Soaking Hay to Remove Excess Soluble Carbohydrate and Potassium

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Purpose

To determine if soaking a variety of different hays in cold or hot water for specified periods of times results in a reduction of the Water Soluble Carbohydrate (WSC) and/or potassium (K) content as a tool in the management of horses with laminitis, insulin resistance or HYPP.

Introduction

Laminitis has long been associated with feeds that are 'too rich'. Unfortunately, this term is far too general to provide a strategy for a practical approach to diet management of laminitic horses. With the new research being conducted on Equine Metabolic Syndrome, hormonal mechanisms implicating intolerance to sugars and insulin resistance are being linked to chronic laminitis. Other current research is focusing on fructan, another type of polysaccharide found in cool season grasses, which can cause drastic changes in gut micro-flora that can set the stage for laminitis. It has been widely accepted that too much grain in the diet can cause these problems, and it has been generally thought that hay cannot have enough sugar content to be an issue for these horses. However, for the last 20 years, plant breeders have been focused on increasing carbohydrate levels in new grass varieties. High sugar levels in forage increase palatability, and therefore intake. This increases weight gain and milk production in cattle. High carbohydrate levels are also one of the mechanisms by which plants become more productive and achieve a competitive advantage over other plants, allowing them to grow earlier in the spring, survive drought, and long, harsh winters. Consequently, selection by plant breeders for these survival traits will also inadvertently select for high carbohydrate levels. New varieties of forage, while a valuable tool for the cattle industry, may be inappropriate for equines prone to laminitis, obesity, or insulin resistance due to high sugar content.

In addition to changing genetics, it has long been known to plant physiologists that certain environmental conditions will cause accumulation of sugars and fructans. Sugar is soluble in water, and at least the shorter chain fructan are soluble, therefore both will be fractions included in the term Water Soluble Carbohydrates (WCS). Sunny days combined with cold nights causes the sugars produced by photosynthesis during the day to accumulate when growth that occurs at night is restricted. Other factors that may increase WSC in hay are drought stress, nutrient deficiencies, and high salt content of the soil. Because there are so many factors that affect the WSC content of hay, appropriate analysis of each batch of hay is the only way we can know. Testing for sugars and starch in feed is a new, emerging technology for commercial forage testing labs, but fortunately the dairy industry is leading the way, as they are having their own problems with high carbohydrate rations creating metabolic acidosis and laminitis.

HYPP (Hyperkalemic Periodic Paralysis) is a hereditary genetic disease found in Quarter Horses of the Impressive line. It is a defect in sodium channeling in the muscle tissue, which can be triggered by high levels of potassium (K) in the blood. Horses with HYPP can experience unpredictable attacks of paralysis, which in severe cases, can lead to collapse and sudden death. The cause of death usually is cardiac arrest and /or respiratory failure. Some testing facilities are showing 1% of the Quarter Horse breed to be homozygous for the trait. Specialists in the treatment of the disease recommend limiting alfalfa in the diet, under the assumption that grass hay is usually lower in potassium. Others recommend a specially formulated complete pellet ration to avoid the often high levels of potassium that can be found in all types of forage.

Sugar, fructan and potassium are all water soluble in both alfalfa and grass hay. Simple sugars, disaccharides, and short chain fructan are soluble in cold water, while the longer chain fructans are soluble in hot water (P. Harrison, USDA-ARS, Forage and Rangeland Research

Lab, personal communication) Potassium in forage is in the ionic form, not bound to any other fractions, and also soluble in water. (V. Allen, Forage and Livestock Systems, Texas Tech. U., personal communication) Soaking hay to reduce dust and allergens for horses that have heaves is already a common practice in horse care. We propose that soaking hay can be a practical method for reducing WSC and potassium in the treatment of horses with laminitis, insulin resistance, or HYPP.

Procedure

Fifteen hay samples of multiple varieties were split into four representative subsamples of up to 50g each. When original sample size was insufficient the samples were split into four samples of equal weight. The four subsamples were designated as A) Dry, no soaking, B) soaked for 30 minutes in room temp. tap water, C) soaked for 60 minutes in room temp. tap water, or D) soaked for 30 minutes in hot tap water. The room temp tap water averaged 27.8 C and the hot tap water, 50.3 C. Samples were soaked in 4 L of water. Upon cessation of the soaking period, the water was poured off and the samples were removed from the beakers and allowed to briefly drain. Samples were placed in aluminum pans and dried at 60 C overnight. Once dry, they were ground through a UDY Cyclone Mill fitted with a 1 mm screen and analyzed for sugar and potassium (K). The Dry (A) samples were simply dried, ground and analyzed.

Sugar was determined using the procedure of Hoover and Webster as outlined in their publication “Determination of Nonstructural Carbohydrates”. Samples were extracted in hot water followed by an acid hydrolysis and reaction with potassium ferricyanide to measure sugar colorimetrically.

Potassium was measured by inductively coupled plasma (ICP) spectroscopy. Samples were “dry” ashed at 500 C for 4 hours followed by a “wet” ash with 6N HCl. The resultant residue was extracted with a mild acid solution (1.5N HNO3 + 0.5N HCl) and analyzed for potassium using a Thermo Jarrell Ash IRIS Advantage inductively coupled plasma radial spectrometer.

Table 1: Results from various soaking treatments

Percent dry matter

	Sugar,%				Potassium,%			
Sample	Dry	30m	60m	30m-hot	Dry	30m	60m	30m-hot
1	10.0	8.0	6.2	8.2	2.68	1.43	1.01	1.39
2	13.0	10.8	10.8	9.9	2.02	1.26	0.92	1.08
3	10.0	9.3	6.6	6.4	2.45	1.63	1.13	1.24
4	16.1	12.2	10.8	10.8	1.89	0.86	0.75	0.61
5	10.6	8.9	9.2	8.9	1.95	1.06	1.06	0.79
6	19.3	20.0	13.9	16.8	1.47	0.94	0.82	0.83
7	12.2	10.4	7.6	11.2	2.49	1.01	0.72	0.92
8	4.4	4.4	3.0	3.6	2.61	1.06	0.71	0.90
9	7.5	4.3	4.1	2.9	1.09	1.22	1.06	1.15
10	7.3	5.1	4.0	3.8	3.45	1.27	1.03	1.12
11	14.2	11.6	10.7	12.2	2.01	1.14	1.06	1.11
12	7.0	5.4	6.2	5.3	1.95	1.11	1.19	1.09
13	8.9	8.7	8.9	8.6	0.96	0.66	0.76	0.68
14	34.4	26.5	22.8	17.6	2.51	1.52	1.23	1.04
15	16.1	8.5	7.1	8.3	1.75	0.85	0.72	0.99
avg	12.7	10.3	8.8	9.0	2.09	1.13	0.94	1.00
Average Reduction		-19%	-31%	-29%		-46%	-55%	-52%

Description of hays used in the test:

1. Alfalfa, 100% San Luis Valley, CO, very bright green, some blooms, leafy, some coarse stems
2. Alfalfa 100% cut in Sept. SLV, very bright green, leafy, some coarse stems, more stems than #1
3. Alfalfa 50%, brome 50%- SLV. duller green. Alfalfa is fairly stemmy with blooms, brome is headed out, and fairly coarse in texture.
4. Alfalfa 75%, brome 25%, SLV, cut in Sept., very bright green, alfalfa is fine stemmed, no blooms, brome is leafy, fine texture, no heads
5. Alfalfa 75%, brome 25%, SLV. Very bright green, alfalfa has some coarse stems, but leafy, brome is fine texture, no heads with a few brown leaves. Same hay as #2, but from a grassy bale.
6. Mixed grass 95%, 5% alfalfa mix, eastern WA, alfalfa is coarse and mature with few leaves, grass is fine textured, and mature, grown under drought stress
7. Brome grass 90%,10% alfalfa, SLV 2001 only one cutting in Aug. Alfalfa over mature and stemmy, brome is headed, coarse, stemmy, duller green, some brown leaves.
8. Fescue/orchard? Mix grass, NC,. dull green with tan, coarse, headed out.
9. Garrison meadow foxtail/brome/Canadian thistle, SLV, 2nd cut, duller green, medium texture, headed out
10. Orchard grass, CA all leaf, no heads, dull green, some brown leaves, fine texture
11. Garrison meadow foxtail 40%/native meadow 60%(Carex, Juncus) SLV, bright green, very fine texture, headed, cut under drought stress,
12. Coastal Bermuda, East TX, pale green/mostly tan, fine textured but stiff, headed out
13. Blue grama grass straw, SLV, mostly tan, very fine stemmed, but stiff, after threshing 2X for seed production.
14. Oat hay, SLV, very bright green, coarse texture, cut in flowering stage, early Oct after many nights with hard freeze, and extremely low humidity (nurse crop for alfalfa)
15. Oat hay, SLV, cut milk-soft dough, pale green to mostly golden

Typical composition of hays appear in Table #2. This data is from hay samples analyzed by the Dairy One Forage during the period spanning from 5/01/02 – 4/30/03. Samples are from across the US and are broken down into four broad categories:

Legume; >85% legume
Mixed Mostly Legume; 50 - 85% legume
Mixed Mostly Grass; 50 – 85% grass
Grass; >85% grass

Table #2. Average values for hays analyzed by the Dairy One Forage Lab from 5/01/02 to 4/30/03. (All values DM basis)

	Legume			MML			MMG			Grass		
	n	avg	sd	n	avg	sd	n	avg	sd	n	avg	sd
CP%	8811	21.3	2.7	2279	16.9	3.1	2868	12.1	3.5	3957	10.8	3.8
ADF%	8731	30.0	3.7	2277	34.7	4.6	2866	38.7	4.3	3918	39.0	4.5
NDF%	8741	38.6	5.3	2277	49.2	7.5	2867	60.4	6.9	3936	63.1	6.4
Sugar%	**3806**	**9.1**	**1.7**	**1072**	**9.0**	**2.0**	**1268**	**9.7**	**2.6**	**1711**	**10.5**	**3.6**
Ca%	7842	1.54	0.27	2219	1.19	0.30	2800	0.74	0.28	3832	0.54	0.22
P%	7842	0.28	0.05	2219	0.28	0.05	2800	0.26	0.07	3832	0.24	0.09
Mg%	7789	0.31	0.06	2210	0.28	0.06	2798	0.23	0.06	3814	0.21	0.08
K%	**7794**	**2.35**	**0.52**	**2212**	**2.08**	**0.47**	**2800**	**1.91**	**0.49**	**3822**	**1.89**	**0.56**

n= number of samples analyzed

Discussion: Factors affecting Sugar levels in Forage:

The San Luis Valley, in south central Colorado, is 7,600 ft. altitude at the valley floor. The high altitude, thin, dry air, extreme diurnal temperature fluctuation, overall cool temperatures and abundant sunshine make it a perfect climate to study the affects of high WSC accumulation in forage. Although it is very feasible to duplicate these conditions in other areas of the country, as shown the data summarized from nationwide tests in table 2, the majority of the samples used in this test are not representative, but might better be considered 'worst case scenario'. Sugar levels this high may be found anywhere that the various environmental conditions conducive to accumulation may manifest. During the 2002 growing year, when these SLV samples were grown, the San Luis Valley experienced an extreme drought. Although everything grown here is under irrigation, most were under sub-optimum irrigation, and there were hotter, drier winds than normal, creating stress conditions even if the soil was wet. Based on known history, the hays that were subjected to notable drought stress were Sample # 6,11 and 15, all of which tested on the higher end for sugar content.

Hay that dries quickly will have more sugar than the same hay dried slowly. This is because cut forage will continue to respire and metabolize sugars until the moisture levels are below about 40%. The drought in 2002 created conditions that both caused more accumulation of sugars in the hay during growth, and the extreme low humidity created optimum conditions for maintaining the high sugar levels during hay drying in the field.

Another known trigger for the accumulation of sugars in forage is cold stress, which is exacerbated by high levels of sunshine. If photosynthesis is at maximum, while respiration and growth during a cold night are slowed, the sugars, which are the products of photosynthesis, accumulate rather than proceeding with assimilation into other plant constituents. This instigates the development of fructan, which is the preferred storage carbohydrate in cool season grasses. Nightly freezes are normal by the end of September in the San Luis Valley, and the data shows that hay cut during this period is higher in sugar as shown by samples 2,4,5 and 14. Sample #14 is a very special case. This was a late planting of oats used as a nurse crop for alfalfa. The week before cutting it was subjected to repeated hard freezes in the low 20 ^{0} F range. The days were very sunny and with low humidity, allowing the hay to dry very quickly, which minimized respiratory losses. The resulting sugar level of 34.4% of dry matter is probably unusual, although it's inclusion in this data set is hopefully educational for just how high sugar levels can get in forage under worst case conditions. This hay is extremely attractive, very palatable, and if purchased without knowledge of its sugar content would undoubtedly make the buyer feel that they had made a very good choice.

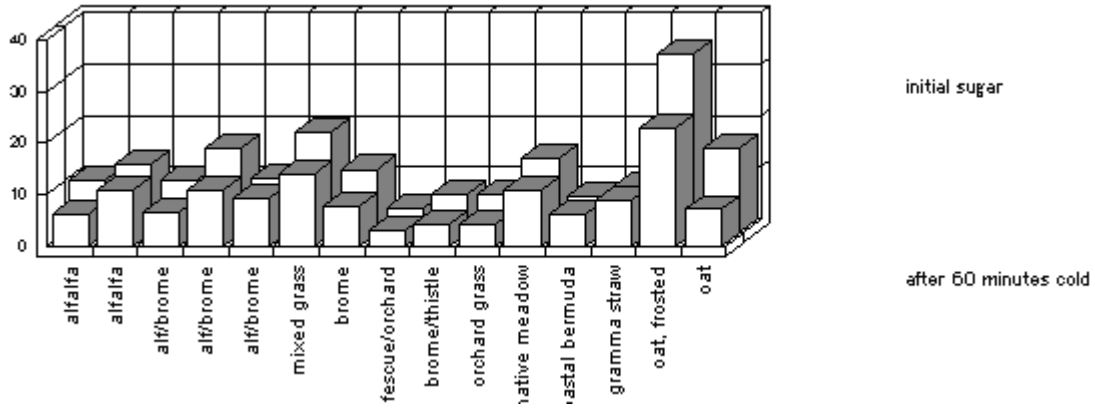
Results: Sugar reduction:

The amount of reduction in sugar content was linear in respect to the period of time that the samples were soaked. The average amount of sugar reduction after 30 and 60 minutes in cold water was18.9 and 30.7%, respectively. Generally, soaking for 60 min in cold water extracted the same amount of sugar as 30 minutes in hot water. Two exceptions were sample #9, which had a considerable amount of Canadian thistle mixed in the hay. The fact that the type of fructan in broadleaf plants is of the inulin type, whereas grass has fructan of the phlein type may be a factor in that longer chain fructan requires hotter water for extraction. One other exception was sample #12, which was Coastal Bermuda grass. This may be explained by the fact that as a C4 plant, Bermuda accumulates starch rather than fructan, which would also be more soluble in hot water. In this study, the amount of WSC remaining after a 60 minutes soak in cold water was strongly correlated (r^2=.892, p=0.0001) to the initial amount of sugar in the sample.

There was a fairly wide range of % reduction in sugars, from a high of 55.9% and a low of zero reduction. There is some correlation with the maturity of the samples. Those that did

not release as much sugar tended to be very mature, stemmy and 'stiff'. An explanation for this might be that high levels of lignin may prevent penetration of water through the tissue. Further studies that quantify other constituents are needed to better define those hays that may not be salvageable by soaking. .

Sugar levels



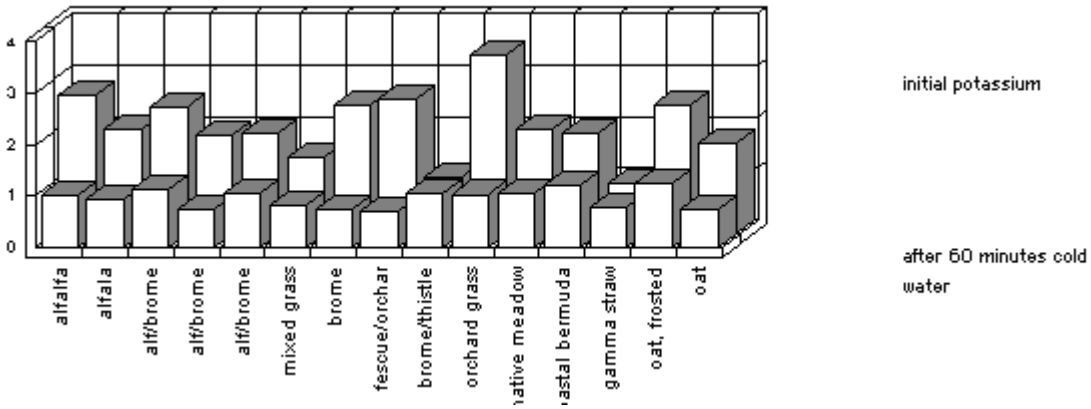
Factors affecting Potassium levels in forage:

Note that the samples highest in potassium in this study included grass and oat hay. Those over 2.5% initial K were an orchard grass hay, a mixed grass, an oat hay, and one alfalfa sample. Potassium levels in soils vary widely by geographic region. Generally speaking, in areas of low rainfall, such as the desert southwest, soils often have high levels of potassium due to high levels in parent material and absence of rainfall to leach out the excess. Areas with high rainfall have soil that is generally lower levels of potassium, and subsequently farmers are often required to add fertilizers containing potassium. Long-term flood irrigation may leach out excess potassium, as it is also fairly soluble in soil. This dissolved potassium may also accumulate in irrigation tail water, and if subsequently returned to the main irrigation canal may increase potassium levels downstream. Application of manure may result in high levels of soil potassium, with poultry manure being especially high. Both grass and alfalfa hays may accumulate high levels of potassium, as clearly shown by the samples used in this study. Attempts to avoid high potassium forages must include analysis, rather than relying on the general trend that grass is lower than alfalfa.

Result: Potassium Reduction:

Potassium was leached out rather easily in this study, with the gradient being steeper over time, showing it to be more soluble than the carbohydrates. Average reduction after 30 minutes in cold water was 45.9%, with 55.0% coming out after 60 minutes in cold water. The range of amount extracted was from 70.1 to 2.8%, with the lowest reduction in the 2 samples that were low initially, having K levels that would not create a problem to HYPP horses to begin with. 30 minutes in hot water extracted generally the same amounts as 60 minutes with cold. There was a trend toward a correlation with amount extracted out vs. the initial amount of K, but this was not significant statistically. The maturity, texture, or stiffness did not seem to affect the amount of K that was extractable.

Potassium levels



Conclusion:

Both sugar and potassium can be leached out of all types of hay in significant amounts by soaking for at least 60 minutes in clean, cold water, or 30 minutes in hot water, and draining. . The average reduction in sugar over 15 samples of a variety of hays was 31%. As the amount of sugars dissolved increased over time, this suggests that a longer soaking period may allow more even more sugar to be leached.

The average reduction of potassium after soaking for 60 minutes in cold water was 55%. Although a couple of the samples did not decrease significantly, these were also low enough in K that they would not create a problem for an HYPP horse before soaking. All the samples, including those very high in potassium, were decreased sufficiently to be considered acceptable forage for a horse with HYPP.

Preliminary data from another lab showed that soluble carbohydrates and potassium were the only nutrients that were reduced by rinsing hay in distilled water. This corresponds with research on the affects of rain damage on alfalfa. Further research that includes complete analysis of all nutrients after soaking for 60 minutes is needed to assure that no other valuable nutrients are being lost by this treatment. More work, with replicated samples to eliminate the effect of testing error is needed.

Horses readily accept wet hay. Caution should be exercised to feed wet hay before it has a chance to mold or heat, which could feasibly degrade protein or other valuable nutrients.