Risks and benefits in agricultural uses of selenium

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Abstract

Selenium deficiency in soils, and subsequently in crops that are grown on them, has been charted in various parts of the world. Use of carefully regulated amounts of supplemental selenium in such areas has been effective in improving productive performance of domestic food-producing animals, and some 30 years' experience has now been gained with various supplementation practices. Coincidentally, there have been instances reported of situations where selenium toxicity has resulted from a combination of naturally-high environmental levels, enhanced by agricultural, environmental and industrial practices, and questions have been raised as to whether continued animal supplementation may contribute to selenium toxicity. This paper examines some of the various factors involved and concludes that presently-established animal supplementation uses of selenium are small compared with other sources of the element and that they do not constitute a hazard to animals, including humans, or the environment.

Introduction

The history of the use of selenium by humanity has been filled with contradictions and controversies. In its biological applications, these have taken the form of initial fear of its toxic qualities, later alleviated by appreciation of its function as an essential nutrient. Then, as these latter uses developed, there has come apprehension about the effects of its continued, long-time application on the integrity of the environment. This paper examines some of the issues involved.

Selenium in Animal Agriculture

Although the first agricultural interest in selenium took the form of concerns about its toxicity in excess, an active interest in benefits from its use developed with demonstrations, worldwide, that it would protect against certain afflictions of livestock that have become known as 'selenium-responsive diseases'. These included liver degeneration in pigs (Eggert et al., 1957), exudative diathesis (Patterson et al., 1957) and pancreatic degeneration (Thompson and Scott, 1970) in poultry and white muscle disease in young ruminant animals (Muth et al., 1958). Predictably, alleviation of such problems improved overall metabolism of the animals concerned, with consequent improvement of the economically-significant processes of growth and reproduction (Robertson and During, 1961; Hartley, 1959). This has naturally led to widespread adoption of selenium supplementation by means of various techniques, in the commercial production of meat, milk, eggs and wool, and these selenium technologies have been applied worldwide now, for about 30 years. Agricultural uses of selenium are compared with other applications in Figure 1.

Among the numerous techniques that have been developed for the relief of selenium deficiency in animals are direct supplementation of livestock, both orally and parenterally, and indirect application as a soil amendment, to enhance selenium levels in crops to be used as livestock feed. Oral administration includes provision of measured doses (usually as sodium selenite) in water solution (drenches), mixture with dry feed or salt-mineral mixes, or the use of ingenious 'heavy pellets' containing selenium and iron filings, which when given to ruminant animals remain in the forestomach and gradually release small amounts of selenium over extended periods of time. This latter method has recently been modified through involvement of an osmotic pump which actively disperses the selenium at constant rates (Campbell et al., 1990). Parenteral use is usually by intramuscular injection, frequently in a preparation which also contains vitamin E. Indirect applications include mixture of appropriate quantities of selenium salts with established fertilisers, such as superphosphates, or use in specially-formulated prills.

Fertiliser application of selenium gives different results in different soils, and in association with certain other mineral elements. Swedish investigators showed that additions of clay or peat to sandy soil tended to decrease the selenium uptake by plants. At a soil pH of 7, increasing the clay content in pots from 7–39% decreased the selenium uptake by 79% for wheat plants and 70% for rape (Johnsson, 1991). Finnish experiments showed that while selenate application to soil increased the selenium content of ryegrass from 0.09–1.17 mg kg\(^{-1}\)g, additions of sulphate limited the selenium increase considerably; addition of
phosphate had little effect, one way or the other, while liming tended to increase selenium uptake by plants when the form applied was selenite (Ylaranta, 1990). In trials on the South Island of New Zealand, where many of the soils are selenium-deficient, herbage selenium levels varied from 200-2,000 ppb on various soil types, immediately after 6 g Se ha\(^{-1}\) was applied. Sulphate applied simultaneously lowered the Se uptake by forage by 46%, although the reduction was transitory (Metherell, 1985). Interestingly, there are no benefits in terms of increased crop yields from selenium soil-treatment, since with few exceptions, plants do not seem to require selenium.

**Amounts of Selenium Used in Agriculture**

The supplementary levels of selenium used have important implications for both the health and productivity of the animal populations involved and for the accumulation of selenium in the environment and subsequent environmental quality. Dietary use of selenium was first calculated to supply 0.1 mg kg\(^{-1}\) of actual selenium in the diet dry matter, in accordance with early research practices (Muth et al., 1958). Later experiences suggested that optimal selenium status in animals could be better accomplished by providing 0.3 mg kg\(^{-1}\) supplementary selenium in the diet (Meyer et al., 1981; Smith and Conrad, 1987) and this level was approved in 1987 by the US Food and Drug Administration. When selenium is offered in mineral mixes, the concentration is prorated on the basis of the relationship that mineral consumption bears to total dietary intake, in accordance with the allowable level in the complete diet. If the selenium is given in a single drench, or by injection, on the other hand, the amount is calculated in relation to the body weight of the animal treated, and is higher than the daily dosage would be, on a continuing basis. The level generally recommended in New Zealand as a single dose, is 0.1 mg kg\(^{-1}\), which translates to 5 mg actual Se per 50 kg ewe. The amounts of Se approved for various types of animal feed are listed in Table 1.

**Considerable experience with the application of selenium to the soil has been gained in Finland and New Zealand, in recognition of the extent of soil-selenium deficiency in both countries. Government authorisation to use selenium in this way was granted in New Zealand in 1982 and in Finland in 1984 (Gupta and Watkinson, 1985). In both countries, care has been taken to calculate the lowest effective levels of application, to ensure safety to the handlers, the consuming animals and to avoid detrimental effects to the environment. Obviously, such practice also maximises economy of the operation.**

The usual rate of application is 10 g of actual selenium, as selenate, per hectare of land and it is commonly applied as prills mixed with superphosphate or other fertiliser (Huphens van der Elst and Watkinson, 1977). Selcote (Agtech Developments (NZ) Limited, Richmond, New Zealand), a commercial preparation widely used in New Zealand, contains selenate crystals within a pellet, which improves safety during handling. Experience has shown further, that satisfactory protection of animals against ill thrift, infertility and white muscle disease can be accomplished without treatment of an entire pasture or range area. Ewes grazing selenium-treated forage for four weeks were protected for eight months of grazing non-treated forage, in a New Zealand trial where the animal stocking rate was moderate. These practices have proven both safe and effective, with the result that between 500,000 and 600,000 hectares of land were treated in 1987, representing about 10% of the market potential in New Zealand (Voerman, 1988).

**Benefits to Animals From Selenium Use**

The benefits from selenium supplementation of livestock, directly or indirectly through grazing-land treatment, in areas of selenium-deficient soils, have been significant. To