Explanation behind the scenes

A horse has unique anatomical and physiological characteristics that relate to nutrition

by Amy Gill, Ph.D.

HORSES are remarkable animals in many ways, but several special physiological and anatomical characteristics make them unique.

Did you know that the microbial populations in the horse's hindgut produce enough B vitamins to meet the horse's requirement at maintenance? Or that healthy horses can produce vitamin C in their livers from glucose and do not have to obtain it through dietary means?

Did you know that horses can use diets that contain fat even though they have no gallbladder and, therefore, no storage of bile, which is needed for fat emulsification and absorption? Did you ever wonder what causes the milky color of the urine of horses that eat high-quality alfalfa hay?

Did you know a horse cannot vomit, making an obstruction or impaction in the stomach potentially lethal? And why horses often will not drink water after they sweat profusely and become electrolyte depleted following intense exercise?

All of these characteristics are unique to the horse. Some are useful, while others are detrimental.

B vitamins from the hindgut

Vitamins are the organic materials that act as catalysts for a variety of reactions that take place within the horse's body. This means they speed up chemical reactions, enabling them to take place more quickly and efficiently than they would otherwise. If these catalysts are missing, as in a vitamin deficiency, normal body functions can break down and make the horse susceptible to disease.

Vitamins are synthesized by the horse, microorganisms, and plants. The horse can produce vitamin D (produced in the skin), vitamin C (produced in the liver from glucose), and the B vitamin niacin (from the amino acid tryptophan). All other vitamins, including A and E, must be obtained through dietary sources. The B vitamins thiamine (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxine (B_6), folic acid (B_9), cyanocobalamin (B_{12}), and biotin are produced by the natural bacteria in the horse's hindgut, which also produces vitamin K.

B vitamins are necessary for healthy functioning of almost all body processes, which is why they are called essential nutrients. B vitamins are water-soluble vitamins and differ from fat-soluble vitamins such as vitamins A, D, K, and E in that they are not stored in the body. Vitamins A and D are stored in the body for three to six months, while vitamins E and K are stored for only one to three weeks.

Water-soluble vitamins need to be consumed on a daily basis. In many instances, B vitamins work together during a biochemical process such as the breakdown and conversion of carbohydrates into glucose for energy production in the body and maintenance of blood vessels and hormone metabolism. B vitamins contribute to the efficient functioning of the nervous system by breaking down fats and proteins. They also support muscle tone in the digestive tract; maintain healthy skin, hair, and eyes; and promote liver health.

Typically horses that are in training, growing, or reproducing are supplemented with additional B vitamins in their daily rations because they rapidly use B vitamins when exposed to higher levels of stress while shipping, racing, or foaling. It is important that commercial feed preparations fed to these classes of horses are fortified with B vitamins. Natural and synthetic vitamin B complexes often are used in feeds, and brewer's yeast is also an excellent source.

High-quality forages also supply a significant amount of B vitamins. Therefore, horses on very low-forage diets (some racehorses are maintained on low-forage diets) and/or under severe stress are likely to become deficient if they are not also being fed a concentrate that has been fortified with B vitamins. Deficiency results in poor appetite, sour attitude, and anemia.

B vitamins, with thiamine in particular, have been fed to horses in an attempt to decrease nervousness, but there is no scientific evidence to support this. Vitamin B_{12} has commonly been marketed to horsemen as a way to enhance performance by increasing mature red blood cell or hematocrit counts, but research conducted to show that administering high levels of B_{12} has this effect is inconclusive.

Biotin often has been supplemented to improve hoof and coat quality, and some individuals appear to respond positively to the higher supplemental levels.

Vitamin C and the liver

In their livers, horses produce the enzyme gulonolactone oxidase, which converts glucose to vitamin C (ascorbic acid). Vitamin C is a powerful antioxidant that works to prevent cellular damage from free radicals, particularly during times of stress or intensive training. When the stress level increases, sometimes the amount of oxidized products inside the cell exceeds the amount of vitamin C in the cell, justifying additional supplementation through dietary means.

However, the benefits of feeding high levels of vitamin C to horses have not been proven in studies as have the benefits of feeding higher levels of vitamin E, which is a powerful antioxidant that protects the cell membrane. Vitamin C, however, helps to recycle vitamin E and therefore improves its effectiveness as an antioxidant.

Regardless, vitamin C has been purported to help prevent bleeding from the lungs and improve immune response. Recent research has shown the need for vitamin C in producing specific proteins, such as collagen, and other structural elements of connective tissue. Because of this connection, many studies have focused on the impact of vitamin C on healing rates, bone modeling, blood vessel integrity, and even tooth formation, in addition to its known antioxidant properties.

Liver and fat emulsification

In the mid-1980s, much research in horse nutrition was focused on the use of feeds containing higher amounts of fats. The theory was to supply an energy-dense substrate (fat contains 2½ times as many calories as grain) that the horse could use during exercise. Studies soon showed that fat was indeed used preferentially over glucose or glycogen during aerobic and long, slow, distance exercise and that horses that were adapted to diets higher in fat would maximize the use of fat over glucose, resulting in a sparing effect on glycogen stored in the muscle.

Horses adapted to higher-fat diets actually develop more mitochondria (site of oxidative metabolism) in the cell, as well as higher concentrations of enzymes required to use fat as an energy source. When faster, more anaerobic work is required, though, glucose or glycogen must be used to fuel muscle, and fat-adapted horses will mobilize and burn fat during warm up and warm down, as well as the parts of the exercise that fluctuate between aerobic and anaerobic.

For example, the middle portion of a race of one mile or longer is not run as fast as the beginning or end of the race, and the opportunity for the horse to reserve glycogen and use fat at this time would be useful.

Current research is focusing more on the healthful benefits of adding fat to equine

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rations, most importantly to reduce the amount of starch fed to horses. This is in an attempt to alleviate metabolic, growth, and exercise disorders that are directly linked to inefficient starch metabolism in the horse.

Today, it is not unusual to see horse feeds that are formulated for high-level performance horses contain as much as 10% to 12% fat. Often these feeds also contain soluble fiber, which together can reduce the starch content of the feed from as much as 50% to 65% starch (typical sweet feeds that contain corn, oats, and barley) down to 25% to 35% starch. These feeds have a higher caloric content, as well, making them suitable for the hard-working racehorse, lactating broodmare, or yearling being prepped for sale.

An additional benefit with higher-fat products is the tractability of the horses that consume this type of feed. This is because the lower starch content helps prevent the "sugar high" often noticed in horses being fed sweet feeds that are covered with molasses.

So why has it taken the horse industry so long to figure out that higher fat in horse rations is a good thing on several different levels?

To begin with, horses are grazing herbivores and really are not meant to eat anything but roughage, so starches and fats are not natural ingredients that are normally found in the diet of grazing or wild horses. It was originally believed that adding grain made the most sense when caloric intake needed to be increased because grains are from plant origins and horses will readily eat them. But once the issues associated with high grain and starch became evident, fat became an alternative feed ingredient out of necessity.

Fat had been widely overlooked as an important ingredient in horse feeds because horses do not have gallbladders to store large amounts of bile salts, the emulsifier needed for the breakdown of fat in the digestive tract. It was speculated that horses might not be able to process the extra fat efficiently without a large supply of bile. As it turned out, this was not the case; the horse's liver apparently can supply enough bile for very efficient fat digestion.

Bile salts emulsify dietary fats in the small intestine, forming mixed micelles, which can then be acted upon by the enzyme lipase, secreted from the pancreas. Lipase further breaks down the fat molecule into fatty acids and glycerol, which are small enough to be transported across the luminal wall of the small intestine.

Further processing allows components to be transported through the lymphatic system and bloodstream, delivering them to muscle cells to be used as fuel or stored as adipose (fat) tissue for later use.

It is now known that the horse tolerates fat up to levels as high as 20% of the total diet (forage, concentrates, and supplements). Diets with this inclusion rate of fat are often recommended for horses that have problems with recurrent exertional rhabdomyolysis, or tying up.

Excess dietary calcium

Calcium and phosphorus are two macrominerals that comprise approximately 70% of the total mineral content in the horse's body. Calcium is responsible for several important metabolic functions, most notably well-mineralized, strong, and dense bones. Ninety-nine percent of the calcium in the horse's body is contained in bones and teeth.

Calcium also plays an important role in several other biochemical processes in the body. They include muscle contraction (release of calcium in the cell causes a voltage drop, precipitating contraction); efficient pumping of blood from the heart; contraction of smooth muscle in the intestines for proper digestion and movement of feed; and nerve conduction and other metabolic reactions such as blood clotting, cell membrane function, regulation of body temperature, and the regulation of activity of many enzymes.

The level of calcium in the horse's bloodstream is tightly regulated by hormones secreted by the horse. Vitamin D, which regulates the uptake of calcium from the intestine and the balance between release or deposition of bone calcium and phosphate, along with the hormones parathyroid hormone and calcitonin, maintain blood calcium levels within a narrow range to ensure normal function of metabolic processes.

Muscle and nerve excitation and contraction are extremely dependent on calcium for proper function. Bones are a good source of stored calcium upon which the horse can rely if blood levels begin to drop during exercise. However, it is preferable to supply adequate amounts of calcium in the diet to meet the horse's requirement so that bone sources are used only in an emergency situation (for example, horses that race at very long distances must use bone stores of calcium during a competition).

When the diet does not provide adequate calcium, the parathyroid hormone stimulates the mobilization of calcium from bones and into the bloodstream. When there is too much calcium in the blood, calcitonin causes the excretion of excess calcium into the urine, and also reduces absorption of calcium from the digestive system. (Rabbits also primarily excrete calcium through the urine, unlike other mammals, which primarily excrete calcium through the bile and feces.)

If a horse suffers from long-term dietary calcium deficiency, significant reabsorption of bone calcium can occur, and this can lead to decreased bone strength or abnormal bone formation. This tightly regulated system exemplifies how the horse's body will sacrifice optimum bone strength formation to maintain the blood calcium levels when necessary.

Feeding calcium-rich hays such as legumes often results in dietary calcium intakes that exceed the horse's requirements. Generally this is not a problem and will not cause problems in the healthy kidney, but excess calcium in the diet might interfere with the absorption of copper, manganese, zinc, and iron. Also, excess zinc inhibits calcium and copper absorption.

The potential for imbalance brings to light the importance of using adequate amounts of minerals and the correct ratios of minerals with respect to each other. Indiscriminate supplementation of minerals resulting in overdosing can be as detrimental as deficiencies.

Finally, enteroliths, the formation of large stones from magnesium and calcium in the digestive tract, have also been linked to the feeding of very high-calcium forages such as very high-quality alfalfa.

Horses cannot vomit

The fact that horses cannot regurgitate food presents a delicate and difficult situation if food becomes impacted in the stomach or an obstruction occurs at the junction of the esophagus and stomach or at the sphincter between the stomach and the beginning of the small intestine.

Horses have a band of muscle around the esophagus as it enters the stomach. This band prevents food from coming back up out of the stomach into the esophagus. Food freely passes down the esophagus into the stomach as the valve relaxes, but the valve squeezes shut the opening and prevents passage of food going back up the esophagus.

Humans have the same sphincters and mechanisms for keeping food in the stomach, but obviously the mechanism can be overridden easily if enough pressure or a toxic substance is present. Horses differ from us because their sphincter valve is so strong, it will not open up under any condition (there are isolated reports of horses throwing up).

Additionally, the horse's esophagus meets the stomach at an angle that enhances the strength of the sphincter valve when the horse's stomach is bloated with food or gas. The stomach wall then pushes against the valve, closing the esophagus even more completely from the stomach. Without veterinary intervention, which normally includes drugs to relax the horse and the insertion of a nasogastric tube to reflux the stomach contents, the mechanics are such that the horse's stomach usually ruptures because the valve will not open.

Another serious and somewhat related condition is choke, or esophageal obstruction in horses. Choke usually occurs in overly aggressive and fast eaters (behavioral origins) and can occur with any type of feed, even forages. Choking blocks the passage of food to the stomach but does not interfere with the ability of the horse to breathe. This is because it occurs in the esophagus, not the windpipe; blockage in humans generally does obstruct breathing.

Often when horses choke or have and obstruction or impaction, food can be seen dribbling out of the horse's nose. This is the food that never reached the horse's stomach. Choking horses may show outward signs of pain, such as pawing and coughing, and act restless or panicked. A choking horse should not continue to eat because feed will simply pile up in the esophagus. This increases the risk that he will aspirate feed into the lungs, which can lead to a secondary infection or pneumonia.

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Spleen's importance to red blood cells

THE HORSE has an enormous amount of red blood cells stored in its spleen that can be called upon when intensive exercise is required.

The spleen is a dense, red-colored structure that is situated high on the left side of the abdomen and lies against the rib cage. There are two basic types of spleens: those that help boost immunity, and the type the horse has, which also serves as a reservoir for red blood cells.

Red blood cells are essential for the transport of oxygen from the lungs to other parts of the body. When a horse begins to exercise, the spleen contracts and releases stored red cells into the bloodstream. The horse's spleen is very large and can release an additional 30% of red blood cells when needed. Therefore, the increase in blood volume associated with splenic contraction provides a tremendous boost in the horse's capacity to transport oxygen during exercise. It is one of the unique physiological attributes of the horse and one reason a horse is such an elite runner.

Splenic contraction also can easily occur when the horse is simply excited. Therefore, measurements of red cell numbers (hematocrit) in samples taken from excited horses are not an accurate assessment of the horse's resting hematocrit.

For the same reason, hematocrit measurements obtained from calm, resting horses are not an accurate assessment of oxygen-carrying capacity or anemia.

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