# Comparing Tolerance of Selenium (Se) as Sodium Selenite or Se Yeast on Blood and Tissue Se Concentrations of Ruminants

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Selenium, whether in organic or inorganic forms, can be fed as high as 40 mg/kg for up to 60 wk without inducing selenium toxicosis. Increasing dietary selenium level regardless of source is an effective means of increasing selenium in blood and tissues.

**Summary**

*The objective of this 60 wk study was to determine the maximum tolerable level of selenium (Se) by feeding Se as sodium selenite or Se yeast at high dietary concentrations to wether sheep. Twenty-eight, two-year-old, Rambouillet-crossbred wethers (137.1 ± 18.7 lb initial body weight) were utilized in a 2 × 4 factorial arrangement with 0.2, 20, 30 and 40 mg/kg dietary Se (as-fed) as either selenite or yeast Se added to a corn-soybean meal basal diet. Average body weight decreased linearly ($P < 0.10$) as dietary Se level increased, though most wethers gained body weight. Serum Se, whole blood Se, and wool Se concentrations from wethers receiving organic Se were greater ($P < 0.01$) than those from wethers receiving inorganic Se. Selenium concentrations in brain, diaphragm, heart, hoof, kidney, liver and loin muscle were affected ($P < 0.05$) by dietary Se concentration, with higher Se concentrations generally observed in tissues from wethers receiving organic Se. Though Se concentrations in serum, blood, wool, and major organs at most times exceeded concentrations previously reported in livestock suffering from Se toxicosis, a pattern of clinical signs of Se toxicosis was not observed in this experiment. Histopathological, microscopic evaluation of liver, kidney, diaphragm, heart, and psoas major muscle did not reveal definitive evidence of Se toxicosis in wethers on any dietary Se treatment. Wethers under our experimental conditions tolerated up to 40 mg/kg dietary Se for 60 wk, though differences in Se source were observed. Contrary to previous thought, the range between optimal and toxic dietary levels is not narrow.*

**Introduction**

Current estimates put the maximum tolerable level of Se at 5 mg/kg for the major livestock species (NRC, 2005) and no differentiation exists for tolerable levels between ruminants and monogastrics. However, Wright and Bell (1966) reported that swine retained 77% and sheep retained 29% of an oral dose of inorganic Se. The NRC makes no distinction between inorganic and organic (e.g., Se yeast or seleno-methionine) forms of Se. Kim and Mahan (2001) reported more accumulation of Se in the plasma and tissues of swine fed high dietary levels of Se as Se yeast compared to the same Se levels as sodium selenite. They concluded that greater than 5 mg/kg dietary Se, regardless of source, did produce signs of Se toxicity in growing swine. Based on these findings and the increasing use of organic forms of Se for supplementation to livestock, an experiment was conducted to determine the maximum tolerable level of Se by feeding Se as sodium selenite or Se yeast at high dietary levels to ruminants.

**Procedure**

This experiment was conducted from June 4, 2002 to July 29, 2003 at the University of Florida Sheep Nutrition Unit located in southwestern Alachua County, FL. Twenty-eight, two-year-old, Rambouillet-crossbred wethers were weighed (137.1 ± 18.7 lb) and randomly assigned to one of eight dietary treatments for a 60 wk study. Dietary treatments were arranged as a 2 × 4 factorial with 0.2, 20, 30 and 40 mg/kg Se (as-fed) as four dietary levels and Se yeast (Sel-Plex; Alltech, Inc.) and sodium selenite (Southeastern Minerals, Inc.) as two Se sources added to a corn-soybean meal-cottonseed hull basal diet. Blood was collected periodically and samples of brain, diaphragm, heart, hoof tip, kidney, liver, and psoas major muscle were collected at slaughter for Se analysis. At termination, blood was again collected and analyzed for albumin and enzymes suggestive of tissue breakdown. Analyses were carried out using standardized procedures.

Brain, diaphragm, heart, hoof tip, kidney, liver, and psoas major Se data were analyzed for effects of treatment using PROC GLM in SAS (SAS for Windows 8e; SAS Inst., Inc., Cary, NC) in a 2 × 4 factorial arrangement. PROC MIXED was used to analyze effects of treatment, time, and the interaction of treatment × time on body weight, serum Se, whole blood Se, and wool Se as repeated measures with a spatial power covariance structure with respect to day and a subplot of animal nested within treatment.

**Results**

Wether body weight was affected by dietary Se level ($P < 0.05$). Body weights of wethers receiving 30 or 40 mg/kg dietary Se as Se yeast decreased from wk 0 to wk 60, whereas wethers receiving all other dietary Se treatments gained weight from wk 0 to wk 60.

Serum Se concentrations measured at wk 12, 24, 48 and 60 ranged from 110 to 3,922 µg/L and increased linearly ($P < 0.05$) as dietary Se level increased, while a quadratic response ($P < 0.05$) was observed at wk 36 (Table 1). Over the entire trial, serum Se increased quadratically ($P < 0.05$) as dietary Se level increased. Wethers receiving organic Se had greater ($P < 0.001$) serum Se than did selenite treated wethers throughout the study. Cristaldi et al. (2004) reported a linear increase in serum Se as dietary Se was increased, however those authors used a maximum level of 10 mg/kg dietary Se as selenite. Our data show that at most collections organic Se produced serum Se of more than double the concentration produced by feeding selenite Se at the same level.

Selenium concentration in new growth wool was measured at wk 12, 24, 36, 48 and 60 (Table 2). Dietary Se concentration, Se source, time, dietary Se concentration × Se source, and dietary Se source × time affected ($P < 0.05$) wool Se. Wool Se ranged from 1.19 to 39.09 mg/kg and increased linearly ($P < 0.001$) as dietary Se increased. Wool Se from wethers receiving organic Se was often more than three-fold greater ($P < 0.001$) than from wethers receiving selenite Se at the same dietary concentration. Wool Se concentrations in the present study were more than ten-fold higher than concentrations of 2 to 2.5 mg/kg in wool from wethers fed up to 10 mg/kg dietary Se as selenite (Cristaldi et al., 2004), but never exceeded 40 mg/kg which is less than 45 mg/kg which was described as the Se concentration in hair of animals suffering from alkali disease (NAS, 1971).

Selenium concentrations, on a dry matter basis, were greatest in liver followed by kidney, heart, hoof, brain, loin, and diaphragm (Table 3). Brain Se concentrations ranged from 1.28 to 32.3 mg/kg and brain Se concentrations from wethers receiving organic Se were greater ($P < 0.001$) than brain Se from wethers receiving selenite Se. These results suggest that Se does cross the blood-brain barrier and that brain Se is influenced by dietary Se source. Diaphragm Se concentration ranged from 0.82 to 26.34 mg/kg and tended to increase linearly ($P = 0.089$) as dietary Se increased. Diaphragm Se concentration was greater ($P < 0.001$) in wethers receiving organic Se than from wethers receiving selenite Se. Heart Se concentration ranged from 1.59 to 33.93 mg/kg and, like brain and diaphragm Se was greater ($P < 0.001$) in wethers receiving organic Se than from wethers receiving selenite Se. Selenium concentrations in the hoof tip increased linearly as dietary Se concentration increased ($P < 0.05$), with wethers receiving organic Se tending ($P = 0.07$) to be greater than those receiving inorganic Se. Kidney Se concentration tended ($P = 0.07$) to respond linearly to increased dietary Se concentration and ranged from 8.43 to 77.61 mg/kg. Kidney Se concentrations from wethers receiving organic Se were greater ($P < 0.01$) than from wethers receiving selenite Se.

Selenium concentrations in liver from wethers receiving organic Se were not different ($P = 0.34$) than liver Se concentrations from wethers receiving selenite Se. Selenium concentrations in the loin muscle (psoas major), which is often consumed ranged from 0.71 to 26.87 mg/kg and tended ($P = 0.12$) to increase linearly as dietary Se concentration was increased. Organic Se was more effective ($P < 0.001$) at increasing Se concentrations in edible tissue than was selenite Se. As daily intake of Se by humans declines in some parts of the world, increasing the Se content of foods for human consumption by manipulating source and level of Se supplementation to livestock is now of interest to food scientists.

Most of the heart, diaphragm, loin, liver, and kidney tissues subjected to histopathological evaluation were free from pathological changes. No pattern associating abnormal pathology to either dietary Se level or source could be established.

Concentrations of albumin and activities of 5 enzymes associated with tissue damage in serum collected at the termination of the experiment were, in general, within or below the normal range for adult sheep. In instances of Se toxicosis, the activities of these enzymes would have been increased due to tissue necrosis. The lack of elevated enzymes, which are suggestive of tissue necrosis, further indicates that the wethers on our study were not suffering from Se toxicosis.

The current estimate of the maximum tolerable level of selenium in ruminants (5 mg/kg diet; NRC, 2005) seems to be grossly underestimated. Selenium, whether in organic or inorganic form, can be fed as high as 40 mg/kg for up to 60 wks without inducing Se toxicosis.

**Literature Cited**

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**Table 1.** Serum Se concentrations of wethers fed four dietary levels of Se as sodium selenite or Se yeast[a]

| | Se source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sodium selenite | | | | Se yeast | | | | |
| | Dietary Se level, mg/kg | | | | | | | | |
| Week | 0.2 | 20 | 30 | 40 | 0.2 | 20 | 30 | 40 | SE |
| | Serum Se, µg/L | | | | | | | | |
| 12 | 157 | 548 | 788 | 1,000 | 412 | 2,583 | 3,210 | 2,458 | 249[bcde] |
| 24 | 130 | 1,683 | 1,487 | 1,724 | 354 | 2,639 | 3,922 | 1,585 | 826[be] |
| 36 | 444 | 851 | 960 | 1,083 | 540 | 3,283 | 2,086 | 1,409 | 250[bcdf] |
| 48 | 110 | 822 | 1,219 | 1,496 | 292 | 2,428 | 2,076 | 1,831 | 253[bce] |
| 60 | 119 | 610 | 886 | 1,250 | 424 | 1,699 | 2,712 | 2,549 | 331[bce] |
| Average | 192 | 903 | 1,068 | 1,311 | 404 | 2,526 | 2,801 | 1,966 | 395[bcdf] |

[a]Data represent least squares means and pooled standard error (SE).
[b]Dietary Se level response ($P < 0.05$).
[c]Selenium source response ($P < 0.05$).
[d]Dietary Se level × Se source interaction ($P < 0.05$).
[e]Dietary Se level linear response ($P < 0.05$).
[f]Dietary Se level quadratic response ($P < 0.05$).

**Table 2.** Wool Se concentrations of wethers fed four dietary levels of Se as sodium selenite or Se yeast[a]

| | Se source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sodium selenite | | | | Se yeast | | | | |
| | Dietary Se level, mg/kg | | | | | | | | |
| Week | 0.2 | 20 | 30 | 40 | 0.2 | 20 | 30 | 40 | SE |
| | Wool Se, mg/kg | | | | | | | | |
| 12 | 1.37 | 3.27 | 6.69 | 4.15 | 3.78 | 12.67 | 21.09 | 24.26 | 3.80[bce] |
| 24 | 1.47 | 3.57 | 5.72 | 11.92 | 7.04 | 31.58 | 35.69 | 37.30 | 2.87[bcd] |
| 36 | 1.68 | 6.02 | 9.85 | 10.85 | 5.70 | 18.99 | 22.79 | 21.29 | 4.72[ce] |
| 48 | 1.19 | 3.15 | 5.64 | 7.23 | 6.39 | 24.81 | 39.09 | 29.65 | 2.22[bcd] |
| 60 | 1.29 | 3.90 | 5.01 | 6.23 | 4.38 | 23.22 | 25.65 | 25.99 | 2.01[bcd] |
| Average | 1.40 | 3.98 | 6.58 | 8.08 | 5.46 | 22.25 | 28.87 | 27.70 | 3.38[bcdefg] |

[a]Data represent least squares means and pooled standard error (SE).
[b]Dietary Se level response ($P < 0.05$).
[c]Selenium source response ($P < 0.05$).
[d]Dietary Se level × Se source interaction ($P < 0.05$).
[e]Dietary Se level linear response ($P < 0.10$).
[f]Time response ($P < 0.05$).
[g]Time × Se source interaction ($P < 0.05$).

**Table 3**. Effects of four dietary levels of Se as sodium selenite or Se yeast on tissue Se of wethers[a]

| | Se source | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sodium selenite | | | | Se yeast | | | | |
| | Dietary Se level, mg/kg | | | | | | | | |
| Tissue | 0.2 | 20 | 30 | 40 | 0.2 | 20 | 30 | 40 | SE |
| | Se concentration, mg/kg | | | | | | | | |
| Brain | 1.28 | 4.22 | 4.74 | 6.87 | 6.12 | 21.90 | 32.30 | 18.71 | 0.99[bcd] |
| Diaphragm | 0.82 | 4.74 | 3.33 | 7.81 | 5.28 | 10.30 | 26.34 | 20.71 | 2.69[bcde] |
| Heart | 1.59 | 3.80 | 5.13 | 6.23 | 6.35 | 23.77 | 28.71 | 33.93 | 2.43[bcd] |
| Hoof | 3.44 | 8.79 | 9.68 | 13.78 | 6.26 | 12.53 | 29.20 | 23.66 | 5.52[ce] |
| Kidney | 8.43 | 19.94 | 27.93 | 27.89 | 22.26 | 33.96 | 77.61 | 36.28 | 6.87[bcde] |
| Liver | 2.66 | 31.72 | 41.42 | 78.18 | 15.67 | 23.42 | 132.73 | 41.24 | 18.17[bde] |
| Loin | 0.71 | 3.13 | 4.41 | 5.13 | 5.73 | 14.69 | 23.51 | 26.87 | 1.05[bcd] |

[a]Data represent least squares means and pooled standard error (SE).

[b]Dietary Se level response ($P < 0.05$).

[c]Selenium source response ($P < 0.05$).

[d]Dietary Se level × Se source interaction ($P < 0.05$).

[e]Dietary Se level linear response ($P < 0.10$).