EFFECT OF SUPRANUTRITIONAL AND ORGANICALLY-BOUND DIETARY SELENIUM ON THE NUTRITIVE VALUE AND CASE LONGEVITY OF BEEF

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Background

Elevated dietary selenium (Se) confers positive health benefits. Although some molecular forms are more potent than others (Ip et al., 2000; Finley and Davis, 2001), total Se intake must be three to ten fold the recommended dietary requirement for advantages, such as tumor inhibition, to be observed (Ip, 1998; Combs, 1999). As such, much effort has been devoted to identifying foods naturally high in or that can be readily enriched with Se (Finley et al., 1996; Lawler et al., 2004). Recently, we reported a 3.4-fold increase in the Se content of muscle from beef steers finished on a supranutritional organically-bound Se (2.7 mg·kg diet^{-1}) diets (Lawler et al., 2004). These diets did not negatively influence steer performance or carcass characteristics. Although some studies have documented the affects of inorganic versus organically-bound forms of dietary Se on the case life characteristics of meat, none have been conducted in beef describing the influence of supranutritional dietary Se. We hypothesized that skeletal muscle, from steers fed supranutritional Se as high Se grain, will have increased Se content, and not differ in nutritive quality and case longevity than muscle from steers fed adequate Se.

Objectives

Assess the nutritive value of *M. gastrocnemius*, and case longevity characteristics of *M. longissimus* from beef steers fed supranutritional dietary Se in the form of high Se wheat.

Materials and methods

Twenty crossbred beef steers (351 ± 24 kg initial body weight [BW]), individually fed (120 days) either 0.35 (n = 11; adequate; NRC, 1996) or 2.70 (n = 9; supranutritional) mg Se·kg BW^{-1}·day^{-1}, were utilized to assess the affects of supranutritional organically-bound Se on the nutritive value of the *M. gastrocnemius* (rear shank), and case longevity of the *M. longissimus* (strip loin; NAMP #180). The Se content of the adequate and supranutritional Se diets provided 9.5 and 65 mg·kg^{-1} BW·d^{-1}, respectively. Diets were similar in feed composition and nutrient content (25 % wheat, 39 % corn, 25 % grass hay, 5 % desugared molasses, and 6 % wheat middling based supplement; 14.0 % crude protein, 2.12 Mcal NEm·kg^{-1} DM, and 1.26 Mcal NEg·kg^{-1}; values expressed on a dry matter basis). High Se wheat (10.3 mg·kg^{-1}) directly replaced the adequate Se wheat (0.40 mg·kg^{-1}) to deliver the supranutritional Se treatment.

Immediately following slaughter (day 121), carcasses were placed in a cooler (4°C) for 48 hours. *M. gastrocnemius* samples (~3 g wet basis) were collected a 0, 6, 12, 24, 36 and 48 hours of the chilling period, wrapped in foil, snap frozen in liquid nitrogen and stored (-80°C) for subsequent analyses. The hour 0 *M. gastrocnemius* samples were analyzed for dry matter, ash, nitrogen, pH, lipids (AOAC, 1990), expressible moisture (Jauregui et al., 1981), and Se. Hydride generation atomic absorption spectrometry was used to analyze for Se following digestion of samples with nitric acid (Finley et al., 1996). All samples collected over time were analyzed for glutathione peroxidase (GSH-Px) activity. The coupled enzyme method of Paglia and Valentine (1967) was used to measure GSH-Px activity using H_2O_2 as the substrate and NADPH as the source of reducing equivalents. A BioRad assay kit (Hercules, CA) was used to determine protein concentrations (Quant microplate reader, Bio-Tek Instruments, Inc., Winooski, VT).

The *M. longissimus lumborum* was removed at the completion of the chilling period (48 hours), and two steaks (2.5 cm) were cut from the anterior end and weighed. Each steak was placed on a styrofoam tray, wrapped with a clear oxygen-permeable film, and displayed in a retail cooler (2.78ºC) for 12 days under fluorescent lighting with 150 lumens of light at the meat surface. Hunter L, a and b were measured daily with a Minolta CR-310 colorimeter (Minolta Corp., Ramsey, NJ) using a 50-mm diameter measurement

area, D65 light source with zero angle of reflectance. Additional subjective measurements were estimated using a scale from 1 (purplish red) to 8 (very dark red); a score of 3 was considered the ideal oxymyoglobin state. To measure drip loss, steaks were removed from their package and exudates on days 2, 4, 8, and 12, weighed, re-wrapped, and returned to the cooler. The amount of drip loss was determined as a percentage of initial weight. At the conclusion of the case life study, steaks were removed from the retail cooler, weighed, and cooked on flat grills to an endpoint temperature of 71 ± 3ºC. Internal temperature was evaluated using a digital thermometer placed in the approximate geometric centre of each steak. The steaks were weighed again after cooking, and cooking loss was calculated as a percentage of initial raw weight.

Nutrient values, moisture measurements and pH were analyzed as a completely randomized design, and drip loss, colour evaluations and GSH-Px data were analyzed as repeated measures using the mixed models procedure of SAS (v8.0; SAS, Cary, NC). The autoregressive order one and the spatial power law covariance structures were used for drip loss and colour evaluations, and GSH-Px activity analyses, respectively.

Results and discussion

M. gastrocnemius samples from steers fed high Se wheat diets had greater Se concentration and GSH-Px activity than the muscle from steers fed adequate Se (Table 1; $p < 0.05$). No sampling hour x treatment interaction was detected for GSH-Px activity throughout the chilling period ($p > 0.05$). This increase in muscle Se content was expected and consistent with other studies where organically-bound forms of Se were fed to barrows (Kim and Mahan, 2001) and steers (Hientz et al., 2001). The predominant form of selenium in high selenium grains and forages is selenomethionine (Olson et al., 1970; Djujic et al., 2000). This selenoamino acid is interchangeable with methionine during translation (Waschulewski and Sunde, 1988; Butler et al., 1989), resulting in Se being temporarily sequestered in the muscle and away from selenoprotein synthesis. However, once the rate of selenomethionine incorporation into protein has been saturated, Se would be released for selenoprotein synthesis at a rate equivalent to methionine/selenomethionine catabolisM. Compared to the 3.4-fold increase in Se concentration, the lack of proportional increase in GSH-Px activity confirms that the maximal responsiveness of GSH-Px synthesis to dietary Se is near or only slightly greater than adequate dietary requirements (Berggen et al., 1999). Although supranutritional Se had no influence on colour change ($p > 0.16$), steaks (*M. longissimus*) from steers fed the high Se wheat diets had less moisture lost (drip loss) over the 12-day case life study (Table 2; $p < 0.01$). This indicates that a supranutritional Se diet results in the mitigation of protein breakdown and subsequent release of water.

Conclusions

Supranutritional dietary selenium, from high selenium wheat, enhanced selenium concentration and glutathionine peroxidase activty of the *M. gastrocnemius*, and decreased drip loss from the *M. longissimus*. Caution should be used when assuming that enhanced Se concentration of a meat product will result in greater product stability during case display. This study clearly demonstrates the nutritive value of beef muscle products can be enhanced using feeds naturally high in selenium without negatively affecting the quality or case longevity of beef muscle.

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Table 1. Post-slaughter (48 hours) attributes of the *M. gastrocnemius* from steers fed either an adequate or supranutritional selenium diet formulated from high selenium wheat.

	Dietary Selenium[1]			
Item	Adequate (0.35 mg·kg diet^{-1})	Supranutritional (2.7 mg·kg diet^{-1})	Standard Error	*P* Value[2]
Dry matter, %	28.51	28.64	0.40	0.81
Selenium[3], µg·g^{-1}	0.37	1.24	0.05	<0.01
Ash[3], %	1.08	1.07	0.01	0.89
Crude protein[3], %	23.21	22.83	0.19	0.16
Lipid[3], %	5.06	5.38	0.46	0.61
pH	5.47	5.48	0.03	0.68
Expressible moisture[4], %	39.25	40.04	1.46	0.70
Glutathione peroxidase[5]	262.06[a]	326.27[b]	19.32	0.04

[1]Dietary selenium expressed on a dry matter basis.
[2]*F* test probability.
[3]Expressed on an "as is" basis.
[4]Expressed as a percentage of initial weight.
[5]Activity = *m*U·mg protein^{-1}·minute^{-1}. Multiple samples were collected during the chilling period, and data were analyzed as repeated measures. No time x treatment interactions were detected; as such, the main effect least squares means are reported.
[ab]Differing superscript within row indicates difference ($P < 0.05$).

Table 2. Case-life[1] characteristics of the *M. longissimus* from steers fed either an adequate or supranutritional selenium diet formulated from high selenium wheat.

Item	Dietary Selenium[2]		Standard Error	*P* Value[3]
	Adequate (0.35 mg·kg diet^{-1})	Supranutritional (2.7 mg·kg diet^{-1})		
Drip Loss, %	3.18a	2.22b	0.22	0.01
Cooking loss[4], %	17.83	18.69	1.15	0.59
Color Estimates[5]				
Hunter a	15.81	16.46	0.32	0.17
Hunter b	6.02	6.23	0.11	0.20
Hunter L	41.03	40.63	0.44	0.53
Subjective[6]	4.64	4.58	0.08	0.59

[1]The case-life was conducted over 12 days and data were analyzed as repeated measures. No time x treatment interactions ($p > 0.05$) were detected; as such, the main effect least squares means are reported.
[2]Dietary selenium expressed on a dry matter basis.
[3]*F* test probability.
[4]Expressed as a percentage of initial weight.
[5]Minolta CR-310 colorimeter, Minolta Corp., Ramsey, NJ.
[6]1 = purplish red and 8 = very dark red; a score of 3 was considered the ideal oxymyoglobin state.
[ab]Differing superscript within row indicates difference ($P < 0.05$).