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Evidence-Based Equine Nutrition

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It is well accepted that horses evolved as grazing animals, with gastrointestinal tracts that are capable of digesting starch, protein, and fat efficiently in the small intestine, also deriving significant nutrition from the fermentation of fiber and other carbohydrates in the cecum and large colon. All vitamin and mineral needs are adequately met with mixtures of forages with the exception of salt, which feral horses obtained from natural salt licks in the wild. Accordingly, most domestic horses that are not subjected to ‘‘unnatural’’ stresses, such as high-level performance or competition, do well on a ration mirroring that of their feral environment, comprised predominantly of free access to good-quality forage, water, and salt.

One of the most difficult problems in equine nutrition research is often the lack of objective and clinically relevant end points. Unlike food animals, in which the only desired nutritional ‘‘benefits’’ can be objectively measured in pounds per day and dollars and cents, the end points in horses often are more subjective and hard to evaluate. For example, it is difficult to quantitate ‘‘better quality coat or hooves’’ or ‘‘more manageable behavior’’ or to assess the relevance of parameters, such as ‘‘time to fatigue’’ and maximum oxygen consumption as measured in treadmill studies, to a real world wherein many other variables come into play in the determination of actual performance.

Nevertheless, this article attempts to present the best evidence (or lack thereof) for some of the most common clinical questions pertaining to such topics as the evaluation of glucose and insulin tolerance and factors that may confound results, dietary management of horses prone to laminitis and rhabdomyolysis, nutritional prevention of gastric ulcers and developmental orthopedic disease (DOD), the efficacy of commonly used herbal products, and feeding geriatric horses.

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The sixth edition of the National Research Council (NRC) *Nutrient Requirements of Horses* contains evidence-based recommendations for some of these clinical topics that were not included in the 1989 edition [1,2]. The exhaustive analyses in the new edition were not available to the author in writing this article, but the recommendations here are based on the same base of literature as well as on some newer studies not available to the 2007 NRC committee members at the time of their deliberations.

Evaluation of glucose and insulin metabolism in horses

There have recently been several in-depth reviews of blood glucose and insulin regulation and evaluation in horses [3–7]. These reviews were stimulated, in part, by a dramatic increase in level 1 and 2 studies that have implicated ‘‘hyperinsulinemia’’ secondary to ‘‘high glycemic index feeds’’ (high nonstructural carbohydrate [NSC] intakes) or abnormal insulin sensitivity to increased risks of laminitis [8–10], DOD [11–14], or rhabdomyolysis [15–18]. Unfortunately, factors that could result in false-‘‘positive’’ or -‘‘negative’’ results are often disregarded in the utilization of the results of these studies, such as exactly what constitutes a high glycemic index feed and consideration of other factors that may affect plasma glucose and insulin concentrations.

Question 1: how do feeds affect blood glucose and insulin concentrations in horses?

Glycemic index

The simple definition of the ‘‘glycemic index’’ of a feed is the plasma glucose response (peak values or area under the curve) to ingestion of a measured amount of that feed compared with a standard reference challenge. In human beings the ‘‘gold standard’’ used is always white bread. In the equine literature, however, the standards have varied. Some researchers have used an equivalent weight of oats [19,20], whereas others have used an oral dose of glucose [21] or the responses of adult horses to standardized amounts of NSCs in the feeds [14]. Insulin responses to the feeds usually have not been considered, but when they have been included, higher glycemic index feeds have usually resulted in higher insulin response curves [14,19,22].

In virtually all studies, regardless of the standards used, the mixtures of corn, oats, and barley combined with molasses (‘‘sweet feeds’’) fed to clinically normal horses cause increases in blood glucose and insulin within as little as 15 minutes of ingestion, with peak values of between 130 and 200 mg/dL at 60 to 90 minutes after feeding, returning to baseline concentrations within 3 to 4 hours after feeding [3,4,14,19–22]. The reported glycemic index of hulled oats and corn is roughly equivalent, but ‘‘naked,’’ or hull-less, oats cause more rapid and higher glucose responses after feeding

[19,20], probably because of the higher digestibility of oat starch in comparison to corn starch [22,23]. Barley has consistently been reported to have the lowest glycemic index of the grains commonly used [19–21]. Peak insulin concentrations in "normal" adult horses to meals composed of a variety of grains and grain mixes have ranged between 20 and 60 microIU/mL [14,22].

Pelleting and extrusion also seem to affect the availability of carbohydrates. The pelleted and extruded concentrates tend to result in lower plasma glucose and insulin responses than do textured feeds with the same basic formulation [3,4,24]. This could be attributable to heat-induced changes in the carbohydrates in the feeds during the pelleting and extrusion process that result in lower digestibility [23,25]. Mixed-concentrate feeds containing restricted amounts of sugars and starch (<12% NSCs) and higher fiber (12%–20% NSCs) and fat (5%–12% NSCs) have significantly reduced postprandial glucose and insulin responses relative to feeds with high starch or sugar content (>30% NSCs) and no added fat [26,27].

Traditionally, the glycemic indices of hays and most forages were assumed to be relatively low, and therefore of no consequence if a horse had access to them before drawing a blood sample to evaluate blood glucose and insulin. Grass hays can contain more than 20% NSCs composed of fructans, starches, and sugars) and can cause significant (>10%) increases in plasma glucose and insulin on ingestion, however [28]. The predominant components of NSCs in grass forages are the water-soluble fructans and sugars, whereas legumes, such as alfalfa and clover, accumulate more of the water-insoluble starches [29,30]. Soluble sugars and starches are rapidly digested and absorbed in the small intestine, causing rapid glycemic responses [3,4]. Fructans, conversely, are not amenable to enzymatic digestion but are rapidly fermentable, potentially contributing to the accumulation of endotoxins and monoamines associated with laminitis [30].

In late fall pastures after freezing overnight temperatures, grasses may accumulate even higher concentrations of NSCs than during their rapid growth in spring [29,31]. Pasture water-soluble content can go from 8% to 17% in the course of a day in certain species of grasses on a warm sunny day in the fall [31]. Sunny warm days, followed by freezing temperatures overnight, result in the highest NSC accumulations [29–31]. It is important to note, however, that despite these large fluctuations, most non–insulin-resistant ponies grazing on even spring and late fall pastures on a regular basis are not adversely affected [32].

Ration adaptation

Horses adapted to high glycemic index (high starch and sugar) concentrate rations have reduced insulin sensitivity and higher insulin responses to carbohydrate challenges relative to horses fed higher fiber (>20%) and fat (5%–7%) rations with low glycemic indices [3,4,7,26,27]. This has led to speculation that feeding horses low glycemic index feeds, with or without added fat, may reduce the incidence of laminitis in insulin-resistant horses

[5–8] as well as the incidence of DOD in susceptible growing horses [3,4,13,14]. Such speculation has yet to be confirmed by clinical trials or controlled studies, however. Interestingly, although horses with polysaccharide storage myopathy have increased insulin sensitivity relative to nonaffected horses [15–17], they also seem to respond to restricted starch intakes, purportedly because of the lower availability of glucose for abnormal glycogen synthesis [16,18].

Feeding supplemental fat has been touted by some as a way to improve insulin sensitivity and reduce hyperinsulinemia [18,33,34]. There is no documentation that supplementing fat to horses alters glucose metabolism, however. To date, most studies investigating fat supplementation have substituted carbohydrate calories with fat; thus, the reported effects on insulin sensitivity [18,26,27] may be a result of the reduction of starch or sugar rather than the fat per se. Nevertheless, it is well documented that high-fat rations ($>7\%$ in the total ration) reduce glucose and glycogen utilization in exercising horses because of higher fat utilization in aerobic efforts [33–35], thereby "sparing" plasma glucose and muscle glycogen for anaerobic efforts. This then results in higher concentrations of glucose and muscle glycogen concentration in fat-supplemented horses during and after standardized exercise tests.

Quality of evidence

The evidence for the relative glycemic index of common grains and sweet feeds is strong, despite disparities in methodology. Unfortunately, at this time, there is no strong evidence for the relative glycemic or insulinemic effects of individual commercial pelleted or extruded products. The long-term effects of feeding high starch or sugar rations versus lower starch and higher fiber and fat have repeatedly been well documented. The effect of supplemental fat alone on glucose and insulin metabolism, and on subsequent plasma glucose and insulin concentrations, needs clarification.

Clinical implications

Feeding "low glycemic index" rations to horses results in lower plasma glucose and insulin responses and increased insulin sensitivity. At this time, a low glycemic index would be a mixed feed with restricted or no molasses, corn or oats, fiber ($>12\%$), and fat ($>5\%$).Clinically normal horses that have adapted to predominantly forage rations differ from those accustomed to consuming large meals of grain-based feeds in their responses to standardized challenges, showing lower and more prolonged responses to a dose of dextrose or meal of grain. If evaluating plasma glucose and insulin concentrations in a clinical case, the relative glycemic index ration to which the horse was adapted needs to be taken into consideration as well as the time since the last meal. Horses that have had access to grass hay or pasture within an hour of sampling also may not have "fasting" or "basal" concentrations of glucose and insulin.

Question 2: what other factors should be taken into account when evaluating glucose and insulin responses?

Exercise

Exercise has been documented to improve insulin sensitivity in obese mature ponies [36] and horses [37]. Mild forced exercise (30 minutes at a walk or trot on a treadmill three times per week) also enhanced insulin sensitivity and glucose clearance in yearling Standardbreds [38].

Obesity

It is well documented that healthy obese horses and ponies tend to be insulin resistant, with abnormally high insulin responses to carbohydrate challenges and high basal insulin concentrations [3,4,27,39]. Weight reduction in obese ponies resulted in significant improvement in insulin sensitivity [36] but was accomplished by increasing exercise in addition to feed restriction. It is not known if only caloric restriction resulting in weight loss would have had the same effect.

Age

Standardbred [11], Thoroughbred [40], and Lippizaner [41] horses 3 to 12 months of age have been reported to have lower insulin sensitivity during standardized glucose challenges than when they are 16 to 24 months of age. Similarly, in a study of Quarter Horse foals [42], one weanling was hyperinsulinemic at 5 to 7 months of age but did not differ from others in its treatment group in subsequent tests. This coincides with the period of highest growth hormone release [42]; it has been shown that exogenously administered somatotropins reduce insulin sensitivity [43,44].

Genetic traits

In a relatively large study of Welsh and Dartmoor ponies ($n = 257$) maintained on pasture [32], there was strong evidence that susceptibility to laminitis was a dominant genetic trait, partially suppressed in male ponies, later proven be associated with compensated insulin resistance [8]. Differences in insulin sensitivity between Standardbred horses and Shetland ponies have also been documented [39].

Diurnal variation and stress

Diurnal or stress-induced elevations in plasma cortisol also reduce insulin sensitivity [4]. This results in higher insulin responses to carbohydrate challenges, although plasma glucose concentration responses may not be altered [3,4,19]. Plasma cortisol has a well-defined diurnal variation, with peak concentrations in the morning hours (7:00–10:00 AM) that gradually decline until 7:00 to 8:00 PM [19,45]. Glucose and insulin responses to a standardized challenge are higher in unstressed horses in the morning than in the early afternoon, but if the horse is stressed by unaccustomed confinement, stressed glucose and insulin concentrations are elevated [3,4].

Quality of evidence

The evidence for obesity, age, and exercise influencing basal and response curves in plasma glucose and insulin is strong. The somewhat weaker evidence for diurnal and stress-induced variations in insulin sensitivity is, however, shored up by strong evidence in the human literature.

Clinical implications

If taking a single or multiple samples of blood to assess glucose and insulin metabolism (see chapter XX for diagnostic protocols), it is important to consider, in addition to feeding history, the age and body condition of the horse. Stressed horses (eg, acute pain) have elevated plasma glucose and insulin concentrations, especially in the morning, that could lead to false conclusions regarding their real insulin sensitivity. Clinically normal horses younger than 1 year of age may have higher fasting plasma glucose and insulin levels than older animals. Therefore "normal ranges" for glucose and insulin established in mature horses should be applied with caution, especially in weanlings and obese animals. To test maximal responses, it is best to run challenges in the morning hours, whereas if an animal is tested in the afternoon, a "within normal range" glucose and insulin response could be misleading.

Feeding insulin-resistant and glucose-intolerant horses

Question 1: what are the best feeds for a horse documented to have insulin resistance or glucose intolerance?

Provision of feeds with restricted starch and sugar content (<12% NSCs) has been well documented to increase insulin sensitivity and glucose tolerance in normal and obese Thoroughbred horses and ponies. That said, the "threshold" for NSCs has not been well established, and efficacy has not been documented in other breeds. Most grass hays would be appropriate as the main component of the ration, but they should be tested for NSC content, especially if the horse has chronic laminitis. If the NSC content of available hays is high (>12%), soaking the hay in warm water for 30 to 60 minutes before feeding leaches out some of the NSCs (and also 30%–50% of the potassium) [10]. High-fat (>7%) and high-fiber concentrate formulas based primarily on beet pulp and barley would be appropriate supplements if additional calories are needed.

The effect of supplementary fat on insulin sensitivity is equivocal. Fat helps to maintain body weight because of its high calorie density but may not be desirable in obese animals for which weight loss is desirable. Because of the high caloric density, if fat is used as a major source of calories in a ration in which the desire is to restrict calories, the amount of feed the horse would be permitted to consume would be drastically reduced. Severe restriction of dry matter intake may predispose the horse to gastric ulceration. Whole grains, especially oats and corn, should be avoided because of their higher glycemic indices.

Feeding young horses

Question 1: what are the critical nutrient concerns in the prevention of developmental orthopedic disease in young horses?

The NRC (1989) recommends that weanlings receive rations containing 70% concentrates to meet their energy, protein, and mineral needs and that yearlings receive 45% to 60% of their total ration in the form of grain-based concentrates, with the rest provided as good-quality forage. No rationale for this recommendation is given, however, and there seems to be no good evidence for it. In a recent survey of feeding practices on 58 Thoroughbred and Quarter Horse breeding farms, it was found that 62% of the farms fed 50% or less of the rations provided to weanlings in the form of grain-based concentrates [46]. Standardbred [38] and draft-cross weanlings and yearlings [47] fed only 40% to 50% of their total caloric intake in the form of grain-based concentrate feeds had growth rates that met or exceeded NRC [2] recommendations. Similarly, draft-cross yearlings fed only 40% of their calories as a concentrate had growth rates that exceeded NRC predictions [47]. As little as 40% of the total caloric intake in the form of concentrates has supported normal to high growth rates in Belgian/Quarter Horse-cross weanlings fed hays of varying quality and nutrient content (S.L. Ralston, unpublished data, 1999–2006). This translates to approximately 0.75% to 1.0% of the foal or weanling body weight per day divided into two or three feedings. Similarly, growth rates and bone densities of Thoroughbred and Quarter Horse weanlings fed a high-fat concentrate at only 50% of the total ration with free access to grass hay did not differ from those offered 65% of their recommended intake in the form of a high-starch ration [48].

In a large study (42 light horse weanlings) in Canada, there were no differences in growth or development between those fed 73% to 77% alfalfa and those fed 63% to 65% grain or grain byproduct concentrates [2,49]. Based on this evidence, it seems that the NRC [1] recommendations for the proportion of concentrates in weanling and yearling rations are excessive.

Feeding high amounts of high starch or sugar (also called "high-energy" feeds in some of the older studies or high glycemic index in more recent reports) concentrates to young horses has now been documented not only to cause insulin resistance [40] but to affect bone mineral content adversely [13]. Feeding high amounts of these feeds was also correlated with a higher incidence of osteochondrosis dissecans (OCD) requiring surgical correction in Thoroughbred yearlings [14]. Rations providing more than 130% of the NRC's recommended amounts of energy for rapid growth in foals cause an increased incidence of DOD, especially if the ration has only 100% or less of the calcium and phosphorus recommended for growth [50–52]. Based on extensive research at several institutions (Virginia Polytech Institute, Rutgers University, and Kentucky Equine Research), it seems that using higher fiber (> 12%) and fat (7%–10%) rations that have relatively low glycemic indices for young horses [14] would be preferable to feeding large quantities of high starch or sugar grain based on such indices as growth responses, bone mineral content, and insulin sensitivity.

Protein content of feeds, if in excess of NRC [2] requirements, has no real impact on DOD if mineral requirements are balanced and met [52–54]. Restricting energy and protein intakes to amounts that result in less than 80% of NRC-predicted average daily gain [2] for 4 months, followed by ad libitum access to balanced rations, resulted in four of six Standardbred weanlings developing flexural deformities, however. This outcome was presumably attributable to the rapid compensatory growth rates the animals experienced; similar results were obtained in a parallel experiment in Thoroughbred weanlings [54]. When Arabian foals from a single breeding farm were restricted to 9% protein feeds that resulted in severe stunting for 140 days and were then offered 20% protein rations, similar compensatory growth rates were seen, but no DOD was observed [55].

Mineral imbalances have been well documented to cause DOD. There seems to be a fairly large range of intakes tolerated, however. In addition, factors like growth rates and mineral interactions should be taken into account. Deficiencies of calcium (intakes greater than 15% less than the 1989 NRC-recommended amounts) or phosphorus intakes in excess of calcium (calcium/phosphorus ratio < 1.0) have reliably resulted in defective bone maturation in controlled studies in growing horses [2]. In controlled studies [2,53], however, calcium intakes in gross excess of the NRC recommendations (> 1.0% and as high as 2.0%) did not result in an increased incidence of growth abnormalities, however. Similarly "marginally low" phosphorus intake in weanlings (0.24%–0.35% versus the 0.45% recommended in growth rations) did not result in an increase in growth abnormalities in light horse weanlings [56]. Therefore, it can be safely concluded that, to date, "optimal" intakes of calcium and phosphorus have not been well established.

Dry matter intakes of zinc in excess of 1000 mg/kg of body weight have resulted in DOD lesions; however, intakes up to 700 mg/kg failed to create problems [2]. Although the effects of zinc deficiency alone were documented in foals fed only 5 mg/kg [2], minimum requirements are not well defined. Mare's milk, for example, provides zinc at a rate of only 17 to 30 mg/kg DM intake [2], and based on the relatively low incidence of DOD in suckling foals less than 3 months of age (before they start to consume significant amounts of dry feed), this would seem to be in an adequate range. In the author's experience based on nutritional consultations on breeding farms in the northeast region of the United States, total ration dry matter zinc concentrations of 30 to 35 mg/kg are not associated with DOD if the other mineral concentrations in the rations are at or greater than recommended concentrations. The NRC [2] recommendation for growth of dry matter intake of zinc at a rate of 40 mg/kg of body weight is based on limited studies. The minimum required intake of magnesium, another mineral of importance for bone growth, has not been determined.

Quality of evidence

The evidence that severe deficits or excesses of calcium, phosphorus, copper, and zinc can adversely affect growth and development in young horses is strong. The evidence for precise minimum and maximum concentrations in rations, or even optimal intakes, for virtually all the minerals that are well documented to be of importance to growing animals in other species is weak or nonexistent in horses.

Clinical significance

Based on the best evidence available, to avoid compensatory accelerated growth rates that may be associated with an increased incidence of DOD at weaning [56], nursing foals should be introduced to mineral-fortified concentrates when they are 1 to 2 months of age. The concentrates offered should contain 14% to 18% protein. A higher percentage of protein (16%–18%) should be used if only grass hay is available because of its lower protein content (6%–12% on average [2]) relative to mixed pastures and legume or legume mix hays (usually $>14\%$ protein dry matter). Weanlings fed rations deficient in protein (less than 12% in total ration dry matter) have reduced growth rates and poor bone mineralization; if they are suddenly placed on adequate rations, they may experience compensatory growth and DOD. Total ration protein intakes of 14% or higher support good growth and development in weanlings of any breed tested to date. Restricting total ration protein to less than 14% in a rapidly growing foal's ration does not result in improved bone growth and may actually be detrimental.

Concentrates should be fed at the rate of 0.25% to 1.0% of body weight, with the emphasis on maintaining lean body condition (ribs not visible but can be felt with mild pressure over the flank; loin, croup, and neck have smooth outlines without creases or visible bony structures). If low amounts of concentrates are fed (less than 0.5% body weight), the addition of a balanced calcium, phosphorus, and trace mineral supplement may be necessary to maintain proper mineral intake. Because pelleted and extruded feeds cause lower glucose and insulin responses than do sweet feeds (see section on evaluation of glucose and insulin metabolism), the former two types of concentrate would be preferable to textured sweet feed mixes, especially in foals from bloodlines or breeds predisposed to DOD.

Ideally, foals should be fed regulated amounts of concentrates that are inaccessible to their dams or other foals at least once, and preferably twice, a day. The dams should be fed the same concentrate if the foal has access to the mare's feed to prevent ingestion of inappropriately balanced concentrates by the growing horse.

Recommendations for mineral content of rations for foals less than 1 year of age cannot be for precise amounts because of the lack of strong evidence for exact requirements and difficulty in achieving a precise "balance" of minerals when formulating rations. Acceptable ranges of total ration mineral intake that, based on the best evidence, support good-quality bone development and growth are more practical and realistic as targets for formulation. These ranges are presented in Table 1.

The total ration intake of the major minerals includes all sources: available forages, concentrates, and other supplements. Weanlings should be fed the same type of concentrate as when they were nursing, and at the same rate as discussed previously, and monitored carefully for signs of excessive weight gain or loss and DOD. Between 0.25% and 1.0% body weight of concentrates used before weaning, divided into two or three meals a day, with free-choice access to good-quality mixed legume or grass hay or pasture, maintains optimal growth rates of most light horse breeds and reduces the risk of DOD. The goal is to maintain steady growth, avoiding sudden increases or decreases, and to maintain body condition. Plain white or trace mineral salt and a good clean source of water should be available free choice at all times.

Based on strong data (S. L. Ralston, unpublished data, 1999–2006) [2], weanling horses voluntarily ingest a maximum of 2.0% to 3.5% of their body weight in dry matter per day. Yearlings can consume 2.0% to 3.0% of their body weight in dry matter per day (S. L. Ralston, unpublished data, 1999–2006) [2]. The recommendations for protein and mineral intakes are based on the assumption that the animals are consuming an average of 2.5% of their body weight per day. Therefore, if intakes are restricted to less than 2.5% of body weight because of high energy density of feeds or other factors, the protein and mineral content of the ration should be increased

Table 1
Recommended nutrient concentrations minerals in total rations fed to rapidly growing young horses

	Range
Calcium	0.8%–1.5%
Phosphorus	0.4%–0.6%[a]
Copper	Feed, 10–20 mg/kg
Zinc	Feed, 40–60 mg/kg[a]

Other minerals, such as manganese, magnesium, selenium, and iron, are important, but there are no reliable data available on requirements of young horses for these nutrients. Also see references in the discussion section.

[a] Minimum amounts, based on type 2 and 3 evidence, may be lower.

Data from National Research Council. Nutrient requirements of horses. 5th edition. Washington (DC): National Academies Press; 1989.

proportionately to provide adequate amounts of the nutrients. Similarly, if trying to determine adequate nutrient concentrations in concentrates to be fed with free access to forage, it is safe to assume that the young horses would consume 2.5% of their body weight minus the amount of concentrate to be fed in the form of the forage per day.

Nutritional prevention of gastric ulcers

Question 1: what is the best feeding regimen to prevent gastric ulceration?

It has been well established that strenuous exercise or training results in gastric ulceration [57] and that intermittent feed deprivation (24 hours of fasting) and confinement also increase the rate and severity of lesions [58]. Even horses fed free-choice grass hay have a greater incidence of gastric ulcers when confined to stalls than when they are maintained on pasture [58].

The role that diet plays in the prevention and treatment of ulcers has only recently been explored [59–61]. In a controlled crossover design study, feeding horses orchard grass hay at a rate of 1.9% of their body weight resulted in more gastric lesions than when the horses were fed 1.9% of their body weight as a mixture of 14% protein sweet feed and alfalfa hay (40%–45% total weight fed as sweet feed divided into two feedings) [59]. Stomach pH and volatile fatty acid production were measured for 24 hours after the morning feeding on test days. The horses fed alfalfa and grain had higher gastric pH but also higher volatile fatty acid production for up to 4 hours after feeding than when adapted to only grass hay. It was hypothesized that the higher calcium and protein content of the alfalfa hay buffered the gastric contents and may have served as a protectant against the adverse effects of the volatile fatty acids generated from fermentation of the grain portion of the ration. Valeric acid, which is produced in greatest quantities during gastric fermentation of carbohydrates (V. Julliand, personal communication, 2006) [59], has been shown to be especially detrimental to gastric mucosal tissues and may be a significant cause of ulceration in horses fed large meals of grains [61]. In controlled studies, feeding corn oil or rice bran oil was not protective against ulceration induced by confinement and exercise [6].

Quality of evidence

It is well documented that feed restriction and strenuous exercise can induce gastric ulceration. Gastric ulcers do not always cause gastric pain [62], however, and the clinical significance of the extremely high rates of ulceration documented in field studies (80%–100% of competitive performance horses) is questionable. The efficacy of feeding regimens, other than the benefits of feeding alfalfa and maximizing pasture access in the prevention of gastric ulceration, has yet to be adequately documented. The correlation between feeding large meals of grain and ulceration is strong but needs to be fully verified in carefully controlled studies.

Clinical significance

Provision of free access to good-quality pasture and offering alfalfa or other high-calcium or high-protein forages may help to prevent gastric ulceration. Sweet feeds (high carbohydrate and high volatile fatty acid production in the stomach if greater than 1 to 2 kg is fed per meal; V. Julliand, personal communication, 2006) should be avoided in horses that are at risk of ulceration (horses subjected to such conditions as high-level performance, confinement to stalls without pasture access, and limited hay). Prolonged fasts (>12 hours) should be avoided if at all possible.

Herbal supplements in horses

Question 1: is there evidence that any of the herbs or nutraceutic agents commonly used in feed supplements are clinically effective?

A 1997 survey of US horse owners found that 70% of horse operations fed at least one nutritional supplement and that nearly 5% fed herbal or nutraceutic supplements [63]. Since then, sales in the herbal market targeting horses have grown exponentially, as evidenced by the number of such products on the market. Most supplements are mixtures of various herbs and "natural" ingredients, with claims ranging from calming effects to immune stimulation. There have been few well-controlled crossover studies testing efficacy of these products. Only herbs and natural ingredients that have at least one controlled study specifically targeting horses and efficacy of claims are discussed.

Bee pollen and propolis

Bee pollen and propolis are resinous substances collected from plants by honey bees and harvested from the hives by the supplement manufacturers. The anecdotal benefits of supplemented bee pollen in horses include improved oxygen utilization, lower heart rate, increased appetite, and firmer muscle tone.

The only controlled study [64] (10 Arabians in endurance training: 5 supplemented and 5 controls) using a "bee pollen" supplement actually tested a product that contained, in addition to bee pollen (37.3 g) and propolis (75 mg), glucosamine hydrogen chloride (HCl), vitamins E and A, five different enzymes and 11 other herbs per 118-g dose. Therefore, the results cannot be attributable solely to the bee pollen or propolis. After supplementation for 18 to 21 days, hay intake and apparent digestion and retention of phosphorus nitrogen, as measured in a 3-day total fecal collection digestion trial, were significantly increased in 3 supplemented horses relative to the 3 pair-matched controls that had been receiving only a placebo. After 42 days of supplementation, physical fitness (based on standardized exercise tests on a treadmill) and immunologic status (leukocyte counts and plasma IgG, IgM, or IgA) did not differ between supplemented horses (n = 5) relative to controls (n = 5), however.

Echinacea

Echinacea (*Echinacea sp*) is commonly touted to have anti-inflammatory and antioxidant properties [65]. Eight horses that were given echinacea for 42 days at a level equivalent to standardized extract at a dose of 1000 mg [65] showed increases in lymphocyte count and decreases in neutrophil count at only day 35 of the 42-day supplementation period, however, and no effect on neutrophil phagocytosis, which does not support the conclusion that there was significant immune stimulation.

Flaxseed

Flaxseed (*Linum usitatissimum*) contains high levels of ω-3 fatty acids and is often reported to enhance a horse's hair coat and hoof quality. In horses, this supplement is marketed for its high ω-3 fatty acid content and is used in coat, skin, and hoof conditioners.

One clinical study tested flaxseed as a treatment for allergic skin diseases in horses and found a significant reduction in the skin test response to *Culicoides*, or "sweet itch," as compared to placebo-treated horses [66]. To the author's knowledge, there have been no other controlled tests of flaxseed in any form on any of the parameters it is advertised to benefit in horses.

Flaxseed is commonly boiled or otherwise processed before feeding to break down the lignified outer layer and to remove cyanogenic compounds [67]. That said, there have been no documented cases of cyanide toxicosis attributed to feeding raw unprocessed flaxseed.

Garlic

Garlic (*Allium sativum*) is purported to have antibacterial, antiviral, antifungal, and antiparasitic properties. Thiosulfinate allicin is supposedly the most active component [68]. There have been no controlled trials demonstrating the efficacy of garlic supplements to repel flies or prevent infections. Toxicity, however, is a possibility. Freeze-dried garlic fed at a rate of greater than 0.4 g/kg of body weight per day resulted in Heinz body anemia in the two horses receiving the supplement [69].

Ginger

Ginger (*Zingiber officinale*) is thought to have antithrombotic, antioxidant, anti-inflammatory, and antibacterial properties. A limited study in horses tested a single oral dose of ginger on anti-inflammatory and cardiovascular responses after exercise [70]. In an uncontrolled study, six horses were administered ginger extract by means of a nasogastric tube 1 hour before exercise and then run on a high-speed treadmill to fatigue. Treated horses had a reduced oxygen consumption per unit time (V_{O_2}) recovery time relative to their performance on the treadmill 1 to 2 weeks before supplementation. Conversely, ginger had a tendency ($P < 0.1$) to increase proinflammatory cytokines tumor necrosis factor (TNF)-α and interferon (IFN)-γ in the blood of supplemented horses. It was speculated that the ginger extract solution irritated the gastrointestinal tract after ingestion, which could be confounded by the increased creatine kinase levels seen after administration as well [70].

Ginseng

Ginseng (*Panax sp*) is commonly used for its reported immunostimulant properties. Ginseng is marketed and sold for use in horses to stimulate the immune system, decrease indices of stress, and increase performance. No controlled research supporting these claims was found in horses, however.

Valerian

Valerian (*Valeriana sp*) is purported to have tranquilizing and sedative properties. No controlled studies have been done in horses to date, but many "calming aids" or "stress relief" supplements include valerian as one of the major active ingredients. The International Federation for Equestrian Sports (FEI) bans this product from use during competition. The basis for the ban, however, is unsubstantiated by clinical trials.

Quality of clinical evidence

Virtually no good evidence exists for significant beneficial effects of supplementation of the various herbal or natural products being marketed. Extensive reviews on the toxicology of herbs in equine medicine reveal that most of the type 1 and 2 evidence is for adverse effects of oversupplementation [71,72].

Clinical significance

Despite manufacturer claims and anecdotal reports of efficacy, to the author's knowledge, none of the herbal supplements have been proven safe or effective for use in horses in well-controlled trials that showed clear benefits. Supplementation with these products cannot be viewed as an evidence-based practice.

Feeding geriatric horses

Question 1: how and when should the ration of an aged horse be changed to meet "geriatric" needs?

Despite controlled studies conducted in the 1980s that showed a reduction in phosphorus, protein, and fiber digestion and lower plasma ascorbic acid in horses older than 20 years of age relative to younger horses fed the same rations [73], horses older than 20 years of age do not necessarily have altered nutritional needs [74,75]. If a horse older than 20 years of age is in good body condition and overall health, no benefits have been found to switching it to a more digestible "senior" feed formulated with higher protein and phosphorus [74]. Horses older than 20 years of age that were unable to maintain Henneke [76] body condition scores greater than 3 on standard hay and grain rations despite good dental care and overall health did gain weight and condition when fed a feed that had increased digestibility and higher quality protein [74].

If old horses start to lose weight, their feed should certainly be evaluated; however, other causes of weight loss need to be ruled out, such as irreparable dental abnormalities (eg, tooth loss); pituitary, renal, or hepatic dysfunction; chronic pain associated with arthritic changes; chronic infections; or neoplasia. Altered nutrition alone may or may not correct all these problems. Although not supported by evidence gained from clinical trials, it is the author's impression that some of the "older horse" feeds on the market may actually be detrimental to horses that have advanced hepatic or pituitary dysfunction.

Reduced digestion of fiber, protein, and phosphorus was reported in horses older than 20 years of age in the 1980s [73]. Based on other studies by the investigators [77,78], it is now hypothesized that chronic parasitic scarring of the large intestine may have been responsible for some of the apparent malabsorption or maldigestion observed in these horses. The digestive alterations observed were virtually identical to those reported for horses after extensive large colon resection, in which the same protocols were utilized to evaluate nutrient digestion as were used in the aged horse studies [77,78], and the aged horses included in the study in the 1980s had not had the lifelong benefit of modern intestinal parasite control [75]. Similar deficits were not found in aged Standardbred horses studied in the 1990s that had had good gastrointestinal parasite control all their lives [75]. The reduction in fiber digestion observed in the original study may also have been attributable to abnormal dentition, although it has been documented that points and hooks less than 3 mm in size do not adversely affect digestion [79] and definitive studies of the effects of gross abnormalities on digestion have not been performed.

The standard indices for renal and hepatic function can be applied to the geriatric horse [80,81]. Further information about indices for pituitary dysfunction can be found in the article on evidence-based endocrinology elsewhere in this issue.

Strength of evidence

The controlled data available on nutritional requirements of old horses are limited and somewhat contradictory, even though conducted by the same researchers.

Clinical significance

Because digestive alterations have not been documented to be present in all older horses and it has been documented that old horses in good body condition do not benefit from dietary change, there is no reason to change a horse's ration on the basis of age alone. Before instituting dietary changes, blood should be drawn for complete blood chemistry to rule out medical causes of weight loss, such as chronic infection, neoplasia, renal dysfunction, or hepatic failure.

If no other medical abnormalities are found, failing older horses may benefit from feeds formulated specifically for geriatric horses. Most major feed companies now offer feeds designed "specifically" for old horses that contain 12% to 16% protein, restricted calcium ($<$1.0%), and increased phosphorus (0.45%–0.6%), based on the original study in the 1980s. These feeds are "predigested" or extruded, purportedly to increase digestibility by reduction in particle size and heat effects [22,23]. These senior feeds are usually not "high calorie," because most are "complete" feeds designed to be fed at the rate of 1.0% to 2.0% of body weight and as the sole source of nutrition, and are therefore formulated to provide only approximately 9.2 MJ/kg.

Senior feeds are not a panacea for aged horses, and it may be best to avoid them under certain circumstances. For example, if the horse has insulin resistance or pituitary dysfunction, a product that has little or no added molasses should be selected so as to restrict intake of NSCs. If the horse cannot maintain good body condition on 1.0% to 2.0% of body weight of the feed divided into three or four feedings, it may be necessary to supplement with products with a higher caloric density, or a high-calorie supplement, such as edible oils or rice bran products.

Calcium intakes in excess of need result in high urinary calcium excretion in horses (S. L. Ralston, unpublished data, 1999–2006). In the author's experience, there is a high incidence of renal and bladder calculi in old horses fed straight alfalfa. Therefore, alfalfa or other high-calcium feeds should be used with caution in failing older horses.

Aged horses with pituitary adenomas were documented to have lower plasma ascorbic acid than did younger healthy horses [80]. Vitamin C supplementation (0.02 g/kg of body weight given twice a day) has been observed to increase antibody response to vaccines in aged horses with pituitary dysfunction (S. L. Ralston, unpublished data, 1999–2006) and may be tried if chronic infections are a problem, although efficacy has not been proven.

Summary

From an evidence-based perspective, there have been many level 1 and 2 studies published on a wide variety of topics in equine nutrition. The numbers of animals used in controlled studies are usually fairly small ($<$10 per treatment group), however, and relevant details needed for critical interpretation of the data are often inadequately described or lacking, especially in some of the older reports that are frequently cited as "evidence" for a nutritional recommendation. In field studies involving larger numbers of animals, there are even more confounding factors (eg, season of data collection and details of locally available feeds, climatic conditions, and management) that are often missing. Furthermore, the results from many of the studies are overinterpreted by veterinarians and the public. Accordingly, veterinarians should pay attention to the quality of available evidence when making nutritional recommendations for horses.

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