Excerpt from Revised *Understanding Equine Nutrition*: Vitamin Function

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Here's a primer on the function of each of the vitamins important to the horse, beginning with the fat-soluble vitamins.

Vitamin A

Function: Vitamin A, also called retinol, is important for the maintenance of good vision, particularly at night. It is also an important factor in bone and muscle growth of young horses, in reproduction, and in healthy skin. New research has revealed that vitamin A has a key role in the immune response to infection as well.

What are the nutritional needs of your horse? Misconceptions abound about how much food horses actually require to remain healthy and perform their designated jobs. ***Understanding Equine Nutrition (Revised Edition)*** helps horse owners sift through all the ingredients and decide on the best nutritional plan for their horse. The revised edition of ***Understanding Equine Nutrition*** contains the latest information from the National Research Council on nutrition requirements for horses.

Author Karen Briggs discusses the different equine food groups in an easy-to-understand manner. Whether the horse is a growing yearling, a high-performance athlete, a weekend pleasure mount, or an in-foal mare, this essential guide will help owners cut through the jargon, sort out the ingredients, and make a feeding plan and menu that is best for their horse. Briggs, a horsewoman and equine nutritionist, resides in Roseneath, Ontario, Canada. She has been a frequent contributor to *The Horse: Your Guide to Equine Health Care* magazine.

Sources: Horses must satisfy all of their daily vitamin A requirements from their diets. Fortunately, green forages and yellow vegetables (such as carrots) are excellent sources of vitamin A's main precursor, beta-carotene, which is broken down by enzymes in the small intestine. The converted vitamin A is then stored in the liver, which can retain a three-to six-month supply, releasing it back into the bloodstream as the horse's body requires (or excreting it if there is an excess).

Not all of the carotenoid pigments the horse takes in on a daily basis are converted to vitamin A; some are absorbed intact and transported to body tissue such as the fat, skin, and ovaries for use and storage. (In the ovaries, beta-carotene has been shown to be involved in the control of progesterone secretion by the corpus luteum, making it a key player in the control of ovulation, embryo implantation, and the maintenance of pregnancy.) A deficiency of beta-carotene interferes with these

functions, and interestingly, cannot be corrected by feeding more vitamin A, as the conversion doesn't seem to be wholly reversible.

Feed companies may supplement their products with vitamin A in the form of retinyl-palmitate or retinyl-acetate, which are more stable than retinol and less vulnerable to degradation over time. These forms are converted to retinol in the small intestine just like beta-carotene.

Signs of deficiency: General signs of a vitamin A deficiency include a depressed appetite, weight loss, a dull haircoat, night blindness (distinguishable from periodic ophthalmia, or moon-blindness, by characteristically cloudy corneas), excessive tearing of the eyes, anemia, and even convulsive seizures. Long-term deficiencies might cause abortion in broodmares, and stallions might suffer decreased libido and soft, flabby testicles. Under normal conditions, the only way a horse can develop a vitamin A deficiency is if he is deprived of hay or pasture for more than six months (allowing time to deplete the stores in the liver). But if horses are going to be fed on very old hay or poor pasture for an extended period of time, vitamin A supplementation is a good idea.

Like all of the fat-soluble vitamins, vitamin A is poorly transported across the placenta. Thus, foals are born vitamin A-deficient. Provided the mare's diet has sufficient beta-carotene, she will provide vitamin A to her foal in her colostrum, but if the foal's colostrum intake is insufficient, the deficiency will persist. Vitamin A-deficient foals might suffer from diarrhea, though they are not usually night-blind.

Signs of Toxicity: Horses can experience vitamin A toxicity; however, as a rule it only occurs when an owner over-supplements the diet. In one study where foals were deliberately fed vitamin A in quantities exceeding 20,000 IU/kg, the results included stunted growth, scaly skin, increased bone size, bone fragility, and decreased blood clotting, leading to internal hemorrhages. There has been no demonstrated benefit to horses by feeding more than 2,000 to 3,000 IU/kg per day. For idle adult horses, 30 IU/kg per day is considered the maintenance vitamin A requirement; growing youngsters and pregnant or lactating mares might need double that.

Vitamin D

Sources: Vitamin D is the "sunshine vitamin," created through chemical reactions of ultraviolet rays from the sun with 7-dehydrocholesterol (synthesized in the horse's skin) and ergosterol (in the dead leaves of plants). Because chlorophyll in living plants blocks out ultraviolet rays, vitamin D begins to be present only after plants have been cut and exposed to sunlight (as in sun-cured hay).

Function: Vitamin D assists in maintaining plasma calcium concentrations by interacting with parathyroid hormone (PTH) and calcitonin. This has the effect of increasing the absorption of both calcium and phosphorus from the intestine. It also assists with mobilizing stored calcium, with an

indirect impact on bone mineralization. Recent research indicates that vitamin D also influences cell growth and differentiation. (Differentiation is the process by which an unspecialized cell becomes specialized into one of the many cells that make up the body, such as a heart, liver, or muscle cell.)

Signs of Deficiency: A vitamin D deficiency results in rickets in the young of most species (including humans). The bones become soft and bendable, resulting in bowed legs and emaciation, and in severe cases, the affected animal will be reluctant to stand. But rickets per se have not been observed in horses with vitamin D deficiencies. However, pony foals deprived of sunlight for five months did demonstrate decreased bone strength, and slower growth and feed intake, as well as irregular growth plates (visible on radiographs).

Most horses are unlikely ever to need vitamin D supplementation. Hay contains approximately 2,000 IU/kg of vitamin D when it is freshly baled, though like all vitamins, it degrades over time, at a rate of about 7.5% per month. Hay more than a year old might not, therefore, meet a horse's vitamin D needs, but as long as the horse receives a few hours of sunlight a day, this should be of no consequence. However, stabled horses with no access to direct sunlight for months on end should have supplementation in their diets: 300 IU/kg (in the total diet) for normal maintenance or 800 IU/kg for growth, pregnancy, and lactation.

Signs of Toxicity: The most common of all vitamin "overdoses," vitamin D toxicity occurs as a result of indiscriminate supplementation (either oral or injectable). Excess vitamin D is stored in the liver, and the effects are cumulative, becoming more obvious after a period of several weeks. They include calcium deposits that collect in the heart valves and walls, the walls of large blood vessels, and the kidney, diaphragm, salivary glands, and gastric mucosa. The result is decreased exercise tolerance, weight loss, stiffness, a decrease in spontaneous activity (with flexor tendons and suspensories often sensitive to palpation), an increased resting heart rate, the development of heart murmurs, and increased water intake and urination. Toxicosis can be confirmed by elevated plasma concentrations.

Vitamin E

Function: Versatile vitamin E enhances immune function, is essential for cellular respiration, is involved in DNA synthesis, and improves the absorption and storage of vitamin A, among other effects. But most importantly, vitamin E and the mineral selenium are anti-oxidants: partners in protecting the horse's body tissues--especially cell membranes, enzymes, and other intracellular compounds--from the damaging effects of oxidation. Inadequate amounts of either one in the horse's system assure that there will be considerable free-radical damage to the tissues.

Sources: Vitamin E is the only vitamin other than A that horses must source from their diets. Green growing forage contains good amounts of vitamin E, but from 30 to 80% of the vitamin's activity is lost during the process of cutting and baling hay, and nearly all of the vitamin E is destroyed in high-

moisture feeds such as haylage. Because not all horses are lucky enough to have good pasture year-round, commercial grain rations are usually fortified with stable forms of vitamin E (alpha-tocopheryl acetate is one).

Signs of Deficiency: Usually grouped with selenium deficiency, which we'll discuss in the next chapter, vitamin E deficiency can cause muscle wastage and malformation (sometimes called "white muscle disease" in foals); subcutaneous edema; infertility; a stiff, stilted "base-wide" gait; a swollen tongue; and inflammation of fatty tissues, or steatitis, by insoluble pigments (often called "yellow-fat disease"), especially in foals. In horses aged two and up, prolonged vitamin E deficiency can contribute to Equine Motor Neuron Disease (EMND), which features the sudden onset of trembling, a constant shifting of the weight in the hind legs when standing, muscle wasting, and prolonged recumbency.

A mild deficiency of vitamin E might only produce a decrease in the horse's immune response, and a slower growth rate in foals,.

Signs of Toxicity: Horses can easily suffer from selenium excesses (selenium has the lowest toxicity level of any mineral important to the equine diet), but vitamin E appears to be safe for horses even at relatively high doses. Because of this, some feed manufacturers use it as a natural anti-oxidant in their grain rations to help prevent spoilage, leading to feed tag values that are far higher than the nutritional requirement of most horses.

No clinical signs of vitamin E toxicosis have been produced, but because very high levels can interfere with the absorption of other fat-soluble vitamins, a conservative maximum level of 1,000 IU/kg in the diet is generally recommended.

Vitamin K

Function: Vitamin K is primarily an activator for blood clotting factors, though it also participates in the activation of other proteins throughout the body. Bone metabolism and vascular (blood vessel) health also benefit from vitamin K.

Sources: Several forms of vitamin K occur in nature, some in green leafy plants and others manufactured by the horse's cecal bacteria. (There is also a synthetic form called menadione that is used as a feed supplement and is metabolized just like natural vitamin K.) While the natural forms of vitamin K are fat-soluble, they are converted to a water-soluble format before they are stored in the horse's liver. As a result, vitamin K is easily excreted in the urine, so the body does not tend to retain a large supply. However, the combination of vitamin K ingested in pasture or hay and that produced in the cecum is considered adequate for any horse's needs under almost all circumstances.

One exception is a vitamin K deficiency induced by sweet clover poisoning. An anticoagulant called dicoumarol (chemically related to warfarin) sometimes occurs in moldy sweet clover hay or haylage. If the moldy hay is ingested over a period of several weeks, the horse's synthesis of vitamin K-dependent clotting factors is impaired. The problem occurs most often in cattle but has been reported in both horses and sheep. If it is left untreated, mortality and the risk of abortion in broodmares can be high.

Vitamin K deficiencies also can result from anything that compromises the gut flora--such as severe colic or diarrhea, abdominal surgery, or antibacterial drugs. Chronic liver disease also can be a factor. And because newborn foals are deficient at birth, vitamin K injections often are recommended to prevent hemorrhagic diseases.

Signs of Deficiency: A long-term vitamin K deficiency decreases blood coagulation. Bleeding from the nose is frequently one of the first signs in horses. Hematomas and/or internal bleeding might also occur, and if sufficient blood is lost, the horse will have pale mucous membranes, a rapid and irregular heartbeat, and depression and weakness.

Signs of Toxicity: Vitamin K toxicity is rare, though injections of the water-soluble form can be dangerous, causing acute renal failure and death. Oral forms of the vitamin appear to be innocuous, fortunately. No ideal levels of vitamin K have been established for the horse, but in a case where supplementation is called for (for example, after a course of antibiotics, or after a serious colic), the usual recommendation is for three to five mg/kg of body weight/day, mixed into the feed, for a week or more.

Water-Soluble Vitamins

Thiamin (Vitamin B1)

Function: Thiamin plays an important role in carbohydrate metabolism and in nerve transmission and stimulation.

Sources: While horses do receive good concentrations of thiamin from their intestinal bacteria, several studies have determined that they also require some more from their diets. Fortunately, most green forage is an excellent source of thiamin (and indeed, all of the "B-complex" vitamins), as is brewer's yeast.

Signs of Deficiency: Thiamin deficiency can occur when horses eat bracken ferns (which contain a compound that inhibits the vitamin's absorption) but is otherwise uncommon. In studies where the deficiency has been artificially produced, horses showed signs of anorexia, loss of coordination, skipped heartbeats, and unusually cold hooves, ears, and muzzles.

Signs of Toxicity: Thiamin toxicity is very unlikely. Dietary intakes of up to 1,000 times the recommended amount have been safely administered to horses without any ill effects. However, injecting doses of 1,000 to 2,000 mg of thiamin might produce a slowed pulse rate and a mild tranquilizing effect (a result that has been disputed in some research). Certainly thiamin has the reputation, in some circles, of being a tranquilizer (probably due to its action in nerve transmission), but it is important to keep in mind that large doses of this vitamin have produced convulsions, labored breathing, and death by respiratory paralysis in dogs, mice, and rabbits. High doses of thiamin also have been suspected, on occasion, to cause the opposite effect in horses--over-excitation.

Riboflavin (Vitamin B2)

Function: The synthesis of adenosine triphosphate (ATP) depends on riboflavin, as do lipid metabolism and the metabolism of certain drugs. Deficiencies (which have not been documented naturally but have been induced in experimental situations) compromise the tissues most in need of oxygen during strenuous exercise.

Sources: Fresh forage (especially legumes such as alfalfa and clover) and yeast supplements are good sources of riboflavin, a vitamin also synthesized by the gut flora.

Signs of Deficiency: Riboflavin deficiency has not been described in horses, but in other species the signs include decreased feed intake, scaly skin and a dull haircoat, inflammation of the lips and tongue, colon ulcers, and eyes that tear and react painfully to light. Irritation to the eyes also results, with increased tearing, sensitivity to light, and inflammation of the surrounding tissues. Some years ago riboflavin was thought to be involved with periodic ophthalmia (moon-blindness); more recent research, however, has absolved it of this responsibility, pointing the finger instead at infection by Leptospira or the parasite Onchocerca cervicalis.

Signs of Toxicity: Horses tolerate high levels of riboflavin very well, and no signs of toxicity have been documented.

Niacin (Nicotinic Acid) and Pantothenic Acid

Function: Niacin is considered a B vitamin but has no numerical designation. It does share qualities of the other B vitamins, however, being important in the regulation of energy metabolism, especially the processing of carbohydrates, amino acids, and fats. Another B vitamin, pantothenic acid (formerly designated vitamin B3), also is involved in the metabolism of carbohydrates, fats, and proteins.

Sources: Both pantothenic acid and niacin are widely available in virtually all vegetable matter, though some forms may be poorly digestible. Niacin is also produced by microbial fermentation in the horse's cecum.

Signs of Deficiency and Toxicity: Actual niacin or pantothenic acid deficiency--or excess, for that matter--has not been described in horses. Theoretically, because like the other members of the B family, these two vitamins are involved in biochemical reactions in the body, the symptoms of deficiency (if clinically induced) would tend to resemble those described for the other B vitamins.

Pyroxidine (Vitamin B6)

Function: Amino acid metabolism is the main function for pyroxidine, but this vitamin also is involved in glycogen utilization, in the synthesis of epinephrine (adrenaline) and norepinephrine, and in the metabolism of fats.

Signs of Deficiency and Toxicity: Again, no signs of deficiency or excess have actually been documented in the horse because pyroxidine is widely available in the diet and is also manufactured by the intestinal flora. However, in humans, high doses of pyroxidine administered on a daily basis have produced signs of sensory nervous system dysfunctions. Dietary levels of up to 50 times the nutritional requirement are considered safe for horses.

Biotin

Function: Most horsepeople are familiar with biotin as a supplement for hooves, but fewer know that it is considered one of the B-complex vitamins. Its primary role is as a co-enzyme in several crucial, but complex, chemical reactions related to metabolism, including the synthesis of glycerol for body fats, RNA, and DNA. It is considered essential for cell proliferation.

Sources: Biotin is readily available in plant material, and manufactured, to a certain level, by the gut microflora. However, researchers debate whether the amount a horse's system produces is adequate for his daily needs. Biotin deficiencies in fish, mink, foxes, pigs, and turkeys have been reported, and, intriguingly, the symptoms that result often include skin, footpad, and/or periople lesions that provide a ready comparison to the thin, shelly hooves some horses grow.

Biotin is a vitamin with which a distinction might be made between the horse's need for it on a nutritional level and the good it might be able to do when administered in much larger amounts. Feeding higher concentrations of biotin makes it, in essence, a pharmaceutical, which has been shown in some cases to improve the quality and speed of hoof horn growth.

Unfortunately, no one has yet established an absolutely optimal level of biotin. The amounts included in most of the popular hoof supplements (from 10 to 30 mg or more) are well above what is considered the base requirement. Fortunately, high levels of biotin are well-tolerated, making biotin supplementation a relatively harmless therapy, even if its results vary from horse to horse and might take six to nine months to become obvious.

Cobalamin (Vitamin B12) and Folacin Folic Acid (Folate)

Function: Both of these vitamins are needed for the synthesis of red blood cells, and a deficiency of either will result in anemia. In addition to this role, B12 also is required for the production of propionate, a major energy source derived from the fermentation of carbohydrates. Folic acid is required for all sorts of chemical reactions, including DNA synthesis, so it's crucial anytime there's a need for rapid cell growth or replacement. It is also receiving some attention as a potentially beneficial supplement for high-performance horses, to help combat anemia.

Sources: While folacin folic acid can be found in green forage, B12 is unique among vitamins in that it is synthesized in nature only by micro-organisms. Although the gut flora seem to produce ample B12, the vitamin is often administered to high-

performance horses to enhance performance, treat or prevent anemia, and stimulate the appetite. So far, there is no evidence to support the belief that supplemental B12 does any of these things, though severely anemic or heavily parasitized horses do appear to respond to it. (It should be pointed out that it is likely far more valuable to treat this type of horse through deworming and a proper diet than through B12 injections, which only increase plasma concentrations of the vitamin for a short period of time.)

Signs of Deficiency/Toxicity: Neither has been reported in horses to date, although horses being treated for equine protozoal myelitis (EPM) can have their folic acid levels compromised by certain drugs.

Vitamin C (Ascorbic Acid)

Function: Most of us are familiar with vitamin C but have heard very little of its function or requirement by horses. It is an anti-oxidant, which protects fats, proteins, and membranes from free radicals. In addition, it enhances the formation of bone and teeth, aids in the utilization of several of the B vitamins as well as cholesterol and glucose, and improves the intestinal absorption of iron. On top of this, it's a component of the connective tissue collagen and several amino acids.

Sources: Humans are one of the few species that, because of the lack of a crucial enzyme, do not synthesize their own vitamin C from glucose in their livers. For most species, including the horse, vitamin C does not need to be taken in daily from the diet, and in fact there is no demonstrated dietary requirement of this vitamin for horses--just as well, as most equines aren't big on citrus fruits.

Signs of Deficiency: The effects of a vitamin C deficiency do not occur in horses, though it is suspected that horses over the age of twenty, or those who have been ill or stressed, might sometimes suffer low plasma concentrations of ascorbic acid that could be associated with wound infections, bleeding from the nose, and an increased susceptibility to disease. Some cases of infertility in both mares and

stallions also have been reported to improve with the supplementation of vitamin C, but this has yet to be confirmed by research. In any case, oral vitamin C has been shown to be poorly absorbed by the horse, and intramuscular injections of the vitamin tend to cause marked tissue irritation. Intravenous administration has been tried, but the body so efficiently eliminates this water-soluble compound that plasma concentrations only remained elevated for a few hours. The form that is sometimes included in feeds, on the off chance it might have some beneficial effect, is ascorbyl palmitate, which horses (but few other species) can absorb fairly well.