**Week 2: Nutrient digestion in the horse**

This section looks at the digestion of the following:

Water

Carbohydrates

Fats and oils

Protein

Vitamins

Minerals

Food contains water and dry matter.

The nutrients contained in dry matter are:

Minerals

Vitamins

Protein

Lipids

Carbohydrates (structural and nonstructural).

Energy is not a nutrient, but it is supplied by nutrients, primarily carbohydrates, and also lipids.

Water is an essential component of the diet. It is required for:

The transport of nutrients around body

Thermal regulation

Metabolism

Excretion of waste products

Gut function.

80 percent of a foal's body weight is water.

60 to 75 percent of a mature horse's body weight is water.

It is essential for horse to have a fresh water supply

The amount of water a horse needs depends on:

The age of a horse

The level of exercise

The type of feed

The moisture content of a diet; horses will drink less if eating high-moisture diets

Environment conditions; in higher temperatures, horses will drink more.

We need to consider the water content of food, as it affects water intake and it affects how we compare feed stuffs.

The water in food is the "moisture content."

Many feed stuffs, such as fresh grass and haylage, have high levels of moisture.

Therefore, when we consider the nutrient content of feed stuffs, we compare them on a dry matter basis.

**Carbohydrates**

Carbohydrate is a collective name for starches, sugars and dietary fiber.

There are two types:

Structural: Those carbohydrates associated with the plant cell wall. These are also referred to as dietary fiber.

Nonstructural: Those associated with the plant cell's contents, such as simple sugars, starches and fructans.

Carbohydrates are the primary energy source that horses use, and they are a major component of feed stuffs.

**The structural carboydrate** is the fibrous fraction of plant. These carbohydrates play a structural role in plant. They provide the plant with rigidity and strength. They are a major source of dietary fiber for the horse. This is an important part of the horse's diet, a major energy source.

Carbohydrates that we'll find in the cell wall are cellulose, hemicellulose, pectin and another component that is not a carbohydrate but is closely associated with them, lignin.

These structural carbohydrates are degraded by microbes in the large intestine. They are not digested in the small intestine environment because the horse lacks the necessary endogenous enzymes to break down these fibrous components.

They travel through to the hindgut where they are degraded by the resident microbial population. This population breaks down these structural carbohydrates to produce volatile fatty acids, predominantly acetate, butyrate and propionate, and the horse absorbs these VFAs across the gut wall and uses them as an energy source.

A byproduct is the production of gases, predominantly carbon dioxide and methane.

Feed stuffs high in fiber include grass, hay, straw and sugar beet pulp.

Lignin is a component of the cell wall closely associated with cell wall carbohydrates. It is negative correlated with digestibility. As plants mature, they lay down more lignin in their cell walls to provide rigidity. This is beneficial to the plant but has a negative impact on the nutritive value of the plant. Lignin reduces the digestibility of these cell wall components and, therefore, lowers the nutritive value of the plant to the animals. Mature plants have more lignin and lower digestibility value. The other part of plant affected by lignin deposition is protein digestibility. Proteins associated with the cell wall are also reduced in digestibility as the amount of lignin increases in the cell wall. Mature plants -- hays and straws -- contain high levels of lignin.

How can you analyze the fibrous fraction?

There are two methods:

We can measure the total cell wall content. We do this by measuring the neutral detergent fiber content. This takes into account the amount of hemicellulose, cellulose and lignin present in the plant.

If we want to look more closely at the fraction of the plant that is less degradable, we can measure the acid detergent fiber content. This measures the cellulose and lignin content of plant cell wall. Those plants with a higher ASF value are typically less degradable than those with a lower ADF value.

**Nonstructural carbohydrates** are those found within the cell contents.

The are also known as the storage carbohydrates of plants. They are the carbohydrates that the plant itself uses as an energy source.

The storage carbohydrates of forage crops include fructans and starches.

Fructans are nonstructural carbohydrates that are the major storage carbohydrates of temperate grasses. They are primarily located in the stem of the plant, and they are made up of polymers of fructose. Fructans are soluble in water; therefore, they fall into the category of water soluble carbohydrates.

In terms of how they are digested in the GI, fructans are not digested in the stomach or small intestine. They may be water soluble carbohydrates, but the horse lacks the endogenous enzymes to break down the fructan to enable it to be digested and absorbed in the SI. Instead, the fructan travels into the LI, where it is degraded by the microbial population, and VFAs are produced and used as an energy source.

Fructans are a natural part of the horse's diet. However, large intakes of fructans can be detrimental to GI health. This can cause digestive upset and can result in the horse developing laminitis.

Other water soluble carbohydrates include the simple sugars glucose, fructose and sucrose. Together, fructans and these simple sugars constitute the water soluble carbohydrate (WSC) fraction of the plant.

The water soluble carbohydrate content of grass is highly variable. In early spring, we see an increase in grass growth. We see lower levels of WSC at this time because the plant is using the WSCs to grow. However, as we move into late spring and summer, we see a decrease in grass growth but an increase in WSC content because the plant is still photosynthesizing and storing fructans, but it's not using them to the same extent for growth.

WSC content changes throughout the year. It is highest in May and still high in August while much lower in March and October. Note that studies show that the highest incidence of laminitis is reported in May.

WSC also varies by year. It can vary considerably in May per year.

There is also a daily variation. At different times of the day, grasses will contain highly variable levels of WSCs. It's a balance between photosynthetic activity and utilization and is affected by light and temperature.

When light intensity is high, plants will be actively photosynthesizing and storing these WSCs.

In early hours, when daylight is lower, there are fewer WSCs in grass. As we move through the day, WSCs peak in the later afternoon to evening. At 6 p.m., they are highest.

Temperature affects this, too. Lower temperatures lead to higher WSCs; lower temperatures reduce grass growth. Instead of the grass using the WSCs, it stores them.

Light intensity plays a role. More light means more photosynthetic activity and more WSCs being stored in the plant.

Water stress is an important factor. Drought leads to higher WSCs because grass needs water to grow. When water is reduced, higher levels of WSCs are stored.

Fertilizer affects WSCs levels. Fertilizer promotes grass growth. Because of this, we see lower levels of WSCs being stored because they are being used.

Cutting and mowing are important. WSCs are stored in the stem. More mature grasses that are more stemmy contain higher levels of WSCs.

Video 2

**Cereal grains**

Starch is the major source of nonstructural carbohydrates found in plants such as cereal grains, forage legumes, roots and tubers and also in lower levels in the leaves and stems of grasses. In temperate grasses, fructans are the major storage carbohydrates. They are present in much higher levels.

The starch content is very low in the stems of leaves and grasses. However, much higher levels are found in forage legumes, such as alfalfa. While alfalfa accumulates starch as the storage carbohydrate, it accumulates only small amounts of starch, typically no more than 5 percent of the dry matter. In contrast, fructans in grasses can be present in up to 40 percent of the dry matter.

Starch in cereal grains is present in much higher levels. In fact, typically this is why cereal grains have high energy contents; anywhere from 40 to 70 percent of dry matter can consist of starch. Starch is digested in the small intestine.

Amylases are enzymes that break down the starch into simple sugars. These simple sugars are then absorbed across the small intestinal gut wall and used as a source of energy. While the horse does produce endogenous enzymes to break down starch in the SI, it has a limited capacity for how much starch it can digest in the small intestine.

If the horse gets too much starch at one meal, some starch travels into the large intestine. This causes disruption to the LI. It can tolerate some starch, but not a large amount. The large intestine is designed to be presented with fibrous material that is less easily degraded, as opposed to starch, which is very rapidly degraded by the microbial population.

**Fats and oils**

Horses' diets are typically low in fats and oils. For example, grasses typically contain lower levels of these. Fats and oils are well digested in the SI by enzymes called lipases, and the end products are absorbed across the gut wall and used as an energy source. Fats and oils have two times the energy of carbohydrates. Horses don't require fats and oils but tolerate them well. They can be a useful way to boost the energy content of the ration.

You can certainly add reasonable levels to the diet, but extremely large levels can cause disruption in the large intestine. Fats and oils that are not digested in the SI that are passed through to the LI can have a detrimental effect on fiber degradability. They can coat the fiber, reducing access to the fiber for the microbial population. The end result is a disruption to the LI environment and reduced fiber degradation and digestibility of the fibrous fraction of the diet. While fats and oils are useful, they must be fed in limited amounts and introduced slowly.

**Protein**

Protein is an essential nutrient required for various functions:

Structural (muscle, skin and hair)

Enzyme production (the catalysts that affect the rate of reactions in the body)

Hormones (chemical messengers that regulate metabolic processes)

Immune compounds (for fighting infections)

Transport compounds (transport of nutrients)

Proteins consist of chains of amino acids.

These are classified into two categories: Essential and nonessential amino acids.

Nonessential are synthesized by the animal and don't have to be supplied in diet, while essential do have to be supplied in the diet.

The essential amino acids are lysine, methionine, threonine, isoleucine, valine, arginine, tryptophan, histidine, and phenylalanine.

Some amino acids are considered first limiting. They are present in the least amount relative to the requirements of the horses.

Lysine is first limiting amino acid in the horse. When looking at protein quality, we need to consider the amount of lysine that is present in the feed stuff.

Protein breakdown begins in the stomach, but no proteins are absorbed in stomach.

The acid environment in the stomach begins to denature the proteins. Pepsin, which is also present in the stomach, partially degrades proteins into smaller peptides. These smaller peptides travel through to the SI environment. In the SI, proteases -- which are enzymes that break down proteins into amino acids -- degrade these peptides to produce amino acids that are absorbed across the SI gut wall. However, proteins associated with the plant cell wall are not digested in the SI. They are passed into the LI, where they are fermented. Soluble proteins present in the cell contents are broken into amino acids and absorbed across the gut wall of the SI. It is the protein digested and absorbed in the SI that is of biological value to horse. Studies suggest that no or little animo acid absorption takes place across the gut wall in the LI. Therefore, it is the protein digested in the SI that contributes to the animo acid production of the horses. Protein available in hindgut is important to maintain a healthy hindgut environment by supporting microbial growth. Protein associated with the cell wall is a necessary part of the diet because it supports microbial growth in the hindgut.

However, when we're selecting protein feeds for horses, it must be of sufficient quality to allow amino acids to be digested in the SI while also supporting the maintenance of the hindgut environment.

**Minerals**

Minerals are also an important part of the diet. They are required for various functions, including:

Growth

As cofactors to enzymes

In the transport of energy

The majority of minerals are absorbed in the small intestine, but some pass through for absorption in the LI.

There are two categories: Macrominerals and microminerals, or trace minerals or trace elements.

Macrominerals are needed in relatively large amounts. They would be provided in amounts of grams per day. Microminerals are needed in smaller quantities and provided in milligrams per day.

**Macrominerals:**

Calcium

Phosphorous

Sodium

Potassium

Magnesium

Sulphur

Chloride

**Microminerals**

Cobalt

Copper

Molybdenum

Zinc

Manganese

Iron

Floride

Iodine

Selenium

Chromium

It's important to consider the ratio of minerals to each other.

The most important is the ratio of calcium to phosphorous. Ideally, this should be in a ratio of two calcium to one phosphorous. Imbalances in this ratio can cause detrimental health issues, particularly in growing horses. If feeding feeds high in phosphorous and low in calcium, such as cereal grains, this can cause imbalance, which can have health implications.

**Vitamins**

Vitamins are required only in small amounts but vital to:

Vision

Immunity

Growth

Bone development

Blood clotting

There are two categories:

The fat-soluble vitamins of A, E, D and K.

The water-soluble vitamins of C and B complex.

Fat soluble vitamins associate with fat to be absorbed and transported in the blood.

Fat soluble vitamins can be stored in the body.

Water-soluble vitamins cannot be stored, so they must be supplied regularly to the horse.

B vitamins are produced by microbial synthesis in the LI, so any disruption to the environment can affect the synthesis of these B vitamins.

For example, diets high in starch not only can affect the LI environment but the production of B vitamins.

Vitamin C is synthesized in the liver. It needs to be regularly supplied to the animal; it is not stored.

When the horse is eating fresh grass, it probably gets its vitamin needs, but this depends on the quality of the forage and also the environmental and management conditions. It is important to ensure horses are receiving vitamins and minerals and all of the other nutrients we've discussed to remain healthy and productive.