Selenium Supplementation Strategies for Livestock in Oregon

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Selenium (Se) is an essential trace mineral for livestock. Selenium deficiencies have been described in many species, including cattle, sheep, goats, horses, swine, white-tailed deer, and elk.

Clinical Se deficiency can cause nutritional myodegeneration, also known as white muscle disease. White muscle disease was first discovered in Oregon in 1958 by Dr. James Oldfield and others at Oregon State University. The disease is characterized by muscle weakness, heart failure, unthriftiness (failure to grow or put on weight), and death. Se deficiency also causes effects that are not immediately observable and result in poor livestock performance (see Table 1, page 3).

Photo by Lynn Ketchum © Oregon State University

Young animals are particularly vulnerable to selenium deficiency.

Selenium is the only micronutrient regulated as a feed additive by the Food and Drug Administration (FDA) because of its potential toxic effects. The FDA first approved selenium supplementation of feedstuffs in 1974 but only for use in swine, chicken, and turkey diets. From 1974 to 1986, the FDA amended regulations for supplementing inorganic Se in feed to include recommendations for sheep, beef and dairy cattle, chickens, and ducks.

In Oregon, the Oregon Department of Agriculture (ODA) requires labeling Se-supplemented feedstuffs because of past toxicity-related events. Selenium, although essential for animals, can be toxic when animals consume certain Se formulations in excess. Thus, it is important that livestock producers understand Se supplementation strategies to protect the health of their herd.

The purpose of this publication is to:

- Provide an overview of the role of Se in the livestock diet
- Discuss supplementation rates
- Provide information on forms of Se and methods of supplementation
- List guidelines for assessing livestock's Se status
- Summarize Se research useful to Oregon livestock producers

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Overview of Selenium in the Livestock Diet

Forage Content

Selenium deficiency in livestock is caused by low Se intake. Livestock forage, whether range, pasture, or hay, generally reflects the available Se content of the soil on which it is grown (see Figure 1). Selenium levels in soil vary regionally. Detailed information on Se in soil can be found through the National Geochemical Survey database (http://mrdata.usgs.gov/geochem).

Figure 1. Regional distribution of forages and grain containing low, variable, or adequate levels of selenium in the United States

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Selenium exists in soil in various forms, including selenides, elemental Se, selenites, selenates, and organic Se compounds. Soil pH influences the bioavailability of Se in plants, meaning the degree to which plants can take Se up in a form that animals can effectively utilize. Acidic soil (lower pH) decreases plant uptake of Se, whereas alkaline conditions (higher pH) increase Se uptake. Other minerals in the soil, such as sulfur, also may lower Se bioavailability in growing plants. In addition, different plant species may take up Se in the soil at varying rates. For example, alfalfa has been shown to take up Se much better than red clover in Se-poor soils.

OSU researchers fed Se-fortified alfalfa hay to weaned beef calves and compared their growth rate to control animals. Calves fed Se-fortified alfalfa hay had higher blood Se concentrations that corresponded to the amount of Se applied to the fields. The calves fed Se-fortified alfalfa hay also weighed up to 10 percent more than calves fed alfalfa without Se fortification. Calves on the Se enriched forage also showed increased antibody titers to a common cattle vaccine, which resulted in an improved vaccination response. Subsequently, in the feedlot, calves previously fed the highest Se concentration in fortified hay had lower death rates and greater slaughter weights compared with other groups in the trial. See References 1 and 2, page 8.

Selenium's Role in Livestock Health

Selenium is found in greatest concentrations in kidney and liver tissues, but also is stored in muscle. Selenium works in close relation with antioxidants, such as vitamin E. Disorders caused by Se deficiency often are characterized by low concentrations of both Se and vitamin E.

Research has shown that skeletal and cardiac muscles of young livestock are most commonly affected by low Se intake. Signs of Se deficiency include muscle stiffness and tremors, motor disturbances, hind-end paralysis, and heart failure. These signs are most commonly observed in animals from 3 to 8 weeks of age. Selenium deficiency also can manifest in older animals as a subclinical disease (a disease or condition that, in its earliest stage, has no obvious signs).

White muscle disease is the most well-known disease caused by Se deficiency. In necropsied animals, greyish-white streaking is evident in skeletal muscle

Table 1. Effects of Selenium Deficiency and Benefits of Selenium Supplementation in Livestock

Livestock	Selenium deficiency	Benefits of selenium supplementation
Cattle	• Poor calf health • Decreased immune function • Failure to thrive • Uterine infection • Mastitis • Retained placenta • Reduced fertility in cows and bulls	• Control of mastitis in dairy herds • Control of retained placenta in dairy herds • Improved calf weight gain • Improved immune system function • Improved fertility
Sheep	• Unthriftiness (failure to grow or put on weight) • Growth depression • Decreased twinning • Immunosuppression • Increased susceptibility to bacterial and viral infections	• Increased fertility • Increased lamb weight gain • Increased lamb vigor • Increased reproductive performance in hot weather • Increased antibody response • Increased ewe colostral antibodies • Improved innate immunity to footrot
Goats	Likely similar to cattle and sheep	Reduced level of mastitis in dairy goats
Horses	• Delayed or reduced immune response to vaccination • Decreased immune function • Myopathy, difficulties in locomotion, suckling, swallowing, respiration, and cardiac function	Information is not available at this time.

myodegeneration and myocardial lesions. In cattle, sheep, and goats, selenium deficiency also can cause abortion, stillbirth, or death shortly after birth. Table 1 summarizes some of the effects of Se deficiency and the benefits of Se supplementation in livestock diets.

A liver biopsy is the best way to determine Se status of an animal, but it may be expensive, time consuming, and management prohibitive for the livestock producer. A blood analysis is a quicker and simpler form of testing Se status in an animal. Selenium concentrations can be measured in whole blood or blood serum. Table 2 (page 4) lists the normal range of whole blood Se concentrations in livestock. In most of Oregon, except for some areas on the eastern side of the state, whole blood Se concentrations generally are below the normal range.

Selenium toxicity and livestock death can occur when animals consume excessive amounts of Se in their diet (for example, if sodium selenite is added to a concentrate or feed in excess of tolerable levels). Death also can occur when excessive amounts of inorganic Se are injected. Eating Se-accumulator plants can also poison animals. These

At OSU's Soap Creek Ranch, mature beef cows that grazed Se-fertilized forage (13.5 grams Se/acre mixed with nitrogen fertilizer) for 6 weeks had significantly higher whole blood Se concentrations post-grazing compared with cows that received 6 weeks of sodium selenite supplementation (200 mg Se/kg salt) through a free choice salt-mineral mix, and compared with a third group of cows that had unlimited access to sodium selenite supplementation (120 mg Se/kg salt) in a salt-mineral mix. Whole blood Se concentrations in Se-forage-fed cows remained higher for the next 4 to 5 months compared with Se-salt-supplemented cows. In this study, the short-term exposure of cattle to Se-fertilized forage increased whole blood Se concentrations within several weeks. These cows maintained adequate Se blood concentrations, even without additional Se supplementation, throughout the grazing period. See Reference 3, page 8.

Table 2. Guidelines for Whole Blood Selenium Concentrations in Livestock

Livestock	Age class	Selenium concentration
Cattle	Calves (0–30 days)	100–250 ng/mL
	Older than 30 days	120–300 ng/mL
Sheep	Lambs–adults	120–350 ng/mL
Goats	Kids–adults	170–300 ng/mL
Horses	Foals (0–30 days)	70–200 ng/mL
	Older than 30 days	160–275 ng/mL

Source: Diagnostic Center for Population and Animal Health, Michigan State University

plants, which include species of *Astragalus*, *Brassica*, and *Stanleya*, survive in soils high in Se. Although livestock do not typically eat these plants, care should be taken when pasturing animals in areas where they grow.

The ODA requires a label on all commercial feeds. Feeds that contain 0.5 ppm Se or more must guarantee the minimum and maximum Se levels on the label. This rule applies to both feed ingredients and mixed feed. It pertains to feeds produced in Oregon, Oregon-based labelers, as well as feed imported into Oregon from other states or countries. The ODA does periodic testing of feeds to monitor Se content. For more information on the Oregon supplemental label and on testing of commercial feeds, see: http://www.oregon.gov/ODA/AHID/ pages/commercial_feed_main.aspx

Thirty ewes from the OSU Sheep Center were sorted randomly into two groups. One group of 15 ewes grazed Se-fertilized pasture (13.5 grams Se/acre mixed with nitrogen fertilizer) for 40 days with no salt mineral supplement provided. Whole blood Se levels were significantly higher for 9 months after grazing the Se-supplemented forage compared with other ewes receiving only the salt mineral supplement containing sodium selenite at 200 mg/kg. See Reference 5, page 8.

Supplementation Rates

In 1987, the FDA set the selenium supplementation rate at 0.3 mg Se/kg (ppm) in feed for cattle, sheep, swine, chickens, turkeys, and ducks. For cattle, salt can be added to feed up to 120 ppm, but must not exceed a daily maximum intake of 3 mg Se/head. For sheep, salt mineral mixtures can be added to feed up to 90 ppm, but must not exceed the maximum daily dose of 0.7 mg Se/head. In 2000, the organic form of Se was approved for adding to beef cattle diets at 0.3 ppm in feed. These amounts are for supplemental Se and do not take into account natural Se concentrations already present in feed. That is why it is important to know the Se content of feeds.

The FDA does not regulate the rate of Se administered to horses; the rate for horses is set through industry standards. However, according to the National Research Council, research has found that 0.1 mg/kg (ppm) in feed is sufficient for the mature horse.

Forms of Selenium

In general, Se supplementation for livestock is either in inorganic or organic forms.

Inorganic Se

Sodium selenite and sodium selenate salts are the two inorganic sources of Se that are approved for use in livestock. The selenite form is used most commonly because of its availability; it is used exclusively in injections. The effects of inorganic Se are variable and often of short duration, with whole blood Se levels maintaining for less than one month.

Organic Se

When Se replaces sulfur in the methionine amino acid, it is considered to be organic Se. The Se in forages exists mainly as selenomethionine. When consumed by animals, this organic form of Se is incorporated into body proteins, such as muscle tissue, in place of methionine. This unique property of selenomethionine results in Se being retained in ruminants much longer than Se from traditional inorganic salt forms, such as sodium selenite.

In another study, 240 ewes were divided into 8 groups and drenched with inorganic and organic forms of Se, respectively. A control group received no Se supplement. Selenium concentrations in ewe blood and milk, as well as in their lambs, were greater in ewes drenched with organic Se yeast compared with ewes drenched with inorganic sodium selenite. In addition, concentrations of Se in the lambs' whole blood, blood serum, and skeletal muscle increased in a dose-response manner, based on the dose of Se received by ewes. Weekly oral drenching of ewes with organic Se yeast during gestation and lactation resulted in a more efficient transfer of Se from ewe to lamb than did weekly oral drenching with inorganic sodium selenite. See References 8, 9, 10, and 11, pages 8 and 9.

Methods of Selenium Supplementation

How much Se an animal retains depends on how the Se is administered. Convenience and cost are two factors that determine the methods for administering Se. These methods include:

- Injections
- Salt-mineral mixes
- Se-fortified feed
- Rumen boluses (currently only approved in California)
- Se fertilization of forage crops (currently only approved in Oregon)

Injections

Injectable preparations containing Se can be given either subcutaneously (just below the skin) or intramuscularly (into the muscle), and must be obtained under veterinarian approval. Injections are often used to enhance the Se status of livestock. For example, Se injection can be used to prevent white muscle disease in young livestock because it will raise the blood levels of Se for a short period of time.

Different concentrations of injectable, inorganic Se are available for different kinds of animals. Be sure to follow label recommendations; overdosage can be toxic to animals.

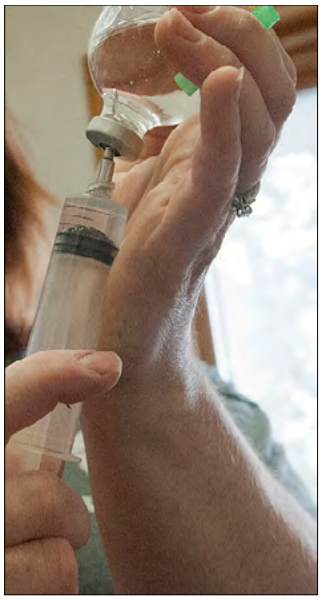

Photo by pennstatenews / CC BY

Preparing an injection.

Mineral supplement

Frequent salt intake provides continuous Se supplementation, as long as the mineral supplement is available for livestock to eat. Salt-mineral mixes exposed to excessive rainfall may cause Se to leach out of the mix or convert to insoluble compounds, which can greatly reduce the intake of usable Se in the diet. When this occurs, it is possible that animals in a herd or flock will not

consume a consistent amount of Se. As a result, a wide range of whole blood Se concentrations may exist in a group of animals consuming Se-supplemented salt-mineral mixes.

Photo by Scott Bauer, USDA

Animal technician administers a bolus to a cow.

Fortified Feed Supplements

Feed supplemented with Se can also be utilized in livestock diets. However, it is important to know whether the Se supplement is inorganic or organic. Animals that consume organic Se retain more Se, and there are fewer concerns about toxicity. Feeding Se-fortified feed can provide a more consistent intake of Se.

Bolus

These small cylinders are only approved for use in cattle in California. The bolus stays in the rumen where it gradually releases Se. A bolus has the advantage of providing Se to animals in grazing areas where supplementation is not feasible.

Fertilization

For over 15 years, research at Oregon State University (OSU) has demonstrated the potential for using Se as a fertilizer to increase Se concentrations in forage for livestock feeds. This approach adds organic Se to an animal's diet through agronomic biofortification. Agronomic biofortification increases concentrations of essential elements (such as Se) in the edible portions of crop plants through enriched fertilization. This practice can potentially overcome the inconsistent intake of salt-mineral mix Se supplementation. Higher amounts of Se can be provided safely with Se fertilization. The Oregon Department of Agriculture (ODA) requires that products containing Se can only be mixed with fertilizer under the direction of a licensed fertilizer dealer.

Photo by Gene Pirelli

Se used as a fertilizer can increase Se concentrations in forage for livestock.

Research in New Zealand, confirmed by OSU trials, found that sodium selenate is the form of Se most efficiently taken up by plants. The recommended level of application is 5 to 10 grams of actual Se per acre to achieve adequate levels of Se in forage. Sodium selenate is 41% Se. An application rate of 12 to 24 grams of sodium selenate per acre will provide the recommended 5 to 10 grams of actual Se per acre.

A pelleted material from New Zealand (called Selcote Ultra) contains sodium selenite that is 4.5 grams of actual Se per pound. This product is approved for use in Oregon by the ODA and can only be mixed with fertilizer by a licensed fertilizer dealer. Recommended application rates of Selcote Ultra are 1 to 2 pounds per acre. Late winter or early spring applications are most effective; however, there

is some evidence that a fall application will provide sufficient Se for plant uptake in the spring. Hay produced from Se-fertilized forage is another excellent source of organic Se. You can obtain Selcote Ultra through your fertilizer dealer.

Guidelines for Providing Selenium Supplementation

The following guidelines will help you:

- Assess the current Se status of your herd or flock
- Develop a Se-supplementation program that takes into account the health of your animals and the economics of your farm or ranch

An important first step in this process is to contact local resource people, such as university Extension faculty or a local veterinarian, to learn more about Se-supplementation methods and costs.

1. Do you live in an area where soil concentrations of Se are low?

   Suggestion: Check the map in this publication (Figure 1, page 2), or check with your local Extension or National Resources Conservation Service office.

2. Do you know if Se levels on your range or pastures are adequate, low, or high?

   Suggestion: Consider sending a sample of your forage to a laboratory that measures Se by the ICP-MS method (e.g., Michigan State University's Diagnostic Center for Population and Animal Health or Utah State Diagnostic Lab).

3. Are you seeing any signs of Se deficiency in your animals?

   Suggestion: Refer to Table 1 (page 3) for signs of Se deficiency in livestock.

4. Are you feeding Se-supplemented feed in addition to range/pasture grazing? If so, where is that feed from?

   Suggestion: Check labels for Se concentration in feed. If not available, consider the Se testing described above.

5. Would you consider testing blood from your entire herd or a representative subsample to look at Se concentrations?

   Suggestion: Work with your veterinarian to determine a plan for taking and submitting samples. Analysis of blood samples is often the most practical way to determine if Se intake from forages and feeds is adequate.

By following these guidelines, you can take the necessary steps to accurately determine the Se status of your livestock herd. Once you have this information, you can develop a plan for Se supplementation that is tailored to your specific needs. Remember, selenium is both an essential micronutrient as well as a potentially toxic substance. Wise use of Se supplementation will benefit livestock producers and contribute to their livestock's overall health.

In a study involving sheep affected with footrot, affected animals were split into two groups. Once monthly, one group was injected with inorganic Se (sodium selenite) and the other with saline solution. The animals were checked periodically over 15 months with respect to footrot lesions and rated on a scale of lesion severity. The footrot-affected sheep that were Se supplemented showed a decrease in footrot lesions over time compared with the non-Se-supplemented group. In addition, adaptive immune responses in Se-supplemented sheep were higher than in non-Se-supplemented sheep. See References 6 and 7, page 8.

Subsequent studies showed that supranutritional Se yeast supplementation does not prevent footrot, but does alter whole blood neutrophil gene expression profiles associated with innate immunity, including reversing those impacted by footrot. Selenium supplementation restores innate and humoral immune response in footrot-affected sheep. See References 12 and 13, page 9.

For information on how to figure out your animals' daily consumption of minerals, see "Mineral Assessment," Oregon State University L&F Circular #0903: http://extension.oregonstate.edu/douglas/sites/default/files/documents/lf/lfc0903.pdf

Research and references

The following research findings may be useful to Oregon livestock producers. Many of these studies have been conducted at Oregon State University.

Beef

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Horses

For more information on Se supplementation in horses see:

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