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# Depletion of selenium in blood, liver and muscle from beef heifers previously fed forages containing high levels of selenium

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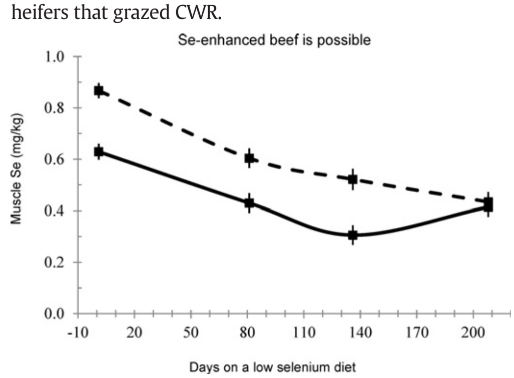
## HIGHLIGHTS

- Se level depletion from blood, liver, muscle in heifers previously on Se-enriched forages
- Se levels decreased but that in liver was more than in whole blood, with muscle lowest
- Low body weight gains the first 82 d of feeding but increased substantially afterwards
- Grazing forages containing high levels of Se can successfully produce Se-enriched beef

## GRAPHICAL ABSTRACT

Concentration of Se (mg/kg wet weight) in muscle tissue from beef heifers that had previously grazed creeping wildrye (CWR; solid line) or tall wheatgrass (TWG; dashed line) for 165 d and were fed a low Se diet for 209 d. Concentration of Se in muscle tissue remained higher in heifers that grazed TWG except at 209 d, compared to heifers that grazed CWR.

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## ABSTRACT

Beef heifers which had grazed 'Jose' tall wheatgrass (TWG; *Thinopyrum ponticum* var. 'Jose'; 10 heifers) and creeping wildrye (CWR; *Leymus triticoides* var. 'Rio'; 10 heifers) with high levels of Se (>2 mg/kg DM) due to growth in saline soils, accumulated high Se levels in blood, liver and muscle (Juchem et al., 2012). We determined the decrease in Se levels in blood, liver and muscle from these heifers, particularly the decrease of Se in muscle, in order to determine the maximum feeding length of a low Se diet (LSeD) required sustaining Se-enriched beef. Immediately after grazing, all heifers were fed a LSeD containing <0.30 mg/kg DM for 209 d. Blood, liver and muscle samples, as well as body weight (BW), were collected at the beginning and end of the LSeD feeding period and at intermediate times. After grazing, CWR and TWG heifers had similar BW, but TWG heifers had higher levels of Se in whole blood (1.19 *versus* 0.81 mg/L), liver (2.67 *versus* 2.12 mg/kg wet weight (WW)), and muscle tissue (0.87 *versus* 0.63 mg/kg WW) than CWR heifers. The Se levels decreased with exposure time to the LSeD and, at 82 d of feeding the LSeD, Se levels were 77 (liver), 49 (blood) and 31% (muscle) lower. The BW gains for both groups were ~0.5 kg/d during the first 82 d of feeding, but increased thereafter. Levels of Cu in serum (0.28 *versus* 0.50 mg/L) and liver (1.14 *versus* 22.9 mg/kg WW) were lower at the end of grazing in TWG heifers,

*Abbreviations:* ADF, acid detergent fiber with residual ash; aNDFom, neutral detergent fiber exclusive of residual ash; BW, body weight; Cu, copper; CP, crude protein; CWR, creeping wild rye; DM, dry matter; LSeD, low Se diet; SJV, San Joaquin Valley; TWG, tall wheatgrass; WW, wet weight.

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and suggested a potential Cu deficiency. Grazing forages with high Se levels can result in Se-enriched beef, but a LSeD feeding period of <82 d is required to maintain enrichment.



## 1. Introduction

The western San Joaquin Valley (SJV) of California (USA) is an important agricultural area, but salinity and drainage problems have challenged sustainability of its agricultural production (Letey et al., 2002). Saline soils unsuitable for salt sensitive crops generate income through production of salt tolerant forages, and agricultural drainage water can be a water source for such production systems (Suyama et al., 2007b). The potential of saline soils irrigated with drainage water for forages that have adequate dry matter (DM) production and forage quality has been demonstrated (Suyama et al., 2007a), but high levels of elements such as Se and S remained a concern (Suyama et al., 2007b; Robinson et al., 2004; Grattan et al., 2004a).

Selenium plays an important role in animal and human well-being and health as an essential nutrient, and natural antioxidant, as well as a potentially toxic element. Limited evidence demonstrates the health promoting properties of Se in humans, such as anticarcinogenic properties (Clark et al., 1996; Reid et al., 2002; Vogt et al., 2003; Waters et al., 2003) and positive impacts on reproductive health (Krsnjavi et al., 1992; Boitani and Puglisi, 2008). The most common option to increase Se intake by humans is Se supplementation tablets. While production of Se-enriched beef (Knowles et al., 2004) is an option, since beef is already a source of dietary Se, the Se concentration of beef products varies by geographical origin (Finley et al., 1996). In 2007, the average red meat consumption in the United States was 85 g/person/d (Daniel et al., 2011), and Finley et al. (1996) calculated that daily intakes of Se from beef in the USA are regional and range from 40 to 100 μg/d. One study supplemented month old calves with 0.3 mg/kg dietary Se for 2 mo and increased the Se concentration in striated muscles from 0.092 to 0.263 μg/g (Pavlata et al., 2001). Fisinin et al. (2009) calculated that 100 g of such a Se-enriched beef would provide 40 to 50% of the USDA recommended daily Se allowance. Consumption of Se-enriched beef is also a safe option since, in order to reach an intake of 400 μg/d, the maximum safe dietary intake, a person would have to consume >1 kg of meat/d for 13 d.

We addressed limitations of forage production on saline soils to grow beef cattle, and its potential to create cattle with Se-enriched beef (Juchem et al., 2012). Because body weight (BW) gains of cattle that grazed high Se CWR and TWG were limited by forage nutrient density, a confinement period after grazing is required to achieve industry standard BW, marbling and subcutaneous carcass fat cover. However a standard low Se finishing diet will reduce the Se concentration in the beef, and so any Se-enriched beef premium would be lost.

Data on rates of Se depletion in blood, liver and muscle of beef heifers consuming Se-enriched forages is very limited. We hypothesized that Se depletion in muscle tissue would be slow enough that an appropriate finishing period would maintain a substantive Se enrichment level in beef. Thus the objective was to determine the extent of Se depletion within blood, liver and muscle from beef heifers that were previously Se loaded due to grazing forages containing high Se levels (*i.e.*, >2 mg/kg DM; Juchem et al., 2012) and the time necessary to sustain elevated levels of Se in muscle. In addition, due to the results, this study discusses the Se/Cu interaction in blood serum and liver.

## 2. Materials and methods

### 2.1. Cattle, housing and diets

Angus beef heifers which had grazed 'Jose' tall wheatgrass (TWG; *Thinopyrum ponticum* var. 'Jose') and creeping wildrye (CWR; *Leymus triticoides* var. 'Rio') that contained high levels of Se (>2 mg/kg DM), due to growth in saline soils, accumulated high Se levels in blood, liver and muscle (Expt. 2 of Juchem et al., 2012). Twenty of these 23 heifers (10 from each forage group) were selected to investigate Se depletion when fed a low Se finishing diet. The two heifer groups (*i.e.*, CWR and TWG) had similar BW at the beginning of the study, 325 and 315 kg respectively, and were ~14 mo old when they were moved to a feedlot ~20 km from the grazing site in Red Rock Ranch located southwest of Five Points (CA, USA). All heifers were housed in a drylot of ~30 m width and 20 m depth, with 30 head spaces at the feed bunk, and had continuous access to fresh water. All heifers were dewormed at the beginning of the feeding phase with 0.5 mg of moxidectin/kg of BW utilizing a pour-on formulation (CYDECTIN® Pour-On, Fort Dodge Animal Health, Fort Dodge, IA, USA), and were fed alfalfa hay during the first 25 d. A total mixed ration (Table 1) containing a low Se level (<0.30 mg/kg DM; LSeD) was then fed for 20 to 30 g/kg refusals, and formulated to meet, or exceed, requirements of growing heifers for a BW gain of 1.1 kg/d (NRC, 2000).

### 2.2. Sample collection

#### 2.2.1. Feed samples, blood and body weight

Feed ingredient samples were collected from every load into premarked plastic bags and stored at room temperature until chemical analysis (Table 1). One load of mineral mixture was fed during the study, but two samples were analyzed for its mineral composition.

Blood was collected from the jugular vein into evacuated tubes (Vacutainer®, Becton Dickinson, Franklin Lakes, NJ, USA), whereas EDTA was the anticoagulant for Se determination in whole blood (BD Hemogard™, 10.8 mg of $K_2$EDTA). Samples for serum mineral levels (BD Hemogard™) were collected at 1, 82, 137 and 209 d and centrifuged at 1500 ×g for 10 min at 5 °C. Whole blood samples were

**Table 1**
Chemical composition (g/kg 105 °C DM[a]) of ingredients and calculated composition of the total mixed ration (TMR) fed to the growing heifers.

| | Hay, Alfalfa | Straw, wheat | Corn grain, rolled | Almond, hulls | Mineral mixture[b] | TMR[c] |
|---|---|---|---|---|---|---|
| *n* | 5 | 3 | 1 | 2 | 2 | – |
| DM, g/kg | 916 | 937 | 905 | 897 | 898 | 737 |
| CP | 170 | 40.4 | 11.3 | 45.9 | 69.0 | 95.2 |
| Fat | 17.8 | 10.8 | 53.4 | 13.4 | 33.0 | 28.2 |
| aNDF[d] | 359 | 677 | 168 | 460 | 106 | 304 |
| Ash | 144 | 178 | 97 | 77 | 125 | 122 |
| P | 1.50 | 0.50 | 4.97 | 2.00 | 5.30 | 2.89 |
| Ca | 26.30 | 3.20 | 7.40 | 2.70 | 20.80 | 16.73 |
| Mg | 2.90 | 2.00 | 3.19 | 1.20 | 2.50 | 2.68 |
| S | 3.16 | 1.70 | 1.94 | 0.45 | 1.86 | 2.28 |
| K | 14.2 | 21.4 | 6.1 | 31.2 | 4.2 | 13.3 |
| Na | 3.28 | 1.99 | 0.09 | 0.22 | 21.36 | 4.13 |
| Cl | 8.80 | 11.50 | 0.60 | 1.10 | 0.90 | 4.84 |
| Zn, mg/kg | 22.8 | 14.9 | 60.4 | 14.2 | 157.9 | 47.3 |
| Mn, mg/kg | 63.2 | 62.0 | 37.6 | 22.3 | 88.5 | 54.2 |
| Fe, mg/kg | 1040 | 1627 | 1671 | 1408 | 216 | 1180 |
| Cu, mg/kg | 76.4 | 37.3 | 43.0 | 44.0 | 278.5 | 85.8 |
| Se, mg/kg | 0.23 | 0.14 | 0.18 | 0.04 | 0.24 | 0.19 |

[a] Dry matter.
[b] The mineral mixture contained 811 g of ground corn/kg on an as fed basis.
[c] Calculated chemical composition of total mixed ration (TMR) based on analyzed chemical composition of individual ingredients. The TMR contained (g/kg DM): 451 g alfalfa hay, 41.5 g wheat straw, 264 g rolled corn grain, 125 g almond hulls, and 118 g mineral mixture. Fresh water was added at 260 g/kg of DM to increase the moisture content.
[d] Neutral detergent fiber assayed with a heat stable amylase, expressed exclusive of residual ash.