Overview of Selenium Toxicosis

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Selenium is an essential element that has a narrow margin of safety, with the difference between adequate and potentially toxic concentrations in the diet being approximately 10- to 20-fold. Feed supplements, resulting in final selenium content of 0.2–0.3 ppm, are added to diets to prevent deficiency and resultant diseases such as white muscle disease in cattle and sheep, exertional myopathy in horses, hepatosis dietetica in pigs, and exudative diathesis in chickens. The maximum tolerable concentrations for selenium in most livestock feed is considered to be 2–5 ppm, although some believe 4–5 ppm can inhibit growth.

Selenium is an essential component of >25 selenoenzymes and selenoproteins. The most recognized of these are the glutathione peroxidase enzymes that act as antioxidants in the body. In excess, selenium potentially has three general toxic effects: the direct inhibition of cellular oxidation/reduction reactions by depleting glutathione and *S*-adenosylmethionine reserves, the production of free radicals that cause oxidative tissue damage, and the replacement of sulfur/sulfur-containing amino acids in the body with selenium/seleno-amino acids. The inhibition of numerous cellular functions by high concentrations of selenium results in acute generalized cytotoxicity. The replacement of sulfur-containing amino acids with seleno-amino acids leads to altered structure and function of cellular components and enzymes due to loss of the disulfide bonds that commonly occur between sulfur-containing amino acids. Loss of these disulfide bonds can alter the three-dimensional configuration of proteins, potentially resulting in loss of or diminished enzyme activity. The most commonly altered sulfur-containing amino acids are methionine and cysteine, which are replaced with selenomethionine and selenocysteine, respectively. Replacement of these amino acids with selenium-containing amino acids also affects cell division and growth. Especially susceptible are the cells that form keratin (keratinocytes) and the sulfur-containing keratin molecule. Selenium therefore weakens the hooves and hair, which tend to fracture when subjected to mechanical stress.

Etiology:

All animal species are susceptible to selenium toxicosis. However, poisoning is more common in forage-eating animals such as cattle, sheep, horses, and other herbivores that may graze selenium-containing plants. Plants may accumulate selenium when the element is found at high concentrations in the soil, but pH and moisture content of the soil play roles in the relative bioavailability of selenium to plants. Generally, selenium is most bioavailable to plants when they grow on more alkaline soils with low rainfall (<50 cm). The alkalinity and low moisture content of the soil tend to allow more of the selenium to be retained as the oxidized form of selenate, which is the most readily available for plant uptake. Because low moisture in the soil decreases the anaerobic environments to greater

depths, drought conditions could allow for more/deeper selenium in the soil to be oxidized into plant-available forms, resulting in year-to-year variability in available selenium for plant uptake.

Selenium-accumulating plants have been categorized based on their relative requirements and ability to accumulate selenium. Obligate indicator plants require large amounts of selenium for growth and contain high selenium concentrations (often >1,000 to 10,000 ppm). Obligate indicators include species of *Astragalus*, *Stanleya*, *Machaeranthera*, *Oonopsis*, and *Xylorhiza*. Facultative indicator plants absorb and tolerate higher concentrations of soil selenium, with accumulations ranging from trace amounts to a few thousand ppm, but they do not require selenium for growth. Facultative indicators include species of *Aster*, *Castilleja*, *Grindelia*, *Atriplex*, *Gatierreaia*, and *Comandra*. Nonaccumulator plants, such as most grasses, passively absorb much lower amounts of selenium from the soil, resulting in trace amounts to a few hundred ppm.

Numerous organic and inorganic chemical forms of selenium are potentially present in plants. Nonaccumulator plants primarily contain selenomethionine, while indicator plants contain more selenate and methylselenocysteine. In comparison, most supplemental dietary sources are in the form of selenite, but selenomethionine supplements are becoming more commonly used in marketed products.

Poisoning may also occur in swine, poultry, and other species consuming grain raised on seleniferous soils or, more commonly, due to errors in feed formulation. Selenium toxicosis after ingestion of selenium-containing shampoos or selenium supplement tablets is rare in small animal pets but can occur. Several factors are known to alter selenium toxicity; however, in general, a single acute oral dose of selenium in the range of 1–10 mg/kg may be lethal in most animals. Parenteral selenium products are also quite toxic, especially to young animals, and have caused deaths in piglets, calves, lambs, and dogs at dosages as low as 1 mg/kg. Younger animals tend to be more susceptible to selenium poisoning, and the chemical forms can result in some differences in relative toxicity.

Diagnosis:

Severity of clinical signs of selenium toxicosis depends on the quantity and duration of exposure. Poisoning in animals is characterized as acute, subchronic, or chronic. Diagnosis is based on clinical signs, necropsy findings, and laboratory confirmation of the presence of high selenium content in an animal's diet (feed, forage, grains, or water), serum, blood, or tissues (eg, kidney, liver). Selenium in the diet at >5 ppm may produce mild clinical effects after prolonged exposure of ≥30 days. Concentrations of 10–25 ppm would be expected to produce severe clinical signs with prolonged exposure. Environmental exposure potential should be based on forage, feed, or water content, not on soil selenium content, because some chemical forms in soil are not available for uptake by plants and would not result in high exposure potential.

Tissue selenium content is the basis for diagnosing selenium poisoning in animals. Organic chemical forms of selenium have greater bioavailability and are retained in the tissues for much longer periods. Thus, timing of the exposure in relation to the collection of tissue, blood, or serum, as well as the chemical form of the selenium exposure, must be taken into account when interpreting the selenium content. In addition, some species variability in regard to concentrations also occurs. In acute toxicosis, the blood and serum selenium concentrations are generally >3–4 ppm, and in chronic toxicosis, it is generally >1–2 ppm. Liver generally contains >3–5 ppm selenium in acute cases, whereas in chronic cases it should be >1.5 ppm. Kidney of selenium-poisoned animals generally contains >1–5 ppm. Hair and hoof wall may have >1.5–5 ppm selenium in chronic poisoning. A "garlicky" odor on the animal's breath may be noted; this finding is more prominent with acute poisoning but can be seen with chronic poisoning as well. The odor is due to elimination pathways

producing methylated selenium metabolites that are volatile and expired but may last for only 1–2 days after an acute poisoning incident.