The ABCs of Vitamin Nutrition

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Although horses only need relatively small quantities of vitamins, the lack of those tiny amounts can be devastating to your horse's health.

Vitamins comprise one of the six general groups of nutrients--the other groups are water, carbohydrates, proteins, fats, and minerals. Vitamins are organic (carbon-containing) compounds needed in relatively small amounts by the body to support normal metabolism, which involves the breakdown and formation of molecules within the body. Vitamins cannot be synthesized within the body in sufficient amounts; therefore, they must be supplied in the horse's diet.

When vitamin amounts are not sufficient at the tissue level, characteristic deficiency symptoms occur for each vitamin. However, there are exceptions to the general definition of vitamins. Sufficient amounts might be produced in some species or stages of development, but not others. For example, humans, guinea pigs, and fruit bats can't produce ascorbic acid (vitamin C) from glucose. In contrast, most horses produce enough vitamin C, but old and sick horses might benefit from supplementation.

History of Vitamins

The curative effects of certain foods have been recorded since ancient times. Hippocrates in Ancient Greece (400 BC) observed that eating liver could cure night blindness, which is a symptom of vitamin A deficiency. In England in 1757, James Lind found that only fresh fruits and vegetables prevented the vitamin C deficiency disease scurvy (a disease characterized by spongy gums, loosening of the teeth, and a bleeding into the skin and mucous membranes). In Italy in 1810, Marzari made the connection between feeding corn and the deficiency disease pellagra (a disease marked by dermatitis, gastrointestinal disorders, mental disturbance, and memory loss).

After experimentation on the cause of beriberi (a deficiency disease marked by inflammatory or degenerative changes of the nerves, digestive system, and heart caused by a lack of or inability to assimilate thiamine), Cashmir Funk of Poland formulated the "vitamin theory of disease." He had isolated nitrogen in each substance that reversed disease and proposed that the four diseases--beriberi, pellagra, scurvy, and rickets (a deficiency disease that affects the young during the period of skeletal growth, characterized especially by soft and deformed bones, and caused by a failure to assimilate and use calcium and phosphorus normally due to inadequate sunlight or vitamin D)--were due to a lack of four different "vital amines" (compounds derived from nitrogen-containing ammonia) in the diet. The term vitamine was used for those substances that prevented disease. At about the same time in England, F.G. Hopkins discovered that some factors in milk were necessary for the growth of rats on purified diets. Funk and Hopkins received the 1929 Nobel Prize in medicine for their work.

Researchers at the University of Wisconsin demonstrated the need for the first fat-soluble vitamin from butterfat and egg yolk. They also found the first of several B vitamins in wheat germ. As more vitamins were discovered, it became clear that they did not all have nitrogen-containing amine groups. Therefore, the "e" was removed from vitamine, leaving the current term vitamin.

Classification and Functions

Vitamins are classified according to their solubility, which determines the site in the body where they function. Body tissues are primarily composed of watery or fatty (oily) substances, the fluids outside and inside cells are water-based, and cell and organelle membranes and nerve tissues contain substantial amounts of fatty substances. Vitamins that function in the watery areas are called water-soluble vitamins, and include vitamin C and the B-complex vitamins. Vitamins that function in the fatty tissues are labeled fat-soluble, and include vitamins A, D, E, and K.

Solubility influences a vitamin's mode of action, storage capability, and toxicity. The B vitamins, except B_{12}, are not stored in the body. They enter the body, make their way into intra-cellular (inside a cell) and extra-cellular (outside a cell) fluids, and are excreted via the urine without much modification. Most water-soluble vitamins function as co-enzymes (lowering the energy required for metabolic reactions) in energy, protein/amino acid, and nucleic acid metabolism. Some are co-substrates (acted upon by enzymes) in enzymatic reactions (such as vitamin C in oxidation/reduction reactions), or are structural components and regulatory agents (such as choline and inositol in phospholipids).

Fat-soluble vitamins A and D are stored in the liver and can be viewed as hormones, since they are produced in one location and function in another location. They are not as easily absorbed as water-soluble vitamins, and can be toxic if over-consumed. Vitamin E and the vitamin A precursor (building block) beta-carotene are stored in adipose (fat) tissue and are not considered toxic. Vitamin K is a co-enzyme and has both water-soluble and fat-soluble varieties; it is necessary for the proper formation of blood clots.

Vitamin A

Vitamin A is a general term for several related compounds, including retinol, retinal, and retinoic acid. Vitamin A is not found in plants. However, beta-carotene and other carotenoids found in green forage and yellow corn are precursors of vitamin A, which is formed within the body.

The beta-carotene content of hay is largely lost during hay curing and storage, although dehydrated hays retain more of their beta-carotene than sun-cured hays. There are reports that all vitamin A activity is lost in hay after six to 12 months.

A three- to six-month supply of vitamin A can be stored in the equine liver. Synthetic forms of beta-carotene are not easily absorbed by horses, so rather than supplementing beta-carotene, supplementation should consist of vitamin A.

Vitamin A aids in vision, bone remodeling, and the maintenance of epithelial (skin) cells. Signs of vitamin A deficiency can include night blindness, excessive lacrimation (tears), hyperkeratinization (hardening) of the cornea and skin, anorexia, elevated cerebrospinal fluid
pressure, convulsions, reproductive failure, and a decline in plasma and liver vitamin A concentrations. Prolonged feeding of large amounts of vitamin A can cause toxicity signs, including bone fragility, hyperostosis (overgrowth or thickening of bone), exfoliated epithelium (peeling skin), teratogenesis (defects in embryos and fetuses), rough hair coat, poor muscle tone, and ataxia (incoordination).

Low red blood cell counts and low levels of plasma cholesterol and albumin might indicate vitamin A toxicity. Severe toxicity (up to 1,000 times of the required minimum amount) can result in depression, alopecia (hair loss), severe bone deformation, and death.

Vitamins are measured with two kinds of units, traditional weight units such as milligrams (mg), and international units (IU), which measure the activity of the vitamins. According to the National Research Council's (NRC) *Nutrient Requirements of Horses* (1989) (online at www.nap.edu/books/030
9039894/html/index. html), an adult horse's vitamin A requirement is 30-60 IU/kg of body weight per day (12,000-24,000 IU for a 400-kg horse), or 72-144 µg beta-carotene.

A recent report of several studies recommended that the vitamin A requirement be doubled in the next version of the NRC. In a two-year study, racehorses in training have benefited from daily supplementation of 50,000 IU of vitamin A by remaining sound longer than control horses.

Vitamin D

Vitamin D_3 (cholecalciferol) is formed in the skin of animals from irradiation of 7-dehydrocholesterol by sunlight. Two vitamin D_3 metabolites (products of vitamin D_3 metabolism) act on the intestines, bones, and kidneys to regulate calcium homeostasis (balance) and promote synthesis of calcium-binding proteins.

There are no documented cases of vitamin D deficiency in horses unless they are kept inside away from all sunlight. Rickets has occurred in foals fed vitamin D-deficient diets and kept in the dark. Vitamin D toxicity, on the other hand, involves calcification of soft tissues, blood vessels, heart, and/or kidneys due to bone resorption abnormalities. Supplementation of vitamin D, if needed, is recommended at 10% of the amount of supplemental vitamin A.

Vitamin E

Vitamin E is a general term for compounds with the biological activity of alpha tocopherol. Vitamin E is a broad-spectrum lipid (fat) antioxidant that functions in cell membranes and improves the immune response in horses. It is also an effective antioxidant in both feeds and body tissues. Acetate forms of vitamin E are stable until digested in the intestine, and they are the most common forms in feeds.

Deficiency of vitamin E can result in several diseases in horses, including equine degererative myeloencephalopathy (EDM) and equine motor neuron disease (EMND), a condition that resembles Lou Gehrig's disease in humans. Vitamin E supplementation of 2,000 to 5,000 IU per day is recommended for healing of nerve tissue in treating equine protozoal myeloencephalitis (EPM). Vitamin E is also recommended for horses prone to tying-up (exertional rhabdomyolysis) and for improvement of reproductive function because a deficiency in vitamin E can cause cellular damage. Horses fed added fat rations probably will benefit from supplemental vitamin E because of its antioxidant activity. Signs of vitamin E toxicity have not been reported in horses.

Recent studies show that the natural-source form of vitamin E is about three to four times more effective in horses than the form in synthetic sources. Wheat germ, stabilized rice bran, and soybean oil are excellent natural sources of vitamin E.

Vitamin K

Vitamin K is required for blood clotting, but no requirement has been established for horses. However, it has been shown that 20 mg/day can be safely fed to performance horses. The use of vitamin K to prevent or lessen exercise-induced pulmonary hemorrhage (EIPH, or bleeding from the lungs in racehorses) is currently being studied. Vitamin K in the diet appears to be non-toxic. However, parenteral, intramuscular, or intravenous administration of 2-8 mg of the vitamin K_3 (menadione) per kilogram of body weight has caused acute renal failure and death in horses.

Vitamin C

Under normal circumstances, horses do not need dietary vitamin C, since they are able to manufacture it from glucose. Under conditions such as hot weather, stress, rapid growth, old age, high-level performance, or dietary deficiency that interferes with vitamin C synthesis, however, horses might benefit from vitamin C supplementation. Further studies are needed to determine the effectiveness of supplementation with vitamin C.

B Vitamins

B vitamins are necessary for the metabolism of carbohydrates, proteins, fats, and nucleic acids. The bran and germ from cereal grains (such as wheat and rice) and brewer's yeast are excellent sources of B vitamins. B vitamins (except B_{12}) are found in good-quality forages and are synthesized by bacteria in the equine hindgut. Vitamin B_{12} is synthesized in adequate amounts when there is sufficient cobalt in the diet.

Dietary B vitamin supplementation might be beneficial in very young, very old, and hard-working horses as well as horses fed high-grain rations. All of these horses might have an altered population of bacteria in the hindgut.

Minimum requirements for thiamine (vitamin B_1) of 3 mg/kg diet dry matter for most horses and 5 mg/kg diet dry matter for working horses have been established by the NRC. That publication also lists a minimum value of 2 mg/kg diet dry matter for riboflavin (vitamin B_2). Optimum levels for supplementation have not been established, but toxicity of B vitamins is very unlikely.

Biotin has received considerable attention recently as a component of hoof supplements. There are conflicting results of studies involving biotin, probably because the total ration and status of the hindgut must be considered when studying the effects of biotin.

Vitamin Requirements of Horses

Horses have some level of need for each vitamin, which depends on their size, age, reproductive status, gender, temperament, and work load. The exact amounts needed are unknown, as there has not been as much vitamin research done in horses as in other species. However, some progress has been made in discovering minimum amounts required to prevent deficiency, maximum amounts that result in toxicity, and optimum ranges for performance (see "Vitamin Requirements" on page 84). Fortunately, the ranges for optimum performance seem to be large enough to allow for reasonable choices for supplementation.

Feeding Recommendations

Before making feeding and supplementation recommendations, amounts of vitamins in feeds should be considered. However, vitamin concentrations are extremely variable in feeds commonly fed to horses. General estimates are available based on analyses of feeds (see "What's In Your Feed?" on page 78), and hay samples can be analyzed by feed companies, universities, or extension services.

Since vitamin concentration in feeds is so variable, providing supplemental vitamins is an economical way of making sure requirements are met. Today, virtually all commercial animal feeds are fortified with vitamins. There is no longer discussion about whether they are needed, but rather in what amounts. In fact, the routine addition of vitamins and minerals to horse feeds has dramatically reduced the incidence of deficiency diseases in the last half of the 20th Century.

Unfortunately, feeding vitamins and minerals as part of grain-based concentrates is not without its problems. A grain-based concentrate can only be made with correct amounts of vitamins and minerals for one feeding rate, which is not always adhered to by horse owners. For example, a feed manufacturer might formulate a feed for a six-pounds-per-day feeding rate. If horse owners feed two pounds or 10 pounds of that concentrate daily, they underfeed or overfeed the vitamins and minerals. Also, many horses need supplemental vitamins and minerals, but become overweight if fed grain mixes on a regular basis.

An alternative to fortified grain mixes is complete vitamin/mineral supplements formulated for horses. These supplements provide vitamins in amounts that will prevent deficiency when used with poor feed and forage sources and approach or supply optimum amounts for performance, growth, and reproduction when fed with good feed and forage sources. Additional calories from grains can then be fed only when necessary. There are also supplements available that can be fed on a free-choice basis to horses on pasture, greatly reducing management time.

The Future of Vitamins

Since the 1989 version of the NRC guidelines was published, hundreds of research studies have been conducted on various topics of equine nutrition. Several groups of people, including members of the Equine Nutrition and Physiology Society, have begun to consider new vitamin requirements based on current research.

The current trend toward greater use of fermentable fibers and added fat to replace some cereal grains in rations will probably result in changes in vitamin and mineral needs. There is a lot of interest in B vitamins for performance horses which consume large amounts of energy-producing feeds and might have compromised hindgut function. Antioxidants, especially vitamin E, are showing a lot of promise in both human and equine nutrition.

Large amounts of vitamins cannot make horses better at their respective sports. However, less than optimal amounts of vitamins can limit performance. In general, the focus in the future will be to report nutrient amounts in minimum, optimum, and toxic amounts, rather than just minimums. As more research is conducted, optimum ranges will be narrowed so that costly excesses can be prevented, and vitamin requirements can be met.