Carbohydrates: What Do We Know? Analyses and Feeds

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Take Home Message

- We can measure fiber and starch accurately, but there are more challenges setting assays that are specific for sugars and fructans.
- We need to learn how carbohydrate type, amount, and horse management affects how the animals respond, to learn to detect sensitive animals in the population, and to learn how to properly manage the diets and the animals together.

Carbohydrates in Feeds

There are a variety of carbohydrates in feeds that can matter nutritionally to the animal (Figure 1). Sugars, starch, fructans, pectins, and neutral detergent fiber (NDF) make up the majority of carbohydrates that we typically find in sufficient quantities to work with (following values given on a dry matter basis[1]). Sugars can be found in fresh forages and hays (3-12%), molasses (>50%), sugar beet pulp (10-20%, very variable), bakery products (variable), and other feeds. Starch is typically found in grains (corn: 70%, oats: 45%, wheat: 62%, barley: 55%) and feeds derived from them. Fructans in the equine diet usually only come from temperate cool season grasses (timothy, brome, bluegrass, etc. composition variable by grass, and weather), but not from forage legumes (alfalfa, clover) or warm season grasses (bluestem, switchgrass). Pectic substances are found in legume forages (15%) and pulps (sugar beet pulp: 30%). Fiber (NDF) comes mainly from forages and increases with maturity, but can also be found in high amounts in the fibrous byproduct feeds. The specific descriptions of the carbohydrates are below Figure 1.

Carbohydrates such as starch and sugars can be digested directly by the animal, whereas fructans, pectins, and NDF can only be digested by gut microbes. There have been discussions and concerns about the impact of dietary sugars and fructans on some animals. The problem is the present lack of information to describe which animals are likely to be sensitive under "normal" conditions, under what conditions the adverse reactions occur (why do some horses founder on spring pasture?), and ability to measure the content of the various carbohydrates in feeds to relate that back to the diets the animals consumed.

Analyzing Carbohydrates in Feeds

It has been challenging to analyze feeds to describe the content of carbohydrates that we think are nutritionally relevant to animals. A main issue has been finding out what the analyses we've been using for years are actually measuring, and trying to find ways to make accurate analyses affordable

[1]Values are approximate averages from analyses in my lab and from the Dairy One Feed Composition Library Website (Dairy One, Ithaca, NY). Values will vary by individual feed.

for those who want to use the numbers to balance diets for their animals. The analyses we have do allow some separation of the water-soluble carbohydrates, but not as perfectly as we would like. Figure 1 shows what carbohydrates the laboratory assays measure. The ethanol-soluble carbohydrates (ESC) include sugars, oligosaccharides, and some of the lower molecular weight fructans. Water-soluble carbohydrates include those in the ESC as well as the rest of the larger fructans. Total nonstructural carbohydrates (TNC) is a method that includes WSC + starch (used by agronomists, not very nutritionally relevant), and nonfiber carbohydrates (NFC) is a calculated value that includes all carbohydrates not in NDF. In addition, starch content of feeds can be measured directly and accurately.

Separate measurement of sugars and fructans is a current focus. This separation matters for the cool season grasses, because they are the main feed source that will contain fructans. The original thought that WSC minus ESC would give us an approximation of this value has not worked. The first reason is apparent from Figure 1: ESC can contain some portion of the fructans. Another unanticipated challenge: because different ways of detecting carbohydrates are used with ESC vs WSC, the results of the two methods are not necessarily equivalent depending on what types of carbohydrates are in the samples. This would explain why WSC minus ESC values are sometimes negative. Reducing sugar assays are used with WSC and phenol-sulfuric acid assays are used with ESC; reducing sugar assays cannot be used with ESC.

We continue to work with the Association of American Feed Control Officials to sort out what assays will be appropriate to measure fructans and sugars. For the moment, if someone wants to most completely measure sugars (coming from sucrose, glucose, and fructose) and fructans together, initial results from my lab suggest using a WSC assay with a reducing sugar assay for detection. If sugars are the primary concern, the ESC assay with phenol-sulfuric acid assay detection would be preferred. Neither assay is perfect, but they can be useful.

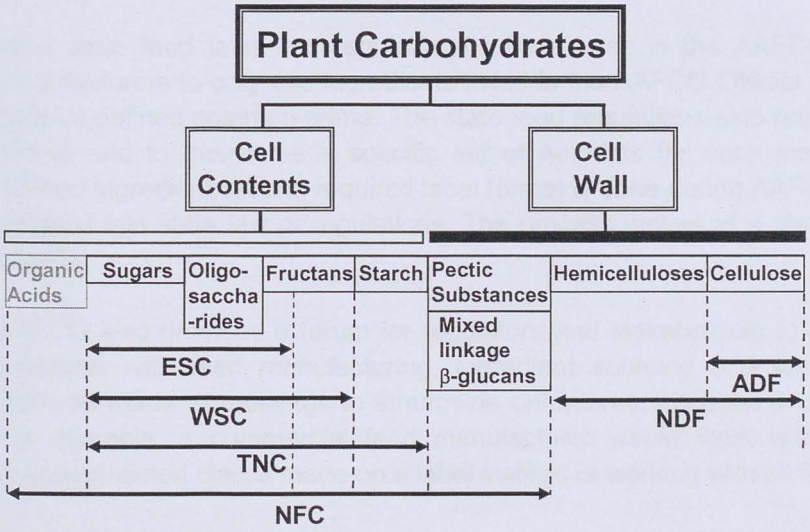

Figure 1. Carbohydrates in plants and how they analyze with common methods.

Sugars (Mono- and Disaccharides): Monosaccharides include glucose, fructose, galactose and other simple sugars. Disaccharides include sucrose (table sugar), lactose (milk sugar), and maltose (breakdown product of starch). Lactose is not very soluble in 80% ethanol.

Oligosaccharides: Are short chains of sugars (3 to 10 or 20 sugars long). Stachyose and raffinose are oligosaccharides in soybean meal. These are fermentable, but not digestible in the small intestine.

Fructans: Carbohydrates made up mostly from fructose. They include short chains (oligosaccharides) and long chains (polysaccharides) of sugars. They are found in cool season grasses, onions, and chicory. All fructans are water soluble, but the shorter chains may be soluble in ethanol solutions.

Ethanol-Soluble Carbohydrates (ESC): Carbohydrates extracted with a specific % ethanol, includes mono- and disaccharides, and varying amounts of oligosaccharides. Even 80% ethanol-soluble carbohydrates will contain at least the small oligosaccharides and fructans.

Water-Soluble Carbohydrates (WSC): Mono- and disaccharides, oligosaccharides, fructans

Total-Nonstructural Carbohydrates (TNC): WSC + starch

NonFiber Carbohydrates (NFC): 100 – (crude protein + NDF + ether extract + ash); value may or may not be corrected for crude protein in NDF so the amount is not subtracted both in crude protein and NDF. Contains organic acids (which are not carbohydrates). This is a rough estimate for carbohydrates and will contain the errors from each of the assays used to calculate it.

Notes