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The Skinny on Carbohydrates and Body Size of Horses

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Introduction

Horses, come in all shape and sizes, as do their owners. Much of what has been researched and learned in human medicine over the last few decades is now being actively investigated for application to common horse problems such as obesity, geriatric medicine, infertility, glycemic indexes of feed, and the art of aging gracefully. Many owners are now exploring long-term strategies for nutritional programs to optimize the health, weight, fitness, and longevity of their horses as they age into their "senior" years. The concepts and mechanisms of carbohydrate utilization in managing these different cases or life stages in horses will be explored from basic physiology to practical application in the stable.

The Basics

The design and functioning of the gastrointestinal tract is the major determinant of how a horse converts feed into chemical components providing energy for bodily activities. The horse was designed as a grazing herbivore that functioned by digesting a continuous supply of roughages or a series of very small meals throughout the day. Horses were not designed to optimally function as twice-a-day, large meal eaters! The horse's digestive system can be divided into two separate but integrated systems consisting of the upper and lower gut. The upper gut consists of the stomach and small intestine. This portion of the horse's digestive tract is very similar to human digestion, where digestion and absorption occurs for fat, protein, soluble carbohydrates, and some vitamins and minerals from the feed. The lower gut consists of the large intestine and cecum which act together as a large fermentation vat which digests fibrous plant material such as cellulose and hemi-cellulose using bacteria. Feed may pass relatively quickly through the upper gut within several hours, but may spend up to three days in the lower gut undergoing bacteria fermentation and absorption. The evolutionary process imposed on the digestive system has allowed for the ability of the horse to adapt *slowly* to changes in diet composition, such as with the seasonal growth of grasses and forages. However, the horse's gastrointestinal tract is not designed to easily adapt to quick changes in different types of feed components, especially those feeds with a high content of soluble carbohydrate (i.e., starches and sugars in grain concentrates). Sudden increases in soluble carbohydrate consumption may cause incomplete digestion and absorption in the upper gut, and some soluble carbohydrates may reach the lower gut causing an extreme alteration in the microbial bacteria population. These deleterious effects in the functioning of the hind gut lead to conditions such as laminitis or colic.

Horses eat to meet their energy needs- which are necessary for maintenance, growth, gestation, lactation, and exercise. At the cellular level, it is essential to have the ability to continually supply the cells with the chemical compound ATP. The molecules of ATP are the building blocks of energy necessary for metabolism throughout the body. Energy is provided to the horse in the feed as carbohydrates, protein and fat which are converted to ATP during various chemical processes within the body, but usually converted to an intermediate form as glucose and volatile fatty acids. There is a rise in glucose concentration in the blood approximately 2 to 3 hours after the consumption of a meal containing carbohydrate. The feeding of soluble carbohydrates to horses has been documented to have beneficial physiological responses such providing energy during lactation and exercise, but has also been implicated in disorders with serious and sometimes irreversible damage such as increased risk in laminitis and colic. Horses also have been shown to suffer some of the same health maladies associated with high glucose concentration as humans. There has been much less research done to show similar relationships between high glycemic diets and comparable equine conditions as in humans, but with limited studies and anecdotal evidence, horses do experience obesity, insulin resistance, and other disorders associated with high carbohydrate (starch) intake.

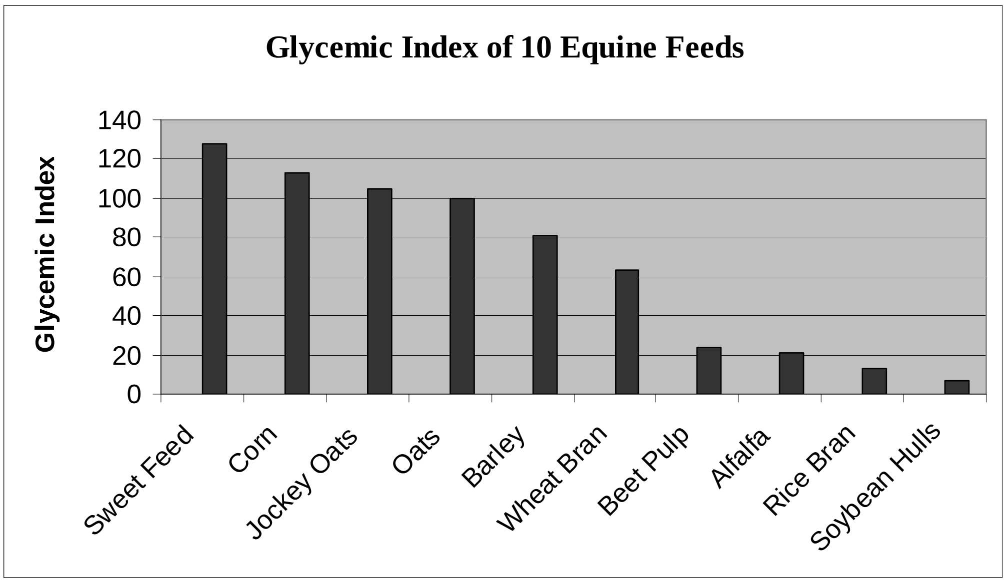
Glycemic Index

In humans but especially older people with a sedentary lifestyle, there is a strong relationship between high glycemic diets with obesity, insulin resistance, coronary heart disease, and possibly cancer. The glycemic index was developed in the 1980's to provide information on blood glucose concentrations produced by different foods after ingestion, because this could not be predicted solely by chemical composition of foods (Jenkins et al., 1981). A glycemic value is determined by comparing the area under the plasma glucose curve to a test food with that of a standard food such as white bread. The glycemic index of the test food is calculated as a percentage of the glucose response to the standard food. Variations in glycemic index can occur in the food due to the starch and sugar content, food form, cooking methods or processing, along with the rate of eating.

The glycemic index of different horse feeds may be of interest because starch and sugar digestion along with glucose metabolism in the horse is similar to humans, and horses have been shown to suffer some of the same metabolic disorders associated with high glucose concentrations or the fluctuations in glucose concentrations as humans. Formulating equine diets that produce attenuated glycemic and insulinemic responses may have health benefits to the horse in avoiding insulin resistance and its undesirable effects related to laminitis and other maladies. Conversely, formulating diets that produce elevations in glucose concentrations may provide an enhanced energy source for some types of athletic performances; particularly exercise in which carbohydrate oxidation supplies a large percentage of the energy required.

In a recent study, ten common equine feeds were used to calculate a glycemic index for horses (Rodiek and Stull, 2007). The amount of feed offered in the meal was calculated on an equal calorie basis between the ten feeds. Jugular blood samples were collected for 300 minutes after feeding and blood plasma was analyzed for glucose concentration. The results showed that blood glucose peaked between 90 to 120 minutes after the meal. The glucose response of oats was chosen as the standard and its glycemic index was set at 100. The four feeds with the highest glycemic index were sweet feed, corn, jockey oats, and oats; these were significantly greater than the lowest valued glycemic index feeds of beet pulp, alfalfa, rice bran, and soy hulls (Figure 1). The intermediate feeds were barley and wheat bran, but these were not significantly different than the other feeds. Thus, two distinct groups of equine feeds can be identified by glycemic index. These two groups reflect different feed types in practical horse nutrition, with the high glycemic group composed of cereal grains and the low glycemic group composed of hay and by-products. Variation in the glycemic index for an individual feeds can be attributed to age of the horse, physiologic state, rate of eating, chemical composition, as well as feed processing.

Figure 1. Glycemic index of 10 common equine feeds (Rodiek and Stull, 2007)



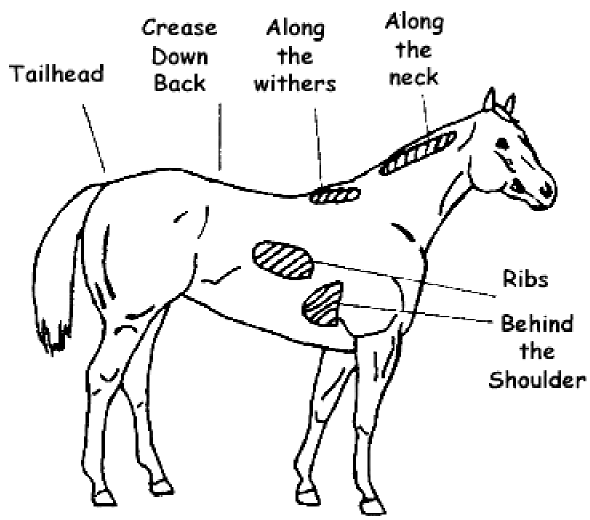
Fat and Skinny Horses

The general shape or appearance of a horse is dependent on its skeleton which is primarily programmed by its genes or breeding. In addition, several other factors contribute to the body image which cannot be manipulate including age and gender, but others such as fitness and body condition can be easily influenced or changed. The physiological response of a long-term exercise program will increase the diameter of individual muscle fibers which compose the various muscles of the horse. Thus, the musculature of the horse will appear more massive and distinctive as a response to the exercise program. Of course, the specific muscles that will respond will depend on which muscles are being "worked" during the conditioning protocol. Another mechanism to influence the body image of a horse is to alter the amount of body fat, which is called "body condition." The horse can accumulate fat as both visceral (abdominal) and subcutaneous (under the skin) fat. The accumulation or loss of fat is directly dependent on the energy content (calories) of the diet for a healthy horse. As the percentage of body fat fluctuates, the appearance or body condition of the horse will easily be recognized.

Both fit and sedentary horses can be considered "fat" or "skinny" based on their body condition. Body condition assessment or scoring system has been developed for horses (Henneke et al., 1983) based on the degree of fat content in the body. The body conditioning scoring system is performed by visual appraisal and palpation of fat deposits on the horse and then assigning a 1 (poor) to 9 (extremely fat) score based on a descriptive reference (Appendix 1). This system was initially developed to appraise breeding mares, and then subsequently to appraise all breeds and genders of horses. Humane officers often use a body conditioning system to assess horses involved in neglect cases and during the rehabilitation process.

Body condition scoring is dependent on the amount of fat deposited in designated body locations of the horse including the neck, withers, loin, tail head, ribs, and behind the shoulder or elbow (Figure 2). These areas are easily visible, but palpation is also used in determining the degree of fatness.

Figure 2. The six body locations of fat deposits used in body condition scoring (Hennneke et al., 1983)



Body condition scoring is a useful tool for assessing individual horses, but can also be helpful in "measuring" the effects of a nutritional program, changes in activity or exercise level, seasonal conditions of the environment, or the health status of the horse. Using the appropriate description provided in the chart (Appendix 1), a score is assigned to each of the six body locations. The individual horse can be assigned a composite body condition score based on the average of the scores from all six locations. There may be some variation between different people assessing the same horse, but the detailed description of each body location for fat deposit will assist in standardizing the scoring between assessors.

A score of between "4 and 6" is generally considered optimal for healthy horses. A general goal for body scores is a "4" for sport horses, a "5" for growing horses, and a "6" for breeding horses. Horses scoring in the "1, 2, 3, 8 or 9" categories should be evaluated for causes such as medical conditions, dental problems, or the lack of proper nutrition. Several considerations should be noted in body scoring assessments. A thick winter hair coat may visually conceal areas particularly of an emaciated body, but palpation of the areas will be useful. Conformation especially of the top line (i.e., protruding withers) can skew the results in one body location, but the other fat depots will reflect any changes in total body fat content. Pony and draft breeds are naturally fleshy and usually score higher (+ 0.5).

When Things Go Wrong

Obesity or emaciation requires the individual management of the horse starting with the identification of the causes. The health of the horse should be determined before any changes in the nutritional program are initiated. A horse that appears overweight may suffer from metabolic disease (Cushing's, hyperthyroidism), but most likely, the horse has overindulged in sweet feeds, over consumed lush pastures, and/or has limited exercise or other physical activity. A healthy horse that is overweight or obese will most likely benefit from a diet that is reduced in the content of energy (calories) and/or an increase in physical activity. Both regimes should be initiated in a step-wise fashion with a slow reduction in total amount of calories in the daily feed or changes in types of feed. Exercise or other activity should be slowly increased over time. Both regimes will lead to a reduction in total body fat. The caloric intake (digestible energy) can be slowly reduced, mainly by withdrawing any soluble carbohydrates (grain) in the diet while feeding good quality hay. A horse that body scores as a "9" may take 3 to 6 months of diligent daily care before obtaining a score of "5 or 6."

Emaciated horses (body condition score of "1 or 2") may suffer from many maladies of health, age, or nutritional basis. Dietary deficiencies can range from complete lack of feed (starvation) to an imbalance (excess or deficiency) of the nutrients (malnutrition) required in the diet such as protein or specific vitamins. Some horses, usually older geriatric horses, may have a decline in their ability to digest and absorbed nutrients in the diet. Many commercial diets are available for the senior horse which facilitates increased digestibility and nutrient content of the diets. Good quality forage is the cornerstone of the geriatric horse, but may be fed in the form of pellets or chopped hay to aid geriatric horses with dental compromise or other challenges.

What Happens During Starvation

Fat and carbohydrates stored in the body are used for energy, exercise, brain function, circulation, etc., and are then replaced with nutrients from food as the normal metabolic energy process for a healthy horse. The cycle is constant and never-ending, even during sleep. During the starvation process, the horse initially uses any fat and carbohydrate stored in his body to supply energy for metabolism. In a starved animal, once this source of fat and carbohydrate is gone, energy is derived from the breakdown of protein. While protein is a component of every tissue, there are no inert stores of it in the body such as there are for fat and carbohydrates. Consequently, the starved body uses protein not only from skeletal muscles, but also from vital tissues such as the heart and even gastrointestinal tissues—tissue that is necessary for life. The starved body cannot select which tissue protein will be metabolized for energy. As time goes by, the horse's survival is in a precarious situation. When a horse loses more than 50% of its body weight, the prognosis for survival is extremely poor.

Refeeding Syndrome in Starved Animals

Refeeding starved animals, including humans, is not an easy process. In humans suffering from starvation caused by illnesses such as anorexia, cancer, or gastrointestinal obstruction, patients can develop "refeeding" syndrome when they are given concentrated calories primarily in the form of glucose. Clinical signs of the refeeding syndrome include heart, respiratory, and kidney failure, coma, convulsions and acute death within 3 to 5 days (Love, 1986; Solomon and Kirby, 1990). This same syndrome has been reported in the literature for horses with abrupt refeeding of horses causing death in 3 days (Kronfeld, 1993). Limited scientific studies have been performed to compare diets suitable to rehabilitate a starved horse and enable the horse to return back to normal body weight. The objective of our study was to test feeds that were commonly available and used in horse rations, so a refeeding program could be implemented easily in any area of the country (Witham et al., 1998).

Three types of feed that were very different in nutrient composition were compared: alfalfa hay, oat hay, and a commercially available complete feed consisting of grain, molasses, fat, and alfalfa. Alfalfa is known to be high in protein (20%) but low in carbohydrate starch (3%). Oat hay is high in fiber but low in protein (7%). The complete feed represented a feed high in carbohydrate concentration, with 19% starch. The three types of feed were given to 22 starved horses that were brought to the UC Davis research site as representative of horses rescued by equine organizations. Horses were fed one of the three diets over a 10-day rehabilitation period, which is the time period critical to successfully transitioning the digestive tract from a starved state to a fed state. Even though the diets were different in composition, these diets were fed in amounts that were equivalent on a caloric basis. Horses that were assigned the oat hay diet received the largest volume of feed, horses fed the complete feed received the smallest amount, and horses fed alfalfa were intermediate in the volume of feed, but all horses received the same number of calories at each meal (Witham et al., 1998).

Which Diet Works Best to Rehabilitate a Starved Horse?

Responses of the horses to the different feeds were similar in response reported for human patients affected with refeeding syndrome. As the horse ate the complete feed which was the high-carbohydrate diet, insulin was released in response to the high level of dietary starch. Insulin facilitates the storage of carbohydrate into cells for future energy use, but it also simultaneously draws the electrolytes phosphorous and magnesium from circulation into the cell. Since the starved horse has no stores of electrolytes, this depletion leads to kidney, heart, and respiratory failure and death in some of the horses. In our studies, these effects did not occur with the initial meal, but usually several days to a week later due to the repetition of insulin release following a high-carbohydrate meal and the cumulative depletion of electrolytes. The oat hay diet was very bulky and caused diarrhea in several horses. Several essential nutrients such as phosphorous and magnesium were low in the oat hay compared with the other diets; thus, this diet did not support a successful rehabilitation. The alfalfa diet had the best results due to its high composition of quality protein, but also contained higher levels of the major electrolytes of magnesium and phosphorous. Since alfalfa hay is very low in carbohydrate content, there were minimal effects due to insulin response and the associated shift in essential electrolytes.

In a subsequent refeeding study using starved horses, alfalfa hay was compared to a diet of the combination alfalfa hay and corn oil. In recent years the use of supplementary corn oil to increase the energy density of a meal has been widely used in nutrition programs for older horses and those horses undergoing intensive training programs. The two diets were fed again on an equal-calorie basis. In healthy horses, the insulin response following a meal of corn was dampened when corn oil was added to the diet. A reduction in insulin release was proposed to be advantageous to the starved horse in controlling the intracellular shift in phosphorous following a meal. The results showed that although corn oil had no harmful effects, substituting calories using corn oil rather than alfalfa decreased the total nutrient content of phosphorous and magnesium in the diet. Thus, the response to the diet combining corn oil and alfalfa showed a decreasing blood phosphorous level over the 10-day period, which was not advantageous to the rehabilitation process. The alfalfa diet was more supportive of the refeeding of the starved horse because it provides a greater intake of dietary phosphorous and magnesium (Stull et al., 2003).

The best approach for initial refeeding of the starved horse consists of frequent small amounts of high-quality alfalfa. This amount should be increased slowly at each meal and the number of feedings decreased gradually over 10 days (Appendix 2 for detailed feeding schedule). After 10 days to 2 weeks, horses can be fed hay in increasing amounts to reach a level of free choice hay. Grain supplementation is not recommended until the horse is near normal body weight, usually 6 months following the initiation of refeeding. Horses will show signs of increased energy after one to two weeks, but may be particularly aggressive at meal times. Ears, eyes and head movement will be the first noticeable movements in extremely emaciated horses. Some weight gain can be achieved in one month, but 3 to 5 months usually are needed to rehabilitate a horse back to a normal body weight. A physical exam of the horse prior to any riding or exercise program is advisable to ascertain any organ damage (i.e., heart) or other limiting disorders.

References

Jenkins, D.J.A., Wolever, T.M.S., and R.H. Taylor. 1981. Glycemic index of foods: a physiological basis for carbohydrate exchange. American Journal of Clinical Nutrition 34:362-366.

Henneke D.R., Potter G.D., Kreider J.L. and B.F. Yeates. 1983. Relationship between condition score, physical measurements and body fat percentage in mares. Equine Veterinary Journal 15(4):371 - 372.

Kronfeld, D.S. 1993. Starvation and malnutrition of horses: recognition and treatment. Journal of Equine Science 13:298-303.

Love, A.N.G. 1986. Metabolic responses to malnutrition: its relevance to enteral feeding. Gut 27(Supplement 1):9-13.

Rodiek, A.V. and C. L. Stull. 2007. Glycemic index of ten common horse feeds. Journal of Equine Veterinary Science 27(5):205-211.

Solomon, S.M. and D.F. Kirby. 1990. The re-feeding syndrome: a review. Journal of Parenteral and Enteral Nutrition 14:90-97.

Stull, C.L., Hullinger, P.J. and A.V. Rodiek. 2003. Fat supplementation to alfalfa diets for refeeding the starved horse. The Professional Animal Scientist 19:47-54.

Witham, C. L. and C. L. Stull. 1998. Metabolic responses of chronically starved horses to refeeding with three isoenergetic diets. Journal of the American Veterinary Medical Association 212(5):691-696.

Appendix 1

Henneke Body Condition Scoring for Horses (Henneke et al., 1983)

	NECK	WITHERS	LOIN	TAILHEAD	RIBS	SHOULDER
1 POOR	Bone structure easily noticeable	Bone structure easily noticeable	Spinous processes project prominently	Tailhead and hook bones project prominently	Ribs project prominently	Bone structure easily noticeable
	Animal extremely emaciated; no fatty tissue can be felt.					
2 VERY THIN (Emaciated)	Faintly discernible	Faintly discernible	Slight fat covering over base of spinous processes. Transverse processes of lumbar vertebrae feel rounded. Spinous processes are prominent.	Tailhead prominent	Ribs prominent	Faintly discernible
3 THIN	Neck accentuated	Withers accentuated	Fat buildup halfway on spinous processes but easily discernible. Transverse processes cannot be felt	Tailhead prominent but individual vertebrae cannot be visually identified. Hook bones appear rounded, but are still discernible. Pin bones not distinguishable.	Slight fat cover over ribs. Ribs easily discernible.	Shoulder accentuated.
4 MODERATELY THIN	Neck not obviously thin	Withers not obviously thin	Negative crease along back	Prominence depends on conformation, fat can be felt. Hook bones not discernible	Faint outline discernible	Shoulder not obviously thin
5 MODERATE	Neck blends smoothly into body	Withers rounded over spinous processes	Back level	Fat around tailhead beginning to feel spongy	Ribs cannot be visually distinguished, but easily felt	Shoulder blends smoothly into body
6 MODERATELY FLESHY	Fat beginning to be deposited	Fat beginning to be deposited	May have slight positive crease down back	Fat around tailhead is soft	Fat over ribs feels spongy	Fat beginning to be deposited
7 FLESHY	Fat deposited along the neck	Fat deposited along withers	May have positive crease down back	Fat around tailhead is soft	Individual ribs can be felt, but noticeable filling between ribs with fat	Fat deposited behind shoulder
8 FAT	Noticeable thickening of neck	Area along withers filled with fat	Positive crease down back	Tailhead fat very soft	Difficult to feel ribs	Area behind should filled in flush with body
	Fat deposited along inner buttocks.					
9 EXTREMELY FAT	Bulging fat	Bulging fat	Obvious crease down back	Building fat around tailhead	Patchy fat appearing over ribs	Bulging fat
	Fat along inner buttocks may rub together. Flank filled in flush.					

Appendix 2

Refeeding Recommendations for the Starved Horse* (Witham et al., 1998)

Day	Number of meals/day	Feed (lbs)/meal	% DE /day
Days 1-3	6 (every 4 hours)	1.0 to1.25 lbs alfalfa	50
Days 4-5	6 (every 4 hours)	1.75 to 2.0 lbs	75
Days 6-10	3 (every 8 hours)	Increase to 5 lbs	100

* Based on a starved horse with a projected normal weight of 1000 lb or 450 kg.

Daily digestible energy (DE) requirement per horse can be calculated using a formula:

$$\text{Mcal DE/day} = 1.4 + 0.03 \text{ Body Weight (kg)}.$$

DE of alfalfa hay is 2.28 Mcal/ kg.

Thus, the DE requirement for the horse is 15 Mcal DE/day, which can be provided with 6.6 kg or 14.5 lb of good quality alfalfa.