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The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; family and consumer sciences; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of the Cooperative Extension system are:

- The federal, state, and local governments cooperatively share in its financial support and program direction.
- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective, and research-based information.
- It provides practical, problem-oriented education for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
- It utilizes research from university, government, and other sources to help people make their own decisions.
- More than a million volunteers help multiply the impact of the Extension professional staff.
- It dispenses no funds to the public.
- It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
- Local programs are developed and carried out in full recognition of national problems and goals.
- The Extension staff educates people through personal contacts, meetings, demonstrations, and the mass media.
- Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

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Feeding Management of the Equine

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Often, it is the way rations are fed rather than their composition that leads to digestive upset in horses.

Even under the best of management, several anatomical peculiarities of the horse's digestive tract predispose horses to digestive disorders such as colic and founder. Under poor feeding management, the onset of these disorders is almost assured. The objective of feeding management is to provide a ration with balanced nutrition in a manner which maximizes nutrient utilization while lessening the occurrence of digestive disorders.

Anatomical Peculiarities of the Equine Digestive Tract

The horse's digestive tract can be divided into two functional divisions: foregut and hindgut. The foregut of the horse is made up of the mouth, esophagus, stomach, and small intestine. It functions similarly to the digestive tract of the pig in that it is made of a simple, one-compartment stomach followed by the small intestine. The hindgut of the horse is comprised of the cecum, large colon, small colon and rectum. The cecum functions much like the rumen of a cow in that it is a relatively large, fermentative vat housing microbes, which aid digestion. These microbes break down nutrient sources that would otherwise be unavailable to the horse. Each part of the digestive tract has peculiarities that relate to feeding management.

Mouth

The mouth is responsible for the initial breakdown and swallowing of feedstuffs. Mastication (chewing) reduces the size of large particle feedstuffs and breaks up the less digestible, outer coverings of grains and forages. Additionally, mastication stimulates salivary glands to release saliva, which assists in lubrication of feed for swallowing. Adequate saliva production also serves to add buffer to the horse's stomach and prevent an excessively acidic environment. Since proper denture conformation is necessary for mastication, inspection of the horses's teeth by a qualified individual should be a routine management procedure. As horses age, dental conformation can be expected to deteriorate. Consequently, older horses require more frequent inspection and treatment of teeth. Signs of poor dental conformation include excessive loss of feed while eating, positioning the jaw or head sideways while chewing, and evidence of general loss of condition and thriftiness.

Esophagus

The diameter and tone of the musculature of the esophagus make it difficult for the horse to expel gas through eructation (belching) or vomiting. These are predisposing features to gastric (stomach) rupture, gastric distention and colic.

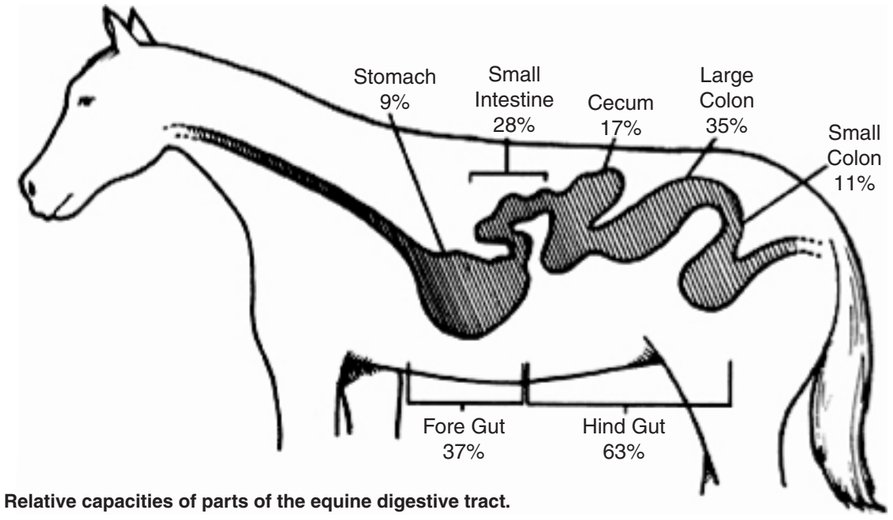

Figure 1. Relative capacities of parts of the equine digestive tract.

Stomach

Compared to most livestock, the size of the horse's stomach is small, about ten percent of the volume of the total digestive tract. The small size makes the rate of flow of ingesta (feed material in the digestive tract) through the stomach relatively fast. Gastric emptying is dependent upon volume, so large meals can be expected to pass more quickly than feed eaten continuously at low volumes. Studies have shown the majority of ingesta passes to the small intestine within 12 hours following a meal.

Small Intestine

The small intestine is the main site of digestion and absorption of protein, energy, vitamins, and minerals. Similar to the stomach, intake level of the feed influences rate of flow of ingesta through the small intestine. Large amounts fed in meal feedings increase rate of flow to the large intestine. Physical form of the feed also influences rate of flow, as pelletized rations pass more quickly than textured grain mixes combined with hay. Liquids pass to the cecum as quickly as a few hours after ingestion of a meal.

Cecum and Colon

Ingesta not previously digested or absorbed in the small intestine flows to the cecum and colon, which make up about 50 percent of the volume of the digestive tract. The cecum and colon house bacterial, protozoal, and fungal populations that function in microbial digestion of ingesta. Many different products of microbial digestion are absorbed by the horse.

Passage of ingesta through the large and small colon is relatively slow. Rates of flow through the colon may take up to several days following the time feed was eaten. The diameter of different segments of the large colon varies abruptly. Additionally, the arrangement includes several flexures where the colon turns back onto itself. Anatomical arrangements such as these predispose the horse to digestive upset when nutrient flow is abnormal.

Nutrient Intake and Digestion

Water

The daily minimal requirement for water has been estimated to vary from five to 20 gallons. Requirements depend on factors such as environmental temperature, workload, production state and intake. Voluntary water intake can be expected to increase with increases in the amount of ration eaten. Also, rations low in digestibility increase water intake. Furthermore, horses can be expected to drink more frequently when exposed to hot environmental temperatures. Horses exercising in temperate environments may have increases of 300 to 400 percent in water requirements for replacement of water that is loss in expired air and sweat. Since restriction of water intake may cause digestive upset, recommendations generally are for free choice access to clean, palatable water.

Energy

Energy is the fuel for chemical reactions that run the various systems of the body. Energy-containing compounds are part of grains, forages and many supplements. Energy is supplied in the form of starch, fiber and fat. Some researchers have recommended that only 0.2 to 0.4 percent of body weight of concentrate should be fed at one time.

Starch is found mainly in grains, and as much as 55 to 85 percent of starch is absorbed in the small intestine. Starch bypassing to the hindgut is digested by microbes and absorbed as volatile fatty acids. Large amounts of starch presented to the hindgut predispose horses to colic because of gaseous products of microbial digestion and abnormal changes in gut pH and fluid balance. The amount of starch bypassing to the hindgut depends on intake level, rate of flow through the digestive tract, and amount of mechanical disruption of the hard seed coats of grains. Results from nutritional studies suggest that approximately two grams starch per pound of a horse's body weight increases starch bypass to the point of causing digestive upset. Small particle size may further increase starch bypass, as ground feed passes more quickly than textured or coarsely processed grain. Considering starch levels in typically formulated grain mixes, recommendations are to split daily grain needs to two daily feedings when grain levels are greater than 0.5 percent of body weight per day (five to six pounds of grain for a 1000 pound horse).

Hay and pasture forage are the most common sources of high fiber feeds fed to horses. Fiber digestion is dependent on the efficiency of digestion from microbial fermentation in the cecum and colon. Compared to cattle, horses are less efficient in digesting most sources of fiber, presumably because of faster rates of passage of ingesta. Also, fiber digestion is dependent on the maturity and type of forage. Mature, stemmy forages are inefficiently digested, whereas digestion of immature, leafy, small-stemmed sources of fiber are similar in horses and cattle. Processing hays in cubes, pellets or chop has little effect on digestibility, provided the horse can masticate its feed adequately.

Fat is a component of most feedstuffs. Nonsupplemented grain mixes typically have minimums of two to three percent fat. Adding additional levels of fat in formulations for grain mixes has become a common practice. This supplementation increases the energy concentration of grain mixes without increasing the amount of starch. Therefore, fat-added feeds have advantages of being more concentrated in energy and safer because of containing less starch as a total part of the energy-containing compounds.

Protein

Proteins supply amino acids. Amino acids are used in a variety of body processes, largely for developing and maintaining lean body tissue. Amino acids are absorbed intact in the small intestine, while protein in the hindgut is absorbed primarily as ammonia. Some of the necessary amino acids (essential) must be absorbed intact because the horse's body cannot synthesize them. Thus, increasing the efficiency of protein digestion in the foregut is desirable. Total tract and prececal digestibility vary with protein source and protein concentration in the diet. Total tract protein digestibility of feeds typically ranges from 40 to 70 percent. As much as 75 percent of protein in soybean meal is digested in the foregut, whereas estimates for pre-cecal forage digestibility range from near zero to 20 percent.

Minerals and Vitamins

Mineral and vitamin imbalances, deficiencies, and toxicity can cause a multitude of health disorders in the horse. In

timing of exercise schedules, labor constraints, and costs are significant management factors that affect feeding management. Deworming, vaccination schedules, ectoparasite control and general hygiene are examples of health practices that relate the nutritional plans and the well-being of the horse.

Effective management also involves treating each horse as an individual. As such, effective management requires an accurate, quantitative record keeping system that allows for individual assessment of each horse.

many cases, recommendations are based on limited research or requirements and have not been established because of absence of research.

Calcium and phosphorus are the two minerals that have received the most research attention. Horses require more calcium than phosphorus and are susceptible to skeletal system disorders when fed less calcium than phosphorus. Additional minerals receiving considerable attention in recent research include copper and zinc, also because of implications related to skeletal growth disorders.

Research information on vitamin requirements is largely absent in equine nutrition. Fresh forage is a major source of vitamins, and most needs are considered met when horses have access to quality hay or pasture. Vitamin A is the most commonly supplemented vitamin in rations, partially because of the large needs for production and growth. Vitamin D is also routinely added, especially to horses who do not receive fresh forage. Vitamin D toxicosis is the most common of all vitamin toxicoses. The needs for vitamin D are less than vitamin A, and recommended upper levels of safe intake are much lower.

Requirements of the other fat-soluble vitamins, E and K, are less clear, and clinical deficiencies and toxicity are not as commonly observed. Sources of vitamin E are routinely added to equine diets to guard against deficiencies that cause myodegeneration (breakdown of muscle). Vitamin K requirements are presumed to be met by synthesis of vitamin K sources by microbes in the cecum and colon. Requirements for B vitamins are largely unknown. B vitamins are assimilated by microbes in the horse's cecum and colon, and these sources are assumed to meet the needs of most horses. However, B vitamin supplements are routinely added to diets of exercising horses because of the role of B vitamins as catalysts for energetic pathways.

Feeding Management Implications

Water

As discussed previously, water intake is important for maintenance of normal body processes. Restrictions in water, such as that caused by voluntary reductions in response to abrupt decreases in environmental temperature or changes in water source, may cause an increase in the incidence of colic. Water intake should be monitored because of numerous health problems associated with dehydration. Monitoring water intake requires frequent inspection of water sources, including the function of automatic waterers. In general, horses should be allowed free access to fresh, palatable water. Horses should be allowed access to water after exercise in order to allow rehydration. Dehydration can be a serious problem in exercising horses, so it is important that water is offered frequently, and that intake is monitored.

The Need for Long-Stem Forage

Rations for horses should be forage based. The digestive system of the horse is designed to intake small meals throughout the day. Natural foraging patterns of horses indicate they eat approximately 16 hours per day. Generally, horses should have access to pastures, hays, or coarsely processed forage at minimal levels of 1 percent of body weight per day. Ideally, forage intake should be maximized. Among other benefits, incorporating longstem forage into rations increases particle size of ingesta, thus slowing rate of passage. It also increases dry matter intake, thus stimulating water intake. Additionally, incorporating long-stem forage reduces the frequency of behavioral problems due to boredome such as tailchewing, woodchewing and coprophagy (feeding on excrement). Many stress related behaviors can also be minimized by allowing greater access to forage. More importantly, prolonging the amount of time a horse spends chewing will also increase the amount it salivates. This is especially important in buffering the acidic environment of the stomach.

Grain mixes should be formulated to balance and add to the value of forages. High quality forages are more concentrated in nutrients and more efficiently digested; thus, lower levels of grain supplementation are necessary. Feeding forages containing weeds, insects, large amounts of indigestible fiber or foreign material will predispose the horse to digestive upset.

Meeting Requirements with Balanced Rations

Nutrient balances are important for all diets. However, horses in production, growth, or performing high levels of athletic competition or work are most likely to develop observable disorders from ingesting an imbalanced ration. A feeding management plan requires knowledge of requirements, an ability to formulate rations, and knowledge of utilization of different feedstuffs.

Growing horses, exercising horses, gestating and lactating mares and stallions during breeding programs require more nutrients than horses at maintenance. Feeding management plans should consider these differences, and farm facilities should separate horses into different production classes. The feeding management plan should also consider the number of different classes of horses, the ability to correctly add supplements on-farm, the ability to feed different number and types of rations, feeding costs and the availability of different feedstuffs.

Meeting requirements also requires knowledge of nutrient content of grains, forages and supplements. Rations have successfully incorporated many different combinations of fresh forage, hays, grains and supplements. However, feedstuffs contain different levels of energy, protein, minerals and vitamins. Knowing the expected nutrient profiles of selected feedstuffs will direct supplementation to meet needs without causing deleterious effects on performance or health.

Estimates of the nutrient content of feedstuffs can be obtained from feed tags on grain mixes, feedstuff tables in animal nutrition texts, professional nutritionists, or by chemical analyses. Because of the variability in forages, farms using significant amounts of hay from a single source should have hay sources routinely tested for nutrient content. This allows a more accurate selection of appropriate concentrates to complement the forage.

Relating Intake, Ration Densities and Requirements

Maximum voluntary daily dry matter intake of rations will normally fall within the range of two to three percent of body weight. Estimates are provided on a dry matter basis instead of as fed so the variation of the water content of feedstuffs can be removed. For example, grains and hays are expected to contain about 10 percent moisture on an as fed basis. Early growth, small grain pasture can be expected to contain more than 60 percent water on an as fed basis. Dry matter will influence the level of voluntary intake much more than water

intake.

Assuming a palatable source of feed, an expected range of dry matter intake relates to approximately 22 to 33 pounds of a mixed grain-hay or total hay diet for a 1,000 pound horse. Maximum voluntary daily dry matter intake may range below or above these expectations as diet palatability, production state of the horse, environmental influences and individual horse variation will influence voluntary intake greatly.

Most diets are formulated to be rationed, so less than maximal voluntary levels can be fed to meet energy needs. Rations that have greater digestible energy densities, e.g. mixed grain and hay rations, can be fed at lower intakes than rations with lower digestible energy densities, e.g. all grass hay ration. The minimal level of daily dry matter needed for horse health has not been determined, and rations are not formulated for a goal of reaching a minimal intake. Rather, considering the digestible energy density of most feedstuffs and benefits for feeding management, it is common to formulate rations to be fed at least 70 to 80 percent of the expected voluntary maximum intake. Voluntary intake of energy dense rations increases the potential for overeating maladies and excessive body condition. Conversely, nutrient needs and intake limitations of some horses may necessitate feeding a more highly energy dense ration as compared to horses with less needs or larger intake capacities.

Rations are balanced to contain specific levels of nutrients, and nutrient levels are expressed as a concentration of the total weight of ration. Nutrient densities are expressed as percent (1 unit of the part/100 units of the whole) for most of the major nutrients. Minerals and vitamin densities, because of such small needs, may be expressed in much lower densities, e.g. mg/kg or IU/kg. These densities assume a certain amount of ration intake to meet requirements as requirements are determined on a nutrient weight basis, i.e. grams of crude protein needed per day.

When estimating the success of meeting requirements with a particular ration, the amount of ration fed and the density of the nutrient of concern must be determined. For example, feeding a 10 percent crude protein ration (weighted average of all sources) at 20 pounds per day would supply 2 pounds of crude protein. Whether or not this amount is sufficient to meet requirements depends on the size, activity level, and production state of the particular horse in question. OSU Fact Sheets ANSI-3997 and ANSI-3928 provide further explanations of nutrient needs and ration evaluation.

Maintaining a Nutrient Balance in Rations

Feedstuffs contain differing levels of nutrients. Grains are relatively higher in energy than forages, some by-product feeds contain high levels of protein and mineral and vitamin levels can be expected to vary greatly between different feed sources. Because of these differences, changing sources or amounts of feedstuffs will alter the nutrient balance in rations. Commercially formulated grain mixes are routinely supplemented with nutrients so the different ratios of grain and hay and different hays that horses are fed will not adversely alter the nutrient profile of the total ration.

Some feeding managers are equipped to properly supplement rations by on-farm addition of ration ingredients, whereas others routinely make unknowledgeable decisions to add many different types of nutrients to the base rations. Unknowledgeable addition of ingredients can easily cause numerous irreversible health problems in all classes of horses. Two problems frequently observed with improper ration adjustments are supplementation without knowledge of need or level of intake before supplementation, and supplementing for one ingredient without recognizing the additional amount of other ingredients a supplement may contain.

Additionally, horses should not be expected to self-regulate their need for most nutrients. This is evidenced by horses overconsuming energy to the point of digestive upset. In addition, horses do not regulate most of their mineral needs under free-choice management. Additional needs for minerals should be met as part of a formulated ration at regulated intakes. The exception to this rule is the free choice offering of salt (sodium chloride). It is generally recommended that all classes of horses be provided salt (plain or trace mineralized) in some form with the constraint that free choice, palatable water is available at all times.

Feeding to Desired Body Condition

Horses in a positive energy balance will store energy as fat, and body fat is reduced when the ration does not provide sufficient nutrients to maintain energy balance. Accurately assessing the fat cover allows for visual appraisal of the energy status of a horse. In general, most horses should be fed a balanced ration at levels that produce moderate to fleshy body condition, thus avoiding extremely thin or obese condition. Because horses in similar production and weight classes will vary in their nutrient needs, routine assessment of body condition of each horse is necessary. While horses in similar production and weight classes are commonly grouped together, those individuals with abnormally high or low body condition may need to be separated further to meet individual needs.

Assessing Energy Sources, Levels, and Utilization in Feeds

Voluntary intake in horses appears to be influenced by a number of factors: weather, palatability of feed, interaction with other horses and energy intake, among others. Regardless, if allowed free access, most horses will consume enough grain to cause digestive upset. As discussed previously, the most common problem with overeating is the consumption of too much starch in a single feeding. Grains vary in the amount of starch, e.g. corn has more starch per pound than oats. Also, there may be differences in foregut digestibility of starch between different grains. Depending on intake, more starch in oats may be digested prececally than corn.

Knowing the energy concentration of the grain mix will assist in determining the amount of ration that is needed to supply energy needs. Generally, the higher the fiber content, the lower the digestible energy content, so crude fiber estimates on feed tags provide some information. Additionally, added-fat feeds will raise or maintain the energy level of feeds while reducing the amount of starch.

The Value of Processing Feeds

Processing increases digestibility of hard seed coat grains and assists in intake of ingredients with different particle sizes in a mix. Feeding finely processed rations such as ground mixes is not recommended because it may decrease palatability, increase dust, increase incidence of gastric upset, and increase the rate of flow of nutrients through the digestive tract.

Pelletizing, micronizing, flaking, rolling, cracking, wafering and extruding are examples of processing methods that are acceptable. Several different pellet sizes have been successfully fed to horses, most ranging from 0.2 to 0.75 inches in diameter. Often, forages are recommended to be fed loose so behavioral abnormalities resulting from boredom are reduced. However, research has shown that cubed (1 1/4 inch in diameter) hay can be fed as the sole source of forage with no reported incidence of behavior abnormalities.

Processing can cause several differences in rate of intake and utilization of nutrients. Completely pelletized rations are consumed faster than textured grains, and is an important management consideration. Extruded feeds are consumed more slowly than pelletized or textured grain mixes. Texture and hardness of grains will determine the value of processing. Small seed grains with hard seed coats such as milo and wheat should be processed to increase utilization of nutrients. The benefit of processing softer seed coated grains, such as oats, is much less. Also, the value of processing grains can differ between horses. Horses with poor denture conformation, such as older horses, may benefit more from processed feeds than others. Also, the value of processing is increased when feeding large quantities of grain to horses with limited capacity, such as rations fed growing horses to obtain maximum gain.

Total rations may be mixed, ground, and processed by pelletizing or extrusion to make a complete feed. Complete feeds have several advantages, most related to ease and convenience of feeding. However, it is most commonly recommended to provide at least 0.75 pounds per 100 pound body weight in long stem forage to supplement these complete feeds to guard against boredom and again to maximize chewing and salivation.

Feeding by Weight of Ration Instead of Volume

Feeding by weight will decrease the chance of overfeeding due to differences in weight per volume of different feeds and different processing methods. For example, corn weighs more per volume than oats, and pelletized feeds weigh more per volume than textured feeds. Consequently, it is recommended to weigh feed periodically to ensure accurate monitoring of intake. This is especially important when changing feed sources. One of the most common causes of digestive upset is overfeeding energy in a single feeding because differences in weight of grain mixes were not taken into account.

Feeding Frequency

In many ways, the horse's digestive physiology is best suited for a continuous, low level supply of feed. However, for management, housing, and production needs, most horses are meal-fed. Meal-feeding large amounts of starch increases starch bypass into the cecum and colon. As discussed previously, large amounts of starch presented to the hindgut increases the frequency of digestive upset. Therefore, it is recommended to split grain into two daily feedings when the daily amount of grain exceeds 0.5 percent body weight (five pounds grain per 1000 pound horse). Those feeding grain to horses at levels of or above one percent of body weight per day should consider splitting amounts into three portions per day. Meal feedings should be separated as much as possible, i.e. 10 to 12 hours between a.m. and p.m. feedings for two daily meals.

Reducing Rate of Intake

Reducing rate of feed intake may be desirable if horses bolt their feed, resulting in choking or digestive upset or if reducing rate of intake decreases competition in group-fed horses. When fed in individual feeders, methods used to slow feed intake in abnormally fast eating horses have included spreading grain out in shallow troughs, placing several large stones in the feed trough, requiring the horse to eat around them, or using spaced bars or feeding rings to limit access to the feed trough. As discussed previously, processing of the ration also influences the rate of intake. While the fiber con-tent or size of pellet does not seem to affect rate of intake, increasing pellet density (hardness) has been shown to slow intake of a pelletized grain mix. It may be desirable to decrease the rate of intake of forage as well, especially to promote digestive health, relieve boredom or manage weight. Several slow feeding hay nets are commercially available or hay feeders designed to slow intake.

Group versus Individual Feeding

In groups, horses tend to do what other horses do. One horse eating encourages others to eat. Similarly, appetite can be stimulated in individually housed horses by allowing a horse to observe other horses eating.

Competition among horses in group-fed situations may allow some horses to consume more feed than needed while others are not allowed access to adequate amounts. In addition, feeding can also cause aggressive interactions that can result in injury. To reduce competition among horses, group-housed horses should be fed grain in individual feeders that are spread out over a large area, i.e. 50 feet between feeders. Additionally, slowing the rate of intake of grain by reducing the desire to eat may reduce competition. Supplementing pastures with free choice hay in times of limited forage production may slow rate of intake of grain because horses may not be as hungry at meal time.

However, even under the best management, horses low on the herd pecking order or stressed because of conditions such as old age or lameness will need to be housed separately to reduce competition.

The Need to Make Gradual Changes in Rations

Grains and hay differ in nutrient content. Changes in the intake level and the physical form of rations should be done gradually over several days to weeks. This practice allows the digestive tract time to adapt to different levels and physical forms of nutrients and is especially important when feeding energy-dense rations. As such, grain amounts should be increased incrementally when changes in management require an immediate need for more energy. For example, increase grain one half pound every two to three days until energy balance is met. For similar reasons, introduce horses to pastures with large amounts of lush forages by limiting access for several days.

Incorporating the Feeding Management Plan with Total Farm Management

The source, ingredient mix and number of rations will depend on numerous management practices that interrelate with the feeding program. The need to transport to events,