Journal of Equine Veterinary Science, Aug. 2005 25(8) p. 338-344

http://www.j-evs.com/home

A Review of Unlikely Sources of Excess Carbohydrate in Equine Diets

Kathryn A. Watts, BS

.

Funded by Animal Health Foundation

Take home message:
Horses with carbohydrate intolerance may encounter excess nonstructural carbohydrates (NSC) in the form of grass hay, dying or dead grass, overgrazed pasture, and weeds, which may be higher in NSC than 'lush' grass.

Introduction

Equines suffering from laminitis, insulin resistance, Equine Metabolic Syndrome, Cushing's, osteochondrosis, and equine polysaccharide storage myopathy (EPSM) require restriction of sugar, starch and/or fructan, which is collectively called Non Structural Carbohydrates (NSC). While there is a great deal of scientific literature in plant science journals regarding factors effecting NSC content of feed and forage, the information is not convenient to veterinarians. The nomenclature that plant scientists use may be unfamiliar to veterinarians, as well as the concepts central to plant physiology. Attempts by some veterinarians to give advice regarding more appropriate feed choices and pasture management practices to owners of carbohydrate intolerant equines may be based on incorrect assumptions, and incomplete understanding of the mechanisms governing NSC concentration in forage.

This review is necessary to dispel some frequent misconceptions regarding NSC content of forage. Some forage that may be intuitively perceived as low in feed value, such as dead grass and weeds, may actually be high enough in NSC to trigger symptoms in susceptible animals. Grass founder has always been blamed on 'lush' grass. The term 'lush' is generally considered to mean green, vigorous, and well hydrated. Advice given by veterinarians on methods to avoid 'lush' grass may actually increase NSC concentration[1]. This review will demonstrate how brown, dead or dying, desiccated grass can have surprisingly high levels of NSC, and explain the concepts of plant physiology that govern NSC accumulation in grass. This may explain onset of some previously mysterious cases of endocrinopathic laminitis, or worsening of symptoms in other diseases involving carbohydrate intolerance.

There are some common misconceptions about the relative levels of Non Structural Carbohydrate (NSC) in horse feeds. While most horse owners recognize that molasses and grain are high in sugar and starch, they do not realize that excess NSC may be found in other portions of horse rations. This review of the NSC content of the non-grain portion of equine rations may provide practitioners and caretakers with information to fine-tune the diets of CHO intolerant equines.

Misconceptions about NSC content of common feeds

The following Table 1 contains data from the online database of Dairy One Forage Analysis Laboratory, of Ithaca, NY over several years. NSC as tested by this lab includes sugar, fructan and starch. Other laboratory tests may not be equivalent, as procedures are not standardized. Evidence reported by owners of horses suffering from refractory endocrinopathic laminitis suggests that replacing high NSC hay with hay containing less than 10% NSC on a dry matter basis may alleviate symptoms.

Table 1. NSC content of some common feeds

	Mean NSC	Normal range
Grass hay	13.8	9.2 -18.4
Alfalfa hay	11.3	8.8 -13.9
Oat hay	22.1	15.0 - 29.1
Straw	11.7	5.2 -18.2
Bermuda hay	13.5	9.4 -17.7
Beet pulp	12.2	7.0 -17.5
Soybean hulls	6.2	3.1 -9.4
Wheat bran	30.8	22.8 -38.9
Oats	54.1	40.7 -67.5
Corn	73.3	69.4 -77.3
Barley	61.6	56.7 -66.6
Molasses	62.0	48.1 -76.0

% dry matter basis, from Dairy One feed composition library, Ithaca, NY
http://www.dairyone.com/Forage/FeedComp/disclaimer.asp

Note that the normal range for grass hay includes a two-fold difference in NSC content. Some grass and hay, and even straw may be too high in sugars for CHO intolerant animals. Many people consider oat hay 'less rich', than the alternative, which is often alfalfa. While alfalfa has more protein than oat hay, it averages half the NSC as oat hay, although it can go as high as 20% NSC under certain conditions. Protein is no longer being implicated as a cause of laminitis in horses. Average oat hay is too high in NSC for most carbohydrate intolerant horses. Note the high normal range of oat hay goes up to 29% of dm. This author has tested pre-heading oat hay repeatedly frozen in late fall that was 35% NSC dm. This is mostly sugar and fructan, not starch, and is not the consequence of fully formed grain. Sugar and fructan are precursors for starch formation, and are found in high levels in the stem before seed heads fully develop, which is when most oat hay is cut. Grass and hay from cool season grasses like orchard, brome, timothy, fescue, and Kentucky bluegrass will tend to be higher in NSC when grown in climates with intense sunlight and/or cooler nights.

Bermuda grass hay is generally considered to be lower in NSC, when compared to cool season grasses, but note the wide range in NSC concentration. Bermuda grass hay is often low in NSC in the southern parts of the US, where high humidity creates cloudy conditions, minimizing photosynthesis and production of sugars, while slow hay drying maximizes respiratory loss of sugars. The same variety of Bermuda may be too high for CHO intolerant horses when grown under sunny, arid conditions, such as found in California. The NSC figures on the higher end of the normal scale will represent these conditions.

Some horses do not thrive on straight alfalfa diets, possibly due to *excess* protein that may then be metabolized as energy. Some horses exhibit sensitivity to even small amounts of alfalfa due to some as yet undefined component other than NSC. Many carbohydrate intolerant horses do well on small amounts of alfalfa necessary to bring protein levels up to optimum when mixed with other low protein grass hay or straw.

It seems logical to many horse owners that brown, stemmy, over mature hay should be low in sugars. While there is a general tendency for over mature hay to be lower in NSC, stressful environmental conditions just before hay cutting are more important than stage of growth. (Chatterton, Watts, unpublished data) Many cases of refractory laminitis have been resolved

after testing disclosed that the coarse, unattractive hay being fed contained unacceptably high levels of NSC. It is imperative that testing for NSC by an appropriate forage testing laboratory be conducted before purchasing hay for CHO intolerant horses.

Bran is considered by many people to be mostly fiber, and is often fed on an occasional basis, such as a special treat on a cold morning, or to an ailing horse. Note that wheat bran averages 31% NSC, which is nearly triple the amount of NSC than average grass hay. Bran also has a very wide range of NSC, depending on how much of the flour has been left in the bran. Some feed stores may substitute wheat middlings or even mill run wheat for wheat bran, and will adamantly contend that it is the same thing as bran. Advise clients of CHO intolerant horses to avoid wheat bran.

Dead grass can be high in NSC

When cool season grasses are subjected to freezing temperatures, growth slows or ceases, but they do not go dormant immediately. If daytime temperatures are above freezing, and are sunny, sugars continue to form and can accumulate. In autumn, those parts of a grass plant that are still green may have the highest sugar and/or fructan concentration of the year. High levels of sugars act as a cryoprotectant in grass, up to a point[2]. Even very high levels of sugars cannot protect against cellular death when temperatures get well below freezing. When plant cells die and rupture from freezing, these accumulated water-soluble sugars and fructans may then be leached out by late fall rains, or early winter snows that melt during the day. However, in areas with little or no rainfall, these accumulated sugars remain in the dead tissue. Under extreme low humidity, snow may sublime rather than melt. Some grasses have a protective, waxy cuticle layer, which resists leaching of nutrients even when completely dead and brown. Such is the case with fescue, which is known for its ability to maintain nutrients when fed as 'standing hay' or 'stockpiled forage'. Dry conditions prevent leaching of accumulated carbohydrates, and even completely dead grass in mid winter may have levels of sugars and/or fructans that are dangerous to horses with CHO intolerance.

This perennial ryegrass contained 39.7% dry matter NSC on Jan. 1, 2004 during a drought. Lack of precipitation prevents leaching of water soluble carbohydrates, such that even dead grass may be too high for laminitic horses to graze.

The grass samples detailed in Table 2 were taken in southern Colorado during a drought. Both the fescue and brome/Kentucky bluegrass pastures caused reoccurrence of laminitis immediately prior to first sampling in 3 chronically laminitic ponies. Total precipitation from November 2003 through end of February 2004 was 1.2 inch of water as snow. The highest amount in a single event contained .23 inch of water. The rest of the samples were pulled from pure stands in plots at Rocky Mountain Research and Consulting, Inc. The fescue pasture was from another site that received a fairly substantial snowfall between the 2 sampling dates. The samples pulled January 1, 2005 received a total of .34 inches of precipitation through November and December.

Table 2: Dead grass in mid-winter under drought conditions

		NSC*	Starch	Sugar/ fructan
Fescue pasture	12-21-03	29.6	1.1	28.5
	01-07-04	15.1	0.3	14.8
Brome/KBG pasture	12-15-03	15.4	1.2	14.2
	01-04-04	9.4	1.1	8.4
	02-21-04	8.6	0.8	7.8
	01-01-05	5.1	1.4	3.7
Crested wheatgrass	01-01-04	13.9	1.1	12.8
	02-23-04	18.2	1.6	16.6
	01-01-05	23.5	0.9	22.7
Orchard grass	01-01-04	20.6	1.6	19.0
	02-23-04	21.8	1.0	20.8
	01-01-05	29.9	1.1	28.8
Tall fescue	01-01-04	31.7	0.8	30.9
	02-23-04	30.3	1.1	29.2
	01-01-05	32.7	1.3	31.4
Perennial ryegrass	01-01-04	39.7	0.7	38.9
	02-23-04	25.2	0.7	24.4
	01-01-05	32.6	1.3	31.3

*Percent of dry matter.
Single reps, Center, Colorado Analysis by Dairy One, Ithaca, NY

Some weeds may be high in NSC

While many horse owners acknowledge that certain horses require restricted access to grass, it is generally thought that weeds have little nutritional value. They are surprised when their horses get laminitis on pasture that is mostly weeds, with very little grass. It is common knowledge to cattle producers that certain weeds have very high nutritional value, especially carbohydrate content. Kochia is acknowledged as palatable, desirable cattle feed in arid regions[3]. Redstem filaree was originally imported to the US as animal fodder by Spanish explorers. It is now a very common weed in the southwest of the US and frequently found in non-irrigated turn out areas after winter rains. It remains green even after a hard freeze, which indicates high simple sugar content. It contains no fructan, but can be high in trisaccharides (P. Harrison, USDA-ARS-Forage Rangeland Research Lab., personal communication) This weed has been implicated in reoccurrence of laminitis in susceptible animals when its presence was the only change in diet.

	NSC	starch	Sugar/ fructan
Dandelion	27.0	1.3	25.7
Redstem filaree	28.1	4.2	23.9
Red clover	18.1	1.8	16.2
Sweet clover	14.1	3.3	10.8
White clover	11.8	.1	11.7
Mallow	12.8	3.3	9.6
Kochia	12.0	3.6	8.4
Quackgrass	18.1	1.6	16.5
Wild oats	26.4	3.4	23.0

Table 3: NSC content some common pasture weeds
% dry matter basis, Single rep,various conditions, Center, Colorado, Analysis by Dairy One, Ithaca, NY

Other weeds cultivated for cattle fodder are chicory and plaintain[4]. Chicory is the source of inulin, a type of fructan used to induce laminitis in horses and cattle in clinical trials[5,6]. Thistles and dandelion also have this same type of fructan[7].

Overgrazed pasture may have higher NSC content

Grass stems are higher in NSC than leaves. The stem base of grass plants is considered a CHO storage organ for many species of grass. The content of CHO is higher when sampled closer to ground level[8]. This is an adaptive advantage, allowing the plant to maintain reserves for re-growth after the tops have been consumed by grazing animals. Thus, stubble left from hay production may be very high in NSC concentration. While overgrazed pasture may limit intake, the concentration of NSC in available forage is higher. If horses with CHO intolerance have free choice, or increased turnout time on such pasture because the caretaker perceives a lessening of risk due to lower intake, they may suffer from this higher NSC concentration.

Organically grown forage may be higher in NSC

There is a common perception that forage grown without the use of commercial fertilizer is somehow more 'natural' and therefore healthier for ill horses. Practitioners of homeopathic medicine sometimes instill fears of chemical residues from pesticides or commercial fertilizers. It is well documented in plant science journals that forages grown under nitrogen or phosphorus deficiency are higher in NSC than forage grown with optimum amounts of fertilizer. [8,9,10,11] If nitrogen is a limiting factor for growth, NSC's accumulate in grass, which would otherwise be utilized for production of fiber and energy. Adequate nitrogen stimulates optimum growth thereby fully utilizing NSC produced during photosynthesis. Unless nutrient requirements are met by some other means, organically grown forage may be higher in NSC.

The following data was collected from the first cutting of forage from an established paddock of irrigated pasture at Rocky Mountain Research & Consulting, Inc. Each treatment was replicated 4 times in a randomized block design. The species represented are mostly Paddock meadow brome and Garrison meadow foxtail, which are standard commercial varieties in the area. Ammonia nitrate was broadcast in March, and irrigation was applied as needed for optimum growth to both fertilized and unfertilized plots. When the paddock was starting to head the end of May, samples for NSC were collected 4 PM, frozen immediately, and shipped frozen for analysis. A light frost occurred the night before sampling. The next day, 2 sq yards of plant material were hand clipped to ground level from each plot, and dried in an oven to obtain dry matter yield. The plots fertilized with ammonia nitrate yielded 3 times more dry matter, and were 29% lower in NSC concentration than unfertilized. This inverse relationship between nitrogen content and NSC concentration corroborates that found in plant science literature.

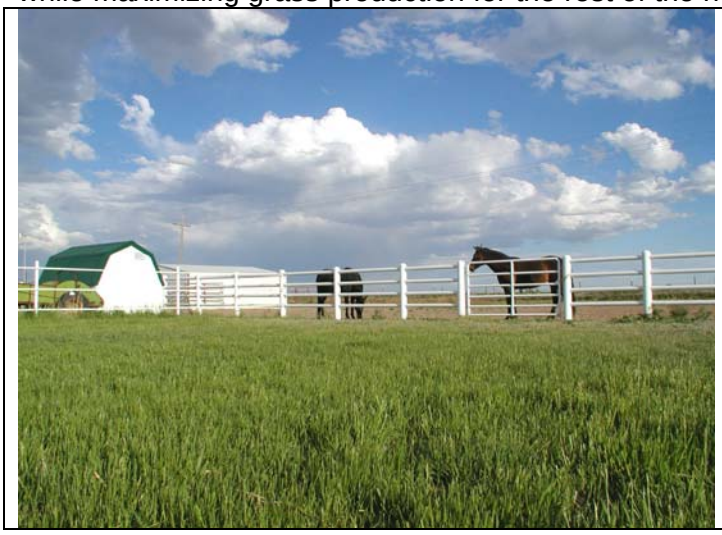
Table 4: NSC Content of Fertilized vs. Non fertilized pasture

	NSC % Dry matter	Yield Tons Dm/ acre	Pounds NSC /acre
35 lbs/acre nitrogen as AmNO3	17.88 b	1.8 a	643 a
No nitrogen	23.10 a	.6 b	277 b

Mean of 4 reps, Duncan's Multiple Range Test, P= .05,
Analysis by Dairy One, Ithaca, NY

The determination as to whether NSC concentration or pounds of NSC per acre is more important will be dependent on how the individual horse's intake is managed. If a horse has continual access to pasture, it is possible to limit grass intake by starving the grass for nitrogen and overgrazing such that the amount of available forage does not exceed or even meet caloric needs. In this scenario, additional hay is often required. Because hay is generally lower in NSC than fresh grass, the higher concentration of NSC in nitrogen deficient grass may be offset by the lower concentration generally found in hay. In this type of situation, susceptible horse's may be at increased risk of over indulging if the pasture is fertilized or irrigated, or a drought breaking rain occurs, which would then create more pounds of NSC per acre, while removing the limitations to intake imposed by slow grass growth.

If the caretaker were limiting intake by restricting access to grass, by use of grazing muzzle, portable fencing, or removal to a dry lot for part of the day, then fertilization, which decreases the concentration of NSC per mouthful of grass, would be the best option. The cost of the above fertilizer treatment was about $15/acre. Tripling grass production on a farm with more horses than grass is an extremely cost effective practice. Additionally, the increased vigor from optimum fertilization permits grass to compete with weeds, supports growth of dense sod that protects from high traffic damage, prevents erosion, and promotes stand longevity so that costly reseeding may not be necessary. Considering that most horse farms only have a few animals that require restriction of NSC intake, utilizing dry lots or grazing muzzles for those individuals, while maximizing grass production for the rest of the herd seems the most logical approach.



Environmental conditions that affect the NSC content of grass are impossible to control. Limiting access to grass if the best way to manage horses with chronic laminitis or obesity. A large dry lot is a must to provide adequate room for self exercise.

Lush grass is not higher in NSC than water stressed grass

Grass founder is often associated with 'lush' grass, although this term does not describe grass that is particularly high in NSC. Many people equate 'lushness' with high water content, vivid green color, and vigorous growth. From this they erroneously conclude that grass with low water content, more brown or dead leaves, or less vigorous growth should be lower in NSC. Veterinarians have blamed irrigation and fertilization for increased risk of grass founder[1]. Searches of plant science journals reveal no association between higher NSC concentration and high water content of grass. Actually, the opposite holds true. Studies on the affect of drought stress on NSC content of grass generally show increased NSC when subjected to long-term drought stress. The affect of water stress on NSC concentration of grass is dependent on species[12], duration of the drought[13], and variety[14]. Some species may respond to drought with dramatic increases in simple sugars[15], while other species may respond to drought by increases in fructan[12,14].

As part of the same fertilizer study mentioned above, the paddock was subjected to simulated drought in mid July by decreasing amount and frequency of irrigation over a 2-week period until the grass was severely drought stressed. The overlapping configuration of irrigation sprinklers created a pattern of drought stress in the test site, with some areas still fairly vigorous and healthy, while the areas without overlapping application at the edges of the paddock went completely brown and dormant. The fertilizer program had no statistically significant affect on the NSC content of the grass under drought stress, indicating that the drought stress was more of a limiting factor to growth than nitrogen deficiency. A set of samples were pulled from only the 35N/acre commercial standard fertilizer plots (4 replications, N=8); one from each of the wettest areas, and one from an adjacent dry area in each plot. These were frozen immediately and shipped frozen to Dairy One, Ithaca, NY. Both wet and dry samples averaged 14.1% dry matter NSC with very little variability between replications. Grass with higher water content, i.e. more 'lush', was not higher in NSC on a dry matter basis. The water stressed samples averaged 4.5% NSC as fed, while the wetter samples averaged 3.8% NSC as fed. Intake of NSC would therefore be higher for a horse eating dry grass, especially in a grazing scheme incorporating restricted turn out time as a means to limit grass intake. Because dry matter content is higher in dry grass, there is more NSC per mouthful of dry grass. There is no advantage to purposely withhold irrigation water as a means to decrease risk of grass founder in susceptible animals. There is risk of increasing NSC in drought stressed grass, depending on species and duration of the drought. Green does not founder horses. High water content of grass does not founder horses. If owners perceive reduced risk by allowing grazing on grass that is not 'lush', their highly susceptible animals may suffer.

Grazing muzzles, strip grazing, or limiting grazing time are all better options than purposely stressing grass by withholding water or fertilizer in an attempt to limit intake by slowing grass growth. "Lush" is a meaningless term to describe grass with high risk for development of laminitis. Healthy grass, growing at a steady rate, is lower in NSC than stressed grass. When describing high risk grass, 'stressed' is a better term. Cold, droughts, over grazing and nutrient deficiency are all stresses that increase NSC concentration in grass. Any forage, including weeds, that a CHO intolerant horse may eat should be appropriately tested for NSC content. Looks can be very deceiving. There is a great deal of plant science literature on carbohydrate content of forage that should be reviewed before making assumptions about pasture management practices to minimize CHO content of forage for horses at risk of laminitis.

References

(1) King, C, Mannsmann RA, Preventing Laminitis in Horses: Dietary Strategies for Horse Owners, Cl Tech in Eq Pract 2004; 3:96-102.

(2) Dionne J, Castonguay Y, Nadeau P, and Desjardins Y. Freezing tolerance and carbohydrate changes during cold acclimation of green-type annual bluegrass (*Poa Annua* L.) ecotypes. Crop Sci 2001;41:443-451.

(3) Beck R, Steer Diets in Southeastern Colorado. J. Range Man.1975;28:48-52.

(4) Sanderson MA, Labreveux M, Hall Mc Elwinger GA, Nutritive Value of Chicory and English Plantain Forage. Crop Sci. 2003;43:1797-1804.

(5) French KR, Pollitt CC, Equine Laminitis: loss of hemidesmosomes in hoof secondary epidermal lamellae correlates to dose in an oligofructose induction model: an ultrastructural study. Equine Vet J 2004;36 (3):230-235.

(6) Thoefner MB, Pollitt CC, van Eps AW, Milinovich G, Trott D, Wattle O, and Andersen P. Acute bovine laminitis: A new induction model using alimentary oligofructose overload. J. Dairy Sci 2004;87:2932-2940.

(7) Suzuki M, Chatterton NJ. Science and Technology of Fructans, Boca Raton, FL: CRC Press, 1993;245-246.

(8) Smith D: Nonstructural Carbohydrates. In Butler GW, Bailey RW ed. Chemistry and Biochemistry of Herbage, vol 1. London: Academic Press, 1973;105-155.

(9) Belesky DP, Wilkinson SR, Stuedemann JA: The influence of nitrogen fertilizer and *Acremonium coenophialum* on soluble carbohydrate content of grazed and non-grased *Festuca arundinace.,* Grass Forage Sci 1991;46:159-166.

(10) Donaghy DJ, Fulkerson WJ: The impact of defoliation frequency and nitrogen fertilizer application in spring on summer survival of perennial ryegrass under grazing in subtropical Australia, Grass Forage Sci 2002;57(4):351.

(11) Morvan-Bertrand A, Boucaud J, Prud'homme M, Influence of initial levels of carbohydrates, fructan, nitrogen and soluble proteins on regrowth of *Lolium perenne* . L. cv. Bravo following defoliation. J Exper Bot 1999;50:1817-1826.

(12) Clark G, Zuther E, Outred H, McManus M, and Heyer A. E. et al, Tissue-specific changes in remobilization of fructan in the xerophytic tussock species *Festuca novae-zelandiae* in response to a water deficit Functional Plant Biol 2004; 31:377-389.

(13) Thomas H, Aneurin RJ, Partioning of sugar in *Lolium perenne* (perennial ryegrass) during drought and on rewatering. New Phytol 1999;142:295-305.

(14) Volaire F, Lelievre F: Production, persistence, and water-soluble carbohydrate accumulation in contrasting populations of *Dactylis glomerata* L. (orchard grass) subjected to severe drought in the south of France. Aust J Agric Res 1997;48:933-44.

(15) Spollen WG, Nelson CJ: Response of fructan to water deficit in growing leaves of tall fescue. Plant Physiol 1994;106:329-336.