EFFECT OF SELENIUM SOURCE ON SELENIUM DIGESTIBILITY AND RETENTION IN EXERCISED THOROUGHBREDS

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Introduction

Performance horses compete in a wide variety of athletic events ranging from high speed racing to 100 mile endurance rides. These types of exercise are known to induce oxidative stress, leading to the generation of free radicals. An increased generation of free radicals may induce lipid peroxidation and tissue damage in both the respiratory system and working muscle. This is particularly true if the animal has a deficient or impaired antioxidant status. Reddy et al. (1998) studied the role of vitamin E and selenium (Se) during exercise-induced oxidative stress in the pulmonary tissue of rats. Vitamin E and/or Se deficiency resulted in generation of free radicals as revealed by electron spin resonance (ESR) spectra in lung tissue, indicating the onset of oxidative stress. When the rats were subjected to a single bout of exhaustive exercise, there was an additional increase in the generation of oxy-free radicals. However, no such signals were recorded in the lung tissue of vitamin E and Se supplemented animals when subjected to a similar exercise program, suggesting that protection is offered by vitamin E and Se in combating oxidative stress. Many antioxidants, including glutathione peroxidase (GSH-Px), are selenoproteins making selenium an extremely important mineral for performance horses.

Although the Food and Drug Administration (FDA) has approved maximal selenium supplementation at 0.3 mg/kg of dry matter in complete feeds for cattle, sheep, and swine (FDA, 1987), selenium supplementation of equine feeds is restricted only by nutritional recommendations and industry practices (NRC, 1989). The selenium requirement for mature idle horses was estimated by the NRC to be 0.1 mg/kg of diet. This requirement is based on studies that evaluated the relationship between selenium intake and blood selenium in mature idle horses (NRC, 1989). Shelle et al. (1985) investigated the effect of supplemental selenium on plasma selenium and on glutathione peroxidase in Arabian and crossbred horses subjected to a conditioning program. They reported that conditioning increased erythrocyte glutathione peroxidase activity and suggested that horses at high work intensities may have higher requirements for selenium than the 0.1 ppm requirement suggested by the NRC. Stowe (1998) has suggested that the appropriate concentration of selenium in the total diet of a horse is 0.3 ppm. This would mean that if a concentrate mix was 50% of the diet and the forage component of the diet supplied 0.06 ppm Se, the grain mix would need to be roughly 0.6 ppm.

Selenium in forages and seed grains is normally present as organic selenium in the form of selenocystine, selenocysteine, and selenomethionine. Sodium selenite and sodium selenate are common inorganic sources of supplemental selenium for horses, and evidence in horses (Podoll et al., 1992) indicates there is no difference between them in potency as measured by blood selenium status. Measurement in laboratory animals,

however, shows that organic plant sources of Se are more potent than inorganic (Frape, 1998). No studies have measured the digestibility and retention of selenium from different selenium sources in horses. Therefore, the following study was conducted to evaluate how exercised Thoroughbreds digest and retain selenium from either sodium selenite or Se-enriched yeast supplemented diets.

Materials and Methods

Four mature trained Thoroughbred geldings were used in a two period switch back design trial. During each period, two horses were fed hay and unfortified concentrate supplemented daily with 2.90 mg of selenium from sodium selenite. SELENITE rations averaged 0.41 ppm Se with ~77% of the total Se provided by the selenite. The other two horses received hay and unfortified concentrate supplemented daily with 2.76 mg of selenium from a Se-enriched yeast (Sel-Plex, Alltech, Inc., Nicholasville, KY). Se-YEAST rations averaged 0.40 ppm Se with ~75% of the total Se provided from the yeast.

During period 1, the horses were fed their selenium supplemented diets for 5 weeks. During the first 4 weeks, the horses were exercised 3 days per week on a high speed treadmill and 3 days per week on a mechanical horse walker. The horses were housed in box stalls at night and were turned out into paddocks during the day with muzzles to prevent grazing.

During week 5 of period 1, a 5 day complete collection digestion trial was conducted. The horses were fitted with collection harnesses that allowed the complete and separate collection of feces and urine. Daily fecal and urinary output was measured and daily samples of each were frozen for later selenium analysis. On day 3 of the digestion trial, the horses completed a competition exercise test (CET) on the high speed treadmill which was designed to simulate the physiological and metabolic stresses of the speed and endurance test of a three-day event (Marlin et al., 1995). The CET was performed on an inclined treadmill (3^0) and consisted of a 10 min walk (*Phase A*) (1.4 m/s), 10 min trot (*Phase A*) (3.7 m/s), 2 min gallop (*Phase B*) (10.7 m/s), 20 min trot (*Phase C*) (3.7 m/s), 10 min walk (*Phase C*) (1.4 m/s) and 8 min canter (*Phase D*) (9.0 m/s). Following exercise, the horses were hand walked for an additional 30 min. Whole blood and plasma samples were taken from the horses immediately before and after the CET and 4 h and 24 h post exercise. Packed cell volume (PCV) was measured in each blood sample using a Coulter Counter S560 (Coulter Electronics, Hialeah, FL, USA). Feed, feces, urine and blood were analyzed for Se according to the fluorometric method of AOAC (1995). Red blood cell (RBC) Se was calculated using the following equation: [Whole blood Se-(plasma Se*(1-PCV))]/PCV.

Following period 1, the selenium supplementation received by each horse was switched for an additional 3 week period. During the first 2 weeks of period 2, the horses followed the same exercise schedule as they had during period 1 followed by a complete collection digestion trial and CET during week 3. The digestibility and retention of selenium from the two supplements were calculated and compared using least squares analyses of variance with general linear models procedures. Data were analyzed using a model that included horse, period and treatment as main effects.

Results and Discussion

Selenium digestibility and retention are shown in Table 1. Horses supplemented with SELENITE excreted significantly more fecal Se than when supplemented with Se-YEAST ($p<.05$). The apparent absorption of SELENITE and Se-YEAST selenium averaged 51.1% and 57.3%, respectively. These digestibility values are intermediate between those reported for pigs and ruminants. In ruminants, selenium absorption is around 35% while in pigs, absorption values of 75-85% have been reported (Leavander, 1986). Mahan and Parrett (1996) measured selenium digestibility in growing pigs weighing around 52 kg. They found that the apparent selenium digestibility of both selenite and Se-enriched yeast averaged about 75% when fed at supplemental levels of 0.3 ppm.

Table 1. Effect of selenium source on balance measurements in exercised horses

	SELENITE	Se-YEAST	SEM	Treatment effect
Se balance, mg/d				
Intake	3.76	3.72	.05	NS
Urine	1.16	1.10	.05	NS
Feces	1.85	1.58	.02	P<.05
Retention	0.75	1.04	.07	P=.11
Apparent absorption (%)	51.1	57.3	1.4	P<.10
Retention (% of intake)	20.4	27.8	1.3	P<.05
Retention (% of absorbed)	39.3	48.6	1.4	P<.05

Selenium retention was significantly higher when the Se-enriched yeast was the added dietary Se source ($p<.05$). Most of the difference in selenium retention was the result of increased selenium absorption since there was no difference in average daily urinary Se excretion between the two supplemental sources. Mahan and Parrett (1996) also found increased Se retention with Se-enriched yeast in growing pigs, but in contrast to the present study, the difference was due to increased urinary excretion of Se in the selenite supplemented animals.

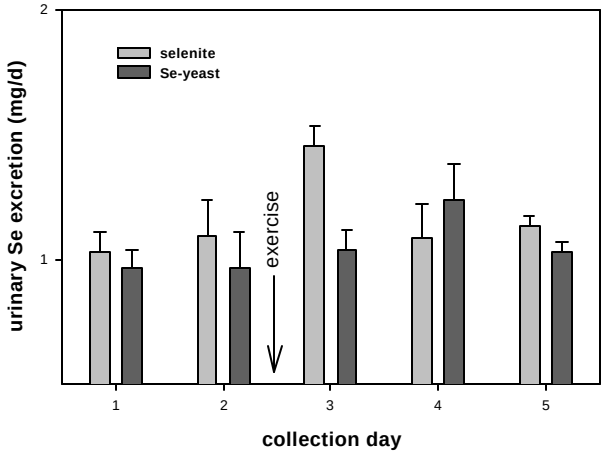

Figure 1. Daily urinary selenium excretion

While average daily urinary Se excretion was not different between treatments, Se excretion following a bout of exercise was affected by Se source. The horses completed the competition exercise test (CET) on the morning of day 3 of the 5 day collection. Following

exercise, Se excretion in the SELENITE group was significantly higher than during day 1 or day 2 of the collection period ($p<.01$)(Figure 1). A similar increase in excretion did not occur in the Se-YEAST group and during day 3 urinary Se excretion was lower in the Se-YEAST group compared to the SELENITE fed horses ($p=.06$).

Blood selenium values are shown in Table 2 and Figure 2. Before exercise, mean plasma values were slightly higher than reference values reported by Stowe and Herdt (1992), but similar to values reported by Shelle et al. (1985) and Snow et al. (1987). Whole blood values were typical for horses receiving Se supplementation (Shellow et al., 1985; Stowe and Herdt, 1992).

Table 2. Blood selenium before and after competition exercise test

	SELENITE	Se-YEAST	SEM	Treatment effect
Whole (ng/mL)				
Pre	205.1	201.0	19.4	NS
Post	216.8	224.5	16.4	NS
4 h	209.2	222.1	17.7	NS
24 h	202.8	198.8	8.2	NS
RBC (ng/mL)				
Pre	277.7	256.9	35.9	NS
Post	239.5	244.4	20.1	NS
4 h	265.2	273.6	39.8	NS
24 h	276.2	235.3	15.7	NS
Plasma (ng/mL)				
Pre	162.0	168.4	12.3	NS
Post	192.7	203.9	12.7	NS
4 h	176.9	192.1	6.5	NS
24 h	161.0	178.0	3.8	P<.10

Both plasma and whole blood Se increased post-exercise ($p<.01$). This agrees with Gallagher and Stowe (1980) who reported an increase in serum Se following a training jog in 45 Standardbred horses. RBC Se was similar between both treatment groups and there was a trend towards a decrease in RBC Se post-exercise. Plasma Se remained elevated in both treatments 4 h post-exercise ($p<.05$). By 24 h post-exercise, the SELENITE plasma Se had returned to pre-exercise levels, while plasma Se from the Se-YEAST supplemented group remained elevated. At this time, Se-YEAST plasma Se was higher than the SELENITE group ($p=.08$).

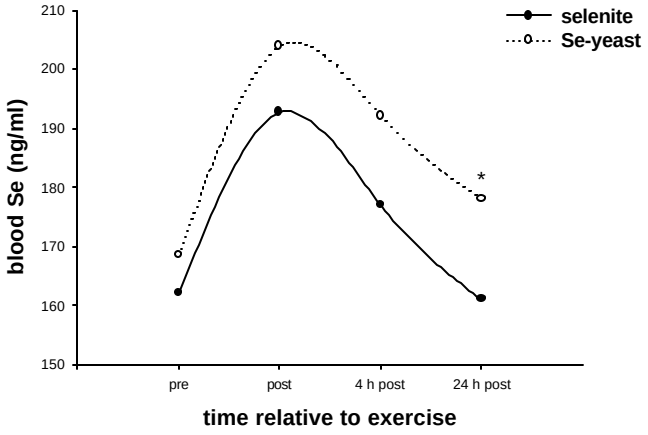

Figure 2. Plasma selenium before and after competition exercise

Conclusions

The digestibility of selenium in horses appears to be intermediate between ruminants and nonruminants. Selenium from Se-enriched yeast was more digestible than from sodium selenite, leading to a greater positive Se balance in these horses. The level of Se supplementation in this study was probably above the horse's requirement since every horse was in positive Se balance and blood Se values were on the high side of normal reference ranges. Since only one level of Se was fed, it is not possible to establish a Se requirement from these data.

Increased urinary Se excretion following exercise in the SELENITE group suggests that the requirement for Se by exercised horses may be dependent on Se source and exercise frequency. The exercise intensity used in this study resulted in an increase in plasma Se in both treatment groups. The source of this increased plasma Se may have been the red blood cells, since there was a trend towards lower RBC Se following exercise. Following exercise, SELENITE plasma Se returned to pre exercise levels while Se-YEAST plasma Se remained elevated at 24 h post exercise. Perhaps part of the Se that was mobilized from the RBC in the SELENITE group during exercise was voided in the urine, leading to an increase in urinary Se excretion during the subsequent 24 hour collection period. After absorption, red blood cells take up inorganic Se and return it to plasma in the reduced (i.e., hydrogen selenide) form, where it binds to plasma proteins and is transported to the liver to become part of the Se pool for selenoprotein formation (Combs and Combs, 1986). Some travels to the kidney and is excreted via urine. Organic selenium (selenoproteins) travels in the blood by amino acid transport mechanisms and is less likely to be lost through urinary excretion.

More research in needed to quantify the Se requirement of horses at different exercise intensities and to determine how the form of dietary Se affects antioxidant status.

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