Organic selenium may be powerful equine antioxidant

Newly FDA-approved organic selenium improves selenium status in exercising horses, weanlings and broodmares. Availability of selenium yeast represents a breakthrough in the equine industry that will assist equine professionals in addressing problems of marginal selenium status that affect the health and productivity of all classes of horses.

By AMY GILL and KATE JACQUES

Performance horses involved in heavy training and competition require excellent-quality feedstuffs chocked full of energy, vitamins and minerals to perform to their fullest potential. Many of the nutrients obtained through dietary means are utilized during exercise for various metabolic processes.

One of the minerals that must be obtained by horses from dietary sources is selenium. Intense exercise increases oxidative metabolism greatly, and because of this, increased oxygen radical formation occurs, causing cellular damage. As an antioxidant, selenium plays a key role in preventing cellular components from damage during exercise.

Selenium is a mineral found in forages and grains. Selenium in natural feeds for horses is normally present as the selenoamino acids selenocystine, selenocysteine and, most commonly, selenomethionine. Sodium selenite and sodium selenate are common inorganic sources of selenium. Some studies conducted with horses have shown little difference in potency between sources when measured as blood selenium status, but studies conducted in other species have shown that organic sources are more potent than inorganic sources.

When selenium is deficient in the diet, muscle damage can occur in the performance horse, and disorders can be manifested in several forms, including cardiomyopathy, myositis or muscle inflammation and white muscle disease (weak muscle). Selenium also plays an important role in limiting free radical damage that occurs during oxidation, the metabolic process by which fats, carbohydrates and proteins are converted to carbon dioxide, water and energy needed for body functions.

Oxidation is the breakdown of the cell's structure due to the action of oxygen-containing compounds. During the oxidative process, free radicals are produced, causing damage to cell structures and membranes, which are highly sensitive to this process.

Selenium is also an integral component of the enzyme glutathione peroxidase (GSH-Px), which counteracts the actions of free radicals, thereby protecting cell membranes. GSH-Px breaks down hydrogen peroxide created by muscles during normal metabolism by converting the hydrogen peroxide into water. If hydrogen peroxide is not broken down by GSH-Px, it builds up in the muscle, and catabolism of the tissues begins to occur.

In concert with vitamin E

Selenium also helps vitamin E work more efficiently. The functions of the two are closely related, and deficiencies of one can be compensated for to some extent if there is an adequate supply of the other. Vitamin E present in the cell membrane will decrease the formation of lipid peroxides. Selenium then acts in the intracellular fluid by promoting breakdown of the lipid peroxides that have formed.

Inadequate amounts of either vitamin E or selenium result in increased oxidation-induced damage and, therefore, similar effects of deficiency. The amount of either vitamin E or selenium the animal needs depends on the amount of the other available. When levels of vitamin E are insufficient, more peroxides form and more selenium is required. On the other hand, if levels of selenium are low, fewer peroxides can be removed, and more vitamin E is needed to prevent further peroxide formation. Ideally, maintaining optimum levels of both nutrients in the body will help to minimize oxidation-induced tissue damage.

Vitamin E and selenium function in different parts of the cell. Selenium is located in the hydrophilic (water-containing) areas inside the cell, while vitamin E is located in the fat-soluble areas of the cell membrane. Vitamin E's role in preventing the oxidation of cell membranes is enhanced with selenium, which takes toxic products and turns them into harmless compounds that the body can safely excrete.

Horses exposed to heavy conditioning, fast growth and pollution can benefit from the supplementation of organic selenium.

Interestingly, when the antioxidant vitamin E disables free radicals, it becomes a minor free radical itself. Other antioxidants such as vitamin C, alpha-lipoic acid and coenzyme Q10 can actually convert the radical form of vitamin E back to its antioxidant form. However, when vitamin C recycles vitamin E, it, too, changes to a free radical. Fortunately, alpha-lipoic acid and GSH-Px can both "recycle" vitamin C back into a potent antioxidant. This phenomenon is known as "antioxidant cycling," a term that de-

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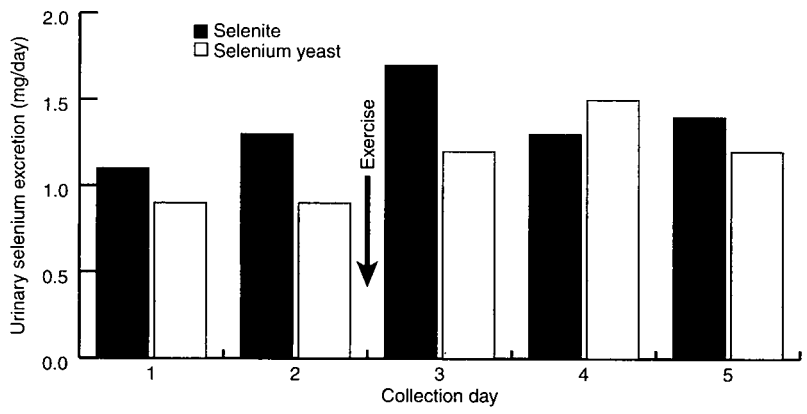
TABLE

Effect of selenium source on balance measurements in exercised horses (from Pagan et al., 1999)

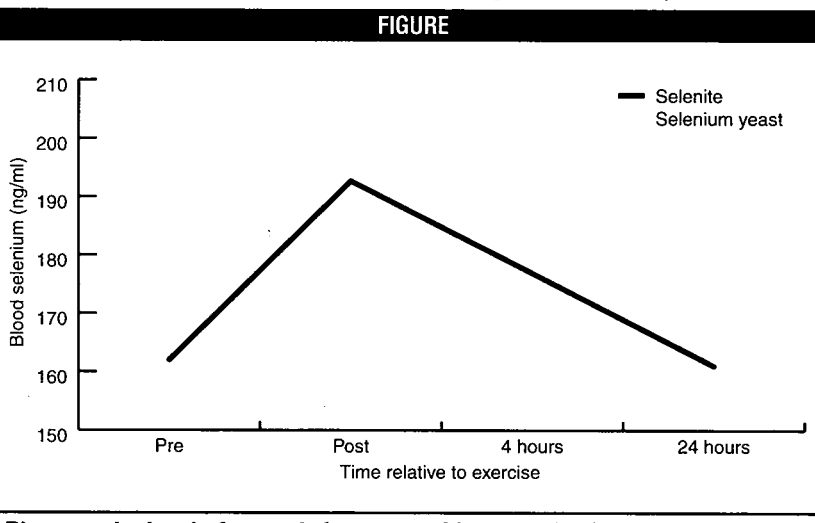
	Selenite	Selenium yeast	Std. error of means	Treatment effect
Selenium balance, mg per day				
Intake	3.76	3.72	0.05	NS
Urine	1.16	1.10	0.05	NS
Feces	1.85	1.58	0.02	$P < 0.05$
Retention	0.75	1.04	0.07	$P = 0.11$
Apparent absorption, %	51.1	57.3	1.4	$P < 0.10$
Retention, % of intake	20.4	27.8	1.3	$P < 0.05$
Retention, % of absorbed	39.3	48.6	1.4	$P < 0.05$

FIGURE



1. Daily urinary selenium excretion (from Pagan et al., 1999).

FIGURE



2. Plasma selenium before and after competition exercise (from Pagan et al., 1999).

scribes how antioxidants work together to extend each others' lives and make each other more powerful.

Vitamin E and selenium are both important to maintaining healthy muscle, and deficiencies in either can cause the signs of rhabdomyolysis, or tying up. By now, it should be apparent that both act to control the damaging effects of free radicals.

Because vitamin E and selenium deficiencies can potentiate tying up, feeding rations fortified with Food & Drug Administration-approved selenium yeast and vitamin E can help prevent muscle disorders in horses, particularly if in an area of the country where selenium soil content is low (the Northeast, Northwest and Great Lakes regions).

It is important to mention, however, that horses prone to tying up should be blood tested to determine if that individual is receiving enough selenium from dietary sources before being supplemented with additional selenium, which could lead to toxicity.

Safest source

An organic selenium product derived from yeast was approved by FDA (based on a review of data and manufacturing methods of Alltech) because, under clinical research conditions, it proved to be an extremely safe source of selenium for horses. Organic selenium is much more easily digested and absorbed by the horse than inorganic forms (selenites and selenates).

The research data and results submitted to the FDA for this clearance in animal feeds included no fewer than 14 dedicated toxicity studies performed at independent testing facilities. Studies addressed acute and chronic toxicity in several different species. In all cases, the toxicity of this form of selenium yeast was assessed in parallel to that of sodium selenite, the traditional inorganic source of selenium used in horse feeds.

Through intense testing on an acute oral toxicity basis, the selenium yeast product was found to be anywhere from 50- to 500-fold less toxic than sodium selenite.

Current recommendations from the National Research Council (NRC) nutrient requirements for horses (1989) for the level of selenium fortification in feedstuffs formulated and fed to horses is 0.1 parts per million of selenium.

This recommendation is for all classes of horses, but it is now recognized in the industry that certain classes of horses, such as broodmares, stallions, growing horses and performance horses, will benefit greatly from numerous health standpoints with a higher inclusion rate of selenium in their diets.

Because selenium yeast has proven to be safe and effective, it has been cleared for addition to equine feeds at the rate of 0.3 ppm or 3 mg per day in the total diet. The higher bioavailability and efficacy of selenium yeast compared to sodium selenite will, no doubt, greatly enhance the well-being of these classes of horses.

Retention in exercising horses

In recent years, several studies have been conducted to examine the effect of organic selenium versus inorganic sources in the exercising horse. Horses engaged in strenuous activity need selenium because exercise increases oxidative metabolism markedly, and this, in turn, causes the mobilization of selenium stored in body tissues to meet the increased antioxidant demand.

The importance of digestion, absorption and retention of organic selenium was studied by researchers at Kentucky Equine Research Inc. They conducted an experiment to evaluate how exercising Thoroughbreds digested and retained either a specific selenium yeast product or sodium selenite.

Four trained horses received 2.90 mg per day of sodium selenite or 2.76 mg per day of the selenium yeast. Sodium selenite-supplemented rations averaged 0.41 ppm selenium with approximately 77% of the total selenium from sodium selenite. Selenium yeast-supplemented rations averaged 0.40 ppm selenium with approximately 75% of the total selenium provided from the yeast.

Horses were fed their selenium-supplemented diets for five weeks. During the first four weeks, horses were exercised three days per week on a high-speed treadmill and three days per week on a mechanical walker. Horses were stabled in box stalls and turned out daily while wearing muzzles to prevent pasture intake.

Selenium balance was determined by a five-day total collection during week 5 of the study period. Daily fecal and urinary output was measured, and daily samples of each were frozen for subsequent measurement of selenium.

The response the horses had while exercising was also studied, and on day 3 of the digestion collection, the horses performed a competition exercise test on the treadmill. This test was designed to simulate the physiological and metabolic stresses normally experienced during the speed and endurance phases of a three-day event. Whole blood, plasma and urine samples were collected just before and after an exercise test, as well as at four and 24 hours post-exercise.

Packed cell volume was measured in each blood sample using Coulter Counter S560. Feed, feces, urine and blood were analyzed for selenium concentration using fluorometric methods described by AOAC (1995).

The key findings in the study were:

• Horses receiving the selenium yeast product had higher digestibility, absorption and retention of selenium (Table; Pagan et al., 1999). Horses supplemented with sodium selenite excreted significantly ($P < 0.05$) more fecal selenium than those supplemented with the selenium yeast product (1.85 versus 1.58 mg per day). The apparent absorption of sodium selenite and selenium yeast averaged 51.1 and 57.3%, respectively. These values fall intermediate between those reported for pigs and ruminants (pigs, 75-85%; ruminants, 35%). Selenium retention was significantly higher for horses consuming the selenium yeast product as opposed to sodium selenite (1.04 versus 0.75 mg per day). This difference was attributed to greater selenium absorption since daily urinary selenium excretion was not different between the two sources.

• Immediately following the exercise

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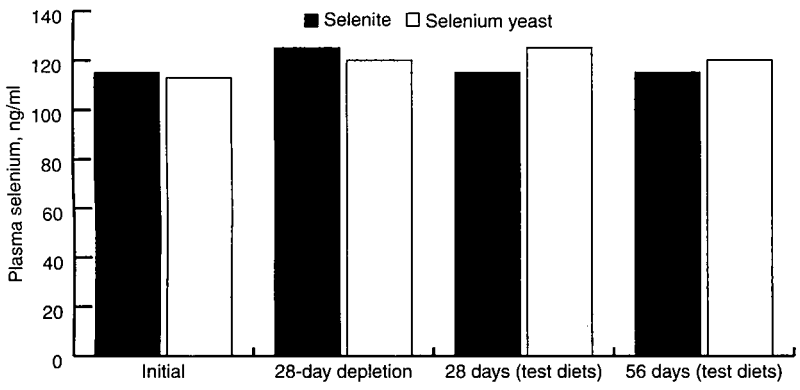
FIGURE



3. Effect of selenium source on plasma selenium of weanling horses (from Jackson and Pagan, 1996).

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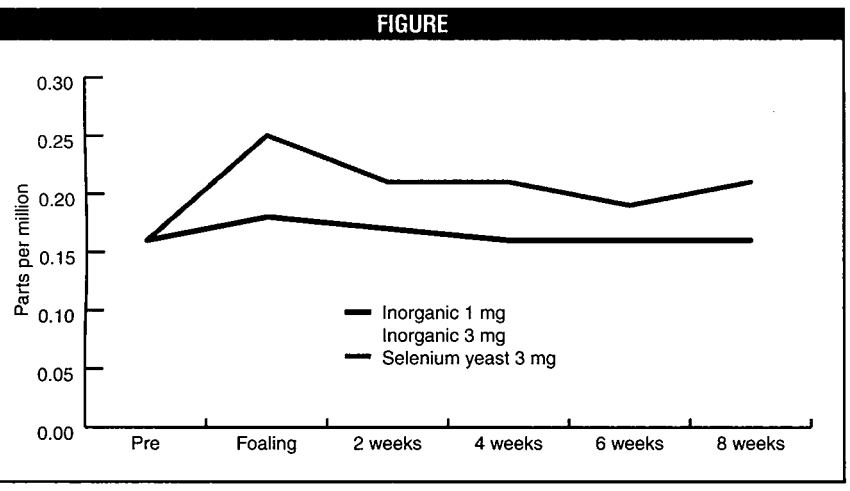

4. Broodmare selenium status (from Janicki, 2001).

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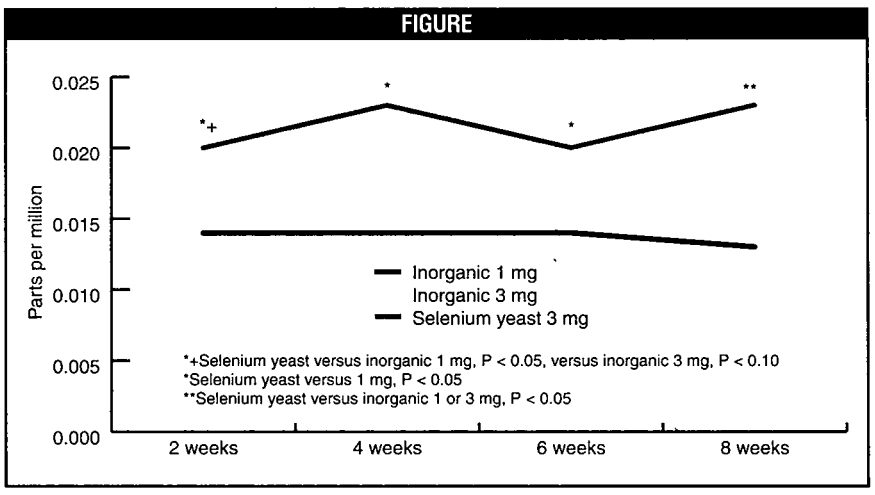

6. Milk selenium content (from Janicki, 2001).

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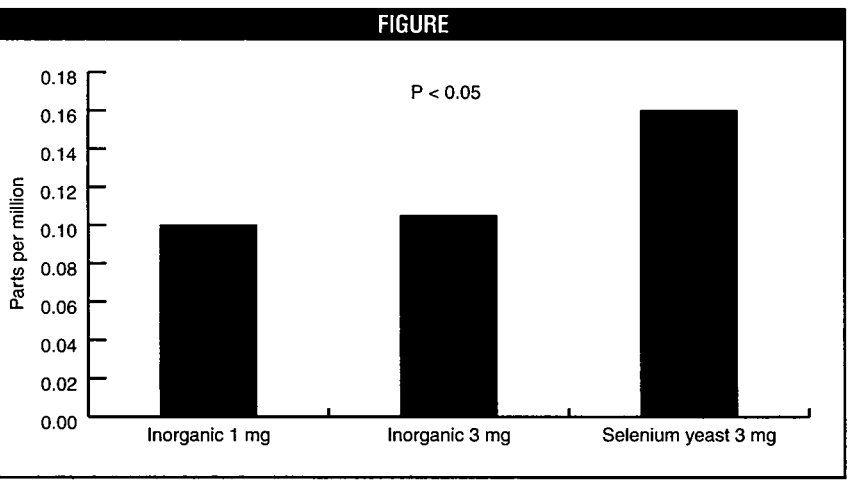
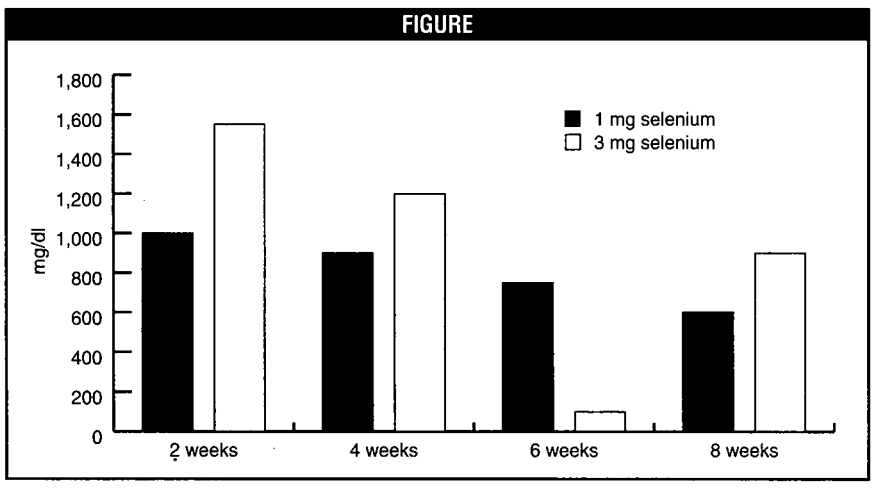


5. Colostrum selenium content (from Janicki, 2001).

FIGURE



7. Mean foal serum IgG (from Janicki, 2001).

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test, urinary excretion of selenium increased significantly in horses fed sodium selenite but not those fed the selenium yeast product ($P < 0.01$; Figure 1; Pagan et al., 1999).

• Plasma and whole blood selenium increased for both groups post-exercise ($P < 0.01$) and plasma selenium at four hours post-exercise ($P < 0.05$; Figure 2; Pagan et al., 1999). At 24 hours post-exercise, plasma selenium returned to pre-exercise levels in horses fed sodium selenite but remained elevated in those fed the selenium yeast product ($P = 0.08$).

• Red blood cell (RBC) selenium was similar between both treatment groups, and there was a trend toward a decrease in RBC selenium post-exercise.

The authors of the study concluded from these data that the selenium yeast product is more digestible and resulted in a more positive selenium balance than sodium selenite. Exercise increases the need for selenium, which is reflected by the mobilization of stored selenium into the blood.

In the present study, it was theorized that the source of increased plasma selenium noted following exercise may have been from RBCs, since there was a trend toward lower RBCs after the exercise test. Following exercise, horses fed sodium selenite had plasma selenium levels return to pre-exercise levels, while horses fed the selenium yeast product had plasma selenium levels elevated even at 24 hours post-exercise.

It was concluded that part of the selenium mobilized from the sodium selenite group may have been voided in the urine.

After absorption, RBCs take up inorganic selenium and return it to the plasma in the reduced form (hydrogen selenide), where it binds to plasma proteins and is transported to the liver to become part of the selenium pool for selenoprotein formation. Some selenium travels to the kidney and is excreted.

Higher urinary excretion of sodium selenite during exercise represents a greater loss of a key antioxidative nutrient required by the exercising horse to prevent oxidative stress.

Organic selenium, however, travels in the blood by amino acid transport mechanisms. Because mobilized selenium yeast is an organic form of selenium, it is less likely to be lost via urine, contributing to a better selenium status in horses fed the product.

Weanlings

A comparison of inorganic selenium versus organic selenium on plasma selenium in weanling horses was conducted by Jackson and Pagan (1996).

Eighteen weanling Thoroughbred horses ranging in age from six to 10 months were randomly assigned to two treatment groups. Prior to the start of the experiment, all horses had been receiving a 32% crude protein (CP) oat balancer, oats and pasture. Horses were then placed on a "depletion" diet for one month followed by two months of either inorganic selenium or the selenium yeast product. The depletion diet was comprised of 16% CP sweet feed and no added trace minerals. During months 2 and 3, experimental diets remained the same as month 1 but with supplemental trace minerals added.

The control group received sodium selenite, and the treatment group the selenium yeast product. Both diets contained the NRC recommended level of 0.1 ppm added selenium.

Blood sampling was conducted via jugular puncture before beginning the depletion diet, after 28 days on the depletion diet and after 28 and 56 days on the test diets. Mineral concentrations were determined using atomic absorption spectrophotometry.

Analyzed data from the experiment showed that plasma selenium declined slightly during the depletion period and then increased once NRC-recommended supplementation levels were resumed (Figure 3; Jackson and Pagan, 1996). Weanlings fed the selenium yeast-supplemented ration had slightly higher plasma selenium levels at the end of one and two months on the fortified diet.

From these results, the authors concluded that a higher plasma level of selenium, such as that seen with weanlings fed the selenium yeast product, could be useful in preventing muscle-related disorders seen in foals and weanlings such as muscular dystrophy and white muscle disease.

Broodmares, foals

Researchers at the University of Kentucky (Janicki, 2001) investigated whether the form and/or level of selenium in the diet had an effect on mare and foal selenium status, GSH-Px activity and antibody titers to influenza.

Fifteen pregnant mares were maintained on pasture and supplemented with alfalfa hay and a commercial concentrate. Mares received 1 or 3 mg selenium per day as selenite selenium or 3 mg per day as the selenium yeast product beginning 55 days pre-foaling to 56 days post-foaling.

The following samples were obtained:
• Colostrum;
• Milk at two, four, six and eight weeks;
• Venous blood at 12 hours for immunoglobulin G (IgG) analysis;
• Mare blood at pre-experiment, two-week intervals until foaling, post-foaling and then two-week intervals;
• Foal blood at 12 hours, two, four, six and eight weeks;
• Foal and mare bodyweights;
• Placental expulsion time, and
• Feed and pasture.

Analysis conducted on the following serum, milk and colostrums:
• Serum and milk selenium concentration;
• Whole blood hemoglobin;
• Whole blood GSH-Px activity;
• Serum and colostrums IgG concentration, and
• Serum influenza antibody titers.

Results of the study showed that prior to foaling, mare selenium status did not differ between treatments but was greater immediately post-foaling and at four and eight weeks in mares receiving the selenium yeast product ($P < 0.05$, Figure 4; Janicki, 2001). Foal serum selenium was consistently higher when their dams were receiving selenium yeast.

Selenium content of colostrum was highest in mares fed the selenium yeast product ($P < 0.05$, Figure 5; Janicki, 2001). Milk selenium concentration was 38% higher in mares consuming selenium yeast compared to those being fed 1 mg selenite selenium and 29% higher than mares consuming 3 mg selenite selenium at all time points (Figure 6; Janicki, 2001).

GSH-Px activity in mares was not influenced by any source or level of selenium supplementation, but foal GSH-Px activity was higher at four, six and eight weeks of age when mares were fed the selenium yeast product ($P < 0.05$). Foal antibody titers were higher when mares were given 3 mg of selenium, and foal IgG at 12 hours post-foaling was highest when born to mares receiving the selenium yeast supplementation. Serum IgG tended to be greater at all time points for foals born to mares receiving selenium yeast supplementation ($P < 0.1$ Figure 7; Janicki, 2001).

One very interesting result was that placental expulsion was twice as fast in mares being fed the selenium yeast product compared to those receiving 3 mg of selenite selenium (39 minutes versus 59 minutes for 3 mg selenium yeast-supplemented mares and 3 mg selenite selenium-supplemented mares, respectively).

From the results of these studies, it can be concluded that supplementation with 3 mg selenium per day through weaning may give foals increased immune status at an earlier age. This may have a carryover effect first during weaning stress and later in life as the horse enters training, particularly for high-intensity work such as race training, where muscle degradation by lipid peroxides occurs at a high rate.

Foals with GSH-Px levels from nursing mares supplemented with organic selenium may be able to handle the negative effects of oxidation more efficiently than non-supplemented foals, and this, in turn, may decrease time to fatigue during a race as well as speeding recovery following heavy work.

Availability of this selenium yeast product represents a breakthrough in the equine industry that will assist equine professionals in addressing problems of marginal selenium status that affect the health and productivity of all classes of horses but, in particular, broodmares, growing horses and performance horses.

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