Nutritional Management of Equine Metabolic Disorders

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There are a number of metabolic disorders that are common in modern breeds of horses. Many of these disorders including equine Cushing's disease (ECD), equine metabolic syndrome (EMS), osteochondrosis (OCD), recurrent equine rhabdomyolysis (RER) and polysaccharide storage myopathy (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. As in humans, excess consumption of calories from carbohydrates is one the major problems in today's equine population. This paper will review the role various carbohydrates play in equine disease and describe feeding programs for managing affected horses.

CARBOHYDRATES IN HORSE FEED

The carbohydrates in equine feeds can be categorized by either their function in the plant or from the way they are digested and utilized 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 hemicellu¬lose. 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 (pri¬marily glucose and fructose) in the small intestine, or they can be fermented in the large intestine to produce volatile fatty acids 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.

Carbohydrates in horse feed can be divided into three categories: (1) A hydrolysable group (CHO-H) including simple sugars, sucrose and some starches that are readily digested in the small intestine and produce increases in blood glucose post-feeding. (2) A rapidly fermentable group (CHO-FR) that yields primarily lactate and the volatile fatty acid (VFA) propionate. This group includes starches that escape digestion in the small intestine as well as galactans, fructans, gums, mucilages and pectins. (3) A slowly fermentable group (CHO-FS) that yields mostly VFA acetate and butyrate. This group includes the compounds captured in neutral detergent fibre (NDF) such as cellulose, hemicellulose and lignocellulose.

Hydrolyzable 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 RER, PSSM, ECD, and developmental orthopedic disease (DOD). It may also adversely affect behavior in certain individuals. 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.

The quantity of blood glucose produced in response to a meal is a useful measure of a feeds CHO-H content. Table 1 contains the glycemic index (GI) of several equine feeds measured at Kentucky Equine Research. GI characterizes the rate of carbohydrate absorbtion after a meal and is defined as the area under the glucose response curve after feeding a measured amount of a test feed. Oats are used as a reference feed.

Table 1: Glycemic Index of equine feeds and forages

Feed	Glycemic Index
Steam Flaked Corn	144
Sweet Feed	129
0ats	100
Beet Pulp & molasses	94
Cracked Corn	90
KERx Re-Leve	81
Beet Pulp	72
Stabilised rice bran (KER Equi-Jewel)	47
Grass hay	47
Lucerne hay	46
Rinsed beet pulp	34

Table 2: Carbohydrate content (DM Basis) of some common equine feeds from feed library of Equi-Analytical Laboratories, Ithaca, NY, USA

	Oats	Corn	Beet pulp	Soy hulls	Legume hay	Grass hay
WSS (%)	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

Carbohydrates in horse feeds have traditionally been esti¬mated by measuring cell wall components as NDF and calculating the remaining carbohydrate by differ-ence as non-fibre carbohydrate (NFC), where NFC = 100 - water - protein - fat - ash - NDF. More recently, laborato¬ries have provided a direct analysis of addi-tional carbohydrates in equine feeds. Table 2 contains the chemical composition of several common equine feedstuffs as analyzed by Equi-ana¬lytical Laborato-ries in Ithaca, NY. In addition to NDF and the calcu-lated values of NFC, Table 2 contains measured levels of water-soluble sugars (WSS) and starch. The sum of WSS and starch is considered the non-structural carbo-hydrate (NSC). WSS 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 WSS in temperate grasses are actually fructans, which should be included in the CHO-FR fraction.

Starch is the predominant carbohydrate in cereal grains. Although all starch is made up of glucose, how the starch molecule is constructed varies and this has a large impact on digestion in the small intestine. Oats has very digestible starch, but corn and barley have small starch molecules that are relatively indigestible unless they are heated. This means steam flaked, extruded or micronized corn or barley will have a much higher GI than the raw grains, rolled barley or cracked corn.

METABOLIC DISORDERS

Equine Cushing's disease (ECD) or pituitary pars inter-media dysfunction (PPID) results from a tumor in the pituitary gland and is frequently recognized in older horses (Frank et al., 2006). The pituitary glands of horses with ECD secrete excessive amounts of adreno-corticotropic hormone (ACTH), which results in an increased secretion of cortisol from the adrenal glands. Horses with ECD are prone to laminitis and may develop cortisol- induced insulin insensitivity which leads to hyperinsulinemia and hyperglycemia.

The best dietary strategy for horses with ECD will depend on several factors. First, since these horses tend to be insulin insensitive, a ration that produces a low glycemic response is essential. Also avoid rations that contain CHO-FR such as lush pasture and high grain meals to reduce the likelihood of laminitis. Many horses will need restricted access to pasture and severe-ly affected horses will need to be taken off pasture altogether to avoid triggering laminitis (Frank 2006). Additionally, the ration must also supply the correct amount of required nutrients for the horse and it must supply the correct caloric intake to maintain or achieve a desired body condition.

ECD horses that are overweight should be fed a ration composed primarily of hay or chaff. Most hays have low glycemic indexes (GI) compared to cereals and sweet feeds. Hay rations should be supplemented with a low-inclusion fortified balancer to provide minerals and vita-mins that may be deficient in the forage. It is thought that horses with ECD suffer oxidative stress (Johnson et al, 2004) so added antioxidants such as Vitamin E and C may be useful. Trace minerals zinc, copper and selenium are also involved in anti-oxidant systems so need to be supplied in adequate quantities in the diet. In addition it has been suggested that chromium can increase insulin sensitivity so this could be included in the supplement as well (Geor 2005).

If an older ECD horse has trouble maintaining weight, its ration can be supplemented with additional calo-ries from a high fat, low starch product. In addition to providing a concentrated source of energy, vegetable oil has been shown to greatly reduce glycemic response to a grain meal, possibly by delaying gastric emptying (Geor et al, 2001). If beet pulp is added to the ration, it should be rinsed to reduce its GI (Groff et al, 2001). Stabilised rice bran also has a low GI (47%) and can be fed as an energy source to horses with ECD with up to 20% of the calories can be provided by fat. Feeds that are designed for senior horses may not be desirable for ECD horses since they may contain ingredients such

as grains or molasses which produce a high glycemic response.

EQUINE METABOLIC SYNDROME (EMS)

Equine metabolic syndrome (EMS) is an endocrine and metabolic disorder which results in insulin resistance (IR) and an increased risk of pasture-associated laminitis (Andrews and Frank, 2008). Horses and ponies with EMS tend to be obese with cresty necks. These animals have often had prior bouts of laminitis and are "easy keepers". A feeding program for EMS horses should be focused on reducing body weight while providing adequate protein, vitamin and mineral intake. It should be a forage based program, but pasture intake should either be restricted with a grazing muzzle and limited turn-out or completely avoided during times of lush growth. Since caloric restriction is important, a concentrated balancer should be used for supplementation.

Hay analysis is recommended to help ensure the NSC content of the hay is low and it is recommended that hay with an NSC level of less than 12% is ideal. If not tested or higher NSC hay is being fed, hay can be soaked for 30 – 60 min in water to reduce the sugar content. Soaking hay for 30 min reduced the soluble sugar content by 39- 50% and led to a significantly reduced glucose and insulin response to feeding (Cottrell et al 2005). It also led to a significant reduction in potassium content and this can have value in quarter horses who are predisposed to hyperkalaemic periodic paralysis. Soaking in hot water will speed up the leaching of sugar from hay but there is no need to soak for more than 1 hour.

RECURRENT EQUINE RHABDOMYOLYSIS (RER)

Recurrent Equine Rhabdomyolysis (RER) is a specific form of tying-up seen in Thoroughbreds, Standardbred and Arabian horses (Valberg et al., 2005). It is an inherited trait caused by abnormal intracellular calcium regulation during muscle contraction. Although the genetic predisposition for RER is evenly divided between males and females, clinical signs of the disease are more often seen in young fillies. Excitement and stress seem to be trigger factors. High grain intakes are associated with tying up in racehorses.

Research at the University of Minnesota in conjunction with Kentucky Equine Research suggests that replacing much of the grain in the diet with a low starch, high fat feed (KERx Re-Leve) will significantly decrease the amount of muscle damage in RER horses. (MacLeay et al., 2000). In a feeding trial, five Thoroughbred horses with RER were exercised on a treadmill for five days a week while they consumed hay and a variety of energy supplements for three weeks at a time. When the daily caloric intake of a high-starch ration was kept low (21 Mcal DE/day), the horses had lower post-exer¬cise serum creatine kinase (CK) than when this feed was increased to provide 28 MCal DE/day (MacLeay et al., 2000). In contrast, if extra calories were provided from a low-starch, high-fat feed (Re-Leve; KERx, Versailles, KY) rather than a grain supplement at 28 MCal/day, no increase in post-exercise serum CK activity occurred. No significant differences in muscle glycogen or lactate concentrations were apparent in these studies.

Most horses with RER have medium to high energy requirements and need significant calories supplied above those found in the forage portion of the ration. An appropriate feed should be fortified to be fed at fairly high levels of intake (4-6 kg/day). It should be low in NSC (‹10%), high in fat (›10%) and supply a significant portion of its energy as fermentable fibre. As Re-Leve is not currently available in Australia, home mix diets can be created using low starch ingredients such as stabilized rice bran, sunflower seeds, vegetable oil, lupins and copra meal along with sources of fermentable fibre such as beet pulp and soyabean hulls. Horses often become reluctant to consume more than 1 cup oil per feed so the use of high fat feeds such as sunflower seeds and rice bran is valuable. These basic feeds would require added mineral and vitamin fortification and it should be noted that whilst vitamin E and selenium are important dietary anti-oxidants and can reduce the severity of muscle damage after work, they do not prevent RER.

POLYSACCHARIDE STORAGE MYOPATHY (PSSM)

Polysaccharide Storage Myopathy (PSSM) is another muscle disorder that is more common in Quarter horses, warm bloods and draft breeds (Valberg et al., 2005). It is characterized by an abnormal accumulation of glycogen in muscle resulting from a hyper-sensitivity of the muscle to insulin. The same type of energy sources used for RER horses is effective for PSSM. Research at Univ. of Minnesota has shown that serum CK levels which are indicative of tying-up were reduced when Quarter horses suffering from PSSM were fed a low starch, high fat feed (Ribeiro et al, 2004). Since these horses have lower energy requirements than RER horses, the concentration of other nutrients needs to be greater than in feeds designed for RER. Horses affected with PSSM are usually good doers and that need less than 10% of their energy from starch and sugar and more than 20% from fat.

OSTEOCHONDROSIS (OCD)

The source of calories for young horses may also be important, as hyperglycemia or hyperinsulinemia have been implicated in the pathogenesis of OCD (Glade et al., 1984; Ralston, 1995). Foals that experience an exaggerated and sus¬tained increase in circulating glucose or insulin in response to a carbohydrate (grain) meal may be predisposed to development of OCD. In vitro studies with foetal and foal chondrocytes sug¬gest that the role of insulin in growth cartilage may be to promote chondrocyte survival or to suppress differentiation and that hyperinsulinemia may be a contributory factor to equine OCD (Henson et al., 1997).

Research from Kentucky Equine Research (Pagan et al., 2001) suggests that hyperinsulinemia may influence the incidence of OCD in growing Thoroughbreds. In this study of 214 weanlings on 6 farms, a high glucose and insulin response to a single concentrate meal was associated with an increased incidence of OCD. Glycemic responses measured in the weanlings were highly correlated with each feed's GI, suggesting that the GI of a farm's feed may play a role in the pathogene¬sis of OCD. In rats, prolonged feeding of a high-GI feed results in basal hyperinsulinemia and an elevated insulin response to an intravenous glucose tolerance test (Pawlak et al., 2001). Hyperinsulinemia may affect chondrocyte maturation, leading to altered matrix metabolism and faulty mineralization or altered cartilage growth by influencing other hormones such as thyroxine (Jeffcott and Henson, 1998).Based on these results, it would be prudent to feed foals concentrates that produce low to moderate glycemic responses.

SUMMARY

The five metabolic disorders discussed above have very different aetiologies yet are all either triggered or aggravated by excessive starch and sugar intake. While all of these horses require lower GI rations, the most appropriate form of energy supplementation depends on the disorder and the individual's energy requirement. ECD horses are insulin insensitive and need a low GI ration, but their energy requirement may vary. Some may be relatively "easy keepers" and benefit from mostly forage rations while others may need extra calories in the form of fat and fermentable fiber. EMS horses and ponies tend to be obese and "good doers" and should be fed mostly forage rations with an appropriate low inclusion balancer. Both ECD and EMS sufferers are prone to laminitis which can be triggered by access to lush pasture so pasture intake should be carefully controlled. Horses with RER and PSSM horses are not insulin insensitive, but both groups benefit from low starch feeds. Fat is an important supplement for both groups, but their energy requirements are different. RER horses tend to need moderate to high energy intakes while PSSM horses typically require fewer calories. OCD may be triggered by high glycemic feeds, but there is no evidence that young growing horses need extremely low GI feeds. In fact, a certain amount of starch in the ration is desirable for young horses, particularly during sales preparation. Diets for young horses should have moderate glycemic indexes and be fortified to promote optimal muscular and skeletal development.

Table 3: Variables related to feeding horses with different metabolic disorders

Metabolic Condition	Energy Need	Insulin Resistant	Fat in Feed	Laminitis Risk
ECD	Low to High	Yes	Low to High	High
EMS	Low	yes	Low	High
RER	Moderate to High	No	High	Low
PSSM	Low to Moderate	No	High	Low
OCD	Low to Moderate	No	Moderate	Low

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