Forages: The Foundation for Equine Gastrointestinal Health

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INTRODUCTION

Horses have evolved over millions of years as grazers, with specialized digestive tracts adapted to digest and utilize diets containing high levels of plant fiber. They are capable of processing large quantities of forage to meet their nutrient demands. In an attempt to maximize growth or productivity, horses are often fed diets that also contain high levels of grains and supplements. Unfortunately, this type of grain supplementation often overshadows the significant contribution that forages make in satisfying the horse's nutrient demands and can lead to serious gastrointestinal disturbances.

Digestive Function

Horses are classified anatomically as nonruminant herbivores or hindgut fermenters. The large intestine of the horse holds about 21 to 24 gallons (80-90 liters) of liquid and houses billions of bacteria and protozoa that produce enzymes which break down (ferment) plant fiber. These microbes are absolutely essential to the horse, because the horse cannot produce these enzymes without them. The by-products of this microbial fermentation provide the horse with a source of energy and micronutrients.

The equine digestive tract is designed in this fashion to allow the horse to ingest large quantities of forage in a continuous fashion. The small capacity of the upper part of the tract is not well-suited for large single meals, a fact that is often ignored by horsemen. Large single meals of grain overwhelm the digestive capacity of the stomach and small intestine, resulting in rapid fermentation of the grain carbohydrates by the microflora in the hindgut. This fermentation may result in a wide range of problems including colic and laminitis.

The fact that horses are hindgut fermenters has several implications for the person feeding the horse. First, since horses are designed to live on forages, any feeding program that neglects fiber will result in undesirable physical and mental consequences. Horses have a psychological need for the full feeling that fiber provides. Horses fed fiber-deficient diets will in extreme cases become chronic woodchewers, 1000-pound termites that can destroy a good deal of fencing or stall front. It is also important to maintain a constant food source for the beneficial bacteria in the hindgut. Not only does the fermentation of fiber provide a great deal of energy for the horse, but the presence of beneficial bacteria prevents the proliferation of other, potentially pathogenic bacteria. Horses, like humans, need a certain amount of bulk to sustain normal digestive function. Horses have an immense digestive system designed to process a large volume of feed at all times. Deprived of that bulk, the many loops of the bowel are more likely to kink or twist, and serious colic can result.

Forage should remain the foundation of a horse's feeding program, regardless of where it is raised or how it is used. Additional grains or protein and mineral supplements should be used only to supply essential nutrients not contained in the forage. This is the most logical and economical way to approach feeding horses, because it eliminates the needless duplication or dangerous excess of fortification. The problem with this method of ration balancing is that the quantity and quality of forage eaten by most horses is not precisely known. Horsemen pay close attention to a difference of a few percentage points of protein in a grain mix, but rarely assay hay or pasture for nutrient content. To compound the problem, intakes of hay and pasture are difficult to measure. This does not mean, however, that reasonable estimates of forage intake cannot be made.

Forage Composition

Forages are composed of two components, cell contents and cell walls. Cell contents contain most of the protein and all of the starch, sugars, lipids, organic acids, and soluble ash found in the plant. These components are degraded by enzymes produced by the horse and are highly digestible. The cell wall contains the fibrous portion of the plant, which is resistant to digestive enzymes produced by the horse. The primary components of the cell wall are cellulose, hemicellulose and lignin. The nutritive value of forages is determined by two factors:

1) Fiber content (the proportion of the plant that is composed of cell wall).
2) Fiber quality (the degree of lignification).

These factors are important because the horse can digest practically all of the cell contents contained in forages, but bacterial fermentation can digest only 50% or less of most plant cell wall. The degree to which plant cell wall is digestible is largely dependent on the amount of lignin that it contains.

Factors Affecting Forage Quality

Many factors affect the quality of forage. Most important of these are the species of plant, stage of maturity, location where the plant was grown, and content of inhibitory substances. All of these factors should be considered when assessing the suitability of a particular forage for horses.

Species. Most plants that serve as forages for horses can be divided into two different categories, grasses and legumes. Grasses contain much structural matter in their leaves and leaf sheaths, and this can be as important as or more important than the stem in holding the plant erect. Examples of grass forages used for horses include temperate species such as timothy, orchard grass, brome grass, and fescue and tropical species like pangola, guinea, Bermuda, and kikuyu. Legumes, on the other hand, tend to be treelike on a miniature scale. Their leaves have very little structural function and tend to be on the ends of woody stems. The primary legumes used as horse forage are alfalfa and clover.

At a similar stage of maturity, legumes tend to be higher in protein, energy, and calcium than grasses. ADF (acid detergent fiber; lignin plus cellulose) does not vary that much between grasses and legumes at the same stage of maturity. NDF (neutral detergent fiber; lignin + cellulose + hemicellulose), however, is much higher in grasses than legumes. This is because grasses contain a great deal more hemicellulose than legumes. Therefore, evaluating the fiber content of forages based on ADF alone underestimates the total cell wall content and overestimates the total energy content of a grass. Remember, hemicellulose is typically only 50% digested in the horse, and cell solubles are almost completely digested. By only considering ADF, the assumption is that the rest of the forage (besides protein, fat, and ash) is soluble sugar. This is truer in legumes, which contain only around 10% hemicellulose, than in grasses, which can have hemicellulose contents of 30% or more. The fiber that is in legumes tends to be less digestible than the fiber in grasses, largely because legumes tend to have higher lignin content per unit of total fiber. This means that the digestible fiber content of grasses is much higher than it is in legumes of similar maturity.

Because of the factors mentioned above, legumes contain 20-25% more digestible energy than grasses at the same maturity. In certain instances, the amount of legume hay fed may be limited so that the horse doesn't get too fat. This can result in intakes of digestible fiber that are below optimal levels, particularly in extremely high-quality hays.

Stage of maturity. Generally, as plants mature they become less digestible. This is because a greater proportion of their mass becomes structural and less metabolic. Legumes tend to mature by decreasing leafiness and increasing the stem-to-leaf ratio. Alfalfa leaves maintain the same level of digestibility throughout their growth. Their stems, however, decrease dramatically in digestibility as they mature. This is because they become highly lignified to support the extra weight of the plant. The ultimate example of lignification for support is the oak tree. The wood of the oak tree is highly lignified and practically indigestible. When pulp wood is processed to make paper, the lignin is removed using harsh chemicals such as sulfuric acid (hence the sulfur smell around paper mills).

The leaves of grasses serve more of a structural function than in legumes. As they mature, these leaves become more lignified and less digestible. Since the stems of certain grasses serve a reserve function, they may actually be more digestible than the leaves of these grasses at a later stage of maturity. When forage is grazed as pasture, its nutrient quality is almost always higher than when it is harvested as hay unless the pasture is the dead aftermath left over from the previous growing season. New spring pasture can be quite low in fiber content and high in soluble carbohydrates. In spring, it is often a good management practice to continue to offer horses on pasture additional hay even if the pasture appears thick and lush. If the horses are getting adequate fiber from the pasture, then they will ignore the hay.

Latitudinal effects. The digestibility of tropical forages averages on the order of 15 units of digestibility lower than temperate forages (Van Soest, 1994). Plants that grow in the tropics have been genetically selected for a larger proportion of protective structures such as lignin to avoid predation. At the other extreme are the perennial plants in the far northern regions of the world. These plants have very short growing seasons and need to store energy in reserves as sugars and fructans rather than in irretrievable substances such as lignin and cellulose. Care should be taken when feeding high-fructan forages to horses since these compounds are poorly digested in the small intestine and may lead to colic or laminitis due to excess lactic acid fermentation in the hindgut.

Inhibitory substances. Besides lignin, a number of other substances in forages can reduce digestibility of fiber and minerals. Silica is used as a structural element complementing lignin to strengthen and add rigidity to cell walls. Alfalfa and other temperate legumes restrict absorption of silica and never contain more than a few hundred ppm in their tissues (Van Soest, 1994). Cereal straws are quite high in silica. This gives the straw a clean, glassy appearance and it also reduces its digestibility. Rice hulls are extremely high in silica and indigestible by horses. There are also substances contained in forages that can inhibit mineral digestibility. Two that are particularly important are phytate and oxalate. Phytates contain phosphorus in a bound form that is unavailable to the horse. Phytate may also inhibit the digestibility of other minerals such as calcium, zinc, and iodine.

Oxalates can reduce the digestibility of calcium in forages if the calcium-to-oxalate ratio in the forage is 0.5 or less on a weight-to-weight basis (Hintz, 1990). This is a common problem in tropical forages which tend to be high in oxalates and low in calcium. Low calcium availability in tropical forages can lead to nutritional secondary hyperparathyroidism or "big head" disease. Therefore, when tropical forages are fed to horses, supplemental sources of calcium should be available.

There is a common misconception that oxalates reduce calcium digestibility in alfalfa hay. This is not true because the calcium:oxalate ratio is much higher than 0.5, even in alfalfa hays that contain high levels of oxalates. Hintz et al. (1984) demonstrated this in an experiment in which no difference was found in the absorption of calcium from alfalfa containing 0.5% and 0.9% oxalic acid in which the calcium: oxalate ratios were 3 and 1.7, respectively. The true digestibility of the calcium from both hays was estimated to be >75%.

Buffering Capacity of Forage

Gastric ulcers are very common in performance horses, affecting over 90% of racehorses and 60% of show horses and most commonly occurring in the upper portion of the horse's stomach, which is composed of nonglandular squamous epithelium. These ulcers are primarily the result of prolonged exposure of this tissue to gastric acid. Unlike the glandular portion of the stomach, the upper half of the equine stomach does not have a mucous layer and does not secrete bicarbonate onto its luminal surface. The only protection that this portion of the stomach has from gastric acid and pepsin comes from saliva production and the buffering capacity of feed.

The high incidence of ulcers seen in performance horses is a man-made problem resulting from the way that we feed and manage these horses, as ulcers are extremely rare in nonexercised horses maintained solely on pasture. Meals of grain or extended periods of fasting lead to excess gastric acid output without adequate saliva production. Additionally, production of VFAs (particularly butyric acid) from the fermentation of grain in the stomach makes the nonglandular epithelium more susceptible to acid damage. Horses secrete acid continually whether they are fed or not. The pH of gastric fluid in horses withheld from feed for several hours has consistently been measured to be 2.0 or less (Murray, 1992). Horses that received free-choice timothy hay for 24 hours had mean gastric pH readings that were significantly higher than fasted horses (Murray and Schusser, 1989). Higher pH readings in hay-fed horses should be expected since forage consumption stimulates saliva production. German researchers measured the amount of saliva produced when horses ate either hay, pasture, or a grain feed (Meyer et al., 1985). When fed hay and fresh grass, they produced twice as much saliva compared to when a grain-based feed was offered.

There is growing evidence that the type of hay fed to horses has a significant impact on acid neutralization and the incidence of gastric ulcers. Tennessee researchers reported a study where 6 horses with gastric cannulae were fed either alfalfa hay and concentrate or brome grass hay without grain supplementation (Nadeau et al., 2000). It was predicted that the alfalfa hay and concentrate diet would produce more ulcers due to greater gastric VFA production and less saliva production compared to when the horses were fed only grass hay. Surprisingly, they found that feeding alfalfa hay and concentrate increased the pH of gastric fluid and reduced the number and severity of squamous mucosal ulceration compared to feeding the diet of brome grass hay. Saliva production was not measured in this study, but it was suggested that the buffering capacity of the alfalfa and/or concentrate was greater than grass hay.

A more recent study at Texas A&M University suggests that the differences seen in the Tennessee study were related to the type of hay fed. In this study, the incidence of ulceration was compared in horses fed a pelleted concentrate along with either Bermuda grass hay or alfalfa hay (Lybbert et al., 2007). Twenty-four Quarter Horse yearlings, 12-16 months of age, were included in a crossover design conducted over a 77-day period consisting of two 28-day periods separated by a 21-day wash-out period. Gastric endoscopy was performed at the beginning of the study, and each horse was assigned an ulcer severity score, using a grading system ranging from 0 (intact gastric epithelium with no hyperemia or hyperkeratosis) to 4 (submucosal penetration). The horses were assigned to one of two treatment groups, using a randomized block method to ensure equivalent ulcer severity scores in the two treatment groups. Group 1 horses were fed a diet consisting of coastal Bermuda grass hay and a pelleted concentrate (15% protein) in a weight:weight ratio of 1:1, and group 2 horses were fed a diet consisting of alfalfa hay and the same concentrate in a weight:weight ratio of 1:1. The horses were housed in small dry lots and subjected to an exercise regimen 3 days/week using a mechanical horse-exerciser. After the end of the first 28-day period, gastroscopy was repeated, and horses were turned out to pasture with no forced exercise and fed a diet comprised of grazing and 1.8 kg/horse of the same pellet. After 21 days in pasture, gastric endoscopy was repeated and diet regimens were switched (i.e., group 1 horses were switched to group 2 and vice versa).

The ulcer severity scores were significantly ($p < 0.001$) lower for horses in the alfalfa hay group than horses fed coastal Bermuda grass hay. Among horses fed alfalfa, 12 had no ulcers at baseline and 11 had ulcer scores of 2 ($N = 6$) or 3 ($N = 5$). Of the 11 horses with ulcer scores >0, all improved by at least two ulcer grades while on the alfalfa diet; 1 of the 12 horses without ulceration developed gastric ulceration during the time it was fed alfalfa. In contrast, of the 12 horses fed coastal Bermuda grass hay that had ulcer scores >0, 5 horses had scores were improved, and only 2 were improved by at least 2 grades; of the 12 horses with initial ulcers scores of 0 fed coastal Bermuda, only 3 remained free of ulcers and 7 developed ulcer scores ≥ 2. Among horses fed coastal Bermuda grass during period 1, ulcer scores did not change significantly between the end of period 1 and the end of the wash-out period; however, the ulcer severity scores of horses fed alfalfa during period 1 were significantly ($p<0.007$) higher after the wash-out period ended than at the end of period 1.

Relative to feeding coastal Bermuda grass hay, feeding alfalfa hay reduced ulcer severity scores in horses with gastric ulceration and prevented ulcer development in 11 of 12 (92%) horses fed alfalfa hay that did not have ulcers, whereas only 25% (3/12) of the horses without evidence of ulceration fed coastal Bermuda grass hay did not appear to develop ulcerations. Moreover, horses that were initially fed alfalfa hay had a significant worsening of ulcer severity scores during the wash-out period.

Alfalfa hay provides greater buffering capacity compared to Bermuda grass hay for several reasons. First, alfalfa contains higher levels of protein and calcium, both of which buffer gastric acid. Also, alfalfa fiber has a higher cation exchange capacity compared to graminaceous plants, due largely to its higher content of lignin and other polyphenolics (Van Soest, 1994). McBurney et al. (1983) showed that alfalfa cell wall has a much higher buffering capacity than either timothy or oat cell wall when titrated with HCl acid.

Jasaitis et al. (1987) measured the in vitro buffering capacity of 52 feeds to determine the buffering capacity range within and among feed types. Buffering capacity was lowest for energy feeds, intermediate for low-protein feeds (15 to 35% crude protein) and grass forages, and highest for high-protein feeds (>35% crude protein) and legume forages.

The buffering capacity of feed and forage plays an important role in the prevention of gastric ulcers in horses. Alfalfa hay has been shown to be effective in reducing the severity of ulcers in horses by providing superior buffering capacity compared to grass hay. Unfortunately, high levels of alfalfa hay may not be desirable for performance horses because of the detrimental effects of excess protein intake (Pagan, 1998). More research is needed to identify other feeds and forages that also possess high buffering capacities while containing more desirable nutrient compositions.

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