CARBOHYDRATES ARE WELL TOLERATED BY MOST HORSES

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The old horse feeding slogan "hay, oats and water" harkens back to a simpler time when horses performed free of feed supplements, drugs and anabolic steroids. It also is a reminder that traditionally cereal grains have been staple feeds for horses. For generations, work horses, racehorses and show horses have been fueled by rations composed mainly of forage and grains. Cereal grains are high in non-structural carbohydrates (NSC). NSC include starch and water-soluble sugars that can be enzymatically digested and absorbed as glucose in the small intestine.

Recently, the use of cereals as a major component of horse feed has been questioned by a small but vocal group of zealots who have used the Internet to effectively voice their opinions. Their concern is based on the somewhat flawed premise that feeding even moderate quantities of NSC will lead to behavior or metabolic disturbances and disease in clinically normal horses. Nonetheless, this has led many feed manufacturers to drastically alter their horse feed formulations to cater to the "low-carb" craze. If horses need a low starch feed, hay is a readily available alternative!

Of course, there are legitimate concerns about feeding excessive NSC to horses. Feeding too much starch in a single meal can overwhelm the small intestine's digestive capacity, resulting in large quantities of starch escaping to the large intestine, where it is rapidly fermented to volatile fatty acids (VFAs) and lactic acid. Changes in the pH of the hindgut due to alterations in the microbial populations and acid profiles may result in hindgut acidosis (HGA). Horses suffering from HGA may develop loose manure, anorexia, behaviour changes, colic or display stereotypical behaviors such as wood chewing and stall weaving. HGA is one of the predisposing factors in laminitis. Furthermore, long-term exposure to pH levels below 5.8 will begin to have deleterious effects on the epithelial lining of the colonic and caecal walls that may affect absorptive capacity. HGA can also result from rapid consumption of grains containing poorly digested starch eg unprocessed wheat, corn or barley or from pastures with high fructan levels. Temperate grasses often have high levels of fructans which are resistant to digestion in the small intestine.

With good feeding management, carbohydrates in grains are well tolerated by most horses. There is, however, a small but important population of horses that do not tolerate carbohydrates well. Knowing how much carbohydrate should be included in a particular horse's daily ration is key to successful feeding.

First some background on carbohydrates in horse feeds. The carbohydrates in equine feeds can be categorised by either their function in the plant or from the way they are digested and utilised by the horse. From a plant perspective, carbohydrates fall into three categories: (1) simple sugars active in plant intermediary metabolism; (2) storage compounds such as sucrose, starch, and fructans; and (3) structural carbohydrates such as pectin, cellulose, and hemicellulose. For the horse, it is more appropriate to classify carbohydrates by where and how quickly they are digested and absorbed. Carbohydrates can either be digested and/or absorbed as monosaccharides (primarily glucose and fructose) in the small intestine, or they can be fermented in the large intestine to produce volatile fatty acids (VFA) or lactic acid. The rate of fermentation and types of end products produced are quite variable and can have significant effects on the health and well-being of the horse.

A physiologically relevant system to categorise carbohydrates in equine diets would be composed of three groups. (1) A hydrolysable group (CHO-H) measured by direct analysis that yields sugars (mainly glucose) for metabolism. This includes simple sugars, sucrose, and some starches that are readily digested in the small intestine and produce fluctuations in blood glucose after feeding. (2) A rapidly fermentable group (CHO-FR) that yields primarily lactate and propionate. This group includes starches that escape digestion in the small intestine as well as galactans, fructans, gums, mucilages, and pectin. (3) A slowly fermentable group (CHO-FS) that yields mostly acetate and butyrate. This group includes the compounds captured in neutral detergent fibre (NDF) such as cellulose, hemicellulose, and lignocellulose. Hydrolysable carbohydrates (CHO-H) are an important component of equine diets, particularly for the performance horse, where blood glucose serves as a major substrate for muscle glycogen synthesis. Too much blood glucose, however, may contribute to or

aggravate certain problems in horses such as equine Cushing's disease (ECD), equine metabolic syndrome (EMS), some developmental orthopedic diseases (DOD), recurrent equine rhabdomyolysis (RER), and polysaccharide storage myopathy (PSSM). It may also adversely affect behavior in certain individuals.

The quantity of blood glucose produced in response to a meal is a useful measure of a feed's CHO-H content. Table 1 contains the glycemic index of several equine feeds measured at Kentucky Equine Research (KER). Glycemic index characterises the rate of carbohydrate absorption after a meal and is defined as the area under the glucose response curve after consumption of a measured amount of a test feed divided by the area under the curve after consumption of a reference meal, in this case oats. Rapidly fermentable carbohydrates (CHO-FR) such as pectin can yield propionate, which is an important gluconeogenic substrate for the horse. However, rapid fermentation can also produce lactic acid, which may lead to a cascade of events culminating in laminitis. Undigested starch from cereals and fructans from pasture are the most likely compounds contributing to lactic acidosis in the hindgut. Slowly fermentable carbohydrates (CHO-FS) from the plant cell wall are absolutely essential to maintain a healthy microbial environment in the horse. These carbohydrates alone, however, may not be able to supply enough energy to fuel a high-performance athlete. Carbohydrates in horse feeds have traditionally been estimated by measuring cell wall components as NDF and calculating the remaining carbohydrate by difference as non fibre carbohydrate (NFC), where NFC = 100 - water - protein - fat - ash - NDF. More recently, laboratories have provided a direct analysis of additional carbohydrates in equine feeds.

Table 1. Glycemic index (GI) of equine feeds and forages.

Feed	Glycemic Index
Sweet feed	129
Whole oats	100
Equine Senior®	100
Beet pulp + molasses	94
Cracked corn	90
Re-Leve®	81
Beet pulp (unrinsed)	72
Orchard grass hay	49
Rice bran	47
Ryegrass hay	47
Alfalfa hay	46
IR Pellet & Orchard grass hay	34
Rinsed beet pulp	34
Bluestem hay	23

Table 2 contains the chemical composition of several common equine feedstuffs as analysed by Equi-Analytical Laboratories in Ithaca, NY. In addition to NDF and the calculated values of NFC, Table 2 contains measured levels of water-soluble sugars (WSC) and starch. The sum of WSC and starch is considered the nonstructural carbohydrate (NSC). WSC in cereal grains and by-products such as beet pulp are composed of simple sugars that produce a pronounced glycemic response and fit into the CHO-H category. By contrast, much of the WSC in temperate grasses are actually fructans, which should be included in the CHO-FR fraction. Therefore, they would have little effect on glycemic response but may contribute to the development of hindgut acidosis and laminitis.

Table 2. Carbohydrate content of some common equine feeds.

	Oats	Corn	Beet pulp	Soy hulls	Legume hay	Grass hay
WSC (%)	3.9	3.5	10.6	3.6	9.0	10.7
Starch (%)	44.3	70.5	1.3	1.7	2.4	2.8
NSC (%)	50.7	73.1	12.1	5.3	11.4	13.3
NFC (%)	50.9	76.4	44.4	19.8	30.8	19.5
NDF (%)	27.9	9.8	41.9	61.7	38.5	63.8

Starch is the predominant carbohydrate fraction in cereal grains. Although all starch is made up of glucose chains, how the starch molecule is constructed varies in different types of grain. These differences in the architecture of individual starches have a large impact on how well they are digested in the horse's small intestine. Of the grains most commonly fed to horses, oats contain the most digestible form of starch, followed by sorghum, corn, and barley. Processing can have a huge effect on precaecal digestibility, particularly in barley, sorghum and corn. In a KER study, steam flaking corn caused a 48% increase in glycemic response compared to coarse cracking. NSC is a mixture of CHO-H and CHO-FR fractions. NSC tends to be higher in CHO-H in processed cereal grains and mixes but may be high in CHO-FR in certain unprocessed cereals or high-fructan forages. NFC represents an even more mixed group of carbohydrates because in addition to the compounds found in NSC, they may also contain significant quantities of pectin and other fermentable compounds not captured in NDF. For instance, beet pulp contains only 12.1% NSC but 44.4% NFC. At present, there is no satisfactory, commercially available analytical method to segment carbohydrates into categories that are physiologically meaningful for the horse.

Performance horses depend on NSC as a major source of dietary energy. Digestion of NSC results in increases in blood glucose. Under the influence of insulin, blood glucose is taken up by the liver, muscle and adipose tissue, and stored as liver glycogen, muscle glycogen or fat. These substrates are later used as fuels for muscle contraction during exercise. Kentucky Equine Research (KER) has evaluated the rations of hundreds of sport horses and racehorses competing successfully at the highest level. The vast majority of these horses consume feeds that contain 30-40% NSC, which supplies 35-50% of the concentrate's digestible energy (DE) content. This is lower than the 44-65% NSC found in straight cereal grain diets since modern performance feeds also derive a significant quantity of DE from fat and fermentable fibre. A typical high-performance ration (forage + concentrate) contains 18-22% NSC, which provides 28-32% of the ration's total DE.

At the other end of the equine spectrum are horses that cannot tolerate even moderate amounts of NSC in their rations. These metabolic disorders may becoming more widely recognized but still only represent a small part of the equine population. Many of these disorders such as ECD, EMS, OCD, RER and PSSM can be managed nutritionally by careful regulation of caloric intake with particular attention paid to the source of energy provided. Although these disorders have very different aetiologies, they are all either triggered or aggravated by excessive starch and sugar intake.

The most prevalent of these disorders is EMS, which results in insulin resistance (IR) and an increased risk of laminitis. Horses and ponies with EMS tend to be obese with cresty necks. These animals often have had prior bouts of laminitis and are easy keepers. Management strategies to reduce the incidence and severity of EMS include exercise, weight loss and a ration that contains no more than 10% NSC.

In between the extremes of the elite equine athlete and the obese, laminitic pony lies the majority of horses in the population. These horses are clinically normal, and while many may be older and sedentary, they have not displayed any signs of EMS. Will a carbohydrate-rich ration make these horses insulin resistant and thus more susceptible to EMS as suggested by the "low-carb" zealots? Are high-fat, low-carbohydrate diets more suitable?

To answer these questions KER recently conducted a study with aged Thoroughbred geldings (21.5 yr ± 3.32 yr; BCS 5.0-6.0) to determine whether an oat-based ration (20% NSC, 31% DE from NSC) or a high-fat ration (12.7% fat, 30% DE from fat) would affect glucose tolerance as compared to an all grass-hay diet (9.4% NSC, 17% DE from NSC). Glucose tolerance was measured using an intravenous glucose tolerance test (IVGTT). In this test, a solution of glucose is infused into the horse and blood samples are taken over a 6-hour period. The amount of time it takes for blood glucose to return to normal indicates how well the horse's liver, muscle and fat cells are able to take up and utilize glucose. Horses with impaired glucose tolerance take longer for blood glucose to return to baseline. Each dietary period of the Latin square design study lasted 28 days. During the IVGTT it took significantly less time (126.6 ± 25.8 min.) for blood glucose to return to baseline in the oat-fed horses compared to either the all-hay (198.4 ± 40 min.) or the high-fat-fed horses (216.7 ± 23.5 min.). These results suggest that feeding normal, non-obese horses a ration with a significant quantity of its calories coming from NSC isn't detrimental and may even improve glucose tolerance.

For obese horses, the level of energy intake is more important than the source of calories. Obesity and lack of exercise are the two predisposing factors for IR and EMS. The main goal of feeding an obese horse is to reduce its caloric intake below its caloric requirement so that it will burn body fat and lose weight. Concentrates containing higher fibre and lower fat and NSC are less calorically dense and can be used to deliver fewer calories without drastically reducing feed intake. Feeding hay and a low-intake balancer pellet is also a good alternative for obese horses. As a management tool for obesity, increasing exercise is just as important as lowering caloric intake since exercise increases caloric expenditure and has been shown to improve insulin sensitivity, even in overweight horses.

In conclusion, horses with specific metabolic issues certainly benefit from low (<10%) NSC diets, but these types of "super low-carb" diets are not necessary for normal sedentary or exercised horses. Concentrates that contain 20-30% NSC and that produce a lower glycemic response than higher NSC performance feeds may be useful for sedentary and lightly exercised horses and for horses that tend to become more excitable on higher glycemic feeds. Heavily exercised performance horses need more NSC in their diets, and cereal grains and grain by-products remain important and cost-effective sources. Inadequate starch and sugar intake in hard working horses fed diets with most energy coming from fat and fibre may lead to delayed replenishment of muscle glycogen stores and slow recovery from competition or training. To paraphrase Mark Twain, "The news of grain's demise in horse feed has been greatly exaggerated."