, potassium, sodium and chlorine, crude protein, crude fibre and soluble ash were analysed simultaneously. Close on 5 000 samples were drawn by 240 stock inspectors during the period November 1933 to October 1935.

Soil samples were taken initially but later eliminated and attention was focussed on the plant sample, taking "representative" forage to match the grazing patterns of animals in each season. The main observations and conclusions of the report are enumerated as follows.

1. There was an obvious difference between grass and bush pastures, especially when considering the low phosphorus content of grasses. Bush on the other hand contained high calcium levels which frequently exceeded 1 % on a dry basis. Grasses of similar origin on calciferous soils had concentrations of approximately 0,3 % . In the same Karoo regions the magnesium content was noted to be frequently above 0,2 % , which concentration is considered desirable in the prevention of hypomagnesaemia for productive animals (Underwood, 1966). The survey also revealed levels well below the minimum concentration of 0,1 % considered necessary for normal requirements. Such low concentrations were noted over extensive areas of Natal (Zululand, Lions River), Transkei (Umtata), Eastern Cape (Bedford), Southern Orange Free State and also Standerton. However, the true significance of magnesium inadequacy was recognized in 1967 when the mineralization of soft tissues was recognized as an induced calcium deposition in the tunica media of blood vessels, precipitated by magnesium inadequacy.

2. The seasonal fluctuation in mineral content was studied in grasses with concentrations of 0,12 to 0,17 % phosphorus being measured in summer which dropped to 0,05 % to 0,07 % in winter. Karoo bush, however, retained an even concentration which was considerably higher than that of grass, particularly in winter.

3. The protein content of grasses showed a cyclic drop in concentration parallel to phosphorus from a range of 7 - 9 % in summer to 3,3 - 4 % in winter, whereas the Karoo bushes of the same area retained protein concentrations of 7 - 10 % throughout the year.

   A key comment, made by the authors in their conclusion, is that "it is clear that the extreme deficiency of protein in our grass pastures during winter is a problem of equal, if not greater importance than that of phosphorus deficiency". This relationship has at times been overlooked, as well as the limiting effect of inadequate digestible nutrient supply due to the sparse plant population. The result is that attempts to measure responses to one of these nutrient requirements have been masked by other limitations.

4. No indication of the relative plant population in the 18 regions is given, which obviously affects deductions when comparing semi-arid regions with those in high rainfall mist belts.

Trace mineral investigations on plant materials have been conducted since 1938 (van der Merwe & Perold, 1967), in the winter rainfall area of the Cape Province and adjoining regions, with special attention having been given to cobalt and copper as the minerals which were considered to have been inadequate. In particular the Humansdorp area was considered deficient in cobalt.

Climical Investigations

Animal studies on copper requirements (Schulz, van der Merwe, van Rensburg & Swart, 1951) in the Southern and Western Cape Coast regions were conducted in detail. These areas produced lambs with typical sway-back symptoms. The necropsy findings were destruction of the myelin in the nervous system, and in extreme cases, symmetrical areas of softening or cavity formation in both the cerebral hemispheres. Liver copper levels in both ewes and lambs were low with corresponding high iron concentrations. Copper administration to pregnant ewes prevented the symptoms and mildly affected lambs recovered with copper administration. However, the lambs with advanced signs of central nervous system damage did not respond, to copper supplementation.

Experiments with potassium iodide as a supplement were not encouraging (Malan, *et al.* 1935). However, later investigations indicated that iodine deficient areas did exist in the foothills of the Natal Drakensberg mountains with clinical cases most prominent in young pigs. This belt is considered to be truly iodine deficient whereas the goitre areas of South West Africa are thought to have goitrogens in the natural pasture which precipitate the pathological changes. Other goitrogenic areas are also recognized such as the Hoeree and Kleinrivier valleys (Blom, 1934), these studies emphasizing the effects of goitrogens on the local human population which practised peculiar eating habits.

Fluorine excess has been associated with deep boreholes containing high concentrations of the mineral in the Western Karoo region, as well as in the Northern Transvaal where cattle have developed mottled teeth and excessive wear even at 2 to 3 years of age and an overall poor appearance even in the presence of abundant good grazing. A further complication of the Western Karoo region is excessive evaporation from storage reservoirs and boreholes yielding low volume high mineral content waters exceeding at times 10 000 parts per million. Such high mineral concentrations are primarily calcium and magnesium carbonates, chlorides and sulphates and though tolerated by some mature stock are detrimental for breeding animals and their offspring.

Excesses of copper and selenium in pastures and sheep livers (Brown, 1969) have been located in the Beaufort West area with symptoms of hair fragility in horses. These excess minerals can be counteracted with the use of sulphur containing licks, which increase their excretion rates (Boyazoglu, Barrett & du Toit, 1972; Boyazoglu, Jordan & Meade (1967). It was, however, observed that farmers also use licks containing up to 5% flowers of sulphur in other areas, without the necessary compensatory addition of the related minerals to counteract expected induced deficiencies of copper and selenium. Induced deficiencies have also been recorded in areas under irrigation such as at Vaalhartz where previously such deficiencies were not recognized. This is attributed to an initially marginally adequate mineral concentration which has become sub-optimum by intensified fertilization and increased yields.

The deviations in mineral balances recorded thus-far have been recognized by pathognomonic symptoms such as sway back, depigmentation (copper); degenerative myopathy, hair fragility (selenium); anaemia (copper, cobalt); goitre (iodine); mottling of teeth (fluorine); pica, botulism (phosphorus). However, such incriminating evidence is not always recognized and frequently long term projects have been conducted to evaluate the effect of mineral deviations both qualitatively and quantitatively.

In South Africa, research work spanning 30 years culminated in the publication of Bisschop (1964) which evaluated the responses by different breeds of cattle of varying ages, production and reproduction potential, using different sources of phosphorus and methods of administration. Even though phosphorus was found to be at its lowest levels in the winter months, the greatest responses to supplementation were found to be in summer, when other nutrients increase at a more rapid rate in plant material than phosphorus. The report concluded that 2 ounces (approximately 60g) of bonemeal per head per day was the satisfactory level of supplementation for non-breeding cattle after weaning while half this quantity could give parallel results in above average seasons. On the other hand, breeding stock required between 3 and 5 ounces of bone meal (8,5 - 14,2 phosphorus) per head per day.

In Rhodesia a series of observations and measurements were conducted by Ward (1968) at the Makoholi experiment station near Fort Victoria over a 6 year period. This work with Mashona cattle supported several of Bisschop's findings and also brought further facts to light. The supplementation of 2 ounces (60g) of bone meal daily yielded an average of over 200 lb (91 kg) extra of weaned calf production per cow over 6 years. The calves grew faster from birth primarily in the summer months, with increased weaning weights of 20%. Furthermore, there was improved fertility and calf viability with a cumulative effect of the 2 factors of over 13% in favour of the bonemeal treatment. Protein supplementation as groundnut cake meal during winter months also had an additive beneficial effect on the bone meal groups. Where bone meal supplementation continued during feedlot feeding there was a further financial gain of 12% at slaughter.

The majority of mineral imbalances are in a category which, though affecting productivity, do not permit clinical diagnosis, as there are no specific symptoms involved and only long term biological experiments have been able to show the effects of corrective supplementation and economic benefits as demonstrated in the Armoedsvlakte and Makoholi research. The research on phosphorus deficiency in particular, required evaluations of production (growth) and reproduction, which were measurable provided other limiting nutrients were not accentuated. In particular, chronic progressive changes are difficult to evaluate. It is, therefore, not surprising that the abnormalities associated with magnesium deficiency (Boyazoglu, 1972 unpublished results) were misinterpreted as inevitable ageing effects, where age of individual animals was not recorded accurately in commercial flocks.

The trace minerals present a more complex picture where marginal imbalances and interactions reduce productivity with non-specific symptoms. Furthermore, it has been recognized that internal parasites, as in the case of strongyles which result in a decrease in the copper content of the liver can mask the true mineral balance.

The challenge to evaluate topical imbalances of a broad spectrum of minerals is certainly formidable when the number of biologically important minerals with their interactions are taken into account. Furthermore the proposed method must be practical and applicable in individual farm investigations so that there will not be dependence on, or limitation to, regional experimental stations.

Chemical Diagnosis

The problem encountered with soil samples (du Toit, Louw & Malan, 1940) as well as selective grazing patterns, point to the animal itself as a more suitable method of sampling the diet of the grazing animal. This automatically eliminates the variables associated with the soil and plant material sampled by conventional methods. It is simple to sample blood and this has been used extensively as a guide to phosphorus levels in diets. This is possible where large numbers of animals are available so as to be able to pool data. Where, however, the trace minerals are to be evaluated, it was found that concentrations in the blood are below one part per million (cobalt, copper and zinc) and meaningful deductions are particularly difficult. Hair samples have also received attention as they represent a more stable biological sample than blood and have higher concentrations for several minerals (zinc 100 ppm). It has been observed (Myburgh, 1969) however, that mineral concentrations in hair differ in their concentrations on a single animal when sampled in different localities on the body.

The liver has received special attention as a biological sample source as this organ is the body's metabolic centre, and most minerals are integral portions of metallo-enzymes which serve as catalysts for metabolic processes. The donor should be free of disease and must have grazed in a specific area for 6 months. Animals younger than 6 months of age and foetuses are considered unsuitable for this purpose. Whereas the biopsy technique has been used in special cases, it is not practical for general use due to the small size of sample, inaccuracy of sampling site on the liver, and the necessary surgical knowledge and post operative care for each animal, Animals freshly slaughtered for domestic consumption, or at abbattoirs, are considered most suitable. A 30 to 60 g liver sample is taken from the edge of the organ and placed in 10% formalin. Whereas single samples are at times accepted for analysis, the minimum number of samples preferred from one locality for diagnostic purposes and corrective supplementation is 3. Advantages of such a formalinized liver sample include the possible direct interpretation to a fresh organ ($P<0{,}05$) and a repeatability with a high degree of accuracy for the first 8 weeks of storage ($P<0{,}01$) (Ehret, 1971.) Whereas differences occur between samples taken from the proximity of large vessels and peripheral parenchyme of the liver, there is a high degree of repeatability between a series of peripheral parenchyme samples taken from one liver ($P<0{,}01$).

The analytical procedure in this laboratory to date made use of a Beckman 979 atomic absorption spectrophotometer with a turbulent flow burned and wet ashing of the sample (Boyazoglu, Barrett, Young & Ebedes, 1972). The process is rapid, permitting a broad spectrum of mineral analysis. There are however limitations in the system as the atomic absorption principle cannot be applied in the analysis of the halogens (chlorine, bromine, iodine). It is also not possible to conduct analyses for sulphur and phosphorus with this apparatus. Limitations of the specific model in use are also evident. Whereas the first 5 years a turbulent flow burner was in use, recently an improved laminar flow burner has been incorporated which appears to have improved accuracy, and reduced the enhanced readings primarily due to light scatter, present in the use of the previous burner. The recent development of the Massmann furnace is of further benefit in improving accuracy and broadening the spectrum of analyses.

Survey

The combination of an atomic absorption unit and a Technicon Auto Analyser has been utilized in a project with the object of mapping mineral deviations of animals in South Africa and adjoining territories with the aid of the liver sampling technique. Emphasis has been placed on cattle and sheep, however pigs, horses, poultry and 16 game species have also been investigated.

The samples were primarily taken from herds or flocks considered as suffering from potential imbalances and were classified according to seven regions (Transvaal, Orange Free State, Natal, Cape Inland, Cape Coast, South West Africa and Swaziland). The wild game samples emanate from the Kruger National Park and the Etosha National Park from culling operations.

In this survey the 6 minerals which received primary attention were copper, manganese, zinc, cobalt, iron and magnesium. In the later stages of the survey phosphorus was incorporated and in isolated cases selenium analyses were conducted by a different method (Allaway & Cary, 1964).

In evaluating the survey several important observations were recorded.

1. There exist marked differences between species with respect to "normal" liver mineral concentrations.
2. The concentrations of individual minerals in a specific liver differ markedly in the expected concentrations (e.g. copper and manganese).
3. The liver mineral concentrations show strong correlations between animals of a species grazing a locality. There were however marked differences between localities within a region.
4. There appeared to be groupings of game species which suggested that feeding patterns may influence mineral concentrations.
5. The "home range" of a species of game affects the accuracy with which it can be used to interpret a locality's mineral status.

Although the study is not complete, over 4000 samples have been analyses thus far which permits some specific conclusions.

Sheep have copper concentrations substantially higher than cattle (69 ppm as compared to 43 ppm) but levels of the remaining minerals are of the same order in the 2 species. Specifically, copper has also been found to be the mineral with the highest frequency of deviations from normality with the Cape coast (cattle, sheep), Natal (sheep) and Orange Free State (sheep) having a higher incidence of this deficiency than other regions. Manganese was found to be lower in cattle samples emanating from the Cape coast (cattle), Natal (cattle, sheep) and Swaziland (cattle). Zinc was inadequate in the Cape coast (sheep), Natal (sheep) and Swaziland (cattle). Magnesium was deficient in Natal (cattle) whereas cobalt was lower in the Orange Free State (sheep) and Natal (sheep).

These regional trends should be treated with caution as substantial standard deviations (Boyazoglu, et al. 1972) were encountered between areas within regions. It is evident that samples must be analysed within a locality prior to the introduction of a corrective lick supplement if a true correction of an imbalance is to be achieved.

The wild game samples can be classified according to the feeding patterns of animals as follows:

Feeding Pattern	Species Example
Grazers	Wildebees, Zebra
Browzers	Kudu, Giraffe
Grazers and Browzers	Elephant, Implala
Carnivores	Lion, Leopard
Omnivores	Baboons

The deductions made here are based on teleological reasoning and are at best speculative, due to the lack of control of movements (elephant) and other multiple influences. It was noted that wildebees had mineral concentrations comparable to cattle whereas all other species had copper levels substantially lower than domestic ruminants (rhinoceros 6,6 ppm). The manganese content was similar between game and domestic species with the exception of low concentrations in the rhinoceros (3,4 as compared to 7 to 8 ppm). The lion samples were exceptionally high in zinc (293 ppm).

The comparison between the Etosha and Kruger National Parks was made on 5 game species sampled at both localities and it appeared as if the trend, with exceptions, was to have higher mineral concentrations in the Kruger National Park. It is possible, however, that internal and external parasites may influence the mineral status of game to a greater degree than in the case of domestic animals.

Conclusions

The role of minerals in animal production has long been recognized, but increasing attention is being directed to requirements and repercussions of imbalances. Mineral adjustments, when accurately formulated, can, at nominal costs bring about substantial benefits.

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