

## Nutrient Requirements of the Foot

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"The hoof is a truly dynamic architecture, and its nutrient supply is critical for its strength and function," said Connie Swenson, PhD, research nutritionist with Zinpro Corporation, at the Second International Equine Conference on Laminitis and Diseases of the Foot (held Nov. 10-11 in West Palm Beach, Fla.). "It bears the physical demands of weight bearing and motion, its internal and external components work as a single integrated unit, and its strength begins at the cellular level with proper synthesis of materials and organization of proteins and lipids."

There are many nutrients that affect growth, she said, and protein and energy are the first limiting nutrients (if they are not present in sufficient amounts, then hoof quality will be poor regardless of what other nutrients are present). Important minerals include calcium (Ca), zinc (Zn), manganese (Mn), copper (Cu), and selenium (Se). Essential vitamins are A, E, and biotin.

"It all comes back to balance," she explained. "You can't just focus on one nutrient. And often we feed them too much of these nutrients."

### **Bone Nutrition**

Swenson defined the importance of several nutrients to bone growth and maintenance as follows:

**Protein (amino acids)**--These are used to synthesize collagen and bone protein matrix.

**Energy**--Fuels all metabolic functions. Swenson noted that cobalt improves forage utilization (getting energy from forage) by increasing hindgut fermentation.

**Calcium and phosphorus**--These minerals are necessary for skeletal soundness, exchange of nutrients and waste between bone, blood, and tissues, and they are deposited in collagen for structural strength. "As we talk

about the connections between bone and dermis (innermost soft tissue layer of the foot), the collagen is very tough and durable," she said.

**Zinc**--This mineral plays a role in growth and repair through cell division, and it is a component of an enzyme that's responsible for collagen synthesis and turnover. "Zinc deficiency hinders protein enzyme systems in the skeleton, muscles, and immune system," Swenson explained.

**Manganese**--This mineral is involved in synthesis of the organic matrix of the skeleton, and as such is essential for proper fetal skeletal development and production of chondroitin sulfate (a major component of cartilage and inhibitor of cartilage-destructive enzymes).

**Copper**--Bone and connective tissue formation depend in part on the presence of copper, which is important in cross-linking of collagen fibers (for strength) through the action of lysyl oxidase, a copper-dependent enzyme. "There are questions on the repeatability of copper supplementation results," Swenson said. "Have we overshot the proper levels of copper supplementation? When you go into most barns, you see many different types of supplements. The horse can be very forgiving of over-formulating diets in terms of trace minerals. Many survive in spite of what we're doing, rather than benefiting from it."

**Vitamin A**--Controls cells responsible for bone re-absorption (which is a normal part of bone remodeling to meet the demands placed on it).

**Vitamin D**--Regulates calcium and phosphorus plasma levels through absorption and bone mineralization/demineralization.

## **Dermis Nutrition**

"The dermis of the foot lies between and attaches the hoof capsule and central axial core (bone)," Swenson explained. "Its flexibility allows the hoof wall and coffin bone to move in different directions during weight bearing."

The dermis is composed primarily of collagen and is anchored to the coffin bone, branching out to form the lamellar interface, she added. It also has nerves that control blood flow and sensation in the foot. It is well

supplied with blood vessels that deliver nutrients to the foot. Its nutritional requirements are as follows:

**Water**--Responsible for tissue hydration and adequate circulation. "In some locations, there are problems with water quality," she commented. "High concentrations of sulfur and/or iron may tie up some other minerals."

**Protein (amino acids)**--Used to synthesize collagen.

**Zinc**--Plays a role in cell division, growth, and repair, collagen synthesis via a zinc-dependent enzyme, and cell membrane protection through its antioxidant activity. "Zinc's antioxidant properties can become very critical," Swenson explained. "You need to start with very viable cells and maintain them in a healthy condition."

**Manganese**--Important in cell membrane protection via antioxidant activity.

**Copper**--Involved with cross-linking of collagen and elastin (in blood vessel walls), through activity of lysyl oxidase.

**Selenium**--Plays a role in cell membrane protection via antioxidant activity from within cells. "However, if selenium is overfed, it becomes a pro-oxidant (causing damage by creating oxygen free radicals) rather than an antioxidant," Swenson warned.

**Vitamin E**--Also important in cell membrane protection, via antioxidant activity at the membrane level. It has a synergistic effect with selenium and glutathione peroxidase. "Vitamin E is fat-soluble at the lipid level (lipids are important components of cell membranes; vitamin E exerts antioxidant activity at cell membranes)," Swenson explained. "Selenium scavenges free radicals in the cytoplasm (within the cells)."

**Vitamin C**--Involved in connective tissue production, collagen production, and blood vessel integrity.

### **Hoof Capsule Nutrition**

"The hoof capsule forms a complex capsule around the foot," Swenson stated. "It consists of a relatively hard, highly modified layer of skin. Its toughness allows it to withstand the forces placed on it, and its flexibility allows it to deform when weight bearing."

The hoof capsule requires several nutrients for proper function, according to Swenson:

**Protein (amino acids)**--Used to synthesize structural proteins, keratin, keratin-associated proteins, cell envelope proteins, and intercellular cementing substance. Lysine is the only amino acid with a recommended level in the diet from the National Research Council. Methionine, however, is important for skin, hooves, tendons, ligaments, and cartilage. Sulfur-containing amino acids (such as methionine and cysteine) are required for cross-linking in proteins such as keratin. Methionine deficiency leads to poor growth, low stress tolerance, hoof and skin problems, and poor adaptation to exercise. The overall amino acid balance is critical, and excessive levels can be at least as problematic as levels that are too low.

"Deficiencies in different nutrients often yield the same clinical signs," Swenson noted. "Sometimes it's tough to diagnose exactly what the problem is."

**Zinc**--Important in basal epidermal cell division and protein synthesis via a zinc-dependent enzyme. Zinc deficiency can cause abnormal skin and hooves, bone and joint problems, and poor wound healing. On the flip side, however, too much zinc depresses copper absorption; loading up on zinc can cause copper deficiency, Swenson said. She noted that some areas have very high zinc levels; in these areas, horses often have copper deficiencies. She suggested a ratio of 3:1-5:1 zinc:copper in the diet.

"Forage often can't supply enough zinc," she noted, adding that bioavailability might be an issue in a horse with poor absorption.

**Manganese**--Functions in cell membrane protection and has antioxidant activity as a free radical scavenger.

**Copper**--Important in the formation of disulfide bonds in keratin and cell envelope proteins via its role in thiol oxidase (an enzyme) production. Copper also functions in cell membrane protection as an antioxidant. Toxicity isn't usually a problem, Swenson said, but too much copper can depress zinc absorption. Deficiency can cause bone and joint disease, tendon and ligament problems, and poor hoof quality. Sulfur, molybdenum, and iron are antagonists (they interfere with copper absorption and activity).

"Zinc, copper, and manganese supplementation yields an improvement in wall quality far and above that of zinc alone," Swenson commented.

**Calcium**--Signals initiation of cell envelope formation that results in fully cornified cells.

**Selenium, Vitamin E**--Function in cell membrane protection, and they act as antioxidants.

**Biotin**--Important in intercellular cementing substance for cell-to-cell adhesion in the outer hoof wall. "Biotin is probably stamped on the front of every hoof supplement out there, but you have to understand the entire process to understand how it helps," Swenson said. "Think of a brick wall. Biotin functions like the mortar holding the bricks together. More biotin can give you better mortar, but you still need good, solid bricks from other nutrients.

"The horse produces some biotin during hindgut fermentation," she explained. "Deficiency is tough to produce. There has been no difference demonstrated between plasma concentrations of biotin in horses with good and bad feet. It seems to be most effective on stratum externum (outer hoof wall) defects, such as in horses with shelly, brittle hoof wall. Toxicity is nonexistent due to efficient elimination in the urine."

**Manganese**--Deficiency causes abnormal bone and joint development, impaired ability to make or repair joint cartilage, and abnormalities in skin, hair, and hooves. "Foals which lacked manganese during gestation knuckle over," said Swenson. Forages normally have adequate levels, but availability is often minimal. Toxicity has not been reported in horses.

**Selenium**--This nutrient is more "touchy" than others; chronic toxicity (possibly caused by supplementing this nutrient to a horse which doesn't need it) can cause lameness, cracking and sloughing of hooves, and loss of mane and tail hair. Deficiency can cause muscular cramping, poor stress tolerance, impaired immunity, and subpar performance.

"Some say this was one factor in Custer's demise--traveling through the South Dakota area where soils are very high in selenium (resulting in problems with his horses)," Swenson commented.

**Vitamin A**--Involved in maintaining epithelial tissue integrity. Deficiency is rare, she said, but occurs when grain and poor-quality hay are fed; inflammation of the coronary band is a result. Plant sources of Vitamin A are usually adequate. One can't create toxicity with beta-carotenes, but it is possible with supplements that contain retinyl palmitate or retinyl acetate. The clinical signs of toxicity include fragile bones and abnormal bone

deposits in the body.

In summary, Swenson stated that building the hoof starts at the cellular level. "Understanding the role of nutrients and how they relate to growth, maintenance, and repair is critical for decision making. Balanced nutrition is the key--feeding high levels of one or more nutrients disrupts the balance."

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