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Effects of Supplementing Selenium to a Beef Cattle Cow-Calf Herd on Tissue Selenium Concentration

[1]G. Valle, [1]L. R. McDowell, [3]D. L. Prichard, [4]P. J. Chenoweth, [3]D. L. Wright,
F. G. Martin[2], [1]W. E. Kunkle and [1]N. S. Wilkinson
[1]Department of Animal Sciences, and [2]Statistics, Gainesville, FL 32611-0910,
[3]North Florida Research and Education Center, Quincy, FL 32351-9506
[4]Kansas State University, College of Veterinary Medicine,
Manhattan, KS 66506-5606

Abstract: In a two year experiment, Angus cows were supplemented with selenium through salt free-choice mineral mixes (yeast form) and two injectable products, Deposel® (barium selenate, long lasting) and Mu-Se® (sodium selenite, short lasting). Plasma selenium levels increased in the two salt mineral mix treatments, whereas in the Mu-Se treatment the values decreased, while the Deposel was able to maintain selenium concentrations. Plasma concentrations in the control were below critical levels (0.03 μg/ml) at the end of the experiment (24 mo) and at the critical level at 18 mo. Plasma values in the Mu-Se treatment were at critical levels at 18 mo and above critical but below adequate at the start and at 6, 12 and 24 mo. The Deposel treatment attained adequacy (0.07 μg/ml) in plasma selenium at 6 mo and at no time was less than the critical level (0.03 μg/ml). Liver selenium concentrations of the control did not attain adequate levels (1.2 mg/kg) during the 2 years, and even though the Deposel treatment reached adequacy only at 24 mo the trend for this treatment was to increase liver selenium concentrations with time. The Mu-Se treatment at no time presented adequate concentrations. The two free-choice salt mineral mixture treatments were found to provide adequate selenium in liver at 6, 12 and 24 mo after treatment began. Colostrum selenium concentrations decreased from the first to the second year, and at no time did any treatment reach adequacy (0.1 mg/L). Milk selenium concentrations declined from 60 to 180 days in the control during the first year, but the concentrations tended to be maintained in all supplemented treatments. During the second year, the selenium concentrations for the Mu-Se treatment declined, while the concentrations were maintained in the Deposel and both free-choice mineral mixture treatments. Deposel provided long lasting reliable protection from selenium deficiency while the yeast form of selenium provided continuous and highest levels of blood, liver and milk selenium concentrations.

Key words: Selenium, Cattle, Supplementation Methods

Introduction

Selenium is an essential nutrient for cattle as selenium deficiency has been associated with nutritional myodegeneration, retained placenta, infertility, abortions, birth of premature, weak or dead calves, decreased immune response and "ill thrift" (Maas, 1983; Corah, 1991; McDowell, 1997). A number of methods of selenium supplementation are available, including both short and long lasting injectable products as well as part of a free-choice mineral supplement. Injectable preparations, which use barium selenate as the source of selenium, have been shown to be long-lasting. Single subcutaneous doses of barium selenate provided a slow sustained release of selenium in sheep for 2 to 4 years (Judson *et al*., 1991). For cattle, MacPherson *et al*. (1988) found barium selenate to be effective for up to one year. Organic Se (Se-yeast) has been shown to have a higher bioavailability than selenium as selenite or selenate in cattle (Awadeh *et al*., 1998; Ortman and Pehrson, 1999) and swine (Mahan, 1999; Mahan, 2000). Organic selenium has improved performance and blood, milk and tissue concentrations.

The objective of the two-year experiment in a beef cow-calf herd was to compare selenium sources. Selenium from two injectable products or included in a free-choice mixture were compared in relation to blood, liver, milk and colostrum selenium concentrations.

Materials and Methods

Seventy-five Angus cows (511 kg average weight, and 5-8 mo pregnant as determined by palpation) were utilized in a two year experiment at the Beef Demonstration Unit of the University of Florida in Chipley, Florida. Cows had body condition scores ranging from 4 to 7.

The duration of the experiment was from December 1996 to December 1998. At the start of the trial, animals were randomly allotted into five groups and treatments as follows: 1) a control (no selenium supplementation), 2) subcutaneous injection of 5 ml of Mu-Se® (5 mg selenium per ml sodium selenite, from label, Burns Biotech Labs, Inc. Oakland, CA 94621) every 6 mo, 3) subcutaneous injection of 9 ml of Deposel® (50 mg selenium per ml as barium selenate, from label, Grampian Pharmaceuticals Ltd, Leyland, Lancashire PR5 3QN, U.K.) administered only at the initiation of the experiment, and 4) use of mineral mix with organic selenium (Se-yeast: Yea-Sacc, Alltech Biotech Center, 3031 Catnip Hill Pike, Nicholasville, KY 49356) administered to two groups as replicates. The free-choice mineral mixture contained 54.5 g/kg Se-yeast (calculated), which resulted in a selenium concentration of 30 mg/kg in the mineral mixture. For both free-choice mixtures the average daily selenium intake was 2.1 mg per cow per day. Each of the five groups consisted of 15 cows which remained in the experiment for the two year duration. At initiation of the experiment and every six months, blood and liver biopsy samples were collected for a total of five collections. Colostrum and milk samples from cows in both years were also collected to determine selenium concentrations. All procedures of this experiment were approved by the Inter-institutional Animal Care and Use Committee (#A303) of the University of Florida.

Blood was collected via jugular venipuncture with an 18-gauge needle into heparinized vacuum blood collection tubes at 0, 6, 12, 18, and 24 mo post-partum. Blood was kept cool at collection site and subsequently transported to the Animal Nutrition laboratory at the University of Florida for further preparation and analysis. Upon arrival at the laboratory, blood was centrifuged for 20 min at 700 × *g*. Following centrifugation, plasma was frozen at -20°C for later analysis. Liver biopsy samples were collected with trocar and cannula by the procedure of Chapman *et al.* (1963) at the 11th intercostal space at 0, 6, 12, 18, and 24 mo post-partum. Colostrum and later produced milk were precisely collected at the given days post-partum to represent days 1, 60, 120 and 180 for each year. Selenium concentrations in all sample types were determined using the Whetter and Ullrey (1978) fluorometric method.

The cows were provided Agrentine bahiagrass and Coastal bermuda pastures (0.05 mg/kg selenium) and grazed ryegrass (0.045 mg/kg selenium) during the winter, and were also fed bahiagrass hay (0.04 mg/kg selenium) during this period. Pastures were sampled for selenium determination once in winter (ryegrass) and once in summer (bermuda and bahiagrass)of each year. Samples were collected at random in a zigzag pattern with the number of samples varying according to the size of the enclosure. Hay was sampled in the winter.

The data were analyzed as a repeated measures model in a completely randomized design using the GLM of SAS (1966) and the means compared by an LSD test. The experimental unit was each individual cow.

Results and Discussion

Cow Plasma Selenium: Cow plasma selenium concentrations at the start of the experiment were not different ($P < 0.05$) among treatments (Table 1) and were similar to data of Ortman and Pehrson (1999) who reported that cows with no selenium supplementation maintained an average plasma concentration of 0.05 μg/ml. McDowell *et al.* (1984) suggest a critical level for plasma selenium to be 0.03 μg/ml. Ellis *et al.* (1997) indicated that normal serum ranges are from 0.05 to 0.10 μg/ml.

Six months later, differences ($P < 0.05$) among treatments were observed, with the control being numerically less than all groups and statistically less than the Deposel and the two free-choice mineral treatments. The Mu-Se treatment animals contained less ($P < 0.05$) plasma selenium than the Deposel and the two free-choice mineral mixture treatment cows. Selenium concentrations for all cows were considered adequate (Gerloff, 1992; Ellis *et al.*, 1997) except for the control animals which was at a critical level (0.03 μg/ml).

At 12 months after the start of the experiment, all selenium supplemented groups had higher ($P < 0.05$) plasma selenium concentrations than the control. The second free-choice supplement group was also higher ($P < 0.05$) than the other treatments. In the second summer (18 mo), the second free-choice supplementation group had higher ($P < 0.05$) plasma selenium than the Control and Mu-Se treatments, and all treatments were below suggested adequacy (0.07 μg/ml), with the control and Mu-Se at a critical level (0.03 μg/ml). At the end of the experiment (24 mo), there were also differences ($P < 0.05$) among treatments with all supplemented animals above those of the control. Mean selenium concentrations of animals receiving selenium were above the critical level of 0.03 μg/ml, while the control was

below, averaging 0.02 μg/ml.
Control and Mu-Se treatments had lower plasma selenium concentrations at the end of the study than at the start two years earlier. The control started with 0.06 μg/ml and ended with 0.02 μg/ml, suggesting that the selenium was being used by the animal at a greater rate than it was being replaced, but in this case no selenium was being supplemented. At the administered dose and frequency (every 6 months) the Mu-Se source of selenium was not sufficient to raise and maintain adequate selenium concentrations in cow plasma. For the two year period, the Deposel treatment maintained the selenium status in cow plasma while both free-choice mineral mixture groups resulted in higher plasma selenium concentrations at the end of the study than the control and Mu-Se groups. It has been reported (Abdelrahman and Kincaid, 1995) that cows with daily intakes of 1 mg/d selenium were unable to maintain adequate selenium concentrations in blood during late gestation. Awadeh *et al.* (1997) found that cows consuming 1.27, 3.98 and 8.57 mg selenium per day had a decline in blood selenium post-partum, except for cows consuming the highest level. For the present experiment, 2.1 mg Se per day for the free-choice groups was sufficient for maintaining plasma selenium.

Cow Liver Selenium: No differences ($P < 0.05$) in liver selenium were found among treatments at the start of the experiment (Table 2). The cow liver selenium concentrations varied from 0.06 to 0.07 mg/kg, values which are below the 1.2 to 2.0 mg/kg considered to be normal liver selenium concentrations (Stowe and Herdt, 1992). The control was lower ($P < 0.05$) than all other treatments at all sampling times after the initial collection. At six months, Mu-Se and Deposel treatment animals were higher ($P < 0.05$) than the control but were lower ($P < 0.05$) than for cattle receiving the two free-choice mineral mixtures. Liver selenium concentrations for both groups of animals receiving the free-choice mineral mixtures were considered adequate for status of this element.
One year (12 mo) after the initiation of the experiment there were differences ($P < 0.05$) among treatments. Liver selenium (0.04 mg/kg) in control animals was lower ($P < 0.05$) than all other groups. The Mu-Se treatment (0.61 mg/kg) animals did not differ ($P < 0.05$) from the Deposel treatment (0.83 mg/kg) and both treatments had less ($P < 0.05$) liver selenium than the free-choice mineral groups (1.36 and 1.30 mg/kg). The control, Mu-Se and Deposel treatments were relatively low in selenium, whereas the two free-choice mineral mixes were adequate.
At 18 mo after initiation of experiment, there were differences ($P < 0.05$) among treatments in liver selenium, with all treatments below an adequate level of 1.2 mg/kg. Control animals were lower and different ($P < 0.05$) from all other treatments. The Mu-Se treatment cows differed ($P < 0.05$) from those of the Deposel and free-choice mineral mix #1 but were similar to free-choice mix #2. The Deposel and free-choice mineral mix #1 cows did not differ ($P < 0.05$) in liver selenium.
At 24 mo (end of experiment), the Deposel treated animals had the highest liver selenium concentration (1.69 mg/kg) and were different ($P < 0.05$) than all other groups followed by the two free-choice mineral mixture animals (1.29 and 1.24 mg/ kg). These treatments had adequate selenium concentrations whereas the control and Mu-Se treatment did not.
The Deposel and two free-choice mineral mixture groups succeeded in raising liver selenium concentrations to adequate levels after two years (1.69, 1.29 and 1.24 mg/kg, respectively), and this was also reflected in plasma selenium concentrations of the cows, which were also adequate at the end of the experiment. The Mu-Se treatment did not reach adequate levels, but at two years had a tendency for higher selenium concentrations. These results have to be considered in the light that this treatment was administered every six months (recommendation by manufacturer is every 4 mo), whereas the Deposel was administered once at the start of the study, while the cattle on the free-choice treatment had continuous access to the selenium containing mineral. Research with cattle and sheep have shown injectable barium selenate to be effective for a year in cattle (MacPherson *et al.*, 1988) and 2 to 4 years in sheep (Judson *et al.*, 1991).
Knowles *et al.* (1999) provided selenium from sodium selenate or selenized yeast (Sel-Plex 50) at two levels (2 and 4 mg/kg) for 133 d. Liver selenium was higher ($P < 0.05$) at higher dietary concentration and for selenized yeast compared to sodium selenite. In our study, the organic selenium source (Se-yeast) was also able to increase selenium in liver, while the inorganic injectable sodium selenite did not, which agrees with the above presented results. However, barium selenate in the present study was also able to raise selenium liver concentrations to adequate levels at 24 mo.
Cows receiving barium selenate had the highest liver selenium at the end of the experiment. This

Table 1: Plasma selenium concentration (µg/ml) of Angus cows under different methods and sources of selenium supplementation (n=375)[a]

	Months of Experiment				
Sources	0	6	12	18	24
Control	0.06[b]	0.03[b]	0.02[b]	0.03[b]	0.02[b]
Sodium selenite[1] (Mu-Se)	0.06[b]	0.04[b]	0.05[c]	0.03[b]	0.05[c]
Barium selenate[2] (Deposel)	0.06[b]	0.07[c]	0.06[c]	0.04[bc]	0.06[cd]
Free-choice[3] mineral #1 (Se-yeast)	0.06[b]	0.08[c]	0.06[c]	0.04[bc]	0.07[d]
Free-choice[3] mineral #2 (Se-yeast)	0.07[b]	0.10[d]	0.08[d]	0.05[c]	0.07[d]

[a]Presented are the LS means. Their standard error = 0.015.
[bcd]Means with different superscripts within a column differ (P < 0.05), by LSD test.
[1]Animals received a subcutaneous injection of 5 ml of Mu-Se (Burns Biotech Labs, Inc.; 5 mg selenium per ml from sodium selenite) every 6 mo.
[2]Animals received a subcutaneous injection of 9 ml of Deposel (Grampian Pharmaceuticals, Ltd.; 50 mg selenium per ml as barium selenate) administered once.
[3]Animals consumed a free-choice mineral mixture with organic selenium (Se-yeast: Yea-Sacc, Alltech) at a rate of 54.5 g/kg of mineral mix, which resulted in 30 mg/kg selenium in mineral mixture.

Table 2: Liver selenium concentration (mg/kg) of Angus cows under different methods and sources of selenium supplementation (n=250)[a]

	Months of Experiment				
Sources	0	6	12	18	24
Control	0.070[b]	0.041[b]	0.043[b]	0.034[b]	0.027[b]
Sodium selenite (Mu-Se)	0.073[b]	0.472[c]	0.612[c]	0.704[c]	0.923[c]
Barium selenate (Deposel)	0.070[b]	0.601[c]	0.826[c]	1.003[d]	1.694[e]
Free-choice mineral #1 (Se-yeast)	0.075[b]	1.611[e]	1.358[d]	0.979[d]	1.287[d]
Free-choice mineral #2 (Se-yeast)	0.063[b]	1.180[d]	1.304[d]	0.909[cd]	1.239[d]

[a]Presented are the LS means. Their standard error = 0.008.
[bcd]Means with different superscripts within a column differ (P < 0.05), by LSD test.

Table 3: Colostrum selenium concentrations (mg/L) of Angus cows in two years under different sources and methods of selenium supplementation (n=80)[a]

	Years of Experiment	
Sources	1	2
Control	0.032[b]	0.024[b]
Sodium selenite (Mu-Se)	0.056[c]	0.035[bc]
Barium selenate (Deposel)	0.071[c]	0.049[c]
Free-choice mineral #1 (Se-yeast)	0.092[d]	0.039[c]
Free-choice mineral #2 (Se-yeast)	0.092[d]	0.065[d]

[a]Presented are the LS means. Their standard error = 0.007
[bcd]Means with different superscripts within a column differ (P < 0.05), by LSD test

Table 4: Milk selenium concentrations (mg/L) of Angus cows under different methods and sources of selenium supplementation (n=240)[a]

	1997			1998		
Sources	60	120	180	60	120	180
Control	0.03[bc]	0.01[b]	0.01[b]	0.01[b]	0.01[b]	0.02[c]
Sodium selenite (Mu-Se)	0.02[b]	0.02[b]	0.02[bc]	0.02[c]	0.02[c]	0.01[b]
Barium selenate (Deposel)	0.02[b]	0.02[b]	0.02[bc]	0.02[c]	0.01[b]	0.02[c]
Free-choice mineral #1 (Se-yeast)	0.03[bc]	0.04[c]	0.03[c]	0.02[c]	0.02[c]	0.02[c]
Free-choice mineral #2 (Se-yeast)	0.04[c]	0.04[c]	0.03[c]	0.02[c]	0.02[c]	0.03[d]

[a]Presented are the LS means. Their standard error = 0.002
[bcd]Means with different superscripts within a column differ (P < 0.05), by LSD test

accumulation of selenium in liver suggests that this slow release product could go on providing selenium to the animal for a longer period than two years, which was the duration of the experiment. However, if this is true, care should be taken at slaughter of culled and/or older cows to avoid using the area where the Deposel was administered. The organic selenium (Se-yeast) also succeeded in providing adequate selenium levels at the end of the two year period, when mixed with the mineral salt.

Cow Colostrum Selenium: During the first year of the experiment there were differences ($P < 0.05$) among treatments in colostrum selenium concentrations (Table 3). The control treatment had the lowest concentration and was different ($P < 0.05$) from all other treatments. Mu-Se was similar to Deposel but lower ($P < 0.05$) than for animals receiving the free-choice mineral treatments. Abdelrahman and Kincaid (1995) have reported selenium concentrations in colostrum of 0.04 to 0.06 mg/L which is similar to concentrations found in the present study.

In the second year, colostrum selenium concentrations declined in all treatments. The control presented the lowest selenium concentration (0.024 mg/L) but was not different ($P < 0.05$) from the Mu-Se. Highest colostrum selenium was found in the cows receiving Deposel and the two free-choice mineral mixtures. The highest selenium concentration was found in the free-choice mineral mixture #2 (0.065 mg/L) and was different ($P < 0.05$) from all other treatments.

There was a tendency for the colostrum selenium concentrations to decline after year 1 to year 2. The values found in the colostrum in this study may not be enough to supply the calves with adequate selenium. It is noted that the average selenium in colostrum for the two free-choice mineral mixes at the end of the experiment (0.052 mg/L) was not very different ($P < 0.05$) than the selenium in colostrum for the Deposel group (0.049 mg/L). According to Campbell *et al.* (1990), the selenium concentration in colostrum is significantly increased by supplementing, but the actual amounts of selenium are small and probably of little importance in the prevention of juvenile nutritional muscular degeneration.

Cow Milk Selenium: Ammerman *et al.* (1980) observed milk selenium concentrations in beef cows declined from 0.015 mg/L two weeks after calving to 0.010 mg/L at eight weeks. Milk selenium concentrations ranging from 0.029 to 0.064 mg/L have been reported in dairy cows by Maus *et al.* (1980). At 60 days after calving (Year 1), the concentrations of selenium in the beef cow's milk (Table 4) of the present study (0.02 to 0.04 mg/L) were above those reported by Ammerman *et al.* (1980) and similar to the lower range of values reported for dairy cattle (Maus *et al.*, 1980). The highest concentrations were for the free-choice mineral mixture treatments (0.03 and 0.04 mg/L) and the lowest (0.02 mg/L) were found in the Mu-Se and Deposel groups.

At 120 days post-calving, the tendency was similar, with the highest concentrations of selenium in milk coming from cows receiving the salt mineral mix treatments. The control was numerically less than all treatments (0.01 mg/L) but not statistically different than Mu-Se and Deposel groups at 0.02 mg/L. At 180 days, again there was a similar trend in both years. During the three periods, milk selenium concentrations were maintained in all treatments, except for the control which decreased noticeably from 0.03 to 0.01 mg/L. All milk selenium concentrations were similar to but mostly above the values reported by Ammerman *et al.* (1980). These authors also reported a decline in milk selenium concentrations with time. Knowles *et al.* (1999) reported that selenized yeast was 2 to 3 times more effective than sodium selenite at increasing milk selenium concentration, and low intakes (2 mg/d selenium) of both supplements were 27% more efficient per mg of selenium administered than were high intakes (4 mg/d selenium). At day 133, milk selenium concentrations were 1.5 to 5.5 times higher in treated cows than in the control group. In the present study, during the first year selenized yeast was 1.5 to 2 times as effective as injectable sodium selenite at 60, 120 and 180 d in raising milk selenium concentrations. During the second year of our study, all sources were equally effective but milk selenium concentrations were mostly lower than in the first year.

During the second year, milk selenium concentrations at 60 days post-partum were 0.02 mg/L for all supplemented groups and higher ($P < 0.05$) than the control. At 120 days post-partum the control presented equal concentration of selenium (0.01 mg/L) as the Deposel treatment. The Mu-Se and both free-choice mineral mixture treatments were not different ($P < 0.05$) but had a higher (0.02 mg/L) selenium concentration than the Deposel and control ($P < 0.05$). At 180 days, milk selenium concentrations were highest (0.03 mg/L) for free-choice mineral mixture # 2 and lowest (0.01 mg/L) for the Mu-Se ($P < 0.05$).

It has been demonstrated that placental transfer of selenium is effective in cattle because the maternal supplementation of cows in late gestation increases selenium reserves in the fetus as well as the newborn, as reported by Van Saun *et al.* (1989) and Abdelrahman and Kincaid (1995). Pre-partum maternal supplementation to cows improves selenium status in calves to a greater extent than post-partum, suggesting that placental transfer of selenium is more efficient than milk transfer (Enjalbert *et al.*, 1999). The selenium level in milk is readily raised by the supplementation of animal diets. Grant and Wilson (1968) obtained substantial milk selenium increases over a period of 3 to 4 weeks from cows receiving a single oral dose or subcutaneous dose of 50 mg selenium as selenate, while levels in untreated cows remained low. Gardner and Hogue (1967) tripled the selenium concentration from milk of ewes fed a low selenium diet when they supplemented the ewes diet with 2.25 mg per day of selenium as selenite. In the present study, only during the first year were the selenium concentrations maintained in all treatments, except for the control which declined. Milk selenium concentrations in this study were relatively low and suggest that calves do not obtain adequate selenium through milk, which would indicate that it is not a good practice to supplement the dam post-partum for the purpose of increasing milk selenium. This is further supported by Campbell *et al.* (1990) who indicate that even though milk selenium is higher in supplemented groups, the actual amount of selenium in milk appears to be too little to be of any nutritional importance in a deficient neonate.

Ortman and Pehrson (1999) and Suoranta *et al.* (1993) have indicated that supplementing inorganic selenium to the dam to alleviate selenium needs in calves is not satisfactory due to the poor capacity of these compounds to increase the selenium content of milk. Ortman and Pehrson (1999) also reported that organic selenium in the form of a yeast product for dairy cows results in higher concentrations of selenium in the milk than supplements of sodium selenite. In this study, however, even though the organic selenium was higher ($P < 0.05$) than the sodium selenite treatment, the concentrations were not adequate (0.07 mg/L) although Bostedt and Schramel (1983) maintain that newborn calves need about 0.04 mg/L of selenium in plasma to meet their needs for normal growth and health. Perry *et al.* (1978) reported that selenium concentrations in milk were not a good indicator of dietary selenium.

The selenite (Mu-Se) treatment was not effective in raising plasma selenium concentrations for long periods while the barium selenate (Deposel) maintained a constant level of selenium in plasma for 2 years. Higher concentrations of selenium in blood, liver and milk were obtained from the selenium-yeast product. The long lasting injectable selenium product Deposel and the use of selenium-yeast product in free-choice mineral mixture are reliable methods of providing selenium to grazing cattle.

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