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The horse evolved as grazing animal that consumed a wide variety of forage plants. Within this array of forages there were a variety of carbohydrates that the horse was able to digest and utilize as an energy source. Today, there are a significant number of horses who, because of their physiological state, can be easily maintained on a high forage diet. Forages, and the carbohydrates they contain, are an important ingredient in all horse diets.

Why then has the horse industry become concerned about the carbohydrates in their horses' diets? This concern has some owners seeking low or no carbohydrate diets for their horses. This concern has even gone so far as to question if grass is safe for their horse. For some situations, horse owners should be concerned, as a number of health problems have been associated with excessive carbohydrate intakes. Horse owners are always on guard to prevent such problems as laminitis or colic, which can be the result of excessive carbohydrate intakes. In reality while the carbohydrate may be the cause it is the horse owner who needs to address

the issue as it is the horse owner that provides the excessive carbohydrate intakes.

The purpose of this presentation is not to downplay the problems associated with carbohydrates and horses, but to put them into perspective. After all, horses were born to eat grass and have been doing so for a long time. Therefore how can horse owners use the feeds available to them to in a safe and effective manner? In order to use these feeding and reduce the risks associated with them it is necessary to understand the sources of carbohydrate in the feeds being used.

As a grazer, the horse relies on forage, which is primarily made up of carbohydrates in different forms. The fiber fraction now referred to a neutral detergent fiber is made up of cellulose and hemicellulose. These forms of carbohydrate are also called polysaccharides as they are made up of multiple units of simple sugars but linked in a fashion that makes them resistant to mammalian enzyme digestion. These carbohydrates when utilized by the horse must be digested through the process of fermentation in the cecum and large intestine of the horse. It is here the microorganisms convert the fiber components into volatile fatty acids which are absorbed and used by the horse as an energy source.

While the horse has an area in the digestive tract that uses microbial fermentation, this area is found in the later segment of the digestive tract. This organization of structures makes the horse a hind gut fermenter. The non fibrous fraction of forages, the other polysaccharides and soluble carbohydrates consumed are broken down by enzymatic digestion which occurs in the small intestine of the horse. This process produces simple sugars such as glucose and is a very energy efficient system for the horse. The combination of both enzymatic digestion and fermentation allow the horse to make good use of that wide variety of carbohydrate provided by both the forages and grains commonly fed.

What are the different carbohydrates are found in common feeds? In forages, there are the fibrous forms, cellulose and hemicellulose, soluble carbohydrates, sugars and starches, and fructans. How these different carbohydrates are digested by the horse makes the difference and this will be discussed later. Table 1 shows the differences in two common forages as it relates to the NDF fractions (structural or fiber carbohydrates), the NFC fractions (non fiber carbohydrates) and the non structural carbohydrates which are made up of the soluble carbohydrate fraction.

Table 1 Carbohydrate fractions in common forages (dry matter basis)

Feedstuff % NDF % NFC % NSC

Alfalfa Hay 43.1 22.0 12.5

Grass Hay 60.9 16.6 13.6

Adapted from NRC 2007

The higher percentage of NDF in the grass hay is a primary reason why a forage of this type has a lower digestible energy value than the alfalfa hay has. This is due to a higher percentage of carbohydrates that are lower in digestibility whereas the alfalfa hay has a much higher percentage of non fibrous carbohydrate that is readily digested in the small intestine resulting in a higher digestible energy value.

Defining the various carbohydrate compounds will aid horse owners in making good decisions on how they should feed their horses. A recent suggestion reported in NRC 2007 divided carbohydrates into three categories. They are:

1) The carbohydrates that are readily hydrolyzed and undergoes enzymatic digestion in the small intestine. This group would include the storage carbohydrates such as starch with the end product of digestion being glucose.

2) The rapidly fermented carbohydrates that are broken down by microbial fermentation in the hind gut. This group includes fructans (a polysaccharide made up of glucose and fructose) resistant starches found in some cereal grains, and some hemicellulose. The products of digestion are the different volatile fatty acids (VFA's).

3) The slowly fermented carbohydrates that are also broken down by microbial fermentation in the hind gut. This group includes the cellulose and hemicellulose (primarily from forages) and also yield VFA's as a product of digestion.

While these categories simplify the process in many areas, laboratory analysis is not readily available to quantify the different carbohydrates. This is changing and in the near future most forage analysis will provide a more comprehensive analysis.

Carbohydrate Concerns

Grain Concerns - Horses will be fed diets high in carbohydrates but there are situations where caution is advised. For the horse at maintenance, energy needs can be easily met with a reasonable quality forage. However, for the performance horse, more calories are required and it has been a common practice to feed a concentrate rations to increase caloric intake. In most situations, this meant feeding cereal grains with high levels of starch. The common grains used in horse diets would be oats, corn and barley. Table 2 (next page) notes the level of starch found in these cereal grains.

Table 2 – Levels of Starch in Common Grains (dry matter basis)

Grain % Starch % NDF

Barley 54 19.6
Oats 44.3 27.9
Corn 72.3 9.1

Adopted from NRC 2007

From this table, it is easy to see why oats have been considered a safer feed. This grain has higher fiber value and lower total starch content than the other cereal grains commonly fed. When fed to horses a greater daily intake would be required to provide a similar starch intake when compared to either corn or barley. This however is not the whole story. Another reason that oats may be safer is the structure of the starch and its relative digestibility. That is because not all starches are created equal. The structure of the starch in the different cereal grains makes some more resistant to enzymatic digestion in the small intestine of the horse. Results from early research trials indicate that over 95% of all starch from cereal grains is digested by the horse. These trials however looked at total tract digestion and the results were not unexpected. It is known that any starch not digested in the small intestine will be rapidly digested by the microbes in the hind gut. Therefore the combination of both types of digestion results in almost total disappearance of starch.

Other research has shown that there are significant differences in the small intestinal digestion of starch from the different cereal grains. Prececal digestion for oat starch is about 85% while the starch from barley and corn is less than 30% digested. This means that there is a significant portion of the starch in corn and barley resistant to enzymatic digestion. As a significant portion of the starch from either barley or corn is not digested before reaching the hind gut there is the possibility that this undigested starch could affect the microbial population causing digestive disturbances increasing the risk for colic and laminitis.

The processing of these grains greatly enhances prececal digestion as heating and mechanical description of the starch granules allows for greater digestion. Tables 3 and 4 provide data on the effect of processing grains on prececal digestion.

Table 3 – Comparison of Small Intestinal Starch Digestion of Processed Corn (%) Whole
Corn Crushed Ground Popped
Digestibility % 28.9 28.9 45.6 90.1
Adapted from NRC 2007

The greater the amount of processing either mechanical (grinding) or heating (popped), alter the structure of the starch granule allowing for greater impact from the enzymes in the small intestine. This increase in prececal digestion can significantly reduce the amount of starch that passes through to the hind gut.

Table 4 – Comparison of Small Intestinal Starch Digestibility of Cereal Grains

	Corn	Rolled Oats	Rolled Barley	Rolled
Prececal Digestion %	80.9	81	95.6	
Total Tract Digestion %	98.9	98.9	98.9	

Adapted from NRC 2007

In addition to processing grain to enhance starch digestion, research has shown that total starch intake also affects how much starch may bypass the small intestine and be presented to the hind gut where it would impact microbial fermentation. It is commonly known that grain overload from excessive consumption can lead to colic or founder. Many times there have been reports of horses getting into the grain bin eating their fill of grain and the result is a foundered or colicky horse. This is due to an excessive amount of starch reaching the hind gut and upsetting the microbial population. This results in a change in the microbial population, VFA production and pH of the hind gut. All of which produce negative results for the horse.

While this excessive consumption is a problem horse owner's need to consider how much they feed on a regular meal basis to prevent excess starch from reaching the hind gut. Current research has developed the recommendation to limit the amount of starch per meal to 2- 3 grams of starch per kg body weight of the horse per meal. This in effect means 2.0-3.0 kg of a typical grain ration per meal for a 500 kg horse. The calculation is based on a common grain ration being about 50% starch. Of interest is this new calculated intake of concentrate is very close to the old recommendation of no more than 0.5% of a horse's body weight in concentrate per meal which works out to 2.5 kg per meal for a 500 kg horse.

Forage Concerns

In recent years, there has been a great deal of interest in the soluble carbohydrates in forages and their affect on horse health. Horse owners have for many years always been concerned about horses developing laminites if they grazed too much lush spring pasture. One possible culprit for this is the polysaccharide fructan which is made up of glucose and fructose units. This carbohydrate is a highly soluble carbohydrate fraction found in forages and is rapidly fermented in the hind gut. Researchers in Australia have used fructan to experimentally induce laminitis in horses. The level used is significantly higher than typically found in pasture grass.

What is fructan and is it new? Fructan is a storage carbohydrate that is produced by the plant during photosynthesis. If it is produced in amounts greater than needed by the plant, it is stored in the stem of the plant and used during periods of reduced photosynthesis. Fructan is not new, being first identified in the early 1800s, but it has become a concern for horse owners, especially those using cool season grasses in pasture and hay due to its linkage to a number of metabolic problems in the horse.

The accumulation of fructan in plants varies widely and is affected by the environmental conditions that affect plant growth. If sunlight is reduced as on a cloudy day and fertility is good, plants will continue to grow and fructan storage will be minimal. However, conditions such as drought where plant growth during the heat of the day may be reduced but photosynthesis continues, fructan levels may increase. Day and night time temperatures can also affect the accumulation of fructans by the plants. When day/night temperatures are in the range of 15/10oF versus 25/15oF greater accumulations of fructans have been reported to occur with the cooler temperatures. Fructan concentrations are also known to vary during the day. Levels in plant material will be low in the morning, increasing during the day and decrease overnight. This constant flux makes this a moving target but for most horses adapted to grazing, these diurnal changes should not be much of a problem.

Managing Carbohydrates in Horse Programs

For horses that have metabolic problems, such as horses that are insulin resistant, have chronic laminitis, are obese, or have Cushing's disease, will require special considerations related to carbohydrates in their diets. These considerations are outside the scope of this paper and while important to the horse owner with horses that fall into these categories they do not make up a large portion of today's horse population.

For the other horses consider the following:

- 1) Adapt horses to the feeding program. When starting to use pasture in the spring, take some time and restrict access to a few hours each day, gradually increasing time on pasture over 10-14 days until the horses are out for the time you intend to allow them to graze. When first introducing the horses to pasture, feed hay prior to turn out so horses are not hungry when turned out. If pasture is making up a significant portion of the horse's nutrient need you may want to restrict the grain being fed to reduce the total carbohydrates the horse is consuming.
- 2) Control grain intakes. Limit amount per meal to 0.5% of body weight. Only feed grain if it is needed to meet the horse's calorie needs.
- 3) Processed grain may be better for horses that require larger daily intakes.
- 4) Monitor your horse's body condition – overweight horses are at greater risk.
- 5) Maximize use of forage in your feeding program. At a minimum, all horses should receive 1% of body weight in long stem forage every day. This is a minimum, you can feed more. While feeding more than 1% of body weight is reasonable horse owners need to feed what the horse requires to meet nutrient needs not all the horse wants to eat. This can be problematic for horses on pastures that are well managed and very productive. How can horse owners deal with horses on pasture? To limit forage intake horse owners may need to consider restricting

access to the pasture by either removing them to a dry lot for some portion of the day or using a grazing muzzle to restrict intake.

Horse owners need to remember that while carbohydrates can cause a number of serious problems for horses it is up to the horse owner to manage the how your horses are fed. Manage the carbohydrates in your horse's diet; don't let them manage you.