A Review of Factors Affecting Carbohydrate Levels in Forage

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Take home message:

Carbohydrate concentration of forages should be taken into account when formulating rations for carbohydrate intolerant equines. Carbohydrate content of pasture and hay are highly variable, and subject to many factors.

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Introduction:

There has been considerable interest recently in equine illnesses that are associated with high levels of carbohydrates (sugars and starch) in equine diets. The illnesses of concern include laminitis, Equine Polysaccharide Storage Myopathy (EPSM), and Equine Metabolic Syndrome (AKA Insulin resistance or Peripheral Cushings). Unfortunately, many individuals involved with the treatment of these diseases have the notion that carbohydrate levels are only significant in grain, when in fact, the amount of carbohydrates present in forages, both fresh forage and in dry hay, may also be very important. Recent work by Longland and Pollit show a possible role of fructan in laminitis. Fructan is a carbohydrate comprised of fructose and is generally found in cool season grasses. Such information suggests the importance of horse owners and equine care advisors becoming educated about the factors affecting

carbohydrate levels in hay and in their learning the best management practices for minimizing hydrolysable and rapidly fermentable carbohydrate content in equine forage, especially for animals prone to laminitis. Dr. Mary Beth Hall has introduced the concept of minimizing Non Structural Carbohydrates (NSC) to the dairy industry to help manage laminitis in high producing dairy cattle. We propose that the concept of reducing specific carbohydrate fractions in the equine diet can be utilized to the same effect.

Factors Affecting Carbohydrate Concentration:

Carbohydrate contents of forage can vary widely due to the interaction of plants and their environment. [1] These variables include: species and variety of the forage, stage of growth, and environmental conditions during plant growth. Environmental factors include temperature, light intensity and availability of water and nutrients.

There are several basic principles of plant physiology important to consider in managing forages. They include:

- Sugars are the substrates for all plant growth, thus, they are critical to plant growth and development.
- Sugars are produced by photosynthesis during daylight.
- At night plants use energy from sugars formed by photosynthesis to grow.
- Whenever the rates of photosynthesis exceed plant growth rates, carbohydrates accumulate.
- At times, plant stresses decrease growth rates more than photosynthesis and carbohydrates accumulate.

- Factors that contribute to plant stress include water [2] and nutrient deficiencies, salty soils, as well as cool temperatures, especially those below 5 ^{o}C. [3]
- High concentrations of carbohydrates (sugar, starch and fructan) are often present in dry hay made from alfalfa or cool-season grasses containing large amounts of carbohydrates. Preliminary data from the first year of a two year field study underway by Rocky Mountain Research and USDA-ARS Forage and Rangeland Research Lab showed that sun dried oat hay, grown under intense sunlight and night time temperatures of <5 ^{0}C maturing in the fall, had up to 4 times the fructan, and 2 times the Total Nonstructural Carb (TNC) content than adjacent oat hay in the same stage of growth, but cut in mid summer, even when the stage of growth was considered 'over mature' for acceptable hay. Stage of growth had very little correlation with either fructan or TNC concentration. (see table 1) Dry hay is lower in carbohydrates than the fresh plant material it was made from because plant tissue continues to respire and use up sugars during the drying process. The faster harvested forage dries, the greater the amount of carbohydrates left in the hay. [4]

'Rules of Thumb' Don't Always Work:

In general, mature plants that are high in fiber are low in carbohydrates. However, environmental conditions have a very large impact on carbohydrate content. Under some circumstances environmental factors may be more important than stage of plant growth. Very young, rapidly growing grass under ideal conditions are often lower in carbohydrates than at later stages of vegetative growth. Conditions in the spring and in

the fall often favor carbohydrate accumulation, regardless of the stage of plant growth. A frost, or a hot, dry wind, may cause rapid changes in carbohydrate concentrations within a very short time. Climate and plant species are so important in determining carbohydrate levels of forages that it is difficult to generalize about carbohydrate concentrations, especially in forages from various parts the country or world. Simple statements such as “avoid grazing lush grass” do not guarantee low carbohydrate levels. Certainly, there are times when ‘lush’ grass is high in carbohydrate. Instances when grass plants are cool temperature stressed, or when in the heading stage, are often troublesome times and should be of concern to care takers of sugar intolerant equines.

Strategies for managing grazing for high-risk equines:

- Choose varieties that tend to be lower in carbohydrates. Some native species of grass are lower in carbohydrates than cultivated varieties of species such as brome, ryegrass or fescue.[5] High carbohydrates grasses have been associated with laminitis and should be avoided as feed for intolerant equines. Work is under way to get better information about the amount of carbohydrates (sugars, starch and fructan) in common pasture varieties of grass.
- Limit grazing time to early morning. Carbohydrates are often lowest from 3 am to 10 am.
- Choose grazing areas that are shaded part of the day. Low sunlight limits the amount of sugars produced by green plants.[6]
- Decrease grazing time or stop grazing completely when grass is under stress from cool temperatures or in some instances frost.

- Do not overgraze pastures. The bottom few inches of grass stems often serve as a plant carbohydrate reservoir and contain high concentrations of non-fiber carbohydrates (NFC). Even though intake may be limited on an overgrazed pasture, horses may still ingest too much carbohydrate due to the high carbohydrate concentrations in stem bases, especially in late fall or during the winter in areas where grasses do not go completely dormant. [7]
- Establish a system of rotational grazing. Graze regrowth to a height of from 4-6 inches, and then move on to another section. Sugar intolerant horses should not graze grass that is starting to head out. Many horses selectively graze seed heads and the concentrations of carbohydrates in seed heads are generally much higher than in leaves.
- Save some areas of the pasture for standing hay to be grazed in winter when it is completely dead and brown—carbohydrates are very low in such grasses.
- Manage pastures for adequate, but not excessive growth. Determine fertilizer application rates from analyses of soil samples. Irrigate as needed to minimize stress without leaching fertilizer.

Choosing hay low in carbohydrates:

- In general, hay cut at a late stage of maturity contains less carbohydrates than when cut at an immature stage. This is true for both grass and alfalfa. It is often advisable to cut grass when the seed heads are readily visible and the plants appear coarse in texture. However, even mature plants may contain high carbohydrates in the fall when temperatures are cool. Premium quality alfalfa cut at pre-bloom, often intended for dairy cattle or high energy requiring race

horses, is often very high in carbohydrates and frequently present risks to sugar intolerant equines. If a horse needs additional energy or protein, feeding a flake a day of alfalfa that was cut in a more mature stage may meet that need. To increase the likelihood that alfalfa hay is low in carbohydrates, it should be stemmy and have many purple flowers.

- Low carbohydrate hay can often be fed free choice, which is an extra bonus for many 'easy keeper' horses that otherwise have to go hungry between their small meals of nutrient rich hay.
- In general, avoid hay that has been cut during stressful conditions.
- Get hay tested for Non Fiber Carbohydrates (NFC) or Non Structural Carbohydrates (NSC). Hay can range from less than 1% and more than 35% NFC on a dry matter basis. A horse with active laminitis should be fed hay that is low in NFC or NSC. Lower is better, but improvement is often seen if hay is less than 15% NFC (dm) or less than 10% NSC (dm).
- Bermuda, bluestem and many of the warm season grasses that make up native prairie hay, particularly in the southern portions of the U. S., differ from northern cool season grasses. Warm season grasses do not contain fructan. However, they may accumulate large amounts of starch but protein levels are generally less than alfalfa. Nevertheless, under proper fertilization and growth conditions these grasses can provide adequate protein for most mature horses. Improved varieties of Bermuda grass can average 12+% protein with optimum management. Less nutrient dense warm season and native grasses are often excellent choices for laminitic horses because they are high in hemicellulose,

which is a slowly fermentable source of digestible energy that will keep blood glucose and insulin levels more stable. Anecdotal evidence for increased impaction colic may possibly be addressed by gradual introduction to Bermuda hay, allowing time for increase of fiber fermenting bacteria necessary to cope with the high levels of hemicellulose, and judicious use in horses with gut motility issues.

- Soaking hay: Sugars are soluble in water, therefore, leaching the sugars out may be a useful first aid treatment for horses with active laminitis. An hour of soaking, draining, and feeding before the hay has a chance to mold will remove much of the soluble sugars from hay. This procedure may not work as well in starch accumulating plants because starch is less soluble than sugars. Protein content should not be affected by soaking in water if hay is fed promptly. Some other soluble nutrients, such as potassium, may be lost but if done on a temporary basis, while low carbohydrate hay is being sought, the benefit of minimizing carbohydrate content could outweigh any short-term loss of other valuable nutrients.

Some laminitic or otherwise sugar intolerant equines may never be able to graze green grass, or eat premium quality hay without risk. Hopefully, as additional information becomes available, owners of high-risk horses and ponies can make more educated choices in selecting forage species that will allow them to optimize grazing for their horses without jeopardizing equine health. Generally, owners do not want to keep horses shut up in stalls, or confined to dry lots away from the rest of their herd simply because they are sugar-intolerant or prone to founder on grass. More research funding

and interdisciplinary cooperation between equine and forage specialists is needed if the mysteries of why some horses develop metabolic problems from eating grass are to be unraveled.

References:

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Table 1
Excerpts from Preliminary data 2002

Oat Hay: Stage of growth vs. environmental conditions

Stage	Harv. date	"fructan"	"starch"	TNC	CP	%NDF
Tiller	5/31/02	6.01	11.12	17.13	21.58	29.00
	7/15/02	6.01 **LL**	12.1	18.11 **LL**	23.63	26.58
Boot	6/22/02	13.59 **EH**	13.01	26.6 **EH**	10.13	37.4
	8/09/02	11.85	12.85	24.71	8.3	42.33
Soft dough	7/31/02	4.03	13.83	17.86	5.2	53.6
	9/24/02	12.6 **LH**	13.84	26.44 **LH**	3.75	48.73
Mature	8/23/02	1.72 **EL**	10.71	12.42 **EL**	4.1	57.65
	10/16/02	8.1	15.4	23.51	3.73	51.35

Carbohydrate expressed as % Dry Wt. Mean of 4 reps

EH early planting highest level **EL** early planting lowest level

LH late planting highest level **LL** late planting lowest level

"fructan" includes free fructose + ½ of the sucrose

"starch" includes free glucose + ½ of the sucrose

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