The Influence of Solar Radiation and Temperature on the Diurnal Fluctuation of NSC in Grass

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Grass pasture is the perfect food for horses. Free choice grazing provides convenient and economical feed, while providing horses with exercise needed to maintain physical and mental health. However, horses with Equine Metabolic Syndrome (aka insulin resistance) and associated laminitis often cannot tolerate free choice grazing year round due to excess Non Structural Carbs (NSC) in grass under certain environmental conditions. Due to lack of understanding of which conditions produce excess sugar in grass, some owners choose to not graze high risk horses at all. The goal of Safergrass.org is to discover pasture management techniques and safer grasses such that horses and ponies with EMS can graze as nature intended, or eat enough hay to keep them full and satisfy their need to chew.

Previous studies have shown that grass in the evening is higher in NSC than grass in the morning, particularly in the upper layers that are subjected to the most sunlight and may contain developing seed heads in late spring (Delegarde, *et al* 2000). This is because sunshine drives photosynthesis; the process by which plants produce sugar. This raises the question of the role of light intensity in the increase in sugar concentration from morning to evening. Might we graze carbohydrate sensitive horses longer on cloudy days? In an effort to maximize grazing for these high risk animals, a study was conducted to quantify the amount of diurnal variation in an improved grass paddock, and correlate the amount of NSC increase to levels of solar radiation.

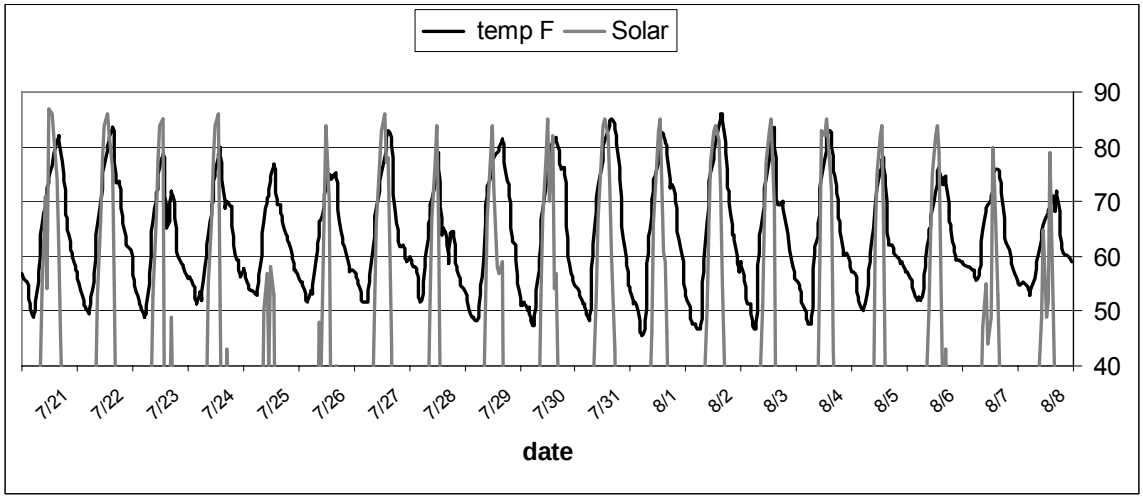
Methods

The test site is a well established, straight grass paddock in a high mountain valley in Colorado. Altitude is 7,600 feet and the soil is a cobbley, loamy sand with less than 1% organic matter. Grass species are all 'improved' varieties recommended for maximum production and nutrient content, consisting primarily of Garrison meadow foxtail (*Alopecurus arundinaceus*) and Paddock meadow brome (*Bromus biebersteinii)* in the areas sampled. Grass was mowed in late spring and the regrowth was around 19 inches tall, very thick, and devoid of any seed heads.

The paddock was irrigated every 3 days, and fertilized for optimum production and growth with ammonia nitrate. The study was conducted during a 12 day period in mid-summer, with fairly consistent temperatures ranging between 50-80°F night/day. The study commenced at the onset of late summer thunderstorm season, which is the time of year when solar radiation levels fluctuate the most in this region. Four replications were assigned as flags set in areas in full sun with similar dense, uniform stands of grass. Random samples were taken within 10 feet of each flag, avoiding sampling adjacent to previously cut grass. Replicated samples were cut 2-3 inches above soil level at 7 AM and 7 PM on three dates. An attempt was made to sample under varying amounts of sunshine, based on weather forecast. The last sampling date was supposed to be partly sunny, but it was the cloudiest day of the period, therefore PM samples were pulled without AM samples. Samples were frozen within 10 minutes to -20C and shipped overnight on dry ice to Dairy One, Ithaca, NY and analyzed for Water Soluble Carbs (WSC), Ethanol Soluble Carbs (ESC), and starch.

Hourly weather data for temperature and solar radiation was collected from an automated weather station affiliated with Colorado AgMet located approx. 1 mile from the test site. Temperature is given in F, and solar radiation was measured in Langley's.

Temperature and Solar Radiation During the test period

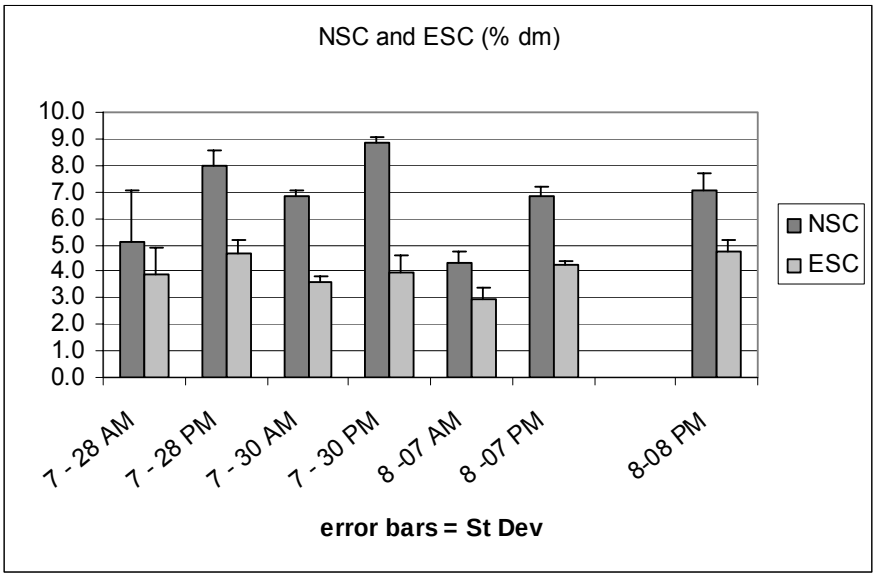


Summery of Solar Radiation and Cloud cover on Sampling Days

July 28- 493 Langley's- clear in AM, cloudy by 2 PM with showers thru evening.
July 30- 657 Langley's -clear all day, hot
Aug. 7- 517 Langley's- cloudy until 8 AM, partly cloudy rest of day.
Aug. 8- 484 Langley's- thin overcast nearly all day.

Results:

Evening samples were significantly higher in NSC than morning samples. The increase in average NSC (sugar, starch and fructan) over the course of one day ranged from 2-3 % of dm. Increases of Ethanol Soluble Carbs (mostly simple sugars) were ≤ 1% dm over the course of one day.



Date	Solar radiation	NSC in PM	Increase in NSC	Accumulated temperature F
28-Jul	493	8.0	2.9	1490.5
30-Jul	657	8.9	2.1	1542.3
7-Aug	517	6.8	2.5	1530.2
8-Aug	484	7.0		

The PM levels of NSC were strongly correlated with solar radiation (SR) the day of sampling and the 2 days prior to sampling, but correlation was weaker for 3 days prior to sampling.

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NSC: Day of Sampling SR	+0.791153
NSC: Day of Sampling + previous day	+0.807936
NSC: Day of Sampling + 2 previous days	+0.451022

The increase in NSC from AM to PM was strongly negatively correlated to solar radiation, -0.93266. When hourly temperature was added over a 24 hour period, the correlation of daily increase in NSC was strongly negatively correlated (-0.95016) to accumulated daily temperature.

Discussion:

There are many factors that interact to determine the concentration of NSC in plants. They include genetic potential of the plant, light intensity and duration, temperature, available nutrients and water, stage of growth and the portion of the plant or vertical distribution within the sward. It is very difficult for plant scientists to control all of these factors when doing field studies such that one factor is isolated and a single affect can be quantified. We must always consider how the unmeasured factors might have affected our results.

Swards of grass are affected by the macroclimate, which can be measured by a nearby weather station. The microclimate surrounding individual grass leaves also have a strong impact on the physiological processes such as photosynthesis and respiration of carbohydrates. The most important factors in a study conducted over a couple weeks might end up being unimportant in a study conducted over the course of a year when weather varied greatly, and grass was sampled under various stages of growth, and nutrient or water availability.

This study did agree with many previous studies, that NSCs are higher in the evening than in the preceding morning. The short duration of this study would eliminate stage of growth or nutrient availability as confounding factors in NSC concentration. Regular irrigation lessened any impact of drought stress, which may increase NSC in grass. By controlling these important factors involved in carbohydrate concentration, the remaining factors of light and temperature hold more significance.

Studies in the United Kingdom have suggested that higher rates of laminitis are associated with bright, sunny days (Harris, *et al* 2006). This study agreed that solar radiation the day of and day before sampling had a fairly strong correlation to evening concentrations of NSCs. This correlation to accumulated daily solar radiation started to fall apart 3 days before sampling, presumably because one of many other factors confounded the results. Because sunlight drives photosynthesis, it might easy to assume that more intense sunlight will cause a higher rate of photosynthesis resulting in a higher daily increase in NSC in grass. In the UK, sunshine may well be the limiting factor in NSC formation in grass. But in this study, conducted where sunlight is generally not a limiting factor, the daily increase in carbohydrates from morning to evening was strongly *negatively* correlated to solar radiation. Why might this happen?

Respiration is the mechanism in which plants use sugars for energy and growth. The enzymes that drive this mechanism are very dependent on temperature. When temperatures are cool, they function poorly and unused sugars accumulate. When temperatures are high, usually around 80F for cool season grasses, these same enzymes are far more efficient and sugars may be used so quickly that NSC concentration may be depleted, especially if photosynthesis (creation of sugars) is limited. The sugars burn off when it's hot. While intense, prolonged solar radiation may make photosynthesis more efficient in cooler temperatures, if it gets so hot that respiration goes into overdrive, the net result may be grass that is quite low in NSC. A good technical review of the complex interactions between temperature and respiration in plants is discussed by Atkin and Tjoelker (2003). During hot weather NSC may be considerably lower in cool season grasses than during cold weather, as long it is not drought stressed.

In this study, the grass was very tall and thick. This was likely very significant to the results. The amount of available sunlight in the microclimate surrounding the grass blades was far less than that measured by the weather station. While the tops of the grass plants had maximum exposure to sunlight, the bottom half of the plants were in shade much of the time. If the grass had been mowed or grazed short, nearly every blade of grass would be exposed to sunlight and the resulting carbohydrate levels might have been quite different. This affect has been noted in other recent studies on carbohydrate in grass, and the authors caution against comparing un-grazed tall grass to grass that has been clipped, mowed or grazed (Griggs *et al*, 2005).

Previous studies conducted in this same paddock under different management practices and environmental conditions have resulted in fresh grass that was far too high in NSC for horses with EMS. In this study conducted in mid-summer, the grass had relatively low levels of NSC; even the PM samples were low enough that a short evening grazing period might be considered for high risk horses. The previously mentioned effect of tall grass being lower in NSC than short grass could be utilized by strip grazing, where the ponies would only have access to the amount of tall grass that they could eat within one day. Previously grazed grass could be fenced off with step-in posts and electric tape. Future studies looking at the affect of mowing vs. not mowing could further our understanding of how pasture management affects NSC content of grass. As always, the duration of 'safe' grazing will be different for individual animals, as well as being dependent on other management aspects such as the amount of exercise for each individual.

Summary:

In evening, grass is higher in Non Structural Carbs than in morning, especially on sunny days. Hot temperatures may cause sugars to burn off, creating low sugar grass and resulting hay, even with lots of sunshine. Horses that are sensitive to excess carbohydrates in grass may be able to graze longer during morning than evening, and longer during hot weather as long as the soil has adequate moisture to prevent drought stress. Caution must be exercised in interpreting studies on grass carbohydrate conducted with different species, in different environments and under different management practices.

References:

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For more information on sugar in grass and management of horses with EMS, please visit www.safergrass.org