PEER REVIEWED

Efficacy of a New Sustained-Release Intraruminal Selenium Bolus

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Abstract

Our objective was to test the efficacy of a new sustained-release selenium (Se) bolus versus negative and positive control beef cattle. Fifty-five English breed heifers (mean initial body weight 546 ± 46 lb; 248 ± 21 kg) were randomly assigned to one of four treatment groups: one 120-day, sustained-release selenium (Se) bolus on day 0 (A-1X); one 120-day, sustained-release Se bolus on day 0 and a second bolus on day 121 (A-2X); one 365-day, sustained-release Se bolus on day 0 (B); and control (C), no supplemental Se. Heifers grazed Se-deficient native foothill range without any additional supplement. Body weights and blood samples were taken for Se analysis from animals in all four groups at days -28, 14, 28, 49, 63, 121, 183, 293 and 365. No evidence of excess Se intake was observed. Both blood and weight data were analyzed in a model with Se treatment as the main effect; a log transformation for blood Se was used to make variances across treatments similar. Blood Se concentrations were similar amongst treatment groups on day -28. However, on days 14, 28, 49, 63, 121, 183, 293 and 365, blood Se concentrations were higher for the three supplemented groups relative to the control group ($P<0.0001$). On day 121, Groups A-2X and B had higher blood Se levels than Group A-1X ($P=0.0001$ and 0.0046, respectively). At days 183 and 293, Group A-2X had the highest blood Se concentrations (231.1 ± 22.7 and 133.4 ± 13.4 ng/ml), with Groups B (136.8 ± 23.0 and 75.8 ± 17.9 ng/ml), A-1X (114.3 ± 16 and 34.8 ± 8.8 ng/ml), and C (21.26 ± 2.8 and 15.53 ± 2.7 ng/ml) having descending Se blood concentrations, respectively. On day 365, Groups A-2X and B had blood Se concentrations above the 50 ng/ml that is considered deficient. Groups A-1X, A-2X and B gained 25.1, 51.0 and 25.7 lb (11.4, 23.2 and 11.7 kg) more than the 219.6 lb (99.8 kg) gain of the control group ($P<0.001$). Selenium supplementation provided sufficient mineral to raise blood Se concentrations above deficient levels. When compared with a single 120-day bolus, the single 365-day bolus prevented blood Se concentrations from falling to deficient levels for a longer period of time.

Keywords: beef cattle, selenium, supplementation, intraruminal bolus

Résumé

Notre objectif était de tester l'efficacité d'un bolus à libération continue de sélénium par rapport à des témoins positifs et négatifs chez des bovins de boucherie. Un total de 55 taures de race anglaise (poids initial moyen 546 ± 46 lb; 248 ± 21 kg) ont été allouées aléatoirement à l'un des quatre traitements suivants: (A-1X) administration au jour 0 d'un bolus à libération continue de sélénium pendant 120 jours; (A-2X) administration au jour 0 d'un bolus à libération continue de sélénium pendant 120 jours et d'un second bolus au jour 121; (B) administration au jour 0 d'un bolus à libération continue de sélénium pendant 365 jours; et (C) un témoin sans bolus. Les taures broutaient dans un pâturage naturel de contrefort pauvre en sélénium sans supplément additionnel. Le poids et des échantillons de sang pour l'analyse de sélénium ont été pris chez tous les animaux des quatre groupes aux jours -28, 14, 28, 49, 63, 121, 183, 293 et 365. Aucun signe d'apport excessif de sélénium n'a été observé (boiterie, alopécie, poil cassant, coronite). Les données pour le poids et pour le sang ont été analysées dans un modèle avec le traitement au sélénium comme facteur principal; une transformation logarithmique de la concentration sanguine de sélénium a été utilisée pour homogénéiser la variance entre les groupes. Il n'y avait pas de différence entre les groupes au niveau du sélénium sanguin au jour -28. Toutefois, aux jours 14, 28, 49, 63, 121, 183, 293 et 365, la concentration sanguine de sélénium était plus élevée

dans les trois groupes supplémentés que dans le groupe témoin ($p < 0.0001$). Au jour 121, la concentration sanguine de sélénium était plus élevée dans le groupe A-2X et le groupe B que dans le groupe A-1X ($p = 0.0001$ et 0.0046, respectivement). Aux jours 183 et 293, la concentration sanguine de sélénium était la plus élevée dans le groupe A-2X (231.1 ± 22.7 et 133.4 ± 13.4 ng/ml) suivi du groupe B (136.8 ± 23.0 et 75.8 ± 17.9 ng/ml), du groupe A-1X (114.3 ± 16 et 34.8 ± 8.8 ng/ml) et du groupe C (21.26 ± 2.8 et 15.53 ± 2.7 ng/ml). Au jour 365, la concentration sanguine de sélénium dans les groupes A-2X et B était supérieure à 50 ng/ml que l'on considère comme le seuil de carence en sélénium. Par rapport au gain de poids de 219.6 lb (99.8 kg) dans le groupe témoin, les taures dans le groupe A-1X ont gagné 25.1 lb (11.4 kg) de plus, celles du groupe A-2X 51.0 lb (23.2 kg) de plus et celles du groupe B 25.7 lb (11.7 kg) de plus ($p < 0.001$). Le supplément de sélénium a permis de maintenir la concentration minérale sanguine de sélénium au-dessus du seuil de carence. En comparaison avec un bolus de 120 jours, le bolus de 365 jours a prévenu la chute de la concentration sanguine de sélénium sous le seuil de carence pendant une plus grande période.

Introduction

Nutritional myodegeneration, a degenerative muscle disease exhibited by young ruminants, was linked to selenium (Se) deficiency in 1958.[11] Other symptoms of Se deficiency in ruminants include decreased resistance to environmental stress and disease, fragility of vascular and erythrocyte membranes, poor reproductive performance, diarrhea and ill thrift.[1,2,3] Information about the beneficial effects of Se led to Food and Drug Administration (FDA) approval of supplementation at 0.3 mg Se/kg diet for cattle.[6]

The amount of Se found in soils and plant communities in California rangelands and pastures cause Se deficiency to be the most commonly diagnosed disease problem in beef cattle as reported by the California Department of Food and Agriculture's Animal Health and Food Safety Laboratory System at University of California, Davis.[4] Previous studies have shown that approximately 65% of beef cattle in California are Se deficient (< 50 ng Se/ml blood).[7,15]

Numerous Se supplementation methods including water additives, injectable Se, intraruminal soluble glass boluses, Se pellets, protein supplements, mineral mixes and Se fertilization of pastures have been utilized.[6] However, due to economic and logistic problems, not all of these methods are equally practical for cattle on range or pasture.

Previous trials with slow-release intraruminal Se boluses have demonstrated both their safety and efficacy.[5] In a previous 220-day study, both Se pellets and osmotic pump boluses proved effective for raising blood Se concentrations in pregnant cows and their calves without causing Se toxicity.[5]

This study was designed to test the efficacy of a new sustained-release Se bolus compared to a negative control (Se-deficient cattle) and a positive control group (cattle supplemented with an osmotic pump bolus that releases 3 mg Se/day).

Materials and Methods

Animal care

Fifty-five English breed beef heifers (546 ± 46 lb; 248 ± 21 kg) were used in this study conducted on native California grassland at the University of California Sierra Foothill Research and Extension Center located approximately 21 miles (34 km) east of Marysville, CA. All heifers had been weaned for at least 28 days prior to the beginning of the experiment. The heifers were stratified by age and body weight at weaning and were randomly assigned to one of four treatment groups. All groups were maintained on a foothill range in a Se-deficient (<0.05 mg Se/kg dry matter) natural environment and did not receive additional nutritional supplements. Cattle were managed using standard management practices and all experimental and management procedures were approved by the Animal Use and Care Administrative Advisory Committee of the University of California, Davis.

Treatments

Group A heifers (18 animals) were orally administered a 120-day, sustained-release Se bolus[a] on day 0 of the study. This bolus releases 3 mg of Se per day after a 14-day lag period, during which time the osmotic pump is becoming fully charged.[8,9] On day 0, Group B heifers (18 animals) were orally administered one 30-g Se bolus[b] which provides Se supplementation for 365 days and contains 10% elemental Se by weight. Group C heifers (19 animals) received no treatment (negative control).

The groups were allowed to graze as a single management unit and did not receive any forage supplements, mineral supplements or salt. Additionally, on day 121, half of Group A cattle were randomly selected to receive a second 120-day, sustained-release Se bolus[a] to maintain an internal positive control group (subgroup A-2X) receiving 3 mg Se per day for an additional 120 days (240 days total). The other half of the Group A heifers did not receive a second bolus and were designated as subgroup (A-1X).

Measurements

Blood samples were collected via jugular venipuncture 28 days prior to initiation of the study (d -28) and at 14, 28, 49, 63, 121, 183, 293 and 365 days in EDTA

tubes and analyzed for whole blood Se concentration by inductively coupled argon plasma emission spectroscopy.[14]

The bolus administered to Group A releases 3 mg Se per day, after an initial charging period of 14 days.[8,9] Therefore, after the day 0 administration of the treatments, additional blood samples were taken from Group A animals at days 42, 77 and 135. Because of the equilibration time lag of the Group A bolus, the recorded blood Se concentration data for Group A animals was adjusted to the sample time 14 days ahead through experimental day 121. This allowed for equal comparisons amongst the treatments. For example, the 14-day blood Se concentration data in the results for Group A animals was actually taken from the 28-day samples. The 28-day data for Group A was taken on day 42 of the experiment, and the 49-day blood Se data was taken from samples on day 63. The 63-day blood Se data for Group A was from blood samples taken on day 77, and the 121-day data was from samples taken on day 135. Sample Se concentration values for days 183, 293 and 365 were the same for all groups.

Heifers were examined on each sampling date for physical evidence of alopecia, lameness, coronitis, or other physical indications of excess Se by evaluators blinded to the treatments. The cattle were subjected to the standard husbandry procedures, including health observations, vaccinations, dewormings and weighing, employed at the Sierra Foothill Research and Extension Center.

Statistical analysis

Preliminary analysis showed increasing variance with increasing blood Se concentrations. Therefore, a log transformation was performed on the blood Se concentration data and analysis of variance was performed using a repeated measures design in Proc Mixed of SAS.[c] Weight gain data were maintained in its original form for analysis of variance using a Proc Mixed in SAS.[c]

Results and Discussion

The 3 mg of Se supplemented per day for 240 days (Group A-2X) raised the blood Se concentration to a high observed value of 231 ng/ml (at day 183), a level safely above deficiency without threatening toxicity.[12] In addition, there was no evidence of excess Se intake in any of the three treatment groups at any time during the study (lameness, alopecia, brittle hair, coronitis).

At all times after treatment, blood Se concentrations were higher for the supplemented groups (A-1X, A-2X and B) than for the control group ($P<0.0001$, Table 1). Type of supplementation had no effect on blood Se concentrations until day 121. On day 121, Groups A-2X and B had higher blood Se concentrations than Group A-1X ($P=0.0001$ and $P=0.0046$, respectively). The A-2X 121-day data was from blood taken on day 135 because of the delay in activating the osmotic pump. Thus, these animals had received additional Se during this time. At days 183 and 293, all four groups had blood Se concentrations significantly different from one another; A-2X had the highest blood Se concentrations (231.1 ± 22.7 and 133.4 ± 13.4 ng/ml), with groups B (136.8 ± 23.0 and 75.8 ± 17.9 ng/ml), A-1X (114.3 ± 16 and 34.8 ± 8.8 ng/ml), and C (21.26 ± 2.8 and 15.53 ± 2.7 ng/ml) having descending Se blood concentrations, respectively. On day 365, all treatments resulted in higher blood Se concentrations than the control ($P<0.001$). In addition, Group A-2X and Group B remained significantly different ($P<0.001$) from Group A-1X. Furthermore, both Group A-2X and B animals maintained blood Se concentrations above 50 ng/ml throughout the trial (365 days). Blood Se concentrations below 50 ng/ml are associated with clinical deficiency symptoms such as retained placenta or NMD.[12]

Group A-1X, Group A-2X and Group B cattle gained 25.1, 51.0 and 25.7 lb (11.4, 23.2 and 11.7 kg) more than the 219.6 lb (99.8 kg) gain of the control animals ($P<0.001$). In addition, Group A-2X gained 25.9 and 25.3

Table 1. Mean (± SEM) blood selenium (Se) concentrations (ng/ml) by treatment from 28 days prior to Se administration to 365 days after initial Se administration. Data for Groups A-1X† and A-2X† has been shifted 14 days to coincide with delayed release associated with the osmotic pump sustained-release Se bolus†.

Treatment†	Day -28	Day 14	Day 28	Day 49	Day 63	Day 121	Day 183	Day 293	Day 365
A-1X	9^a ± 5	88^b ± 5	118^b ± 5	138^b ± 5	159^b ± 5	136^b ± 4	114^b ± 4	35^b ± 4	25^b ± 4
A-2X						202^c ± 4	231^d ± 4	133^d ± 4	71^c ± 4
B	9^a ± 5	78^b ± 5	110^b ± 5	145^b ± 5	160^b ± 5	174^c ± 3	137^c ± 3	76^c ± 3	67^c ± 3
C	9^a ± 5	7^a ± 5	7^a ± 5	8^a ± 5	9^a ± 5	12^a ± 3	21^a ± 3	16^a ± 3	15^a ± 3

†A-1X, one Dura-Se® sustained-release Se bolus on day 0; A-2X, one Dura-Se® sustained-release Se bolus on day 0 and day 121; B, one Se-365® Se bolus on day 0; C, no selenium supplementation.

[a,b,c,d] Means without a common superscript differ ($P<0.05$).

lb (11.8 and 11.5 kg) more than ($P<0.001$) Group A-1X and Group B, respectively, suggesting a beneficial effect of maintaining higher blood Se concentrations. The increased gain associated with Se supplementation in this study is substantial; however, previous reports have shown varied results.[10,13] These disparate results may be due to the length of the trial, sample size and the secondary nutrients available to the animal. In this 365-day study, animals on California foothill rangeland were provided no mineral supplementation other than Se to the treatment groups.

Conclusions

This study demonstrates the safety and efficacy of a new bolus designed to administer Se to grazing cattle. Furthermore, this study suggests that low blood Se concentrations may inhibit growth and reports a significant increase in growth with higher blood Se concentrations compared to Se-deficient controls.

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Endnotes

[a] Dura-Se® bolus, Schering-Plough Animal Health, Summit, NJ 07901
[b] Se-365 selenium bolus, Pacific Trace Minerals, Inc., Clarksburg, CA 95612
[c] SAS Institute, Inc., Cary, NC 27513

References

1. Agergaard N, Jensen PT: Procedure for blood glutathione peroxidase determination in cattle and swine. *Acta Vet Scand* 23:515-527, 1982.
2. Burrows GE, Brodie B, Thedford TR: Selenium supplementation for young beef cattle in Kenya. *Bull An Hlth Prod Afr* 27:139-143, 1979.
3. Byers FM, Moxon AL: Protein and selenium levels for growing and finishing beef cattle. *J Anim Sci* 50:1136-1144, 1980.
4. CAHFS Laboratory System Annual Report 2000. School of Veterinary Medicine, UC Davis, pp 24-25, 2001.
5. Campbell DT, Maas J, Weber DW: Safety and efficacy of two sustained-release selenium supplements and the associated placental and colostral transfer of selenium in beef cattle. *Am J Vet Res* 51:813-817, 1990.
6. Council for Agricultural Science and Technology: Risks and benefits of selenium in agriculture. Ames, Iowa, CAST, pp 5-17, 1994.
7. Dunbar JR, Norman BB, Oliver MN: Preliminary report on the survey of selenium whole blood values of beef herds in twelve central and coastal California counties, in *Selenium Contents in Animal and Human Food Crops Grown in California*, pp 81-83. Cooperative Extension, University of California Division of Agriculture and Natural Resources, Publication 3330. Oakland, California, 1988.
8. Eckenhoff JB: Extended duration, programmable, rate controlled dosage forms to meet the needs of the animal health business. Proc 1986 Mid-Year Drug Meeting, sponsored by the Animal Health Institute, 1986.
9. Eckenhoff JB: Veterinary dosage forms using principles of osmosis. *Proc International Symposium Controlled Release Bioactive Material* 15:227-230, 1998.
10. Koller LD, South PJ, Exon JH, Whitbeck GA: Selenium deficiency of beef cattle in Idaho and Washington and a practical means of prevention. *Cornell Vet* 73:323-332, 1983.
11. Logan EF, Rice DA, Smyth JA, Ellis WA: Weak calf syndrome and parenteral selenium supplementation. *Vet Rec* 126:163-164, 1990.
12. Maas J: Diagnosis and management of selenium-responsive diseases in cattle. *Compend Contin Educ Pract Vet* 7:393-399, 1983.
13. Swecker WS, Eversole DE, Thatcher CD, Blodgett DJ, Schurig GG, Meldrum JB: Influence of supplemental selenium on humoral immune responses in weaned beef calves. *Am J Vet Res* 50:1760-1763, 1989.
14. Tracy ML, Moller G: Continuous flow generation for inductively coupled argon plasma spectrometric analysis. Part I: Selenium. *J Assoc Anal Chem* 73:404-410, 1990.
15. Williams JD: A survey into selenium deficiency in cattle in Northern California. Master of Preventative Veterinary Medicine Thesis, University of California, Davis, 1980.

Abstract

Beef herd poisoning due to ingestion of tansy ragwort in southwestern Ontario

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Deaths attributed to *Senecio jacobaea* were investigated. The animal presented was a mature bull that was lethargic and dragging its feet. The bull was euthanized and 3 other cows died. Significantly, this disease has not been documented in Ontario before, and clinical signs of icterus or hepatoencephalopathy were not observed.