THE CARBOHYDRATE WEB

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Introduction

During the past ten years, many equine practitioners and horse owners have requested low carbohydrate diets for horses. Several disease states have now been shown to be sensitive to the carbohydrate content of the diet. These disease states include: Tying-up, Cushing's Disease, Laminitis, Insulin Resistance (IR), Obesity and Osteochondrosis Dissecans (OCD). With this increasing trend to request low carbohydrate diets, equine nutritionists and feed manufacturers began to test dietary ingredients to determine carbohydrate content. Recently, the method of reporting the carbohydrate fractions in feed has been changed to enhance our understanding of carbohydrate. The following paper will outline the progression in carbohydrate testing and present recommendations for the dietary content of specific carbohydrate fractions in diseased or sensitive horses.

In The Beginning

The original group responsible for analysis and definition of plant carbohydrate were the plant scientists. These scientists defined plant carbohydrate into two types: Structural and Non-Structural.

Structural Carbohydrate

Structural carbohydrates are typically found in the cell wall of the plant and are often referred to as fiber. Analytically the major carbohydrates associated with the cell wall are cellulose, hemicellulose and lignin. Technically, lignin is not a carbohydrate since it is based on alcohol rather than glucose. These carbohydrates are represented on a laboratory analysis report as Neutral Detergent Fiber (NDF). Baled hay, mature pasture grass, beet pulp and soybean seed coats are good sources of structural (fibrous) carbohydrate. Structural carbohydrates are resistant to enzyme digestion in the small intestine and must be fermented by bacteria in the horse's hindgut. Bacterial fermentation of fiber yields volatile fatty acids (VFA's). VFA's are absorbed from the hindgut and are transported to the liver were they are converted to energy substrates for the horse. The overall digestibility of fibrous carbohydrate is quite variable,

depending on the distribution of cellulose, hemicellulose and lignin in the carbohydrate fraction. Since lignin is non-digestible by bacterial fermentation the higher the degree of lignin present the lower the overall digestibility. Thus, as plants mature and increase their lignin content, their digestibility is decreased. The overall digestibility of NDF in good quality forages by horses varies from 40-50 percent.

Non-Structural Carbohydrate (NSC)

Non-Structural Carbohydrate (NSC) is carbohydrate associated with the inner portion of the plant cell, or plant cell contents. Sugar may also be found in intercellular spaces. This sugar is the lost from hay when it is soaked in water prior to feeding. The plant cell includes NSC along with protein, lipids, organic acids and soluble ash. NSC is made up sugars, disaccharides, starches and fructans. In warm season grasses (C4 type plants), starch is the primary storage carbohydrate, whereas in cool season grasses (C3 type plants) fructan is the primary storage carbohydrate. As a practical point, commonly fed legumes such as clover and alfalfa do not contain fructan, and store carbohydrate as starch. Enzymes in the horse's small intestine break down sugars and starch to monosaccharides (simple sugars) that are absorbed and circulate in the blood as glucose. Fructans are resistant to mammalian enzyme digestion and must be fermented by bacteria in the horse's hindgut. Sugar and starch are highly digestible, greater than 95%, within the length of equine digestive tract. Bacteria located in the hindgut ferment any starch or sugar that is not digested by enzymes in the small intestine. Unfortunately, fermentation of sugar, starch and fructan by hindgut microorganisms can produce lactic acidosis that destroys the environment within the hindgut leading to death of the microorganisms and health concerns such as colic and laminitis.

Reasons For Change

The original system of separating carbohydrates into structural and non-structural worked well for plant scientists. The problem of using this system for horses was twofold. First, the enzymatic methods used to classify these carbohydrates were not standardized among feed analysis laboratories. This resulted in large variation in results obtained from one lab to another lab. Feed companies often used this to their advantage in reporting carbohydrate values of commercial feeds. The second pitfall of this system is that it did not classify carbohydrates according to the fate, or the affect, it had on the horse. In other

words, is the carbohydrate fermentable or does it cause a rapid glycemic response?

Feed analytical laboratories and state feed regulatory bodies are experimenting with new carbohydrate separation methods. The new techniques will allow further analytic breakdown of carbohydrate fractions according to their fate in the horse. They will also establish consistency in laboratory methods and thus test results. Ultimately, this would allow feed manufacturers to guarantee the carbohydrate fractions on feed packaging, allow feed regulatory officials to test for these carbohydrates, and most importantly assist consumers in selecting appropriate feeds.

The New System

The new carbohydrate analysis system continues to report structural carbohydrate as Neutral Detergent Fiber (NDF). However, the new system defines what used to be Non-Structural Carbohydrate (NSC) as Water Soluble Carbohydrate (WSC), Ethanol Soluble Carbohydrate (ESC) and Starch.

WSC – This is an acronym for Water Soluble Carbohydrate. These carbohydrates are extracted from a sample by dissolving them in water and then hydrolyzing with a strong acid. It consists of simple sugars + all fructans + some glucans and pectin. The simple sugars are digested in the small intestine and influence glycemic response (blood sugar). The fructans are typically fermented in the large intestine and should not impact blood sugar in horses, although research is lacking.

ESC – This is an acronym for Ethanol Soluble Carbohydrate. These carbohydrates are extracted from a sample in an 80% ethanol solution. This carbohydrate fraction is a subset of the WSC number and represents the sugar fractions that directly influence blood sugar, and the most rapidly fermentable fructans. It consists of simple sugars and short-chain length fructans.

Starch – A polysaccharide composed on repeating glucose units. Starch is found mainly in grains and is typically digested in the small intestine. Starch is also found in small amounts in many types of hay.

Fructans – carbohydrates that are made of fructose chains, sometimes with glucose molecules included. These can vary in the number of fructose molecules

(chain length). Fructose is considered to be a complex carbohydrate that requires fermentation to be digested. Thus, fructans are thought to be digested in the large intestine. This issue requires some research to clarify the digestive process in horses. Fructans are rarely analyzed separately in a feed sample since they are completely included in the WSC fraction and partially included in the ESC fraction.

The following table lists carbohydrate fractions from the Dairy One Forage Analysis Laboratory.

Ingredient	WSC	ESC	Starch	NSC
Alfalfa Hay	8.9	7.2	2.1	11
Grass Hay	10.7	7.8	2.3	13
Straw	6.5	3.7	2.3	8.8
Beet Pulp	10.6	10.2	1.4	11.8
Soybean Hulls	3.5	1.5	1.6	5.1
Corn	1.8	2.4	72	73.8
Barley	7.1	2.1	54.6	59.5
Oats	3.2	3.0	44.3	48.6

What Do We Tell Our Clients?

With new detail on carbohydrate analysis, we need to figure out what to recommend for our clients with diseased or sensitive horses. The following are several key points in talking with horse clients.

1. The term "NSC" currently is quickly becoming a dead issue. We should quit using the term and adapt to new terminology. One of the first questions asked about the new system is how does it compare to the old NSC method? The addition of WSC + Starch is the closest to what plant scientists call NSC.

2. For horses that are sensitive to sugar (Insulin Resistant, Cushing's, Tying-up) we need to evaluate the ESC + Starch value of a feed. The values listed below represent acceptable ranges for the total diet.

   Acceptable numeric values: ESC + Starch (Dry Matter Basis)

   Sick Horse: ESC + Starch = < 8%

   Non-Sick Sensitive Horse: ESC + Starch = <10%

Concerned Customer: ESC + Starch = <12%

3. For horses that have laminitis, we need to evaluate the WSC + Starch value of a feed. The values listed below represent acceptable ranges for the total diet.

   Acceptable numeric value: WSC + Starch (Dry Matter Basis)

   Horse with laminitis: WSC + Starch = <10%

4. I do not feel we can ignore the WSC value when talking about sugar sensitive horses. Therefore, for any horse that is sick (actively displaying symptoms) the WSC value should not exceed 10% dry matter. This is based on anecdotal evidence of a large number of horses, and will be updated with clinical research as it becomes available.

5. When comparing samples for clients, always utilize the same laboratory and always refer to terms on a dry matter basis.

6. We do not have all the answers, but we are staying current with research and medical evidence. We will always try to recommend feeds that will ultimately help the horse.