NUTRITIONAL MANAGEMENT OF EQUINE MEDICAL CONDITIONS
To support “Feeding Options for Special Needs Horses”

Karen E. Davison, Ph.D. and J. Kathleen Young, Ph.D., Purina Animal Nutrition, LLC

Nutritional management of normal healthy horses involves meeting their protein, vitamin, mineral and energy requirements. The age, activity level, and stage of reproduction all affect those nutrient requirements and there are commercial feeds designed specifically to address the nutritional needs of each lifestyle. There are medical conditions affecting some horses that may be better managed with specific nutritional manipulations. These conditions aren’t caused or cured by diet but alterations in the diet may help reduce severity or expression of symptoms associated with the condition. In any situation where diet manipulation may help better control a medical condition, it is always important to keep the total balance of the ration in mind. Focusing on a single component of the diet may create deficiencies or imbalances in other aspects of the ration. For long-term success, balance of the total diet must be maintained.

The National Research Council (2007) provides guidelines for nutritional management of specific disease conditions in the horse. In addition, Equine Clinical Nutrition by Lon Lewis (1995) is a valuable reference for nutritional management of certain medical issues in the horse. This paper will briefly review feeding guidelines for some of the identified nutritionally related medical conditions.

Hyperkalemic Periodic Paralysis

Hyperkalemic Periodic Paralysis (HYPP) is a genetic mutation tracing to a single Quarter Horse Stallion, Impressive. The muscle cells of affected horses have a disturbance in the regulation of movement of sodium and potassium ions allowing a constant leaking of sodium into the cell causing potassium to move out. As a consequence, some muscle cells experience repetitive depolarization which represents clinically as muscle fasciculation. During severe episodes the contractions can become tetanic causing the horse to become recumbent. In these cases serum potassium concentrations may rise from 3 – 4 mEq/L to 12 mEq/L or higher. This marked rise in serum potassium is useful in differentiating HYPP from other muscle diseases.

Dietary management of HYPP horses involves limiting dietary intake of potassium and promoting entry of potassium into cells. Research has established a threshold of 1% or less potassium in the diet as the target to help lower the risk of clinical episodes. This proves to be difficult since forages, hay and pasture, consistently contain 2 – 3% potassium. Grass varieties tend to run closer to 2% while alfalfa will generally run 2.5% or higher. Practical experience would suggest that due to forages being digested primarily in the large intestine and potassium being absorbed from the small intestine, the higher level of potassium in forages isn’t as critical to the management of HYPP. Even so, current recommendations are to limit or eliminate alfalfa from diets of HYPP horses and utilize grass varieties instead. The threshold of 1% potassium in the diet typically focuses on the concentrate portion of the diet. Due to potassium content of typical ingredients, sweet feeds and grains have lower potassium content than pelleted feeds. In addition, sweet feeds and grains generally have higher starch and sugar content which may be beneficial to HYPP horses as a higher postprandial insulin response to a meal may help drive more potassium into the cells.

Exertional Rhabdomyolysis Syndromes

Two forms of chronic exertional rhabdomyolysis have been described: 1) Recurrent exertional rhabdomyolysis (RER) which commonly affects Thoroughbreds but may be seen in Arabs and Standardbreds; and 2) Polysaccharide Storage Myopathy (PSSM) which is more prevalent in Quarter horses but also affects Warmbloods, Paints, Draft breeds and others. RER has been identified as a heritable defect in intracellular calcium regulation while PSSM is describes as a heritable defect causing increased storage of muscle glycogen which may be accompanied by amylase-resistant polysaccharide. To date two versions of PSSM have been identified, Type 1 PSSM horses have both elevated concentrations of muscle glycogen and the amylase-resistant polysaccharide and Type 2 PSSM horses have only elevated glycogen stores.

Both RER and PSSM appear to be better managed by reducing starch and sugar and increasing the calories supplied by fat in the diet. RER horses respond to moderate starch and sugar diets with moderately high fat content. The positive response appears to be related to a less excitable demeanor in RER affected horses eating this type of diet rather than any direct effect on intracellular calcium regulation.
horses are generally more sensitive to dietary starch and sugar content and require a more restricted diet with regards to calories supplied by starch and sugar. They also may benefit from higher fat levels in the diet. There doesn’t appear to be a one-size-fits-all diet for PSSM horses, a diet that works well on one may not work on another, but the general direction is the same. Continue to reduce starch and sugar content and increase fat content until symptoms are better managed. The current suggested goal is in the range of 10 – 15% of the daily calorie intake to be supplied by starch and sugar, non-structural carbohydrates (NSC), and a similar amount of calories supplied by fat. This isn’t the same as feeding a 10 – 15% NSC feed. For example a feed containing 13% NSC and 1300 calories per pound would be supplying 18% of the calories from NSC; a feed containing 16% NSC and 1900 calories per pound would be supplying 15% of the calories from NSC. Specific numbers aren’t as important as general direction, control starch and sugar and utilize dietary fat for added calories. Implementation of a daily turnout and exercise program is reportedly as important to successful management of PSSM horses as diet manipulation.

**Developmental Orthopedic Disease**

Developmental orthopedic disease (DOD) refers to a complex of musculoskeletal abnormalities that can affect growing horses. Conditions included in this complex are angular limb deformities, physitis, subchondral bone cysts, osteochondrosis, flexural deformities and cervical vertebral malformation. DOD’s are multifactorial involving genetics, environment and nutrition. The collective risk for developmental bone disorders in a specific foal originate with the breed risk, inherited joint conformation of the foal, prenatal and postnatal diet, housing practices and exercise conditions during the critical growth period from birth to at least 2 years of age. Traditionally, rapid growth rates have been implicated as increasing the risk of DOD as heavier foals reportedly tend to have a higher incidence of some types of DOD. However, in some studies there have been no weight or height differences between affected and non-affected foals and in one study affected foals tended to weigh less than non-affected foals.

Although nutrition certainly plays a significant role in foal growth, the complexity of the relationship among nutrients and their involvement in abnormal bone growth are not fully elucidated. Excess dietary protein has been considered a contributing nutritional factor, although this theory has not been substantiated through sound research. Excessive dietary energy, especially when not supported by the proper balance and quality of protein, vitamins and minerals has been identified as a risk factor. The source of dietary energy has been suspected as a possible factor in the incidence of DOD. The theory postulated is that diets high in starch and sugar would increase the risk of DOD when compared with diets higher in fats and fibers and lower in starch and sugar but data do not consistently bear that out.

To date, no cause and effect has been determined for any single nutrient, ratios of nutrients or nutrient sources and the development of DOD in young horses. Current recommendations for reducing the risk of DOD would be to provide adequate protein, vitamins and minerals to the broodmare in late gestation. Upon foaling, provide a well-balanced commercial feed formulated specifically for foal growth and development, monitor body condition and growth rate and make adjustments in feed intake to support a steady, consistent growth rate and a moderate body condition (ribs covered but very easy to feel). Foals at elevated risk for DOD due to known genetic predisposition or high-risk management practices and foals that grow at an exceptionally rapid rate or become overweight on recommended feeding programs, may benefit from eating a concentrated protein, vitamin and mineral “ration balancer”. These products provide appropriate protein, vitamin and mineral balance to support growth but are designed to be fed in low, 1 – 2 pound per day, feeding rates so control energy intake and help slow growth rates.

**Laminitis**

Laminitis can occur as the result of many different causative factors including, excessive ingestion of rapidly fermentable carbohydrates, endotoxemia, black walnut shavings, excessive concussion, obesity and insulin resistance, glucocorticoid administration and endocrine disturbances. Several factors have been associated with the onset of laminitis but the exact triggering mechanism remains unknown.

Diet-related factors are rarely the cause of laminitis other than cases associated with metabolic issues such as Equine Metabolic Syndrome (EMS) and Pars Pituitary Intermedia Dysfunction (PPID). Diet management of EMS horses to minimize the risk of founder involves restricting calories along with increasing exercise if possible, to precipitate weight loss and considerable restriction of dietary starch and sugar content. This can be accomplished by feeding a moderate quality grass hay, preferably one with a known low ethanol soluble sugar content (ESC), restricted to 1 – 1.5% of ideal body weight and feeding either a very low calorie formulated feed or a ration balancer. It is important to provide adequate protein,
vitamins and minerals while controlling the calorie content of the diet to create loss of body fat during weight loss and not lose muscle mass.

**Nutritional Secondary Hyperparathyroidism**

Commonly known as “Big Head Disease” or “Bran Disease”, nutritional secondary hyperparathyroidism is a metabolic bone disease associated with the feeding excess phosphorus or inadequate calcium. Horses from weanling to 7 years of age are most commonly affected although reported in older horses as well. This condition is often associated with feeding large amounts of wheat or rice bran due to their severely inverted calcium:phosphorus ratio. Corn distiller’s byproducts and corn gluten feed, are also very high in phosphorus and extremely low in calcium. Nutritional management involves feeding a diet with a calcium:phosphorus ration of a minimum of 1:1, preferably 2:1 and a maximum of 6:1. Adding calcium to rations high in bran or corn by-products can correct the ratio but the ration will remain excessively high in phosphorus.

**Gastric Ulcer Syndrome**

Equine Gastric Ulcer Syndrome (EGUS) is also a multi-factorial condition. Non-nutritional factors include exercise, stall confinement, temperament, and trailering. Repeated oral administration of hypertonic electrolyte solutions, a common practice during endurance races, has reportedly increased the severity and number of nonglandular gastric ulcers. Other nutritional factors suspected to contribute to a higher risk of ulceration include, feeding large meals of high starch rations and prolonged periods of fasting. The current feeding recommendations for high risk horses include feeding a lower starch/sugar, higher fat/fiber concentrate, feed alfalfa or alfalfa mix hay to help buffer gastric acid production and to provide smaller more frequent meals.

**References**

1. References can be obtained upon request from the author
A winning performance is the culmination of sourcing good genetics, properly managing the development and training, providing excellent veterinary care and delivering appropriate nutrition. Anyone can be lucky enough to win once in awhile and horses indeed have tremendous heart. Even so, luck and heart can only go so far. When nutrition and health care are lacking, the ability to consistently win is greatly impaired. Performance nutrition is primarily about fueling the body to do the work, but it also involves providing a complete balance of nutrients to help sustain the body to work time and time again.

**Fueling the System**

Fueling the system involves converting chemical energy into mechanical energy. The body has three “fuel tanks” of stored substrate to supply the chemical energy. Body stores of fat, glycogen and protein can all be metabolized to produce adenosine triphosphate (ATP) which fuels muscle cells to do the mechanical work. There is limited data in horses, but in other species proteins (amino acids) are not a major contributor of substrate during exercise. In humans, proteins provide less than 2% of energy needed for exercise lasting less than an hour. This is slightly increased to 5% of energy requirement after 3 – 5 hours of work. When glycogen stores are inadequate, proteins may provide up to 10% of the energy for exercise. Protein is much more important in the body for use as structural proteins, antibodies, enzymes, hormones and other functional components.

The substrates used to provide energy during exercise come from a combination of three energy systems within muscle fibers themselves: Intramuscular stores of ATP and creatine phosphate (CP) – cleavage of the phosphate from ATP or the CP molecule supplies energy until ATP production from stored substrates (e.g. glucose) begins. Anaerobic glycolysis – metabolism of glycogen and glucose to lactic acid, does not require oxygen and is therefore classified as anaerobic metabolism. Oxidative phosphorylation – complete oxidation of fatty acids and glucose to CO2 and water in mitochondria; requires oxygen and therefore classified as aerobic metabolism.

By far, the primary fuels are fatty acids and glucose. Fatty acids are released from triglyceride stores in adipose tissue and in muscle, while glucose is derived from the breakdown of liver and muscle glycogen and synthesis of glucose in the liver. A shortage of fatty acids is not usually an issue during exercise, but limited glycogen stores can certainly lead to fatigue during prolonged work and reduced performance in sprint work. The main advantage of anaerobic glycolysis is the very rapid rate of ATP re-synthesis. The main disadvantage is the rapid decline in intracellular pH that occurs as lactate and hydrogen ions accumulate – muscle pH can fall as low as 6.4 during maximal exercise. This decrease in muscle pH contributes to the onset of fatigue because both glycolysis and excitation-contraction coupling are impaired in an acidic environment.

The relative contribution of these systems to energy utilization during exercise is determined by the intensity and duration of exercise, muscle fiber composition, fitness level of the horse, and availability of substrates. Composition of the diet and adaptation to the diet also plays a role. Work is never fueled by a single system but is always fueled by a combination of aerobic and anaerobic metabolism, just a difference in the relative contribution of each. Glucose can be metabolized aerobically twice as fast as fat for ATP re-synthesis (fat is regarded as a “slow fuel”). Therefore, as running speed/intensity increases, ATP re-synthesis becomes increasingly reliant on the metabolism of glycogen and glucose, with a proportional decrease in the use of fat.

When glycogen is low or depleted, ability to do intense work is limited, time to exhaustion is reduced and perceived exhaustion is increased. Subjects don’t work as long or as hard so maintaining adequate glycogen stores is critical to optimal performance. Glycogen stores will be 50% higher when a high soluble carbohydrate meal is consumed immediately after intense work and will be replenished more rapidly if the meal includes simple sugars instead of complex carbohydrates. Muscle glycogen replenishment in the horse is slower than in humans, taking 72 hours after glycogen-depleting exercise to replenish muscle glycogen stores. Replenishment is significantly faster for horses receiving a high soluble carbohydrate diet.
**Dietary Energy**

Horses eat plants, and plants store energy primarily as carbohydrates and a small amount of fat. Dietary carbohydrates are composed of either starch and sugars or fibers. Hay and pasture provide more calories from fibers, though some grass and hay can have relatively high sugar content. Grains such as oats, corn and barley provide more calories from starch. Calories from fibers are converted in the body primarily to volatile fatty acids. Only one VFA, propionic acid, can be used for gluconeogenesis and the amount of propionic acid produced is related to the level of starch in the diet. Therefore, fiber may be adequate for meeting maintenance energy requirements, but has limited ability to supply glucose for work or quickly replenish depleted glycogen stores. Starch and sugar calories are absorbed as glucose, which is available immediately for work or is stored as glycogen. Once the glycogen fuel tanks are full, additional starch and sugar calories will contribute to body fat stores. Other dietary calorie sources include fats and protein. Excess dietary protein can be deaminated and the carbon skeleton metabolized for energy, but protein is a metabolically expensive energy source, producing 3 – 6 times more heat than the utilization of carbohydrates or fats and increasing water and electrolyte loss during exercise.

Fats are very calorie dense and energetically efficient, providing 2.25 times the calories by weight as starch and sugar and generating much less heat of digestion than carbohydrates, especially fibers. Essentially, 1 pound of fat (2 cups of vegetable oil) provides the same number of calories as 3 pounds of oats. The ideal amount of dietary fat to achieve optimum performance has not been determined. However, field experience suggests that as fat level of a concentrate increases, palatability problems and feed refusals begin to increase as well. There appears to be an individual tolerance level of fat consumption for individual horses. When taken to extremes, such as providing 37% of net energy from soy oil, a reduction in fiber digestion was reported.

Fats are the primary fuel for aerobic work while glycogen is the primary fuel for anaerobic work. Dietary fats and fibers cannot quickly replenish glycogen stores. This is important when designing feeding programs for competition horses. There has been much interest among horse owners in rations with reduced non-structural carbohydrate (NSC; starch and sugar) and higher fat and fiber levels. While that type of diet may address concerns over behavior issues and concerns about starch digestion and metabolism, if the pendulum swings too far, there is potential to leave performance horses without the necessary glucose substrate to perform the work. When horses were fed adequate calories from a very low starch diet (78% alfalfa, 15% corn oil, 5% casein) for 5 days while working at a heavy workload, muscle glycogen levels fell from 19.31 g/kg to 5.63 g/kg and time to fatigue was reduced from 53.4 minutes to 34.30 minutes. This would indicate that a high fat, high fiber diet, with very low starch content, will not support the glycogen needs of a hard working performance horse, particularly a horse doing anaerobic work. It is important that a feed designed for hard working performance horses provide adequate amounts and the proper blend of calorie sources to help replenish those fuel tanks within hours following feeding. Lower glycogen stores lead to earlier onset of fatigue, and transition the body to burning more protein to meet energy needs.

**Dietary Requirements for Performance**

Requirements for all nutrients increase with increasing work, however, meeting energy requirements drives the train, so to speak. If the diet does not provide sufficient energy to meet the increased demands associated with harder workload, loss of body condition and decreased performance will ensue. Assessing dietary energy intake by body condition scoring is a simple management technique that should be employed by all horse owners. A condition score between 5 and 6, on a 1 – 9 scale, is ideal for most athletic horses. Thinner horses (condition score <5) may be at a disadvantage because of low energy reserves and catabolism of muscle tissue, while overweight horses (>6) could experience detrimental effects due to excess weight and the insulating effect of a thicker fat cover.

Contrary to some belief, exercise does increase the requirement for dietary protein to support developing muscle mass, repair damaged muscle tissue and replace nitrogen (a component of protein) lost in sweat. The ratio of protein relative to calories doesn’t change, so the increase in protein requirement is usually met by the increase in feed intake necessary to meet higher energy demands. The exception to that is when an owner top-dresses the existing feed with a fat supplement, such as vegetable oil, that provides only calories and no additional protein or other nutrients.

Dietary protein is necessary to provide essential amino acids. Not all dietary protein sources provide similar amino acid balance, nor are all protein sources digested in the same location of the digestive tract. This results in very different end products of digestion and animal performance due to
dietary protein sources. Alfalfa hay, which is very high in protein and has a good amino acid balance, is
digested primarily in the hindgut of the horse. At this site there is no appreciable amino acid absorption,
and the protein digested yields ammonia that is excreted in the urine. So, even though the total protein
amount provide by alfalfa hay is high, alfalfa won’t provide the same results in the horse as protein
provided by sources digested mainly in the small intestine such as soybean meal.

There is some concern regarding high protein intake actually hindering athletic performance. It is
possible that high protein diets increase daily water requirements because of the obligate increase in urinary
nitrogen excretion associated with catabolism of excess amino acid intake, but data on this issue are scant.
Extremely high protein intake (>7 g crude protein/kg bwt) has reportedly resulted in a 2- to 3-fold increase
in water intake. However, the practical relevance of these data is questionable because this level of protein
intake is considerably higher than that normally consumed by most horses. Deficiency in amino acid
balance from low protein diets is generally a bigger concern than excesses in total protein intake.

Determining whether protein (more specifically amino acid) requirements are being met is more difficult
than determining if energy requirements are being met, but there are some visual indicators for observant
horse owners. Horses fed adequate calories but inadequate amount or quality of protein will maintain fat
cover over ribs, but lose muscle mass over the back and loin, have a dull hair coat and slower hoof growth.

Similar to protein, requirements for vitamins and minerals increase with increased work load but
the ratios of these nutrients relative to calorie requirements remain consistent. Therefore, these increased
needs are met when a properly fortified performance horse feed is provided in adequate amounts to meet
energy demands. Vitamins and minerals are needed in very small quantities, and moderate deficiencies or
excesses aren’t easily recognized through visual appraisal of the horse. However, maintaining adequate
levels of these nutrients is important to long-term health, soundness and performance of the horse. This is
especially true for nutrients involved in energy metabolism such as B-vitamins, electrolytes such as
sodium, potassium and chloride, structural minerals such as calcium and phosphorus, and anti-oxidants
such as vitamin E. Vitamin C and some B-vitamins, including biotin, riboflavin and niacin, have no
established dietary requirement in the horse. These vitamins are adequately synthesized in the digestive
tract to prevent deficiency symptoms. Feeding excessive levels of vitamins and minerals has not proven to
be beneficial to performance, and in many cases can actually become detrimental. Therefore, choosing a
properly fortified feed designed for performance horses is a more accurate approach to vitamin and mineral
nutrition than trying to individually supplement these nutrients.

References

1. References can be obtained upon request from the author
The various stages of reproduction and growth present specific nutritional requirements to support those lifestyles beyond those needed to support horses at maintenance. The various stages of reproduction in broodmares (early gestation, late gestation, and lactation) and stallions (breeding and non-breeding) represent heavier nutritional demands similar to increasing work load for performance horses. Growing horses have very specific needs for nutrients to support growth and development but also have the limitation on volume of intake due to smaller body size. Rations for young growing horses need to be of excellent quality and more concentrated to meet these higher demands in a smaller quantity of feed.

**Stallions**

Breeding season represents an increased workload for a breeding stallion. The level of that workload depends on the number of mares booked for the season and the breeding procedures. A Thoroughbred stallion breeding by live cover will work harder than a Quarter horse stallion covering the same number of mares with artificial insemination. A stallion during the off-season has nutrient demands similar to a maintenance horse, breeding season increases the nutrient requirements to those of a performance horse doing light to moderate work. Starting with a base of 1.5 – 2% of body weight in good quality hay, a breeding stallion should be fed a feed formulated to support performance horses and fed at a rate to support moderate body condition (5 – 6 on the Henneke body condition score chart). Overweight stallions may have reduced libido and the excess weight can add strain to aging joints whereas underweight stallions may have reduced fertility.

**Broodmares**

A well-managed broodmare can produce a healthy foal every year. To do that, she must be in one of three phases of reproduction at some time through the year, early gestation, late gestation or lactation. At one point, she will be in lactation and early gestation at the same time. The mare’s feeding program must be adjusted according to stage of production.

Body condition may be the single largest factor affecting reproductive performance of mares. Those maintained in moderate to fleshy condition (5 – 6 on the Henneke body condition scoring system) tend to cycle earlier in the year, require fewer cycles to become pregnant, have higher conception rates and are more likely to maintain early pregnancies than are thinner mares. This is especially true when mares are lactating or reach 15 years of age or older. Management of body condition is simply a matter of supplying adequate calories to meet her demands. Feed amounts should be adjusted to support higher energy demands and maintain consistent body condition through the different stages of reproduction.

A non-lactating, pregnant mare in early gestation (the first 7 months) has nutrient requirements very similar to those of any mature horse at maintenance. The developing fetus is only gaining 0.2 pounds/day at this stage of development. Grazing good quality pasture or consuming good quality hay at about 2 - 3% of their body weight per day will usually support good body condition at this stage. Mineral requirement, especially trace minerals, will not be met on an all-forage diet and at minimum a good quality free-choice horse mineral should be provided during this time. A trace mineral salt block will not be sufficient as they are 95 – 98% salt and won’t provide adequate amount of mineral. Ration balancer products are concentrated protein, vitamin and mineral pellets formulated to be fed at 1 – 2 pounds per day. These products are a great choice for insuring adequate intake of these important nutrients without excessive intake of calories when hay or pasture is maintaining the mare in good condition. When pasture or hay is not adequate to maintain good body condition a quality formulated feed should be provided at 0.3 – 0.75 percent of body weight to maintain good condition and provide adequate nutrient balance. The amount of feed should be adjusted according to body condition.

As the mare enters the last 3 – 4 months of gestation, nutrient requirements increase to support more rapid growth of the fetus, now gaining an average of 1 pound/day. The only way to provide nutritional support for fetal growth is through the mare. This is one time where body condition of the mare can be misleading. Mares may be in fleshy condition but still be deficient in protein, vitamins and mineral intake needed to support fetal development. During the 10th month of gestation the greatest amount of mineral retention occurs in the unborn foal and this must be supported through the mare’s diet. A supplemental feeding program is necessary to properly support growth and development at this time and
this is generally accomplished by feeding a commercially available feed formulated for mares and foals. If the mare is significantly overweight and can’t eat the minimum recommended 3 – 4 pounds per day of the formulated feed, a ration balancer would be an option for meeting the nutrient demands in a lower feeding rate.

Once the foal is born and begins to nurse, the mare’s nutrient demands increase significantly. The protein and energy requirements almost double from early gestation to lactation, as do calcium, phosphorus and vitamin A requirements. This is a critical nutritional period for the mare, especially if there are plans to breed her for a foal next year. Mare’s produce an average of 3 gallons of milk per day through a 5-month lactation. High producing mares produce as much as 4 gallons per day. Milk production peaks at 14 – 30 days and slowly declines through the lactation period. In the fourth month of lactation, mare’s milk provides less than 30% of the total energy needed by her foal. Providing lactating mares with a quality formulated feed that includes added fats and high quality protein can help slow the downward curve of milk production and milk nutrient content. This will translate to a growth advantage for the nursing foal. Feeding rates are varied depending on the amount and quality of hay or pasture mares have access to and individual metabolic demands for maintenance and milk production. Feed intake must be gradually increased to support the high demands of this stage of production and may require dividing the daily ration into 3 meals per day.

**Growing Horses**

Foal growth and development begins before birth and proper nutrition of the mare during late gestation is important to give the foal the best start possible. From birth, foals are eating and growing machines. They will nurse 70 or more times a day and consume as much as 30 pounds of milk per day in the first months. They will also mimic their mothers and begin to nibble dry feed and pasture or hay within a few days after birth. Newborn foals are born weighing approximately 10% of their mature weight and standing at roughly 60% of their mature height. By the time they are six months of age, on average, they will reach 50% of their mature weight and 80% of their mature height. Foals grow faster in this first six months than any other time. This critical growth phase requires proper nutrition and feeding management to give the young horse a great start toward becoming a sound, healthy adult.

Early in life, nothing beats mother’s milk for nutritional support. By the second month of lactation, mare’s milk has declined in nutrient content and quantity produced such that mare’s milk alone will not provide adequate nutrition for optimum foal growth. From this time forward, a foal receiving only mare’s milk will grow at a reduced rate. Additional nutritional supplementation is necessary for foals to achieve optimum growth and development. Controlled feeding of a high quality foal feed at consistent rates will best support a smooth, steady growth curve.

Nutritional supplementation for suckling foals should take into account the relatively small capacity of the foal’s digestive system. A foal feed should provide high quality, very digestible nutritional support in a concentrated form, such that large intakes are not necessary to meet nutrient requirements. When feeding a properly balanced foal feed, the recommendation is for the suckling foal to eat one pound of dry feed per month of age per day while still nursing. This means that a 2 month old foal would eat 2 pounds per day; a 3 month old foal would eat 3 pounds, etc. The goal is to simply make up the difference between what mare’s milk provides and what the foal’s nutritional requirements are without providing excesses. Foals allowed free-choice creep feed may over-eat and gain excessive weight which may be detrimental to sound structural development. The nutrients of greatest concern for suckling foals are calories or energy, amino acids from quality protein sources, calcium, phosphorus, copper and zinc. Providing these nutrients in the proper ratios and from high quality ingredients will support consistent and optimum growth rates. Shortages or imbalances in any of these nutrients can result in impaired growth and increase the risk of developmental bone disorders that can lead to unsoundness later in life.

Developmental orthopedic diseases (DOD’s) are one of the primary concerns for most owners of growing foals. Genetics and environmental factors do play a role in the incidence of DOD’s in young, growing horses, so proper nutrition alone can’t always prevent occurrence of all DOD’s. However, it is well documented that inadequate nutrition certainly increases the risk and the severity of DOD’s and proper nutrition can reduce the incidence. So, it is very important to feed a good foal feed to suckling foals, but to also pay attention to how it is fed.

One common problem in feeding suckling foals is to rely totally on mare’s milk and pasture or to feed the mare a ration not balanced for growing foals and allowing the foal to eat along with the mare. Then, after weaning, provide large quantities of a good foal feed, or even free-choice foal feed, to
accomplish maximum growth. In these cases, foals will have been growing slower than optimum while still nursing the mare. When a better plane of nutrition is provided, the body will try to catch up to where it would have been if optimum nutrition had been available all along. This compensatory growth, where a foal grows extremely fast, often leads to the foal developing contracted tendons or other DOD’s. It is much better to provide a well-balanced foal feed in prescribed amounts to support optimum growth from the beginning. This supports a steady rate of growth and will give the suckling foal the best start possible.

Feeding mares and foals individually offers the most precise method of supplemental feeding to the foal. However, many farms don’t have the labor or the facilities to do this. Creep feeders are an option but must be monitored to make sure mares cannot get in and that mares or foals can’t get injured around them. Creep-fed foals should be grouped and fed amounts appropriate for their age. Otherwise, older more aggressive foals will overeat. Mares and foals are often fed together, which actually works pretty well. As the foal begins to need more feed, the mare’s requirements decline, so it averages out pretty close. It is important that feed troughs are at a height the foal can reach and there is plenty of space available for all mares and foals to eat at the same time.

Foals eating a high quality foal feed can be weaned by four months of age with no detriment to growth and development. Actually, at that point, weaning can be more cost effective for the mare owner and more nutritionally accurate for the foal. Once foals are weaned, mares go on maintenance rations, which are often less than half of what was required during lactation. The weanling should stay on foal feed, but intake should be increased to 1.5 – 2.0 lbs per 100 lbs of body weight and fed with a similar amount of good quality hay or the equivalent in pasture. The amount of feed offered should be adjusted to support moderate body condition, meeting nutritional requirements for growth without the youngster becoming overweight.

References

1. References can be obtained upon request from the author
As a non-ruminant herbivore, a plant-eater with no rumen, the horse has a digestive system quite unique among livestock species. The architecture of the horse’s gut, with a simple stomach and a functional cecum, allows the horse to be more effective at utilizing fibers than other monogastrics but less effective than ruminants. The horse’s cecum is a fermentation vat similar to a rumen but is located in the hindgut instead of the foregut. This arrangement creates very different digestion of diet components. Horses evolved as continuous grazers and are able to be very effective at grazing the most immature, easily digested plants when allowed unlimited free-range grazing. This system works well with the horse’s small stomach and hindgut fermentation but presents some challenges for modern horses under common management programs.

Many horse owners have the opinion that if horses were fed more like Mother Nature intended, they would have fewer health and behavior problems. While that sounds reasonable, there are some potential problems with that logic. Mother Nature manages horses on 25,000 acres or so of free-range grazing and produces horses that mature at 5 – 6 years of age often weighing around 750 – 800 lbs at maturity, produce foals only in “good years”, and that on average may live into their late teens. In addition, horses out in nature have the physical demands of slow traveling daily to find water and forage and possibly outrunning a predator from time to time. This doesn’t line up with the facilities that most horse owners have at their disposal and don’t mimic the goals or physical demands most current horse owners place on their horses. So, the challenge is to properly feed and manage the horse to meet current goals and demands while considering the limitations of their digestive system. An understanding of how and where nutrient absorption takes place within the digestive system of the horse is important for making effective feeding recommendations.

The segments of the horse’s digestive system (mouth, esophagus, stomach, small intestine, cecum, large colon, small colon, rectum and anus) each play a role in the assimilation and digestion of food, absorption of nutrients and elimination of waste. Horse saliva contains minimal amylase and though there is some bacterial fermentation of starch and sugars in the nonglandular section of the stomach, little digestion occurs in the stomach. The small intestine, cecum, large colon and small colon play the most significant role in digestion and nutrient absorption in the horse.

The small intestine is the major organ of digestion in the horse. The primary mode of digestion in the small intestine is enzymatic digestion of proteins, fats and non-structural carbohydrates (starch and sugar). Historically horses were thought to have limited ability to digest fats because they lack a gall bladder. However, due to continuous secretion of bile into the small intestine, horses are very efficient at digesting dietary fats. Diets higher in unsaturated fats can potentially reduce milk fat and fiber digestion in dairy cows due to inhibitory effects on cellulolytic microorganisms in the rumen. This is not a potential concern in horses due to dietary fats being digested and absorbed in the small intestine and not normally advancing to the cecum where fiber digestion occurs in the horse. There is a risk if the diet contains high enough fat to overwhelm the capacity of the small intestine. When taken to extremes, such as providing 37% of net energy from soy oil, fiber digestion was reduced but rations including up to 10% fat added to the concentrate haven’t caused a depression of fiber digestion in the horse.

Horses don’t actually have a requirement for protein but instead require protein sources that can be readily digested and provide the needed amino acid balance. Total tract nitrogen digestion is essentially 100% primarily due to the compensatory effect of the hind gut. However, total tract nitrogen digestion isn’t reflective of amino acid availability to the horse. Protein consumed by a ruminant is immediately exposed to microbial fermentation which can alter the original amino acid balance of the diet for the benefit the animal. This does not apply to the horse because microbial fermentation takes place primarily in the hindgut and amino acid absorption takes place in the small intestine, with little appreciable amino acid absorption from the hindgut. Nitrogen absorbed from protein digestion in the cecum and colon is primarily as ammonia. This is important when designing rations for horses to meet amino acid needs. Consider alfalfa hay which typically contains twice as much lysine as oats. However, since alfalfa is forage and digested primarily in the hindgut, only a small percentage of the lysine from alfalfa is available for absorption by the horse. The lysine from oats contributes to the amino acid balance of the horse to a much greater extent than the lysine from alfalfa. The quality of the hay affects prececal digestion of the protein...
and subsequent contribution to amino acid balance. Compared to very good Coastal bermudagrass hay (11.7% protein), lower protein alfalfa hay (15% protein) has lower prececal digestion. Both have lower prececal digestion than high protein alfalfa (18%). Very good Coastal hay will contribute more to the amino acid balance than moderate to poor quality alfalfa. Even though the 15% protein alfalfa still has higher total protein, the hay is more mature and lower in digestibility. This concept applies to concentrate feeds as well. Two feeds can have similar protein content but very different contribution to amino acid balance in the horse due to amino acid content and site of digestion of the ingredients.

Non-structural carbohydrates (NSC) are also completely digested through the total tract of the horse but, once again, the end products of digestion from the small intestine are very different from those in the hindgut. The simple sugars from molasses and grasses are easily digested in the small intestine. Glucose is absorbed directly into the bloodstream while enzymes located on the small intestinal lining make other sugars available to the body. Starch from grain must be broken down to smaller sugars. Then, the enzymes on the intestinal lining act on the smaller sugars until they are in an absorbable form. Amylase, released by the pancreas when ingesta enters the duodenum, is the catalyst for the first step. Due to rate of passage and the limited amount of amylase present, there is an upper limit to NSC digestion and absorption in the small intestine of the horse. The upper limit, based on the amount of NSC per meal required to precipitate a decline in cecal pH, has been reported to range from 2.2 – 4.4 pounds of starch per meal. That translates to from 4 – 8 pounds of oats per meal. The source of starch in the diet may have a bigger effect on starch reaching the hindgut than the amount of starch per meal. Oat starch is the most readily digested in the small intestine, followed by barley and corn starch. Processing of the grain does improve prececal digestion of the starch component. Starch that reaches the hindgut will be readily fermented causing a shift in numbers of cellulolytic bacteria in favor of lactic acid microbes, which results in a decline in pH (hindgut acidosis). When this shift is significant and happens rapidly, the risk for digestive upset increases. Starch fermentation in the hindgut yields volatile fatty acids (VFA’s) which will be absorbed and utilized for energy production.

Structural carbohydrates (fibers) are actually linkages of simple sugars similar to starch but in fibers these sugars are held together by β-linkages which can only be broken by microbial cellulase. Therefore, fibers pass through the small intestine largely undigested. Fibers are represented by different fractions including cellulose, hemicellulose and lignin. Cellulose and hemicellulose are readily broken down by microbial fermentation. The lignin fraction is not digestible and will be passed in the feces. The type of dietary fiber greatly influences its nutritional value – for example, over-mature hay will be relatively high in lignin which depresses digestibility of the fiber and nutrients locked within the fiber structure of the plant. Other fiber sources such as young grass, beet pulp and soy hulls are highly digestible. The maturity of the plant at time of harvest has the most influence on the makeup of the fiber fraction of the forage. As was seen with digestibility of protein from different hays, the fiber fractions of the forage will impact digestion and absorption of other nutrients as well. For example, alfalfa hay is high in calcium but since calcium is absorbed in the small intestines, the calcium from alfalfa isn’t nearly as available to the horse as calcium from more readily digested sources.

The majority of minerals, other than phosphorus, are absorbed primarily in the small intestine. In ruminants, swine and dogs, phosphorus absorption has been shown to occur mainly in the small intestine but in horses the major sites of net phosphorus absorption are the dorsal large colon and small colon. Phosphorus is absorbed in the small intestine of the horse as well but there is a net secretion of phosphorus into the upper small intestine. It is hypothesized that the horse, being a hindgut fermenter may utilize the phosphate as an important and effective buffer against the VFA’s produced by bacterial fermentation. Mineral nutrition is very complicated due to the variation in mineral sources and potential for levels of one mineral to affect the absorption of other minerals. Despite the research data suggesting minimal to no difference in biological utilization or animal performance, many feed products and supplements will make claims of improved animal performance due to the addition of organic (chelated) mineral sources. There are strong marketing claims touting the benefits of organic trace minerals for horses, including prevention of developmental orthopedic disease, muscle abnormalities, improved cartilage development and increased foaling rates. In most of these products, the chelated minerals are supplying around 30% of the total amount of the mineral in question with the remainder provided by the inorganic source. The published research, which often used 50 – 100% organic mineral, doesn’t support these claims. Chelated forms are commercially available for copper, zinc, manganese and cobalt. Recent work investigating the absorption and utilization of organic calcium and magnesium found no advantage in calcium or magnesium balance from replacing 40% of the inorganic mineral with a proteinate. The high cost of chelated minerals,
combined with lack of improved performance, really doesn’t justify the inclusion of these mineral sources in diets for horses at this time.

Vitamins are primarily absorbed in the small intestine of the horse. Microbial synthesis of vitamin K and some B vitamins occurs in the hindgut. Horses fed a diet with less than 0.01 mg biotin/kg DM had biotin concentrations in ingesta in the anterior large colon of 3.8 mg/kg DM and in the anterior small colon of 2.3 mg/kg DM. Similar results are reported with folic acid, B12, pantothenic acid and B6. Vitamin C is synthesized in the liver from glucose.

Another very important function of the large intestine is the absorption of water. Horses consume from 5 – 20 gallons of water per day, depending on activity level, composition of the diet and ambient temperature. Much of that water is absorbed in the small intestines by passive diffusion driven by the absorption of sugars, amino acids and salts. A large quantity of water, combined with mucus, enzymes and cellular debris, is secreted into small intestine as part of the digestive process – about 30 gallons (100 liters) for a 500 kg (1100 lb) horse. Much of this fluid is reabsorbed as the ingesta moves through the various sections of the large colon. The final step in the digestive process occurs in the small colon, where the waste material is formed into semi-solid fecal balls that are evacuated through the rectum and anus.

References

1. References can be obtained upon request from the author
Why should horse owners be concerned about hay quality for their horses? Horses need to be fed at least one percent of their body weight daily (dry matter) as forage. Most horses are fed more than that; many receive two or more percent of their body weight per day in grass or hay (on a dry matter basis). This means that a 1000 pound horse may easily eat 15-20 pounds per day of hay, along with 3-6 pounds of a grain ration. When problems occur that may relate to nutrition, horse owners usually look at the grain ration. However, when the vast majority of the horse’s diet is hay or grass, we also need to pay attention to the important nutritional role that forage plays in the horse’s total nutrient status, and the quality of the hay greatly dictates the nutritional value.

There are several factors that affect the hay quality, therefore the nutrient content. The higher the hay quality, the better the horse’s digestive tract is able to digest and absorb the nutrients contained in the hay.

The factors that affect the quality of the hay include plant species, fertilization, maturity at time of harvest, season at which hay is harvested, climate conditions, storage conditions, and age (time since cutting). The maturity of the plant at time of harvest has more impact on the hay quality than any other factor. Young, leafy, immature plants contain more protein, energy and minerals than older, stemmier plants. As a plant matures, it contains more indigestible fiber (lignin), therefore is less digestible for the horse, as well as containing less protein, energy and minerals. To ensure high quality hay, plants should be harvested at the proper stage of maturity, for instance, timothy should be cut in the pre-bloom or early-bloom stage for the highest nutrient content.

Plant species (e.g. grass vs. legume) has an impact on the nutrient content of the hay, but not to the extent that most horse owners believe. The maturity of the plant when it was cut has much more influence, because plant cell walls becomes more lignified as the plant matures, so a mature plant contains more indigestible fiber than an immature plant. Alfalfa tends to have more protein, energy and calcium than grass hays, but research has shown that a good quality grass hay may provide more nutrients than a medium or low quality alfalfa because the higher quality grass hay is more digestible (less fibrous). For example, for protein to be of value to a horse in providing essential amino acids, it must be digested and absorbed in the horse’s small intestine. Since the fiber in hay is digested through fermentation by the microbial population in the horse’s cecum and large intestine, the higher the
fiber content in the hay, the more of the hay passes undigested through the upper gut, thus much of the protein is not available for digestion until the digesta has already passed through the small intestine. In one study, when horses were fed medium quality alfalfa hay, only 2% of the protein was digested in the upper gut. This means that 98% of the protein was not available for absorption as amino acids in the small intestine, so of no benefit as essential amino acids to the horses. Horse owners sometimes feel that alfalfa is always a better choice for horses than grass hays, but that is not necessarily true. Further, very high quality alfalfa may not provide enough fiber to maintain a healthy hind gut in the horse. A certain amount of indigestible fiber (bulk) is necessary to ensure the health of the microbes in the hind gut, as well as help maintain proper motility in the hind gut.

Fertilization primarily affects yield per acre rather than nutrition of any one bale of hay. The season at which the hay is harvested affects quality in that digestibility is highest for forages harvested in the spring, somewhat lower in mid to late summer, and then it rises slightly in autumn. Climate conditions, such as excessive moisture or drought can affect the quality of hay, especially since climate conditions can affect when the hay is cut. Often the plants become more mature than optimum because climate conditions are not conducive to harvesting at the best time.

Storage conditions and age (time since cutting) primarily affect vitamin content of hays. Many vitamins are not very stable over time and lose biological activity. Environmental conditions such as heat, sunlight and rain can hasten the loss of vitamin activity in hay.

Characteristics to look for in choosing high quality hay include:
High leaf to stem ratio (indicates less mature plants)
Small diameter stems (indicates less mature plants)
Few seed head or blooms (indicates less mature plants)
Fresh smell and appearance
Cleanliness
Color (faded, yellow or brown color may indicate aged hay or poor storage conditions)

Hay analysis may provide more information, but the results need to be interpreted with caution. For instance, the crude protein determined by analysis does not indicate the site of digestion in the horse. A hay that tests high in crude protein and also high in acid detergent fiber (ADF) is not well digested in the horse’s upper gut, thus the amino acids from the protein are not readily available for absorption in the upper gut. A hay with lower crude protein and lower ADF may actually provide more nutrients, including protein, energy and minerals to the horse.
CARBOHYDRATES IN FORAGES

J. Kathleen Young, Ph.D.
Equine Nutritionist
Manager, Equine Technical Services
Purina Animal Nutrition LLC

Due to the incidence of several diseases that have been associated with “carbohydrate intolerance” in horses, there has been increased attention paid to the amount of carbohydrates in the diet. However, there appear to be some misconceptions in the horse industry regarding carbohydrates in forages.

Carbohydrates include sugars, starches and fibers, all of which are found in plants, including grains, pasture and hay. Dietary carbohydrates include those carbohydrates found as components of the cell walls of plants (structural carbohydrates) and those found within the cell contents (nonstructural carbohydrates or NSC). Sugars and starches (hydrolyzable carbohydrates) fall into the NSC category, while dietary fibers are considered structural carbohydrates.

Simple sugars are usually only a minimal presence in horse’s diet, even when the horse is eating a sweet feed with molasses. In plants, simple sugars are utilized as fuel for growth or respiration; when excess sugars accumulate they are stored as polysaccharides. In the horse, simple sugars are primarily digested and absorbed in the small intestine. Starches are polysaccharides formed of several simple sugars linked together, and are found primarily in grains and in the immature leafy portions of plants. During digestion, starches are broken down into the simple sugar building blocks (predominantly glucose), which are absorbed primarily in the small intestine. Glucose may then either be used as fuel immediately, stored as glycogen (usually the major fuel source for aerobic and anaerobic activity) by the horse, or stored as fat (also a fuel source for aerobic activity). NSC that passes through the small intestine undigested will be fermented by microbes in the hindgut. If starch intake exceeds 0.2-0.4% of the horse’s body weight per feeding, the amount of starch digestion in the horse’s hind gut will increase considerably, and the resulting disruption to the hindgut microflora may contribute to the development of colic and/or laminitis. Starches that are fermented in the hind gut will not be broken down into glucose molecules, but instead will result in volatile fatty acids (VFA’s), which will then be absorbed and used as fuel or stored.

Fibers are also formed by the linkages of simple sugars (again primarily glucose), but the linkages between sugar molecules are beta bonds, rather than the alpha bonds found in starches, and mammalian systems do not synthesize the enzymes necessary to break beta bonds. Therefore, fibers are not digested in the horse’s upper gut. Cellulolytic microorganisms in the cecum and large intestine do possess the enzymes for digesting beta bonds, so the digestible fibers (including hemicellulose and cellulose) are fermented by the microbes in the horse’s hindgut.
into VFA’s, which are then absorbed. These VFA’s are also a source of energy for aerobic activity. Some fibers (lignin) are completely indigestible in the horse’s digestive system, and pass on through, providing necessary bulk in the diet.

**Soluble Carbohydrates in Forages**

The category of soluble carbohydrates includes nonstructural carbohydrates and also rapidly fermentable carbohydrates such as fructans that are not included in the structural carbohydrate grouping.

During the process of photosynthesis, plants manufacture sugars that are either used for metabolic processes such as growth, or are stored as polysaccharides such as starches or fructans. The storage form of the sugars depends on the plant species. For most plants, the principal storage polysaccharide is starch. Starch is produced and stored in the chloroplasts of the plant, therefore the production of starch is self-limited by the storage capacity. However for a significant number of species (primarily the cool season grasses) much of the excess sugars are stored as fructans. Storage of fructans occurs in various places throughout the plant, so fructan production can continue as long as conditions are favorable for sugar formation. In certain situations, such as the warm sunny days and chilly nights that we see in the spring and the fall, the plants use fewer sugars for growth, and therefore store more as polysaccharides. In one study, hydrolyzable carbohydrate content of pastures peaked in April and November, and was lowest in June and September.

Other environmental conditions that can affect the amount of polysaccharide storage in plants include drought stress, duration and intensity of sunlight, salinity (salt content) of soil, and overall health of the plant. Overgrazed pastures also may have higher soluble carb content. Many grass species store polysaccharides in the stem base, allowing the plants to maintain reserves for growth after grazing animals have removed the upper portions.

Horses that appear to be intolerant of excess soluble carbs in their diets may need alternate forage sources during conditions in which plants manufacture and store excess starch and/or fructans. According to some evidence, hay with higher levels of soluble carbs may trigger episodes of laminitis in high risk horses.

Some suggested strategies for managing grazing for horses that appear to be at risk for laminitis and/or colic include:

- Utilizing a grazing muzzle to reduce intake of pasture
- Choose grasses that tend to be lower in soluble carbs
- Limit grazing time to when plants tend to be lowest in soluble carbs
  (approximately 3:00 am to 10:00 am)
- Limit or eliminate grazing when grass is stressed due to cool temperatures
- Do not allow horses to overgraze pastures
- Maintain a system of rotational grazing to minimize grazing of grasses that
are starting to head out (seed heads tend to be higher in starch/sugars)

Suggestions for choosing hay lower in soluble carbs include:
Choose hay that was cut at a later stage of maturity
Avoid hay that was cut under conditions stressful to the plant
Utilize warm season grass hays (usually do not contain fructans)
Utilize hay that has been allowed to dry slowly, as cut plants will continue
to metabolize sugars until moisture content is low

Soaking hay before feeding has been suggested for high risk horses. Simple sugars and fructans are soluble in water, so soaking in cold water for at least 60 minutes or hot water for at least 30 minutes appears to reduce those carbohydrate fractions. Starch is not as water soluble, so soaking hay has little effect on the starch concentration of hay.

An important aspect to keep in mind when choosing and recommending hays for “carbohydrate intolerant” horses is that the factors that reduce soluble carbs in hays also reduce the amount and availability of other essential nutrients. For instance, lower NSC hay tends to be higher in indigestible fiber, thus protein and other nutrients will be less available for digestion and absorption in the upper gut, possibly resulting in nutritional deficiencies. Further, if hay is soaked, soluble proteins, vitamins and minerals will be reduced along with soluble carbohydrates. It is therefore essential to offer another source of nutrients to ensure that the horse receives adequate protein, vitamins and minerals to meet nutritional demands.
REFERENCES

Bade, D. Management for high quality hay. In: Texas Horse Owner’s Reference Guide. Texas A&M University, Equine Sciences Program, Department of Animal Science, College Station, TX.


Freeman, D.W., and L. Rommann. Use of forages for horses. In: Texas Horse Owner’s Reference Guide. Texas A&M University, Equine Sciences Program, Department of Animal Science, College Station, TX.


Gibbs, P.G., and K. Davison. Selection and use of roughage in horse feeding. In: Texas Horse Owner’s Reference Guide. Texas A&M University, Equine Sciences Program, Department of Animal Science, College Station, TX.


