An integral part of nutrition

Mineral imbalances can lead to health issues in horses

by Amy Gill, Ph.D.

HORSES EAT a variety of forages and concentrates that contain carbohydrates, proteins, fats, vitamins, and minerals, which they use for different metabolic processes:

- Carbohydrates and fats provide digestible energy, or source of calories, for muscular contraction and all metabolic processes, including cell and tissue growth;
- Dietary protein is broken down into amino acids, which are used to synthesize new protein or rebuild damaged tissues; and
- Vitamins and minerals are used in many biochemical reactions.

Minerals, which are inorganic molecules also called elements, are derived from the earth. They can be incorporated into living tissue (organic) but eventually return to earth in the inorganic form when excreted by the horse, or as ash once the animal is buried or cremated. Basically, minerals are chemical molecules that are used in a variety of ways but cannot be reduced to simpler substances.

Minerals are essential to the physical and mental well-being of horses. They are components of all cells, including blood cells, as well as nerve, muscle, bone, teeth, hormones, and soft tissue. Many other minerals are an integral part of enzymes that catalyze biochemical reactions such as energy production, metabolism, nerve transmission, muscle contraction, and cell permeability.

Macro and micro

Macrominerals, which have established daily intake requirements, are the elements needed in large concentrations from the diet. They include calcium, phosphorus, chlorine, potassium, sulfur, sodium, and magnesium.

Microminerals, or trace minerals, are required only in minute amounts but also must be obtained from the diet. Microminerals with established requirements include iron, copper, zinc, iodine, cobalt, selenium, and manganese. Other elements or minerals that can be stored in tissue include some of the toxic metals (lead, aluminum, cadmium, and mercury).

Macrominerals are expressed in the diet as a percentage (%), while microminerals are expressed as "parts per million" (ppm or mg/kg) because they are required in much smaller amounts. Some macrominerals, such as the electrolyte minerals sodium, potassium, and chloride, are required in large dietary quantities to help regulate fluid and acid-base balance. The macrominerals calcium, phosphorus, and magnesium are required to build healthy bone tissue during growth and repair. Microminerals, however, are more commonly incorporated into enzymes that catalyze biological reactions.

Because research to determine mineral requirements in horses is ongoing, new requirements might emerge. For example, chromium and silicon are two trace minerals obtained through the diet. Though established recommendations have not been made for either element, both appear to be important nutrients for horses because:

Bioavailabilities of zinc, copper, and selenium sources

	% relative bioavailability
Zinc	
Proteinate	100
Sulfate	100
Oxide	50
Copper	
Lysine (amino acid)	100
Methionine (amino acid)	110
Sulfate	100
Carbonate	85
Oxide	30
Selenium	
Seleno methionine	150
Calcium selenite	100
Sodium selenite	100
Seleno yeast	100

Bioavailability estimates are expressed as a percentage of a recognized standard and do not refer to the amount of mineral absorbed or retained. In most cases, the amount of mineral absorbed is less than 50% of the intake.

Source: "Feeding organic and inorganic sources of trace minerals for swine production," by Heather Hellman, graduate research assistant, and Marcia Carlson, state extension swine nutrition specialist, Department of Animal Sciences, University of Missouri

- Chromium plays a role in carbohydrate metabolism and could help reduce insulin resistance in certain individuals; and
- Silicon facilitates the uptake of calcium and phosphorus into developing bone, which might help improve the bone's strength. Increased bone density will help prevent injuries and breakdowns and assist in the healing of fractures. Silicon also is needed to improve the strength of connective tissues such as tendons, ligaments, and collagen.

Calcium and magnesium

Rations fed to a horse must be balanced for all nutrients and energy, meaning the nutrients from the forage and concentrates meet—but do not grossly exceed—what the horse requires to stay healthy and perform well.

Because minerals work with each other and with other nutrients, imbalances of any mineral can lead to health issues. Think of mineral nutrition collectively as a group. Too little of an essential mineral can lead to deficiency, and excesses can cause toxicities. This is important because, as the intake of a mineral increases past the requirement, the excess amount the horse absorbs and retains can be harmful.

A mineral the horse does not absorb might bind other minerals, decreasing their availability and possibly causing a deficiency of those minerals. Therefore, indiscriminate addition of a single mineral to the horse's diet is not recommended.

The ratio of minerals relative to each other is as important as the total amount supplied in the diet. Inverted ratios can affect the availability of other minerals even if they are ingested in the correct amounts. One of the best examples is the ratio of calcium to phosphorus, which should never be less than 1:1 (recommended is 1.5:1) in an equine diet.

The reason for this tight ratio is because the horse's digestive system requires that a molecule of calcium be grouped with each molecule of phosphorus before the intestinal wall can absorb it. If calcium is not available in sufficient amounts, it will be mobilized from the bone. Over time, an inverted calcium-phosphorus ratio causes bones to become weak and porous and more susceptible to stress fractures and breakage.

Though not recommended, excessive calcium intake can be tolerated in horses. Alfalfa hay contains a high percentage of calcium, but it is fine to feed to all classes of horses because calcium consumed beyond the requirement is excreted by the horse in urine. Weanlings can tolerate a ratio of 3:1 and adult horses 6:1 as long as the phosphorus requirement is met. If this ratio becomes inverted, abnormal bone growth can occur in the horse.

Another example of the importance of having the correct ratio of a mineral in relation to others occurs when magnesium is

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Selenium plays several roles in equine nutrition

SOME OF THE MOST interesting research in equine mineral nutrition is focusing on organic selenium. Many areas of the country have selenium-deficient soils, and feeds grown in these soils also are low in selenium content. Diets formulated for horses always should have selenium fortification.

Selenium is a mineral found in forages and grains that plays several roles in the horse's body, most importantly as an antioxidant during strenuous exercise. Selenium also is used in the process of building innate and acquired immunity, in growth, and in various aspects of reproduction.

Selenium deficiency is commonly associated with muscle damage in foals born to deficient mares and in performance horses. It 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, which damage cell structures; cellular membranes are highly sensitive to this process. Selenium is an integral component of the enzyme glutathione peroxidase (GSHPx), which counteracts the actions of free radicals, thereby protecting cell membranes.

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 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. Ideally, maintaining optimum levels of both nutrients in the body will help to minimize oxidation-induced tissue damage.

Benefit in mares

Researchers at the University of Kentucky investigated whether the form and/or level of selenium in the diet had an effect on the status of selenium in a mare and foal, on GSHPx activity, and antibody titers to influenza.

Mares received one milligram or three milligrams of selenium per day as selenite selenium or three milligrams per day as organic selenium yeast beginning 55 days before foaling to 56 days after foaling. Results of the study showed that prior to foaling, the status of selenium did not differ between treatments but was greater immediately after foaling and at four and eight weeks in mares receiving organic selenium yeast.

Selenium in the serum portion of foals' blood was consistently higher when mares received organic selenium yeast. The selenium content of colostrum was highest in mares fed organic selenium yeast.

GSHPx activity was not influenced by any source or level of selenium supplementation, but foal GSHPx activity was higher, especially when mares were fed organic selenium yeast. Foal antibody titers were higher when mares were given three milligrams of selenium, and foal immunoglobulin at 12 hours after foaling was highest in foals born to mares receiving the organic selenium yeast supplementation.

One interesting result was that placental expulsion was faster in mares fed organic selenium yeast as compared with those receiving three milligrams of selenite selenium (39 minutes versus 59 minutes).

Racehorse study

A study conducted by Kentucky Equine Research investigated the importance of the digestion, absorption, and retention of organic selenium in an experiment to evaluate how exercising Thoroughbreds digested and retained either organic selenium yeast or sodium selenite.

Four trained horses received 2.9 milligrams a day of either organic selenium yeast or sodium selenite. Selenium balance was determined by total collection, which involves measuring precisely how much selenium the horses consumed and what amount was excreted in the feces, allowing for an accurate assessment of how much selenium was retained. The response the horses had while exercising also was studied. Samples of whole blood, plasma, and urine were collected just before and after an exercise test, as well as at four and 24 hours after exercise. Key findings in the study were:

- Horses receiving organic selenium yeast had higher digestibility, absorption, and retention of selenium;
- During exercise, urinary excretion of selenium increased in horses fed sodium selenite, but not those fed organic selenium yeast; and
- Plasma selenium remained elevated at four hours after exercise, but at 24 hours after exercise had returned to pre-exercise levels in horses fed sodium selenite but remained elevated in those fed organic selenium yeast.

Authors of the study concluded from these data that organic selenium yeast is more digestible and resulted in a more positive selenium balance than sodium selenite.—*Amy Gill, Ph.D.*

supplemented to reduce nervousness in horses. Severe magnesium deficiency is rare in horses, but symptoms include muscle tremors, poor work capacity, insulin resistance, excitability, and, in extreme cases, convulsions.

Generally, a horse's common diet provides more than adequate amounts of magnesium, but nervous individuals could respond positively to additional supplementation. However, excess magnesium can interfere with calcium metabolism and reduce absorption, so it is important that the ratio of calcium to magnesium remains at 2.5:1.

The total calcium requirement for a mature, 1,100-pound horse is 20 to 40 grams per day depending on level of work being performed; the magnesium requirement is 6.75 to 13.7 grams per day. If the magnesium level is increased, calcium also might need to be increased to prevent low absorption levels.

While supplementation of minerals to balance the diet of horses is a necessity, indiscriminately adding these nutrients to an already balanced feeding program will increase the chance of producing toxic levels and ratio imbalances.

Mineral availability

Minerals vary in how the horse absorbs and uses them. The bioavailability of a mineral, or its relative availability to the animal, is determined by its interaction with other minerals or dietary components as previously mentioned. The more bioavailable a mineral becomes, the lower the dietary concentration needs to be to meet the daily requirement in the horse.

Correction

IN THE BOX titled "Sample of hay analysis suitable for weanlings" in the Feed and Nutrition article "Time to grow on their own" in the September 10 issue of THOROUGHBRED TIMES, the correct amount of digestible energy (calories) is 950 per pound, not 9,500 per pound.

Additionally, the more highly absorbable the mineral, the less the mineral is excreted to the environment—an increasingly important issue. As new restrictions are imposed on the inclusion of dietary trace minerals in animal feeds, feed manufacturers seek alternatives that are economical, yet maintain performance and reduce nutrient excretion.

Inorganic minerals traditionally have been used in horse feeds and are listed as oxides or sulfates on feed tags. Recently, technology that combines the inorganic mineral with an organic molecule has become an alternative to using inorganic minerals in feeds. Organic minerals are also called "chelates" or "proteinates."

Chelation involves the attachment of the mineral to an amino acid or other organic component so the two do not disassociate in the digestive system, essentially protecting the mineral so it can be absorbed across the luminal wall of the small intestine intact. For some minerals, a chelated compound is better than other forms, but for others, absorption is not improved with complexing. For minerals that are better fed as a chelate, absorption is more efficient due to a neutral electrical charge.

Nonchelated inorganic minerals have either a positive or negative charge. Both calcium and magnesium are examples where chelated forms are not any better absorbed than inorganic forms, such as calcium carbonate and magnesium oxide. Both are easily separated, and the calcium and magnesium ions are well absorbed.

Because digestibility of oxides is low, they

Calcium retention important in young horses in training

MANY YOUNG HORSES in training eventually have some type of skeletal injury. Weak bones and subsequent injuries cost training days but also can lead to catastrophic bone failure and breakdown.

Fortunately, feeding and management practices can help improve the quality of bone. Recent research on mineral metabolism in young horses has produced helpful techniques to reduce the risk of skeletal injuries in young exercising horses.

In 1997, Texas A&M University researchers found that the cannon bone undergoes a period of demineralization and remineralization following initial onset of training in response to the strain. They discovered that bone is the most demineralized and therefore the weakest about 60 days following the onset of training. That period generally corresponds to the time that young racehorses begin to have speed work incorporated into their daily training regime.

Not surprisingly, the study revealed that bone injuries occurred mostly at 60 to 70 days after the onset of training. The apparent bone demineralization and remineralization phenomenon caused researchers to question whether the process would alter the mineral requirements of young horses in training.

Apparently, the regulation of calcium balance in these horses is affected by whether calcium is being deposited into bone or being removed from bone. When calcium is being removed from bone, some of it can be lost in urine. Loss of calcium in this manner could increase the dietary requirement for calcium in order to keep the horse in calcium balance and promote new bone formation.

To answer these questions, Texas A&M conducted new research in 2004 to determine the effects of training on mineral balance and bone quality. Investigators found that training affected the absorption, urinary excretion, and retention of calcium:

- Following 64 days of training, which corresponds to the period when bone is being demineralized, calcium absorption is reduced and urinary excretion of calcium is increased. That results in reduced retention of calcium; and
- After 128 days of training, when new bone is being formed, calcium absorption is increased, urinary calcium loss is reduced, and calcium retention is increased.

The study shows that training affects calcium balance and might influence the dietary requirement for calcium and other minerals. Subsequent studies from the same researchers were designed to determine the requirements for calcium, phosphorus, and magnesium during a period of bone demineralization and remineralization of new bone.

During the studies, young horses in training were fed varying amounts of calcium to determine calcium balance in the exercising horse. The amounts of calcium fed in the study were based as a percentage of current National Research Council recommendations. At day 64, calcium retention was not maximized even at 175% of current recommendation.

This means that when the horses are in the state of bone demineralization and concurrent reduced calcium absorption and increased urinary loss of calcium, their dietary calcium requirements are increased dramatically. At day 128, when calcium absorption returns to normal levels and urinary losses are reduced, calcium retention is maximized at 130% of current recommendations.

Although horses are more efficient at absorbing and retaining available calcium at this time, the dietary requirement to maximize calcium retention is still increased significantly over current recommendations. Therefore, diets of young horses in training should be formulated to reflect the increased need for calcium to offset calcium losses during bone demineralization and promote new bone growth during the remineralization phase.

Approximate calcium, phosphorus, and magnesium requirements for first six months after young horses enter training

	Calcium		Phosphorus		Magnesium	
	Grams/day	% of diet	Grams/day	% of diet	Grams/day	% of diet
First three months	65	0.65	35	0.35	15	0.15
Four to six months	50	0.50	25	0.25	15	0.15

Source: "Mineral requirements of juvenile horses in training," Gary D. Potter, Ph.D., professor, section leader, Equine Science, Department of Animal Science, Texas A&M University

Magnesium requirements

While exact phosphorus requirements were not determined from the Texas A&M study, by maintaining the correct ratio of calcium to phosphorus researchers assumed that phosphorus requirements increase similarly to calcium requirements due to training. The most dramatic effect of training, however, was on magnesium requirements.

When the horses were in a state of bone demineralization, demand for magnesium was increased, but not as much as when they were in the remineralization phase. Magnesium retention was not maximized during the remineralization phase even when the horses were fed 200% of the current recommendation for magnesium.

This large discrepancy in increased need for magnesium and current requirements must be accounted for when formulating feed rations for young horses in training. The data from this research clearly showed that requirements for magnesium during bone modeling/remodeling increase dramatically relative to National Research Council recommendations.

—Amy Gill, Ph.D.

are inexpensive to feed. Sulfates are slightly higher in digestibility but cost more to incorporate into a ration. Organic minerals, however, require more processing than oxides and sulfates and are the most expensive to use. There are many different forms of organic minerals, and bioavailability varies depending on what type of molecule they are attached to (see box titled "Bioavailabilities of zinc, copper, and selenium sources"). Most commonly, zinc, copper, and selenium have higher absorption as proteinates.

Feed companies often use a combination of mineral sources, but to achieve the most benefit, organic minerals should comprise at least 25% of the total mineral supplementation.

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