Equine Nutrition

Equine Science – Chapter 7

Nutrition is a very important part of the equine industry in the United States. Without proper nutrition, horses would not be able to carry out their daily tasks in an optimal manner. Racehorses would not be able to perform at extreme speeds. Jumpers would not make it around the course and over the fences. Driving horses would not be able to pull carriages. Farm and ranch horses would not be able to put in an honest day's work. Pleasure and show horses would not have the energy to perform. Even broodmares would not produce enough milk to feed their foals.

The nutritional status of equines in the United States is generally very good. In contrast to the situation in many other parts of the world, nutritional problems in this country are more likely to be associated with overfeeding than with underfeeding. The U.S. has an abundance of good pasture and hay crops – which are mostly what the single-stomached, plant-eating horse needs to thrive.

Rule of Thumb

A generally accepted basic "rule of thumb" that useful when feeding horses: A horse should be fed approximately 2.0 pounds of total food per day for every 100 pounds of body weight. Another way to say that is that a horse should ingest approximately 2% of its body weight in total food each day. This rule is appropriate for feeding an average horse that is on a "maintenance diet". However, it may not be adequate for an animal that is young and growing, working hard, reproducing, pregnant or lactating.

Applying the rule – an example

- 1200-pound horse x (2.0 pounds of food/100 pounds of body weight) = 24 pounds of total food intake per day

Or, applying the rule the other way

- 1200-pound horse x .02 of body weight = 24 pounds of total food intake per day.

The total amount of food intake includes the amount of forage (pasture or hay) and any grain (another term for grain is "concentrate") that is being fed. The calculated amount of daily food should be weighed on a "dry matter" basis.

Grain, or concentrate, should not exceed more than 40% of the total daily diet. In fact, many horse require little or no grain to meet their daily nutrient needs.

One factor in determining whether a horse needs grain, and in what amount, is the quality and quantity of forage available to the animal. Other factors depend on the horse itself: the work it does, its "production" statue (is it pregnant or lactating?), and its individual growth needs.

To meet an animal's nutritional needs, the "rule of thumb" for total daily intake must be evaluated and adjusted for:

- the type of work
- amount or type of production (fitting/fattening, reproduction and/or lactation)
- phase of growth

A Few Examples

Total food intake per day for:

- maintenance – as little as 1.6 to 2 pounds per 100 pounds of body weight, or 1.6 to 2.0% of body weight
- lactating broodmare – as much as 2.5 to 3 pounds per 100 pounds of body weight, or 2.5 to 3.0% of body weight

Animals should be observed daily to help ensure that they are being well maintained at optimal body condition: not too thin and not too fat. The ration of individual animals may need adjusting based on these observations.

The Function of the Equine Digestive Tract

In order to understand equine nutrition, one must first understand some information about the digestive tract of the horse. This chapter will provide a basic description of the equine digestive tract and the major function of each of its parts.

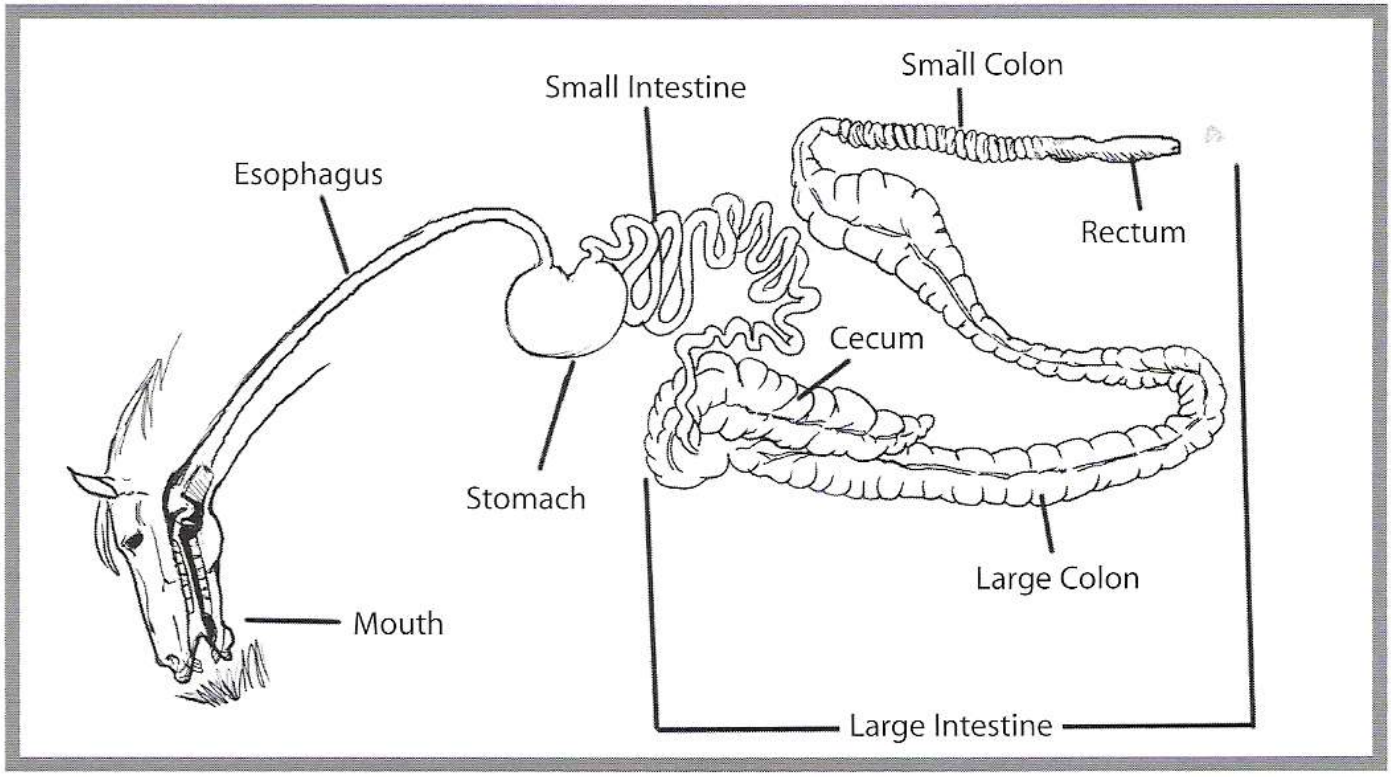
The two major functions of the digestive tract are:

- digestion – the breakdown of food into its smaller components
- absorption – the update of these components by the digestive system.

The equine digestive tract is composed of 5 major parts:

- mouth
- esophagus
- stomach
- small intestine
- large intestine

This books "Anatomy" chapter includes more detailed drawings of the horse's digestive tract.



Simple presentation of the digestive tract — not anatomically presented and not to scale.

Mouth

- **Digestive process** – the mouth is where the first breakdown of food begins, by the mechanical process known as mastication or chewing. This process reduces the particle size of the food and increases the amount of surface area, setting the stage for the digestive process. Mastication also stimulates the release of saliva from the salivary glands in the mouth. Saliva initiates the breakdown of starch in the chewed food, beginning the process of digestion.
- **Length** – approximately 1.5 feet
- **Volume** – small amounts
- **Rate of Passage** – 2 to 3 minutes of chewing
- **Capacity** – small amount and only during the eating process

- **Additional Information** – scientific studies have shown that when large amounts of saliva are released during the mastication process, there is a decrease in the fluids in the bloodstream, and that during the digestive process more blood is directed to the digestive tract and away from other parts of the body.

Esophagus

- **Digestive Process** – the esophagus is the tube that takes food from the mouth to the stomach. Its main function is to move food in that one direction by a process known as peristalsis.
- **Length** – approximately 4 to 5 feet
- **Volume** – small amounts
- **Capacity** – small amount and only during the eating process
- **Rate of Passage** – very quick
- **Additional Information** – the horse has a valve at the top of the stomach that prevents food from reentering the esophagus once it has reached the stomach. The valve also prevents the horse from passing gas (burping) back up the esophagus. This unique factor can cause some very serious problems, since the ability to vomit or burp would help a horse alleviate digestive-system upsets. In some cases, the buildup of pressure created by the inability to vomit or release gas through the esophagus has caused horses' stomachs to burst. It is thought that a very tight esophageal sphincter muscle is responsible for this inability to vomit or burp. Some other factors may also be involved.

Stomach

- **Digestive Process** – the stomach secretes acids and enzymes that help break down the food and continue the digestive process.
- **Length** – approximately .5 to 1 foot
- **Volume** – approximately 8% of digestive tract
- **Capacity** – approximately 2 to 4 gallons
- **Rate of Passage** – liquids can pass from a horse's stomach in as little as 15 to 30 minutes; dry matter may take as long as 12 hours; 75% of the stomach contents are gone in 30 minutes. Food matter leaves the stomach as a liquid or slurry.
- **Additional Information** – compared to the size of a horse's body and the capacity of the whole digestive tract, the stomach is very small. Because the stomach is so small, the rate of passage of food to and from the stomach is relatively fast. For these reasons, it is best to feed horses small and frequent meals, rather than larger and less frequent meals.

Small Intestine

- **Digestive Process** – the small intestine is where most of the work of the horse's digestive system takes place. Digestion and absorption of protein, vitamins and minerals, and energy contained in foodstuff occur here, with the help of digestive enzymes. Most of the fat-soluble vitamins are absorbed in the small intestine; these include vitamins A, D, E, and K. The body also absorbs two important minerals here: calcium and some of its intake of phosphorous. The simple, more soluble carbohydrates (non-fibrous carbohydrates) are digested and absorbed in the small intestine as well. These soluble carbohydrates include simple sugars and starch, which will be used as energy sources. Fat is another energy source that is digested and absorbed in the small intestine.
- **Length** – approximately 70 feet long
- **Volume** – approximately 30% of the volume of the digestive tract
- **Capacity** – 10 to 12 gallons
- **Rate of Passage** – 2 to 3 hours
- **Additional Information** – it should be noted that the horse does not have a gall bladder. This fact led to a longstanding belief that horses could not digest fat. However, research has shown that they can digest and utilize fat in the diet quite well. Bile produced by the horse's liver and secreted into the small intestine emulsifies (breaks down) fat. Much but not all of this fat digestion occurs in the small intestine. Food moves fairly quickly through the small intestine, and its contents are usually fairly watery in composition. No fiber digestion or absorption takes place in the small intestine.

Large Intestine ("Hind Gut")

The large intestine in the horse includes several different components. It can be described as comprising as many as 7 different parts. For the purposes of this chapter, the large intestine of the horse will be described as having 4 major parts: the cecum, large colon, small colon and rectum.

Cecum

- **Digestive Process** – the cecum is known as the "fermentation vat" in the digestive process of the horse. Bacteria, protozoa and fungi are the microbes that run this fermentation process. They work by releasing enzymes that break down and digest the more complicated fibrous carbohydrates (mostly plant fibers), which as composed of cellulose and hemicelluloses. The cecum is the major site for fiber digestion of forage eaten by the horse.
- **Length** – approximately 4 feet
- **Volume** – about 15% of the volume of the digestive tract
- **Capacity** – 7 to 8 gallons
- **Rate of Passage** – slow; can take up to 2 days
- **Additional Information** – food moves through the large intestine much more slowly than through other parts of the equine digestive system. Large amounts of water are absorbed here. The cecum in the horse is the physiological equivalent of the appendix in humans, but it does more work and is critical to the functioning of the horse's digestive tract.

Large Colon

- **Digestive Process** – further digests the nutrients in foodstuffs by fermentation, including continuing the breakdown of plant fiber. The main function of the large colon is water absorption.
- **Length** – approximately 12 feet
- **Volume** – about 38% of the volume of the digestive tract
- **Capacity** – about 14 to 16 gallons
- **Rate of Passage** – about 36 to 48 hours
- **Additional Information** – in this "segmented" part of the digestive tract, most of the water is removed from the remaining material and formation of fecal balls begins.

Small Colon

- **Digestive Process** – more water absorption occurs here. Most of the digestive process is not complete, and available nutrients have been removed from the foodstuff.
- **Length** – approximately 10 feet
- **Volume** – about 9% of the volume of the digestive tract
- **Capacity** – approximately 5 gallons
- **Rate of Passage** – no documentation found
- **Additional Information** – the remaining food material now becomes mostly solid and forms fecal balls – which are ready to be expelled from the body.

Rectum

- **Digestive Process** – responsible for the excretion of waste material out of the body
- **Length** – approximately 1 foot
- **Volume** – small amount, only during the defecation process. Material is not retained in the rectum.
- **Capacity** – small amount; material is quickly passed out of the body as fecal balls
- **Rate of Passage** – immediate evacuation once fecal balls enter the rectum
- **Additional Information** – the average total time food takes to travel through the horse's body, from intake through the mouth to waste excretion through the rectum, is approximately 36 to 72 hours (2 to 3 days). The average 1,000-pound horse produces 40 to 50 pounds of manure a day, or 7 to 9 tons per year (includes the weight of water in manure an during waste, but not the weight of the bedding). So the average horse owner moves approximately 8 tons of manure per year per horse: a true testament to the fitness level or horse owners!

The Basic Nutrients

To maintain a healthy body, the horse's diet must meet the animal's requirements for 5 basic nutrients:

- **Water** – approximately 5 to 10 gallons per day but his varies greatly depending on the animal's size and weight, environmental temperature, type and amount of foodstuff consumed, and amount of exercise, work, or production.
- **Protein** – approximately 8 to 15% of a horse's dietary needs
- **Vitamins** – approximately 1% of a horse's dietary needs
- **Energy** – approximately 80 to 90% of the horse's dietary needs. Energy itself is not a nutrient; however, there are "energy-producing nutrients" that are fed to horses, including:
    - **Carbohydrates**
    - **Starch**
    - **Sugar**
    - **Fiber or cellulose – the "fibrous" part of plants**
    - **Fat**

The intake of these nutrients in the proper amounts and proportions makes it possible for the horse to perform the functions of:

- Maintenance
- Growth
- Production (fitting/fattening, reproduction and/or lactation)
- And work

Water

Horses, like other living things, cannot live without water. Water is needed to carry other nutrients throughout the body and to help regulate body temperature. Approximately 65 to 75% of a horse's total body weight is made up of water. If a horse loses 10% of its body water, serious condition can result. The loss of 20% of body water can result in death!

A 1,000-pound equine typically consumes anywhere from 5 to 10 gallons of water per day. Intake varies from animal to animal and is affected by environmental temperature, exercise, type of food being consumed, age, health, pregnancy or lactation, etc.

Water is contained in all cells and fluids in the body and is essential for the following:

- Production of saliva
- Regulation of body temperature
- Chemical reactions involved in digestion, absorption and metabolism
- Normal cell function
- Lubrication of different body parts and systems for normal function of joints, hearing, central nervous system, sight and more.

Horses obtain some water from within their bodies as a result of digestive and metabolic reactions that take place inside the body to support its functioning. When the body processes proteins, carbohydrates and fats, "metabolic water" is an end result.

Any excess water in the horse's body is excreted in urine, feces, sweat and from the lungs as water vapor – a by-product of respiration.

Serious health problems, such as impaction colic and dehydration, can result from lack of water. Therefore, it is essential that horses have clean, fresh water available at all times. In colder climates, for example, the temperature of available water can cause horses to limit their intake. A severe form of colic, known as impaction colic, can result if caretakers do not provided warmed water or otherwise ensure that a horse has adequate water intake.

There are only a few situations in which water should be limited and not offered "free choice" to horses. Hot, heavily exercised horses should not be allowed access to large quantities or water. Instead, they should be offered small amounts over a period of time, allowing the body to return gradually to a more normal temperature – a process known as "cooling out". With certain types of colic, the intake of additional water may actually worsen the problem; therefore, always consult a veterinarian if you suspect colic. Another example where water intake may need to be monitored and/or reduced would be just prior to a race or other intense physical exercise. In these cases the intake of large amounts of water may need to be limited.

Protein

Protein, a vital component of all animals' diets, should make up 8 to 15% of a horse's ration.

Proteins are made up of a "chain" of many smaller parts known as amino acids. Different proteins contain different amino acids. (An analogy made by Lon D Lewis in his equine-nutrition book, Feeding and Care of the Horse, is that "if amino acids were letters in the alphabet, proteins would be worlds.")

The amino acids are often referred to as the "building blocks" of the body. They are the basic materials from which bone, muscle, and soft tissue are "built". Amino acids also make up enzymes, blood, hormones, hoof, hair and more.

In nature, there are 22 different amino acids that exist and can make up protein chains. All amino acids include carbon, oxygen and hydrogen molecules. What makes them different from carbohydrates or fat is that amino acids also include a nitrogen molecule – and in some case they include a sulfur, phosphorous or iron molecule as well.

During the process of digesting, enzymes and acids in the horse's digestive tract break down protein in foodstuffs into the amino acids that make up the protein's chain. The amino acids are absorbed through the wall of the small intestine and into the bloodstream by way of the liver. The amino acids are then sent in all directions throughout the body. At this point, they are still mostly in the same form as when they were absorbed in the small intestine.

The horse's body has the ability to change ("synthesize") some amino acids into different amino acids when the body needs them. However, it cannot synthesize all of the amino acids needed to run its very complicated body systems. The amino acids that cannot be synthesized in sufficient amounts are known as essential amino acids. These amino acids must be supplied by a protein source in the horse's diet. (The amino acids that can be synthesized within the body are called the non-essential amino acids.)

Today, most commercial feed products are formulated to include essential amino acids. The essential amino acids are particularly important to young, growing equines.

Protein can also be an energy source. However, fat and carbohydrates are much more efficient energy sources, as they produce must less heat while being turned into energy. The excess heat produced by the body when breaking protein down into energy may be acceptable in the cold months, but it could be detrimental to a horse doing hard work in the warmer months of the year. Heat exhaustion could result. Thus, feeding protein is not an efficient way of delivering energy to the body.

The protein that is not broken down into amino acids and absorbed in the horse's gastrointestinal ("G.I.") tract is not stored as protein in the body. Instead, it is chemically broken down, releasing nitrogen, carbon, hydrogen and oxygen molecules from the amino acids that make up the protein chain. The nitrogen released from this breakdown is excreted from the body in urine. The carbon, hydrogen and oxygen molecules are stored in the body and available to be used as a source of energy by the horse.

There are two terms that horse owners should be familiar with when talking about prptein sources in a horse's diet:

- **crude protein (CP)** – this number estimates all of the nitrogen content of the feedstuff. CP is not a good estimate of how much of the nitrogen in feedstuff is from a protein source, or of how much would actually be available to the horse during the process of digestion.
- **disgestible crude protein (DCP)** – this number represents protein content based upon nitrogen content in the feedstuff. DCP estimates what would actually be available to the horse during the process of digestion.

Both crude protein and digestible crude protein are expressed as percentages.

Urea is an inexpensive "non-protein" source of nitrogen that is added to many livestock-animal rations. Bacteria in the rumen (first stomach) of cattle and other "ruminant" livestock easily process urea. However, they horse has no rumen and in general cannot utilize urea. In fact, urea can be toxic to horses, especially to growing animals. Therefore, even though it may be cheap and readily available, horse owners need to understand that it is not a good source of nitrogen for horses.

A lack of protein in a horse's diet can produce any or all of the following effects:

- decreased growth rates
- decreased appetite
- body tissue loss
- muscle loss
- slow hoof growth
- poor hair coat
- lack of energy to do work or perform at peak performance levels.

The lack of adequate and quality protein in young, growing animals can have permanent negative effects. Remember, protein and the amino acids contained in protein are the building blocks of the animal's body. Protein can be supplied and/or added to the horse's diet in many ways.

- Some plant sources of protein:
    - Forages – from pasture or hay (dried grass hay, such as timothy, or legumes, such as alfalfa)
    - Grains – cereal grains such as oats, corn, sorghum, barley, wheat or rye
    - High-protein sources – soybean meal and canola meal are the best high-protein sources for horses, due to their amino-acid content and balance; other choice include linseed meal, cottonseed meal, corn gluten meal, sunflower meal, brewer's yeast, rice bran, etc.
- Some animal sources of protein:
    - Milk protein – from milk sources or milk-processing by-products (such as whey)
    - Egg protein – from egg products
    - Fish meal – from fish or fish-processing by-products
    - Meat-industry waste products – from meat products or meal-processing by-products (such as bone meal and blood meal).

Vitamins

Vitamins are necessary for all body functions. However, horses and other living things need vitamins in only very small – what is referred to as "minute" – amounts. In general, vitamin requirements are expressed in International Units per kilogram of body weight, or IU/kg. An interesting fact about vitamins is that many of them can be produced by the horse, in its digestive tract, as it needs them.

Vitamins belong to one of two types:

- Fat-soluble vitamins – a group that includes vitamins A,D,E and K
- Water-soluble vitamins – a group that includes the B complex vitamins and vitamin C

Bacteria in the horse's digestive tract can produce all vitamins except vitamin A and E, which must be obtained from the diet.

Once of the biggest misconceptions about vitamins is that "if a little big is good, a little more is even better." In fact, because daily vitamin requirements are so small, overdosing is very easy to do – and many vitamins, if fed in excess, can be toxic to horses.

Each species of animal has its own unique vitamin requirements, and the vitamin requirements of one species do not necessary apply to another. The amount of research done on equine nutrition so far is comparatively limited. Much more is known about the vitamin requirements of humans, and even of other livestock species. One thing that is known is that most horses grazing on high-quality pastures are not likely to have vitamin deficiencies. Pastures are an excellent source of both fat- and water-soluble vitamins.

The Fat-Soluble Vitamins

Vitamin A

- **Function** – need for vision, especially night vision; needed for healthy skin, muscles, and bone (especially in growing animals); involved in reproductive function; an "antioxidant" that helps to prevent damage to cells
- **Sources** – beta-carotene is the "precursor" that horses need for microbes to produce vitamin A in the small intestine; green forages, pasture, hay, and yellow vegetables (such as carrots) are all excellent sources of beta-carotene; remember that hay stored for more than 1 year can lose beta-carotene content
- **Deficiency** – causes loss of appetite, weight loss, dull hair coat, poor vision (especially night vision), excessive tearing of the eyes, and anemia; can cause poor reproductive performance in both mares and stallions.
- **Toxicity** – causes stunted growth in young animals, poor skin quality, bone abnormalities, decreased blood clotting

Vitamin D

- **Function** – called the "sunshine vitamin"; needed for mineral utilization and bone formation; involved in the absorption and use of calcium and phosphorous.
- **Source** – synthesized in the horse's skin from ultraviolet rays of the sun; another source is cut and "sun-cured" plants – hays; however vitamin D is not produced until the plant is cut and then sun-cured
- **Deficiency** – causes rickets; a condition in which bones soften, bend and bow out; rickets occurs in most mammal species, including humans
- **Toxicity** – seen in horses, a cumulative effect over time; excess vitamin D stimulates abnormally high absorption of calcium and phosphorous; the excess calcium deposits in the heart, blood vessels, salivary gland, diaphragm and other organs; signs include inability to exercise, increased resting heart rate, sensitivity in leg tendons, increased water intake and urination

Vitamin E

- **Function** – enhances the immune system; essential for normal functional of all cells in the body; involved in DNA production; enhances absorption and storage of vitamin A by body; known as an "antioxidant" that helps to prevent damage to cells
- **Source** – green, growing pastures are a good source of vitamin E; since many horses lack access to pasture, they must get vitamin E from their foodstuffs; microbes in the equine digestive tract can produce some vitamin E, but generally not enough to meet nutrient needs; therefore, most horses should receive vitamin E supplements in their diet
- **Deficiency** – may be seen in combination with a selenium deficiency; causes "white-muscle disease" in foals; muscle wasting, infertility, decreased immunity, slowed growth rate in young animals; current research has determined an association with EDM (equine degenerative myeloencephalopathy) and EMND (equine motor-neuron disease); more research is in progress, and vitamin E supplementation may have a positive effect on these conditions.
- **Toxicity** – vitamin E is relatively non-toxic; however, excess vitamin E in the diet can decrease absorption of other fat-soluble vitamins.

Vitamin K

- **Function** – needed for production of factors that ensure proper clotting of the blood
- **Source** – bacteria in the horse's cecum produce large amounts of vitamin K; also available from green, leafy plants – in either pasture or hay
- **Deficiency** – rare in horses, because the cecum produces large quantities of vitamin K; however, moldy sweet clover or hay containing moldy sweet clover can induce a deficiency, impairing blood-clotting and increasing risk of abortion in broodmares; disruption of bacteria in the intestine – from such causes as colic, diarrhea, or antibacterial drugs – can impair vitamin K production; signs of deficiency include nosebleeds and hemotomas
- **Toxicity** – rare in horses; vitamin K is an interesting vitamin: in nature, vitamin K is a fat-soluble-vitamin supplied from plants, but the horse's body converts fat-soluble vitamin K to water-soluble vitamin K, which it stores in the liver and can excrete in the urine; for this reason, large amounts of vitamin K are not stored by the body; an injectable form of water-soluble vitamin K can be toxic to horses, causing kidney failure and death; however, the oral/fat-soluble form of vitamin K does not seem to be toxic to horses.

The Water-Soluble Vitamins

The B-Complex vitamins:

- **Vitamin B_1 (Thiamin)**
  - **Function** – aids nerve function and carbohydrate metabolism
  - **Source** – most green forages – pasture or hay – are good sources, as are cereal grains; dried brewer's yeast is an excellent source; also produced in the horse's intestinal tract
  - **Deficiency** – uncommon except when horses may ingest bracken fern or the plant horsetail; stabled and exercising horses may exhibit lower blood levels of vitamin B_1; some supplementation in a horse's diet may be merited; signs of deficiency may include loss of appetite and body weight, weakness, lack of coordination, skipped heartbeats, nervousness and diminished growth rate
  - **Toxicity** – unlikely in horses; however, toxicity has been seen from thiamin injections (both intramuscular and intravenous); toxic effects are mild: decreased heart rate; a mile tranquilizing effect has been reported but also debated and not clearly documented by research; sever toxic effects documented in other species – death resulting from respiratory and heart failure – have not been seen in horses.

- **Vitamin B_2 (Riboflavin)**
  - **Function** – needed for proper oxygen utilization by cells in the process of producing energy in the body
  - **Source** – yeast is high in vitamin B_s, as are pasture forages; some B_s is produced naturally in the horse's digestive tract
  - **Deficiency** – causes decreased food intake, scaly skin, dull and dry hair coat, stiff gait, hind-end muscle weakness; inflammation of the lips and tongue, colon ulcers, and diarrhea; research as disproved any link between B_2 deficiency and "moon blindness" (also known as periodic ophthalmia or recurrent uveitis)
  - **Toxicity** – no documented toxicity in the horse
- **Vitamin B_6 (Pyroxidine)**
  - **Function** – promotes amino-acid and fat metabolism; needed for the body to make the hormones epinephrine (adrenaline) and norepinephrine
  - **Source** – readily available in the average equine diet from forages and grains; mainly absorbed in the small intestine from feedstuff; also produced by microbes in the cecum and colon
  - **Deficiency** – not documented in the horse
  - **Toxicity** – no documented in the horse; excess vitamin B_6 is easily excreted from the body in the urine
- **Vitamin B_{12} (Cobalamin)**
  - **Function** – needed to produce red blood cells, for DNA synthesis, growth and nerve function; vitamin B_{12} contains cobalt
  - **Source** – forages; most is produced by microbes in the colon of the horse; cobalt is needed in the feedstuff for this process; vitamin B_{12} is absorbed in the colon; many race horses are given B_{12} injections to increase red blood cells in the bloodstream – to date, there is little scientific evidence supporting this usefulness of such injections, since microbes in the horse's digestive tract are already producing B_{12}, and since injections increase blood levels of B_{12} for only very short periods of time, after which most of the vitamin is excreted in the urine
  - **Deficiency** – no documented deficiency in horses; if adequate levels of cobalt are in the diet, the horse's body produces enough vitamin B_{12} in the large intestine; in other species, deficiency results in anemia, weight loss, poor hair coat and poor performance.
  - **Toxicity** – no documented toxicity in the horse; no known toxicity by injection, either.
- **Biotin**
  - **Function** – involved in metabolism of body fats, RNA and DNA; used as a dietary supplement to promote healthy hooves.
  - **Source** – plant and animal tissues; yeast; soybeans, cow peas, cauliflower, egg yolk, and liver; in the horse, biotin is produced by microbe activity in the large intestine
  - **Deficiency** – requirements of the horse not yet scientifically determined; grass eaters such as horses are unlikely to have biotin deficiencies if the microbes in the digestive tract are healthy and functioning properly (something that antibacterial drugs can disturb)
  - **Toxicity** – no document in the horse
- **Folic Acid**
  - **Function** – involved in DNA production; needed for production of red blood cells
  - **Source** – pasture is the best source for the horse; also synthesized in the intestine of adult horses
  - **Deficiency** – not common in the horse; anemia (insufficient numbers of red blood cells) would result; when anemia results, the red blood cells may actually attempt to compensate and become larger than normal; horses on green grass are less likely to exhibit anemia than horse on hay and grain diets; research indicates that folic acid is lost in sweat during exercise and that exercise also increase the production of red blood cells – thus, folic acid requirements are even higher in exercised horses.
  - **Toxicity** – none known in the horse; although injection of folic acid has been documented to cause toxicity in rats, any toxic effect in injection in horses has not been documented and is not known.
- **Niacin**
  - **Function** – needed for metabolism of energy-producing nutrients (especially amino acids, carbohydrates and fats)
  - **Source** – cereal grains, leafy forages, vegetable sources and animal by-products
  - **Deficiency** – not documented in the horse
  - **Toxicity** – not documented in the horse; little is known about toxicity from niacin in the horse.
- **Pantothenic Acid**
  - **Function** – needed for metabolism of carbohydrates, fats and protein
  - **Source** – widely available in plant and animal tissue; pasture, hay and grain are good sources for horses; also produced in horse's intestine by microbe activity
  - **Deficiency** – not documented in the horse
  - **Toxicity** – injection in rats has caused toxicity – the toxic effect in horse has not been documented and is not known

- **Vitamin C (Ascorbic Acid)**
    - **Function** – an antioxidant, it protects fats, proteins and membranes in the body from the damage of oxidation (breakdown) by what are termed "free radicals" in the body; important for bone and tooth formation; aids in the use of B vitamins, cholesterol, glucose and iron; an important part of connective tissue and collagen; involved in amino acid formation
    - **Source** – horse can produce vitamin C from glucose in the liver; vegetable and fruit contain vitamin C; cereal grain contain almost none; easily destroyed by heat, light, or exposed to minerals in feeds or supplements, so supplement and feed manufacturers add a protective coating to help decrease this breakdown
    - **Deficiency** – none in horses; unlike people, horses do not need vitamin C in their diets, though supplementation may be beneficial, particularly in older (over age 20), ill or stressed horses; vitamin C may also reduce stallion sperm-tail abnormalities; continued oral ingestion is the only effective means of supplying ascorbic acid to horses
    - **Toxicity** – injection can cause local irritation; only intravenous injection causes increases in vitamin C content of the blood – but for no more than 4 hours.

Minerals

The horse requires at least 14 minerals for healthy body functioning. Minerals are used for complex metabolic interactions and internal chemical reactions. Minerals are broken down into two group:

- Macro-minerals
- Micro-minerals or "trace" minerals

The seven macro-minerals required by the horse:

- calcium
- chloride
- magnesium
- phosphorus
- potassium
- sodium
- sulfur.

The seven micro-minerals or "trace" minerals required by the horse:

- cobalt
- copper
- iodine
- iron
- manganese
- selenium
- zinc.

In the United States, it is recommended that a horses' diet by supplemented with salt and trace minerals in the feed or, at a minium, that a trace-mineral salt block be available to horses at all times.

In general recommendations for macro-minerals are expressed as a percentage (%) of the diet or in grams/day. Recommendations for micro- or "trace" minerals are expressed in parts per million (ppm) or milligrams/day.

Macro-Minerals

- **Calcium**
    - **Function** – the "partner" mineral to phosphorus (see below); needed for bone and tooth health; involved in bone structure and strength; important for bone growth in young/growing animals; needed for muscle contraction and relaxation; needed for blood-clotting; plays a role in temperature regulation
    - **Source** – plants, ground limestone, oyster shells; grass and hay diets generally have ample calcium; alfalfa and other legume hays are rich in calcium; grains are very low in calcium content; absorbed in the horse's small intestine
    - **Deficiency** – calcium deficiencies can result if a horse is deficient in vitamin D, which is needed for the proper utilization, absorption and metabolism of calcium; calcium also interact in the proper utilization of other minerals; older horse are less able to absorb calcium; deficiencies can result in decreased bone density, fractures, other bone problems, stiff movement,

lameness, weight loss and tooth problems; because cereal grains supply very little calcium, diets low in forage and high in grain can create deficiency problems; calcium deficiency can also result from an excess of phosphorus in the horse's diet, which causes a decrease in calcium absorption and can result in "bighead disease" (osteodystrophia fibrosa)
    - **Toxicity** – maintaining the correct calcium:phosphorus ratio is extremely important in the equine diet; for young/growing animals, it should be between 1:1 and 2:1; for adult animals, it sould be between 1:1 and 3:1,; because wheat bran has a high phosphorus content with an inverted calcium:phosphorus ratio, diets high in wheat bran can cause imbalances by binding up the available calcium in the horse's body
- **Chloride and Sodium (Sodium Chloride or Salt)**
    - **Function** – chloride and sodium go together; sodium chloride, or salt, is needed to regulate body fluids/water metabolism; it is also critical to the process of sweating, conduction of electrical impulses for nerves and muscles, and maintenance of electrolyte balance; chloride is needed for the production of bile and digestive-tract secretions.
    - **Source** – horses' rations should contain .5% to 1% sodium chloride; many commercial feeds do not contain adequate amounts of salt; as mentioned above, equine-nutrition specialists in the U.S. recommend adding a salt/trace mineral mixture to the horse's daily diet (in feed or free-choice), or at least making a trace-mineralized salt block available to the horse at all times.
    - **Deficiency** – rare; horses in a regular exercise of conditioning program typically require more sale; horses tend to crave slat and will usually lick enough from a trace-mineralized salt block to meet their sodium requirements; although chloride requirements have yet to be scientifically established for the horse, it appears that if a horse's sodium requirements are met, its chloride needs are also met
    - **Toxicity** – horses tolerate high levels of sodium chloride – and if they have adequate salt and water available on a daily basis, they are not likely to over-consume; salt toxicity has been seen in horses drinking salt water (bring), horses fed salt when "salt hungry" (from having no access to salt/salt lick for a prolonged time), and horse that have had more than 2% salt added to their diets without access to adequate water; signs of salt toxicity include colic, diarrhea, frequent urination, weakness, staggering, paralysis of the hind limbs, going down and being unable to stand; death can result
- **Magnesium**
    - **Function** – important for bone health; involved in enzyme function
    - **Source** – most commercial feeds contain adequate amounts, as do most good-quality hays; supplements; trace-mineralized sale blocks; green, rapidly growing pasture are a poor source of magnesium
    - **Deficiency** – rare, but has been seen in lactating mares, foals, animals in transport or otherwise under stress; the condition known as lactating, transit, grass or wintery "tetany" can result – with low blood magnesium levels causing nervousness, muscle tremors, staggering, increased respiration rate, sweating, convulsion, or the animal going down and paddling – and can result in death; an intravenous solution of magnesium and calcium, given promptly, can save the animal; necropsy or dead animals shows evidence of mineralization of arteries, some organs and muscle tissue
    - **Toxicity** – non documented in the horse
- **Phosphorus**
    - **Function** – the "partner" mineral to calcium (see above); important for healthy bones and teeth; needed by the body to metabolize and use energy
    - **Source** – mare's milk is a fairly good source; cereal grains are higher in phosphorus but contain almost no calcium and (as mentioned previously) can cause imbalances in the calcium:phosphorus ratio; absorbed in the large intestine of the horse; the phosphorus content of forage is related to the soil on which the forage is grown; soils in some parts of the United States are deficient in phosphorus
    - **Deficiency** – can lead to decreased bone density; stiff movement, lameness, weight loss, and bone fractures
    - **Toxicity** – excess phosphorus in the equine diet binds calcium and decreases calcium absorption; a calcium:phosphorus ratio of less than 1:1 cause calcium deficiencies; can result in "big-head disease" or hyperparathyroidism (an overactive parathyroid gland).
- **Potassium**
    - **Function** – critical for regulating osmotic pressure of the body's cells; helps maintain the acid/base balance of cells; needed for nerve-impulse transmission, proper muscle function, and carbohydrate metabolism
    - **Source** – forages, both pastures and hays, are good sources; oilseed meals; molasses also has high content
    - **Deficiency** – usually seen in horses on high-grain/low-forage diets; also seen in horses in heave exercise regimes, which tend to lose large amounts of potassium in sweat and urine; signs include fatigue, muscle weakness, lethargy, exercise intolerance and decreased food and water consumption; deficiencies have been documented in young, growing foals fed high-grain diets; deficient animals go off feed, lose weight and become unthrifty; feed a high-potassium substance, such as potassium carbonate or potassium chloride, until normal feed consumption resumes
    - **Toxicity** – potassium is not generally toxic to horses, as it is readily excreted in the urine; the exception: horses of Quarter Horse breeding that trace back to the stallion Impressive and suffer from HYPP (hyperkalemic period paralysis) need low-potassium diets because potassium accumulates in their bodies

- **Sulfur**
  - **Function** – an essential elements of several amino acids, some B vitamins, insulin, other body constituents and chondroitin sulfate (a component of cartilage, hoof and joint lubricants)
  - **Source** – water, commercial feed
  - **Deficiency** – none known in the horse
  - **Toxicity** – little is known of toxicity in the horse; an incident of accidental poisoning of adult horses fed a concentrated sulfur compound known as "flower of sulfur" results in lethargy, colic, a foaming yellow discharge from the nose, labored breaking – and eventual dead of 2 of the 12 horse affected

Micro-Minerals

- **Cobalt**
  - **Function** – part of vitamin B_{12} molecules; needed for synthesis of vitamin B_{12} in the cecum/large intestine of the horse, for production of red blood cells and for carbohydrate and fat metabolism
  - **Source** – pasture with adequate cobalt in the soil
  - **Deficiency** – cobalt is an integral part of vitamin B_{12}; if adequate cobalt is supplied to the horse, no vitamin B_{12} deficiency should occur, since microbes in the digestive tract synthesize B_{12}; no known cobalt deficiency documented in the horse, either naturally or in research studies
  - **Toxicity** – none documented in the horse
- **Copper**
  - **Function** – needed for synthesis of red blood cells, healthy bone formation, proper absorption, utilization and transport of iron, synthesis of melanin for pigment in the hair and proper synthesis of collagen; important for healthy connective tissue and cartilage; aids in production of "elastin" – which is needed for flexibility and strength of blood vessels; the liver regulates copper metabolism
  - **Source** – best source is trace mineralized salt containing copper carbonate or copper sulfate; also in commercial horse feeds
  - **Deficiency** – has been see in the U.S. in areas where pasture and hays are grown on sandy soils or in swampy, mucky, or peat-type soils; diets high in zinc, sulfur and iron may decrease proper utilization of copper; deficiency is seen more in foals than in adult horses; results in abnormal bone and cartilage growth, causing stilted gait, lameness and swelling of the fetlock joints; some incidence of bony growths above and below the fetlock joints, known as "DOD", or developmental orthopedic disease; copper injections have been used to reduce or eliminate symptoms
  - **Toxicity** – in the horse, seen only at very high levels in research studies
- **Iodine**
  - **Function** – need to synthesis of thyroid hormones, which are responsible for regulation of body metabolism and body heat; the thyroid gland, placenta and lactating mammary gland can accumulate iodine from the bloodstream; iodine is passed to the foal through the mare's milk; interestingly, horses with either too much or too little iodine in the diet may show enlargement of the thyroid gland (known as goiter); microscopic examination of a sample of thyroid tissue may help with diagnosis
  - **Source** – iodized salt is a good source
  - **Deficiency** – enlargement of the thyroid gland; low blood-plasma levers of T_3 and T_4 (thyroid hormones: T_3 is triiodothyronine and T_4 is thyroxine) are helpful for determining deficiency in adult horses but not reliable in foals; foals with a deficiency can be still-born or born weak and unable to stand or nurse, though their dams may show no visible signs of deficiency; deficiency most seen in the Midwest, referred to as the "goiter belt" of the United States; certain plants interfere with iodine use in the horse's body: kale, white clover, rutabaga, turnips, cabbage, broccoli and other "giotrogenic" plants
  - **Toxicity** – goiter results; feedstuffs and supplements containing very high levels of iodine, such as kelp (a seaweed), can cause dietary problems for horse; toxicity can also results from the use of multiple supplements that contain iodine.
- **Iron**
  - **Function** – needed for oxygen storage and transport in the cells of the body; 60% or the body's iron is contained in hemoglobin in the red blood cells and 20% in myoglobin in muscle tissue; absorbed primarily in the small intesting; copper is essential for the absorption, transport, and utilization of iron; blood tests are available to determine hematocrit and blood-hemoglobin levels to establish the horse's iron status; however, these tests are not sensitive until blood iron levels are quite low; determining blood ferritin levels is another and more accurate test for a horse's iron status
  - **Source** – pasture, hay and grains; most common feedstuffs provide adequate levels of iron in the diet
  - **Deficiency** – anemia results; iron deficiency in a horse's blod is usually due to blood loss, either excessive (from injury, for example) or prolonged (possibly caused by parasite overload); dietary deficiency not usually seen in the horse; the horse has large stores of red blood cells in the spleen, which it draws on during exercise or excitement; this ability to draw on reserves can mask iron deficiencies for quite some time; ferritin test are a very good indicator for deficiency and are not affected by the release of red blood cells from the spleen

    - **Toxicity** – usually not from dietary sources but from iron injections, to which some horses have demonstrated allergic reactions (fatal in some cases); foals appear more sensitive to iron toxicity; ferritan testing is the most accurate way to determine excessive levels of iron; signs of iron toxicity may include depression, dehydration, diarrhea and liver failure, as well as death; excess iron can deplete the body of zinc and increase susceptibility to bacterial infections; the horse's body has not means of excreting excessive iron
- **Manganese**
    - **Function** – essential for fat and carbohydrate metabolism and for growth and reproduction; needed for the synthesis of chondroitin sulfate, which promotes healthy cartilage; needed for bone formation, especially of the limbs, skull and inner ear; acts as a "scavenger" that ties up free radicals, thus helping to prevent oxidative damage to cells
    - **Source** – pasture, hay and grains (except corn)
    - **Deficiency** – not known in the horse
    - **Toxicity** – not known in the horse
- **Selenium**
    - **Function** – a very important micro-mineral; absorbed in the small and large intestine; acts as a "partner" with vitamin E in helping to prevent cell damage due to oxidation; selenium is needed to produce an enzyme that protects the water-based portion of cells, and vitamin E protects the fat-based portion of cells, so together the two act as "antioxidants" or cell protectors; also involved in DNA and vitamin C synthesis; enhances immune-system function, vitamin A utilization, and many other functions; a diagnostic blood test for selenium status is available, with blood-sample storage time and temperature being critical for accurate results.
    - **Source** – pasture, hay and grain can supply selenium, but supplements are the most reliable source because soil levels of selenium in the U.S. vary so widely; 37 states have areas known to be selenium-deficient; 8 states have areas that are selenium-deficient and also areas where selenium levels are so high they can be toxic; selenium content can vary from field to field or even within the same field; plants grown on soil with a more basic pH are more likely to take up selenium, especially in areas with little rainfall; and soil with a more acidic pH is more likely to produce plants that are selenium-deficient; for these reasons, a feed with equine selenium content may be toxic in one region and deficient in another; be careful with selenium supplements because the margin of safety is relatively narrow; to estimate the total selenium you horse is ingesting, have your forage source (hay and pasture) analyzed for selenium content and pay attention to the selenium content in all feed and supplements you are giving.
    - **Deficiency** – causes an affliction known as "white muscle disease", more common in your horses; signs include: weakness, impaired movement, difficulty swallowing, trouble nursing, problems with respiratory and heart function, degeneration of smooth, skeletal and heart muscle; in selenium-deficient areas, some veterinarians recommend giving newborn foals a selenium/vitamin E injection
    - **Toxicity** – can result from ingestion of plants containing high levels of selenium or from overuse of supplements; margin between needed and toxic levels is very narrow; signs of toxicity include sweating, blind staggers, colic, diarrhea, increased respiratory and heart rates, loss of appetite, unthriftiness, head pressing, hair loss (especially mane and tail), and hoof loss with separation at the coronary band; a garlic odor on the breath is a good clue indication possible selenium toxicity
- **Zinc**
    - **Function** – part of the structure of enzymes involved in protein and carbohydrate metabolism; a component of skin and hair; involved in bone growth and development
    - **Source** – commercial feeds and supplements; zinc is absorbed based on the need of the body; update can be affected by the levels of other minerals in the body
    - **Deficiency** – not usually a problem in the horse; excess calcium in the diet decreases the absorption of zinc in horses; DOD (developmental orthopedic disease) or bone-growth problems can occur in young horses
    - **Toxicity** – toxicity has been seen in horses grazing pastures near industrial plants with high levels of zinc in air emissions; excess zinc in water can be a problem – this may occur when copper and galvanized pipes are joined during the plumbing process; seen more in young animals; signs include bone-growth deformities, stiff gaits, lameness, reluctance to move, low head carriage, arched back, anemia, poor condition, and decreased growth rate, blood and organ tissues contain high levels of zinc

The Energy-Producing Nutrients

How the horse's body produces energy can be a very complicated concept. But an understanding of this concept is important for proper feeding management and maintaining horses in good body condition. For equines, the 2 basic energy-producing nutrients are:

- Carbohydrates
- Fats (also known as "lipds")

Carbohydrates and fats are very efficient at producing energy. As mentioned earlier, protein can and does supply energy, but much less efficiently than carbohydrates and fat.

Horses' energy requirements vary greatly, depending upon many different factors. Among these factors are:

- maintenance needs
- work or exercise (type, speed, duration)
- the animal's condition
- the amount of weight the animals is carrying or pulling
- terrain over which the animal works or exercises – hills, flat ground, rough, etc
- growth
- reproduction status
- lactation (milk production)
- environmental temperature and humidity
- and more.

In addition, as with any other living thing, metabolism rates vary greatly from on individual to another. For all of these reasons, establishing energy requirements for a particular horse has always been a difficult task.

Yet the task of establishing energy requirements is necessary – because a diet that fails to provide adequate amounts can cause:

- slowed growth rate in young animals
- a decrease in body weight
- unthrifty condition
- fatigue in working or exercising animals
- reduced milk production

A diet that provides too much energy can also cause problems:

- obesity
- colic
- founder
- poor reproductive function (in some excessively fat mares and stallions)
- decreased life span.

In order to understand energy, one must understand some simple chemistry principles. Thes will be discussed in the description of carbohydrates and fats.

Carbohydrates

Carbohydrates are chemical compounds contained in all plants and in the grains produced by plants. Carbohydrates are the major energy source for horses, supplying much of the fuel needed to run the body's functions.

Carbohydrates are made up of carbon atoms. They also include hydrogen and oxygen atoms. Compounds that are considered to be carbohydrates include:

- sugar
    - simple sugars – known as "monosaccharides"
    - complex sugars – known as "polysaccharides"
- starch
- fiber
- and other related compounds.

When talking about digestion in the horse, carbohydrates are divided into 2 main categories:

- **Non-fiber carbohydrates** – also referred to as nitrogen-free extracts of NFE, these are the carbohydrates that are more easily broken down and more readily absorbed by the horse's digestive tract (and so are also referred to as the "soluble carbohydrates"). They are mainly made up of starch and sugar molecules that are broken down in the stomach and small intestine. This occurs before they get to

the large intestine and is referred to as pre-cecal digestion (meaning “before the cecum”). The enzymes present in the horse’s digestive tract can easily break down most of the non-fibrous carbohydrates or nitrogen-free extracts

- **Fiber** – the carbohydrate portion of plants and grains, including cellulose, hemicelluloses and lignin. These carbohydrate compounds are mainly broken down by bacterial (microbe) action in the “hind gut”, beginning in the cecum and continuing through the rest of the large intestine. This is referred to as post-cecal digestion, meaning “in or after the cecum”; it is also referred to as “hind-gut fermentation”. NOTE: Scientific research in the 1980s by Peter Van Soest made it possible to further break down fiber into its many different components. These components include: NDF – neutral detergent fiber, ADF – acid detergent fiber, cellulose, hemicelluloses and lignin. More discussion of fiber and its components would be too complicated for this purposes of this book.

Equines are designed to eat mostly forages (both pasture and hays) and to have a high amount of fiber in their diets. Be careful not to feed your horse too much grain (concentrate). An interesting fact about fiber and equines: Research has shown that donkeys are more efficient in digesting fiber than horses and ponies. Thus, donkeys can be fed higher-fiber diets than some equine species.

Both nitrogen-free-extracts (the non-fiber carbohydrates) and fiber release energy when broken down in the digestive tract of the horse. Energy not needed by the body at the time of digestion is stored in the form of flycogen – an end product of the digestion of starches, sugars and fiber. Glycogen is stored in the : kidney, liver and muscles. If at any time the glycogen-storage capacity of the kidneys, liver and muscles is full, the body stores the excess simple sugars or “monosaccharides” as fat. It can use stored glycogen and fat to meet energy requirements when needed.

Fat

Fat is another energy source for equines. Like carbohydrates, fat is made up of carbon, hydrogen and oxygen, Fat is a more concentrated energy source than those normally fed to equines (carbohydrates and protein), supplying about 2.5 times more energy per gram than either carbohydrates or protein. Fat sources for equines can have plant or animal origins.

In the past, horsemen believed that equines could not digest and utilize fat well. But studes now indicate that horse can digest and utilize fats from both plant and animal sources quite well.

Equines can utilize fat and oils from plants more easily than fats from animal sources (usually by animal by-products). Plant oils can provide the horse approximately 3 times as much energy as can grains (in comparisons based on equal weight of product). The amount of energy varies somewhat depending on the plant and/or grain source. For example: One cup of corn oil provides about 4 times the energy supplied by the average equine commercial grain product, based upon weight (the weight of one cup of corn oil compared to the amount of commercial grain equaling the weight of the corn oil).

The average equine diet contains very little fat compared to the average human diet. Nutritionists typically recommend that human diets have 30% or less total fat content. Most equine feeds contain very small amounts of fat – approximately 2.0 to 3.5%. Even “high-fat” equine feeds typically contain no more than 8 to 10% fat.

Adding fat to the equine diet has been proven to increase :growth, performance or work, reproductive function and milk production. Equine diets should not contain more than 20% fat. Research indicates that there may be advantages to feeding horses some fat in place of some carbohydrates in the diet:

- no negative effect on the pH of the cecum – this helps to maintain healthy microbes and decreases the changes for colic and laminitis
- increased performance, especially in racing or activities such as barrel racing, which require great use of energy for short periods of time.

Fat in the equine diet helps carry the fat-soluble vitamins through the horse’s digestive tract. Fat is digested mainly in the small intestine. Fat is indeed a good energy source for equines.

As with any alteration to a horse's diet, take precautions when adding fat or substituting fat for some carbohydrate content. Make change gradually and over a period of time.

Summary

Proper and adequate nutrition is essential to the health of your horse. Understanding basic nutritional concepts is one of the responsibilities of horse ownership and is essential for good feeding-management practices. Supplying your horse with the nutrients and energy it needs can help you keep it healthy and enhance its performance. The nutrition that equines receive in the United States is generally very good. In most parts of the U.S., the climate and growing conditions make it possible for adequate access to good forages (pasture and hay) that can supply most of the basic nutritional requirements of the average horse. Forages are also an excellent source of vitamins and minerals. The essential nutrients equines require include:

- water
- protein
- vitamins
- minerals
- energy
    - carbohjydrates
        - starch
        - sugar
        - fiber
    - fat

Do not forget that water is extremely important to the horse's health and- with very few exceptions – should be available at all times.

HOW TO MEASURE ENERGY:

Energy in a horse's diet comes from carbohydrate, fat, and protein. In the past, the energy value in an equine diet was calculated for TDN or "total digestible nutrients."

Scientific methods make it possible to break down the nutritional components in the equine diet:

- protein
    - DCP = digestible crude protein
- carbohydrates
    - DCF = digestible crude fiber
    - DNFE = digestible nitrogen-free extract
- fat
    - DEE = digestible ether extract

TDN = % DCP + % DCF + % DNFE + (% DEE X 2.25)

Modern nutrition experts express energy by a different method that more accurately measures the total energy contained in the diet. *Energy is measured and expressed* in **calories.** (One calorie = the amount of heat required to raise the temperature of one gram of water by 1° C.) The total energy in an equine diet — also known as **"Gross Energy"** — is expressed as the sum of the following:

- DE = digestible energy
- ME = metabolizable energy
- NE = net energy.

Gross Energy = Digestible Energy + Metabolizable Energy + Net Energy

This chapter includes a significant amount of information. If you absorb a majority of what it covers, you will know much more than most horse owners and be well on your way to becoming a very knowledgable horse person.

No one expects you to keep all these facts in your head. However, you can keep them at your fingertips by using this chapter as a reference for equine nutritional information.