Use Selenium Cautiously When Feeding Livestock
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Selenium Supplementation of Livestock and Poultry Feeds

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Selenium (Se) was shown to be an essential dietary nutrient in 1957, approximately 20 years after its toxic effects were recognized. Since then, much research has been devoted to understanding the role of this essential trace element in metabolic processes. Selenium is a component of an essential enzyme that protects cells, especially muscle and red blood cells, from damage by products of oxygen metabolism. The body is aided in this protective effect by vitamin E. The National Research Council (NRC) first estimated the Se requirement for most species to be 0.1 parts per million (ppm); 0.2 ppm for turkeys. One ppm is equivalent to 1 milligram per kilogram, or 1 ounce per 31.25 tons.

Selenium Deficiency

Selenium deficiency signs in a variety of species include muscular dystrophy (degeneration—white muscle disease), increased concentrations of certain blood serum enzymes (glutamic oxalacetic transaminase (SGOT) and lactic dehydrogenase (LDH), decreased pancreatic function, exudative diathesis in chickens, and liver degeneration in most species. Retained placenta, some aspects of infertility in cattle and birds, weakness in newborns, difficulty in suckling and related disorders have been reported to respond favorably to Se supplementation, in which the interrelated role of vitamin E may also be involved.

Certain signs of inadequate Se and vitamin E (alpha-tocopherol) are similar. One function of both nutrients is to maintain proper functioning cell walls between cells in the body, particularly in muscle and blood. Each acts on a different portion of this protective mechanism, so they cannot substitute for each other in farm animals. In most instances, farm animals should receive both supplemental Se and vitamin E for maximum health and productivity. Giving only one of these nutrients will not prevent the similar signs of deficiency of the other nutrient. The vitamin E content of feeds decreases markedly during storage, and cattle fed continuously on stored feeds have very low concentrations of vitamin E in their blood and milk.

Selenium deficiencies occur when crops fed to livestock are grown on soils low in Se or when soil conditions, such as low soil pH, decrease the availability of the soil Se to the plants. In areas such as the Pacific Northwest, some Great Lakes states—Ohio and Michigan—New England states and Florida, which have inherently low soil Se, local grains and forages may not meet animals' Se requirements.

Approved Supplemental Dietary Selenium

By 1970, scientists had petitioned the Food and Drug Administration (FDA) to permit commercial dietary Se supplementation. The first federal legislation allowing Se supplementation for selected species was approved in 1974 after the FDA had thoroughly considered the benefits and risks of the practice to livestock, as well as to the human population. The current FDA-approved rates for commercial Se supplementation of feeds for several species are given in Table 1. Horses were intentionally not included in the FDA legislation because they are not normally used for human consumption in the United States.

Selenium Supplements Available

A variety of supplements with inorganic Se (sodium selenite or selenate) are available. These are

Table 1. Levels of selenium approved by the FDA for addition to animal feeds.

Beef Cattle —May add to complete feed at a level less than or equal to 0.1 parts per million (ppm) or in a feed supplement not to exceed 1 mg Se/head/day. It can be added up to 20 ppm in salt mineral mixture for free choice feeding at a rate not to exceed 1 mg Se/head/day.

Dairy cattle —May add to a complete feed (total ration) at a level not to exceed 0.1 ppm Se.

Sheep—May add in a complete feed at a level not to exceed 0.1 ppm, or it can be added in a feed supplement for limited feeding at a level not to exceed 0.23 mg Se/head/day. Also approved for free choice feeding in salt mineral mix up to 30 ppm at rates not to exceed 0.23 mg Se/head/day.

Swine—May add up to 0.3 ppm Se to swine starter rations and up to 0.1 ppm for total rations for other age groups of swine.

Chickens—May add up to 0.1 ppm in complete poultry feeds, including feeds for laying hens.

Turkeys—May add up to 0.2 ppm in complete turkey feeds.

listed in Table 2. The 200 ppm Se premix (90.7 mg Se/pound) was established because 1 pound of premix added per ton of feed provides 0.1 ppm supplemental Se, the FDA-approved rate for most species. This premix commonly has a ground limestone base, is normally sold in 50-pound bags and is a versatile, inexpensive source of supplemental Se. Bags of Se 200 should be stored where animals cannot accidentally consume this material. The Se-supplemented trace mineral salts, designed primarily for cattle and sheep, are normally not available in the block form and so must be fed as loose salt. The 30 ppm Se trace mineral salt designed for sheep contains no supplemental copper because sheep are more susceptible to copper toxicity than cattle.

Injectable forms of Se and vitamin E continue to be available through veterinarians in four concentrations: .25, 1, 2.5 and 5 mg Se per ml. These are appropriate adjunct sources of Se and Vitamin E. Serum and tissue Se responses to proper amounts of the injectable products are rapid and increase serum Se for three to six weeks. The cost per unit of Se by the injectable route is at least 100 times that of selenium given orally, and there is a low incidence of fatal anaphylactic reactions following Se/vitamin E injections.

The Se naturally present in crops is largely in an organic form in which the Se substitutes for S in amino acids. The natural Se is usually more efficiently retained than inorganic Se. Selenium content of forages and grains varies greatly, and forages and grains grown in Michigan usually contain less than .05 ppm Se, while similar crops from Se-adequate states may contain 0.5 to 1 ppm Se. Plants associated with Se toxicity—sometimes called Se accumulator plants—can contain 100 to 10,000 ppm Se. Consumption of these plants produces acute and chronic forms of Se toxicity among cattle, horses and sheep in defined areas of the Plains and Mountain states. The maximum tolerable level for Se varies somewhat with the species but is generally considered to be 2 ppm or greater.

Table 2. Commercially available sources of selenium (Se).

Selenium 200—contains 90.7 mg Se/lb of premix, or 200 ppm Se. This is the most common source of supplemental Se for mixing into premixes or diets for livestock and poultry. It is manufactured by several companies.
Selenium premixes made by various companies that contain 20 to 40 mg Se/lb plus other vitamins—particularly E—and minerals.
Trace mineral salt containing 20 ppm Se for free choice feeding to most livestock except sheep.
Trace mineral sheep salt containing 30 ppm Se (without copper) for free choice feeding to sheep.
Mineral mixes containing 15 to 25 ppm Se.
Commercial protein supplements or other grain mixes containing about 1 ppm Se, especially for ruminants.
Selenium premixes containing 1.4 percent or more Se.
Molasses mixes, liquid or block, may have Se added.

Assessing the Selenium Status of Livestock

The concentration of Se in blood (serum, plasma or whole) is a good indicator of Se intake for most farm animals but not for poultry. Tissue Se, particularly in the liver, as well as the Se-containing enzyme glutathione peroxidase, can also be measured and are preferred for assessing the status of birds and some other species. Serum Se concentrations considered normal vary somewhat with the age of the animal, other diet nutrients and the species. Some desired serum Se concentrations for several classes are:

Milking cows—.07 micrograms (ug)/ml (ppm).

Dairy calves, beef calves and beef cows—.06 ug/ml.

Suckling foals—.07 ug/ml.

Adult mares—.14 ug/ml.

Weanling pigs—.10 ug/ml.

Adult sows —.12 ug/ml.

Suckling lambs—.08 ug/ml.

Mature ewes—.10 ug/ml.

Serum values in excess of .25 ug/ml for most species, except carnivores, are believed to reflect more than adequate selenium intakes, and values less than half of those above are considered to indicate Se deficiency.

Selenium assays of serum, tissue and feed can be obtained by sending the samples to the MSU Animal Health Diagnostic Laboratory, P.O. Box 30076, Lansing, MI 48909. As of April 1, 1986, the charges for these assays were $7 per serum sample, $10 per liver sample and $15 per feed sample. Blood serum samples from several animals representing different age groups or stages of reproductive cycle should be taken initially to assess the Se status of any animal group.

Appropriate Selenium Intake

The FDA-approved rates for Se supplementation (Table 1) may provide sufficient Se intake in many areas of the United States; however, there is increasing evidence that the approved rates are usually inadequate to maintain normal blood and tissue Se levels in animals raised in selenium-deficient areas such as Ohio and Michigan. This is illustrated in Table 3, which shows that at least 5 mg supplemental Se per cow per day was required to attain a normal serum Se concentration. Because commercial feed manufacturers cannot legally exceed the FDA-

Table 3. Serum Se concentrations before and after giving three amounts of supplemental Se.

Se 200 premix per cow/day lb	Supplemental Se per day mg	Serum Se concentrations (ug/ml) Weeks on supplementation 0	2	4	8
0.000	0.00	0.026	0.023	0.022	0.021
0.027	2.5	0.033	0.056	0.052	0.052
0.054	5.0	0.030	0.071	0.071	0.063
0.110	10.0	0.049	0.068	0.079	0.067

approved limits for Se supplementation, livestock owners have incorporated additional dietary Se on the farm to alleviate selenium-responsive "disease." This can be accomplished by incorporating additional Se 200 (90.7 mg Se/lb, 5.7 mg/oz) into a grain mixture or into the total mixed diet. Each pound of Se 200 added per ton will increase Se concentration by 0.1 ppm Se in that mixture. When rations are high in moisture—such as silage or high moisture corn—the added Se on a per unit dry matter (DM) should be calculated. Feeding adult cows 5 mg supplemental Se per day will increase dietary Se by 0.2 ppm for milking cows and 0.4 ppm for beef cows. These intakes are above the present FDA-suggested allowance but will not increase the Se content of milk. Feeding milking animals 10 mg Se/day should be avoided, however, because that practice may increase milk Se content.

Calculations of Supplemental Selenium Intake

Because several feeds could contain added Se and producers need to keep intake within desirable limits, they need to know how to calculate supplemental Se intake. This calculation requires knowledge of the Se concentration added to the feeds and the amount of each feed fed, plus metric equivalents.

Example Calculations:

1. Animals are fed 10 lb of a grain mixture that had 4 lb of Se 200 added per ton. What quantity of added Se does this 10 lb furnish?
   a) 4 lb of Se 200 contains (4 x 90.7 mg Se/lb) 362.8 mg Se.
   b) 362.8 mg ÷ 2,000 lb = .181 mg Se/lb grain mix.
   c) 10 lb x .181 mg Se/lb = 1.81 mg supplemental Se fed that animal in 10 lb of grain mix.
2. How much Se is consumed daily by an animal eating 3 ounces per day of a trace mineral (TM) salt containing 20 ppm Se?
   a) 3 oz divided by 16 = .187 lb TM salt consumed.
   b) .187 lb x .454 kg/lb = .085 kg TM salt consumed per day.
   c) 20 ppm Se = 20 mg Se/kg TM salt.
   d) 20 mg x .085 kg = 1.7 mg Se consumed/day from TM salt.
3. How much selenium is consumed by a cow fed 5 lb of a 38% protein grain mix containing 1 ppm Se on an as-fed basis?
   a) 5 lb x 0.454 kg/lb = 2.27 kg.
   b) 1 ppm Se = 1 mg Se/kg grain mix.
   c) 1 mg Se/kg x 2.27 kg = 2.27 mg Se in 5 lb of that grain mix.
4. If an animal consumes 46 lb of dry matter per day from a total mix ration (TMR) assayed to contain 0.04 ppm Se on a dry matter basis, how much Se 200 premix must be added to provide a daily intake of 5 mg Se?
   a) 46 lb x 0.454 kg/lb = 20.9 kg DM consumed.
   b) 0.04 ppm Se = 0.04 mg Se/kg.
   c) 20.9 kg x 0.04 mg Se/kg = 0.83 mg Se consumed from TMR.
   d) 5.0 - 0.83 = 4.17 mg Se required from Se 200 premix.
   e) Se 200 premix contains 90.7 mg Se/lb.
   f) 4.17 divided by 90.7 = 0.046 lb of premix required per 46 lb diet DM.
   g) 0.046 lb x 454 g/lb = 20.9 g Se 200 premix required.
5. Assume 60 animals are fed daily a feed mixture of 46 lb DM that is 76.6% DM weighing 3,603 lb, as-is basis. How much Se 200 should be added to this mixture to provide 4.17 mg added Se/animal/day?
   a) from example 4, 0.046 lb of Se 200 contains 4.17 mg Se.
   b) 60 animals x .046 lb/animal = 2.76 lb of Se 200 should be added to the 3,603 lb mixed feed. This provides 4.17 mg added Se/animal/day, making the diet contain 0.2 ppm added Se on a DM basis (4.17 mg ÷ 20.9 kg = 0.2 ppm).
6. The producer wants to feed 1 mg Se/day to an animal that is fed 4 lb of grain mixture per day. How much Se 200 should be added to the 4 lb of grain, and how much should be added to the ton of feed to be mixed?
   a) 1 mg Se desired ÷ 90.7 mg/Se/lb in Se 200 = 0.1103 lb Se 200 per 4 lb of mix.
   b) 2,000 lb/ton ÷ 4 lb fed/day = 500 animal days of feed/ton.
   c) 500 x .01103 = 5.51 lb of Se 200 to add to the 1 ton of grain to be mixed.

Recommended Amounts of Selenium For Farm Animals

Some guidelines for the use of Se in livestock feeds are in Table 4. One column lists the requirement from NRC sources as ppm of diet DM, while another column lists suggested amounts of dietary Se based on observations of the authors and their colleagues. Tolerable levels should never be exceeded, even for one day.

Table 4. Minimal dietary selenium concentration, suggested daily intake of selenium and maximum tolerable levels of selenium for livestock and poultry.

Animal	Information source	Minimum required	Suggested daily amount	Maximum tolerable levels for adult animals[a]	
		ppm	mg/head/day	ppm	approx. mg/head day
Dairy cattle	NRC, 1986	0.2	4-7	2	60.0
Beef cattle	NRC, 1984	0.2	3-5	2	30.0
Sheep		0.1	.2- .4	2	5.0
Swine					
Starter	NRC, 1979	0.3	.7-1.1	2	----
Grower-finisher		0.1	.3- .8	2	> 5.0
Horses	NRC, 1978	0.1	1.0-3.0	2	>25.0
Chickens	NRC, 1984	0.15	.01-.03	10	> 1.4
Turkeys	NRC, 1984	0.20	.06-.08	10	> 3.0

[a]Mineral tolerances of domestic livestock. NRC, Washington, D.C. 1980.

Selenium Toxicity

As already mentioned, Se in sufficient quantities can be toxic to livestock, poultry and humans. It is therefore imperative that Se premixes be handled carefully so as to prevent any livestock access to the bags of premix, to avoid inhaling dust of the premix, to ensure proper mixing of the premixes into the diet or into ration ingredients, and to measure the quantities added very accurately. Fortunately, the toxic levels of Se are at least 10 to 20 times the recommended feeding levels. Probably the greatest incidence of Se toxicity occurs in neonates and pregnant females, which can be given inappropriate quantities of injectable selenium. Excess oral administration could also occur and should be prevented. Some manifestations of low, intermediate and high levels of Se toxicity are presented in Table 5.

Table 5. Signs of toxicity from excess selenium ingestion.

Toxicity level	Manifestations
Low—ingestion of 25 to 50 times the required level for several months (chronic)	Lack of vitality (ill thrift), emaciation, hoof malformation and sloughing, joint stiffness and lameness; hair loss from body, mane or tail; reproductive failure; decreased egg hatchability; liver cirrhosis and dysfunction; kidney malfunction.
Intermediate—ingestion of up to 100 times required Se for several weeks (subchronic poisoning)	Signs of low dose plus subnormal temperature; cardiac insufficiency; swollen and inflamed eyelids; impaired vision; labored breathing; paralysis; death.
High—ingestion of one large amount of Se (acute poisoning)	Abnormal, drooping posture; elevated temperature; increased urine excretion; diarrhea; labored breathing; weakness and collapse; vomiting; ataxia; internal hemorrhages; death.

Summary

Selenium is an essential trace element that is deficient in many feedstuffs grown on selenium-deficient soils. Selenium-responsive syndromes can be reduced by selenium supplementation of livestock and poultry rations, a practice now approved by the FDA. The current FDA-approved rate of 0.1 ppm supplemental Se in diets for poultry and older swine is apparently satisfactory. In selenium-deficient areas, however, that level may not allow desirable blood and serum concentrations in cattle, sheep and horses. Additional selenium can be added to diets at the farm, but amounts must be carefully monitored because of potential selenium toxicity problems. Selenium-containing premixes must be used with care.

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