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In recent years the popular equine press has expressed concern about the linkage between the common plant carbohydrate fructan and laminitis that occurs when horses are introduced to pasture and during the grazing season. Most of the information is factual and based on science, but some of the connection to pasture management for horses on the Prairie Provinces is not applicable and may cause needless concern to horse owners.

What is a fructan?

Fructans are part of the non structural carbohydrate fraction of cool-season grasses. They are complex carbohydrates like starch in that they are made up of smaller monosaccharide units. Starches are made up of chain links of glucose, whereas fructans are made up of fructose links. Starches, fructans and the simpler sugars, glucose, fructose and sucrose and a few others really increase the level of digestible energy in the diets of most livestock and are included to increase weight gain or energy to do work or athletics. All of the non-structural carbohydrate

fraction, except starch, can be separated from dried or dead plant material by soaking or extracting in water and are also called water soluble carbohydrates (WSC). Usually when fructans are determined they are included along with the other sugars that are soluble in water. Starches may be removed from plant material by incubating with enzymes (e.g.) amylases or extracting with weak acids. Fructans are smaller and lighter, having fewer links in their chains than starch and break up easier to carry out functions in the plant, especially in response to changing environmental conditions. Structural carbohydrates form the fibrous back bone of the plant found in the cell walls. They are cellulose and hemicellulose. They are digested slowly and incompletely by bacteria in the animal digestive system. We can separate them from dried plant material by extracting in neutral and acid detergents (e.g. NDF and ADF).

Horse Factors versus Pasture Factors

Pasture and other feeding systems for horses depend on a horse's dietary requirements based on work level, age and stage of pregnancy for mares. This is essentially matching pasture characteristics (yield and quality) to the physiological state and activities to feed the horse efficiently. The same principle may be used to reduce the risk of laminitis if risk exists.

Horse Factors

How do nonstructural carbohydrates cause laminitis?

The equine digestive tract is designed to process low to medium quality forage, eaten in small frequent meals. After ingestion the fibrous forage diet consists of relatively large pieces of fibrous material that move slowly. By contrast concentrate or grain-based diets have little fiber, chewed particles are small and the starch moves quickly through the digestive tract. The first part of the digestive tract (stomach and small intestine) digests and absorbs food materials that are broken down enzymatically and quickly. The back end of the digestive tract or large intestine consists of the caecum and colon which digests fiber and complex carbohydrates using bacteria that are adapted to the diet. Bacteria break up the cellulose, starch and fructans into glucose or fructose, by fermenting them, deriving energy, acids and gases as products. Fiber takes longer to digest and so fibrous feed resides much longer in this back compartment. Certain bacteria are adapted to grain-type rations and others to forage-type rations. When a horse eats a lot of grain or carbohydrate-rich forage, like spring pasture and corn or barley silage a lot of undigested starch or fructan or both is dumped rapidly into the large intestine, perhaps creating a backed-up pipeline. More lactic acid and gas is produced than normal, unadapted bacteria may die and blood sugar levels usually rise and remain high. Acidosis and colic or pain occurs in the intestine. Digesta movement in the intestine may cease. Blood flow is directed to the digestive tract and does not reach the foot. Harmful physiological and physical changes occur in the malnourished foot and hoof resulting in founder. Depending on the interpretation, founder is caused by the high starch-fructan diet or a rapid change in the diet to which the horse was not accustomed and the intestinal bacteria not adapted.

Breed or type of horse

Certain breeds appear to be more predisposed to pasture laminitis than others, but there is variation among individuals among and within breeds. Ponies appear to be more pre-disposed than horses. Easy-keepers may be more prone than angular-bodied types through an association with insulin resistance. Thus ponies, Morgans, mustangs, Warm bloods and Saddlebreds may tend to have more pasture laminitis problems, while thoroughbreds may not. Many individuals in the higher risk breeds or body types have no laminitis problems with pasture.

Insulin Resistance

Insulin has a role in activating physiological mechanisms that move glucose from the blood to be converted to stored energy and body tissue. Some horses require more insulin than others to move the same quantity of glucose out of the blood stream. Thus blood sugar levels remain higher than necessary. These horses are more susceptible to founder, after ingesting large amounts of starch or fructan. Horses that are kept on high concentrate diets, particularly in the absence of exercise, may lose sensitivity to insulin. Obese animals with a body condition score (BCS) greater than 7 may fit this category. Some mares at later stages of pregnancy appear to develop this problem, but usually recover after giving birth.

Exercise and BCS

Aerobic exercise is known to impact partitioning of feed energy into muscle and fat. Horses that are conditioned tend to be efficient in removing blood glucose and also tend to have a desirable BCS between 4 and 6. In cases of heavy exercise horses may require added concentrates in their diets to maintain BCS within this range. Horses on diets such as these should be fed small meals, frequently, with roughage available to them.

Adaption to Diet

Micro-flora species in the large intestine of horses adapt to the diets that are fed. Species that exist when horses are fed grain can thrive and survive under slightly acid conditions, but forage fed horses host bacteria that are accustomed to a more neutral environment. When rations change abruptly intestinal bacteria have to change and in doing so some of the species die off, while new species need time to multiply and grow to accommodate the new feed stuff. The dead bacteria give off metabolites which may be toxic or set off triggers for colic and founder.

Previous history

Generally horses which have previously experienced laminitis from grain overdose or pasture

may be susceptible again.

Pasture and Forage Factors

Crop species

Only cool season grasses contain fructans. Virtually all pasture species grown for pasture on the Canadian Prairies are of this type. Legumes such as alfalfa and clovers contain starch and some other types of WSC, but no fructans. Warm season grass species such as corn, millet, sorghum, big bluestem, Bermuda grass and switchgrass also do not contain fructan, but they can contain a lot of WSC and some starch. For example corn stalks can contain 30% WSC as a percent of dry matter mostly, sucrose, which is the principle sugar in sugar cane. Examples of cool season species are those listed in this article.

Much of the research relative to laminitis has been conducted where perennial ryegrass is grown and recommendations have been generated out of this. Perennial ryegrass is not used on the Prairie Provinces, because it is not winter hardy, although it may be found in some seed mixes. Most long-term pastures in Central and Northern Alberta contain Kentucky bluegrass, smooth brome grass and quackgrass. Some timothy and orchardgrass may be found depending on location and topography. In eastern and southern Alberta crested wheatgrass is likely to be a pasture component. Alfalfa is usually part of a pasture mix, initially, but rarely survives in horse pastures. White and red clover may be observed in Central and Northern Alberta pastures.

Water soluble carbohydrate content of brome grass pastures during June were not high, but appeared to double after second growth that might be grazed in September. However, WSC in Italian ryegrass, an annual, and a relative of perennial ryegrass had considerably higher WSC content in the fall than the others. Italian ryegrass is not used routinely in Alberta horse pastures, although it has been used on occasion. Horse owners might be cautious about this species choice as it may constitute a laminitis risk, depending on the specific horse factors considered. Ryegrass not only has a high WSC content, but a lower fiber level than other grass species.

How much fructan is in the pasture?

The amount of non-structural carbohydrate in the pasture depends on many factors and the amount of fructan in the fraction varies as well. Fructan is only part of the fraction.

Values shown in Table 2 are percentages of non structural carbohydrate not of dry matter. Of

the species shown fructans and fructose at most represented 50% of the non structural fraction of cool season grasses. Starch represented significant proportions, especially in smooth bromegrass, where fructan content per se was relatively low. All of the carbohydrate groups shown in Table 2 are much more digestible and available to the horses digestive system than fiber (structural carbohydrate), but fructan and starch are the complex carbohydrates that would end up in the large intestine.

Time of Day

The WSC content at any time of day is a trade-off between sugar production and use by the plant in it's' growth processes. Sugar production occurs through photosynthesis during the daylight hours. Respiration converts sugar into plant bio-chemical energy and structural materials day and night, but the pool of WSC in the plant reduces more at night in the absence of photosynthesis. The amount of carbohydrate left over is simply the net residue or pool that is unused; it represents an energy buffer for the plant to deal with "hard times".

Table 3 shows the difference between maximum and minimum non structural carbohydrate contents during afternoon-evening and morning. Hay cut in late afternoon will have higher WSC contents than in morning. Whether this difference is significant or not depends on how long it takes for the hay to dry before baling. The slower the hay drying rate the more WSC will decrease due to lingering effects of respiration for the plant cells which remain alive and by bacteria and mould growing on the hay while it dries. If hay is rained-on during drying, some WSC will leach out. Grazing in the early morning may minimize WSC intake by the horse. Because most livestock prefer the higher sugar containing forage, the horse may be induced to consume more forage and therefore more fructan when grazing during afternoon than in morning.

Time of Year

Incidence of laminitis increases during summer compared to winter and is most intense during spring and fall (Longland and Bird 2006; Harris et al 2006). These times do coincide with periods of high WSC in forage crops and pastures. However, we have seen higher values in August and September than in spring at Lacombe (Table 1). Very early spring green-up in April and early May likely has WSC that are similar or greater than fall values. Pasture yields at this time are very low and in the interest of good pasture management should not be grazed by any type of livestock. Research conducted at Agassiz BC showed April and May values for orchardgrass approaching 30% WSC (Bowden et al. 1968), which might be a concern.

Where are the fructans?

Within plant cells fructans are stored in vacuoles, whereas starch is stored in chloroplasts or

amyloplasts. The equine literature (e.g. Longland and Bird 2006; Harris et al 2006) concludes that the non structural carbohydrate is highly concentrated in stems and seed head portion of the pasture or forage crop. Fructan is used a source of energy for leaf and stem growth in the absence of photosynthesis. Thus fructan is drawn towards the leaf and stem bases which are areas of active growth (Figure 1). After cutting and during winter most of the fructan is in the crowns and stubble. These are positions where horses would not likely graze if pasture growth is adequate and a rotational grazing system is used. Horses would likely prefer to graze leaf material in the upper parts of the pasture canopy. Hay consists of 50 to 60% stem; therefore, it would be hard to avoid harvesting stems with it.

During the day Griggs et al (2005) showed that sugars are concentrated more towards the top of the canopy and may move towards the base during the night. This makes sense as most of the light for photosynthesis is captured in the top part of the canopy. During the night there will be a movement towards the base as sugar moves to the areas of greatest need (growth points) or towards storage organs such as corms in timothy.

Stage and Growth

Stage of development, growth rate, temperature and hours of sunlight or photoperiod all play a role in WSC content at any time.

Photosynthesis, which produces sugar, is not as sensitive to temperature as respiration, which consumes sugar. Photosynthetic rate is relatively high with high light intensity, with the pasture in full sunlight, and low under shade. In spring, and especially first spring growth, light intensity is high and temperature relatively cool. Sugar is abundant and growth rate, which creates the demand for energy is low. Thus leafy vegetative material in the pasture has high WSC content (Table 4), especially during the late afternoon. As temperature increases and growth rates increase, the sugar content of the whole plant decreases because: 1. the higher plant weight requires more carbohydrate for maintenance, 2. the higher temperature increases growth rate and therefore respiratory processes relative to photosynthesis. 3. At temperatures above 25 to 30o C cool-season grasses reduce photosynthetic rate.

Stem development occurs as grasses move into stages desirable for hay production and in concert WSC decreases (Table 4). Jung et al. (1976) did not observe higher carbohydrate contents at later stages of floral development as indicated by Harris et al. (2006).

Cold and Drought

The advancement of late fall and winter will cause fructan content to increase in the root and crown area of cool-season grass. This WSC is used for energy by the plant to survive freezing temperatures for green leaves under snow and roots and crowns in the soil or at the soil surface. The energy is used to provide an anti-freeze effect in the live, dormant cells and to build and maintain chemical materials that keep cell membranes pliable and waterproof under freezing temperatures. Similar effects may occur during drought. Equine writers have indicated

that brown leaves and stems of grasses under drought conditions will have high concentrations of sugar and should not be grazed. This could occur under conditions of extreme high temperatures, but rarely happens under Alberta conditions. Plant leaves die routinely as new ones form during spring and summer and the amount of dead material increases towards fall. More leaves die over winter. Thus, stockpiled pastures (Table 5) are a mixture of live and dead plant material. In the normal process of leaf death both sugar and protein move from the older dying leaves to areas of intense growth or the crown and root as winter approaches. However, the old leaves and stems retain enough feeding value to sustain livestock at a maintenance level where grazing is the main activity. In spring a well planned pasture should have a mixture of dead and live leaves. The dead leaves will have a low WSC content and this may help in diluting carbohydrate content of early spring pastures.

Management

Management practices which enhance growth generally reduce WSC content. Thus application of fertilizer nitrogen will reduce sugar content in the forage. Equine writers such as Harris et al. (2006) have suggested not using cool-season grasses in pastures. This is not a viable option for almost all of Western Canada, because all of our pastures contain cool-season grasses and we have no warm-season grasses that are adapted.

Stockpiled pasture which has been given a long rest period between grazing and cutting and grazing again should have a low WSC content and increasing fiber content due to accumulation of dead leaves (Table 5). This pasture may be grazed during fall and early winter and if BCS is monitored closely could provide an ideal pasture for weight control of idle horses. Horses need to be in plump condition in the fall, have adequate yields of stockpiled forage available to graze and be provided with a source of good water. As winter wears on horses will need to be supplemented with hay or grain. In spring new green leaves will emerge through the old stockpiled stand providing an overall pasture that has a low to moderate WSC content until late spring early-summer pastures develop.

Optimizing the Horse and Pasture Factors

Every year some horses will suffer from pasture laminitis. So, viable strategies need to be formed by horse owners and managers to reduce this risk. Rarely will a single horse or pasture factor raise the risk level to the point of laminitis concern, but the wrong combination of factors may be critical.

Minimum WSC content to cause digestive disturbance

In order to estimate what levels of ingested WSC that are tolerable related to hours of grazing it may be useful to know the maximum WSC that might be ingested in a day. It has been

suggested that hind gut dysfunction might occur in a range of 2 to 4 kg (5 to 10 lbs of grain) starch equivalent ingested per day by a 500 kg (1,100 lb) horse (Longland and Bird 2006). However, the amounts that might trigger laminitis will vary widely among individual horses for the reasons given previously. Longland and Bird (2006) indicated that daily intakes of pasture could vary from 1.5 to 5.4% of body weight, but could easily be lower depending on pasture yield and quality. In order to complete the calculation one needs to know WSC concentration in the fresh pasture at all times of the day and year. Methods exist to do this, but the sheer variability of the concentration and the threshold ingestion value for the individual may make these measurements trivial.

Really! Is your horse at risk of pasture laminitis?

Yes, because of the horses complicated digestive system there is a risk, but is the risk high or low.? In terms of WSC of which fructan is a significant component areas to the right and lower portions of Table 6 may be a guide to reducing risk. The following are a few guidelines to reduce risk.

1. Horses that have had laminitis previously provide a signal that they are prone to it and precautions should be taken to avoid spring pastures and rapid changes in diet (High risk). However, these horses could be fed low to medium quality hay (higher in fiber) in a manner that intakes are controlled over a long period of time.

2. Fat or obese horses may or may not be prone to laminitis, but constitute a greater risk factor than those having regular exercise and at a BCS of 4 to 6. These horses should be moved on to pasture gradually. (Medium to high risk)

Pastures need to be regarded as part of a horse's balanced diet . A 1,100 lb horse should be close to maintaining weight on 22 lb of hay each day (e.g. Table 6) when average quality hay is fed. However, the available energy in 22 lb dry matter of spring or early summer pasture (Table 6) may exceed requirements and will be greater than the same amount consumed in the mid-summer or winter. Thus restricted pasture access is likely necessary.

3. Change of diet in spring. In spring, horse owners look forward to moving all activities outside, including feeding. During winter a dry feed is normally used (e.g. less than 15 % moisture). The 1,100 lb horse and its' intestinal microflora will adapt to 22 lbs of dry feed, (26 lbs as fed) fed in two or three meals daily. (Medium to High Risk)

At spring pasture turnout the horse is looking at a cafeteria of appealing feeds in the pasture and is induced to consume them rapidly. Even if the horse consumes 22 lb of pasture dry matter it will be accompanied by a slushy mass containing 110 to almost 200 lb of water (10 to 20 gal), 5.5 lbs of protein (may only require 2.6 lb), that may be high in non protein nitrogen, 4.4 lbs of WSC and 12.1 lbs of fiber.

While the horses gut may be able to accommodate this mass, it is vastly different than a diet of dry hay and grain fed during winter. The quantity of WSC consumed may place the horse in an 'at risk' category, but the other feed constituents may push a laminitis risk over the edge.

This should encourage horse owners to move on to pasture gradually. However, while holding off pasture at night during an adjustment period may be wise, turning horses out "empty" is not. Feeding horses high fiber hay overnight prior to morning turnout may moderate digestive disturbances due to consumption of fresh pasture, because it increases the dietary fiber intake, which may slow down digesta movement. Feeding the hay in a "hay net" should force the horse to feed over a longer period of time.

4. Fall pasture: Horses which have been exposed to pasture all season and are in optimum BCS likely have a low risk to laminitis. This is because they have become adapted to feeding on pasture and usually this pasture is accompanied by more dietary fiber earlier in the season. Horses that carry with them other risk factors, such as previous history or physiological tendencies may have to be monitored closely or removed. However, late fall and winter pasture offer opportunities to manage the horse's weight in a positive manner. (Low Risk).

Conclusion

Because Alberta pasture consists almost entirely of cool-season grasses it is not possible to avoid fructans on pasture. Pasture is a valuable feed source and must be regarded as part of a diet that has to be balanced based on the size, condition and activities of the horse. The pasture has to be assessed according to its abilities to fulfill the dietary requirements or not. Feeding strategies have to be addressed accordingly. Thus pasture fructans are only one factor in mitigating laminitis risk and have to be judged according to the total risk of laminitis to the individual horse in question.

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